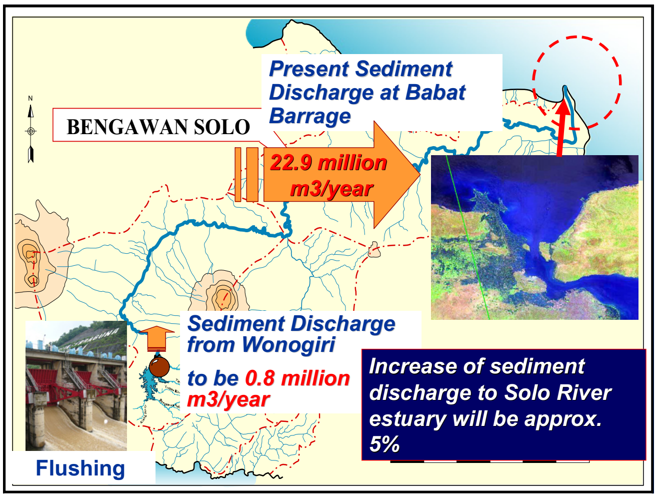


BENGAWAN SOLO

Present Sediment Discharge at Babat Barrage

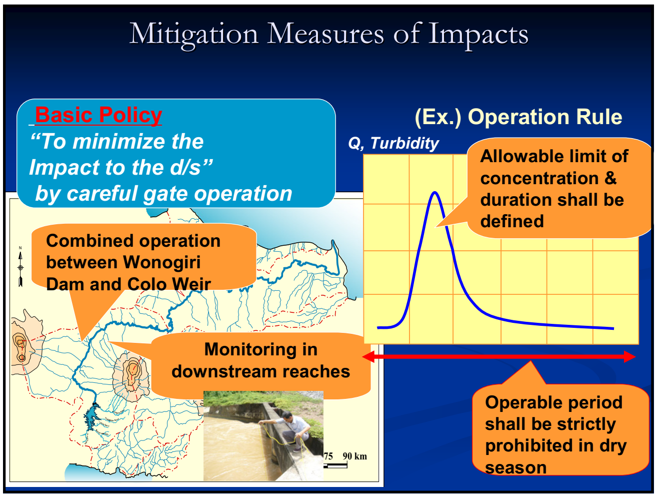
22.9 million m3/year

Sediment Discharge from Wonogiri

to be 0.8 million m3/year

Increase of sediment discharge to Solo River estuary will be approx. 5%

Flushing



Mitigation Measures of Impacts

Basic Policy
"To minimize the Impact to the d/s" by careful gate operation

Combined operation between Wonogiri Dam and Colo Weir

Monitoring in downstream reaches

(Ex.) Operation Rule

Q, Turbidity

Allowable limit of concentration & duration shall be defined

Operable period shall be strictly prohibited in dry season

Thank You very much
for Your Kind Attention !

Estimating sediment volume into Brantas River after eruption of Kelud volcano on 1990

Mr. Takeshi Shimizu
National Institute for Land and Infrastructure Management

IEstimating Sediment volume into Brantas River after eruption of Kelud Voncano on 1990

Takeshi SHIMIZU[1], Nobutomo OSANAI[1] and Hideyuki ITOU[1]

[1]*National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan*

The Brantas River that flows through East Java Province, the Republic of Indonesia, is the second largest river. It has 11,800km^2 catchment areas and total length of the river approximately 320km. The Brantas River Basin has been developed based on the 1st to 4th master plans since the Second World War. The purpose of master plans was mainly dam constructions in the middle stream and upstream for flood control, water supply for agricultural and industrial use, and electricity generation. The each plan was almost successfully completed.

In the Brantas River Basin, several active volcanoes located, originally sediment production is intense. The Brantas River Basin now has two serious water and sediment related problems as followed as bellows.

(a) The decrease of reservoir's effective capacity due to sediment inflow to the reservoirs in the middle stream and upstream.

(b) The riverbed degradation due to sand mining in the lower stream.

Related to the decrease of reservoir's effective capacity, a total annual average 3 million m^3 of sediment has flowed into reservoirs, and already filled approximately 43% of the reservoirs in 2003.

The riverbed degradation has increased the risk of damage such as the flood disasters, lateral erosion, and constructions flow out. The main factor of the riverbed degradation is considered sand mining. More than 4 million m^3 of sediment were excavated from the river bed in 2000.

Moreover, volcanic materials supply due to the eruption sometimes gives additional effect along the basin. Especially Kelud volcano (elevation: 1,731m) indicates high activity; it might give serious effects to the basin.

The aim of this study is to estimating the sediment volume into Brantas River Basin after Kelud volcano eruption on 1990 using numerical simulation.

Keywords: Water and Sediment Management, Brantas river, volcanic eruption

Estimating sediment volume into Brantas River after eruption of Kelud volcano on 1990

SHIMIZU Takeshi, OSANAI Nobutomo and KOGA Shozo

Erosion and Sediment Control Division,
Nation Institute for Land and Infrastructure Management

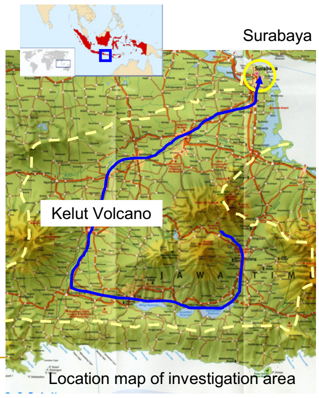
The 2nd International Workshop on Water and Sediment Management
Malang, Indonesia
22-23 November, 2007,

Investigation Area

> Brantas River(basin area : 11,800 km^2, river length : 320 km) is located on the Island of Java, Indonesia.

>There are active volcanoes such as Kelud.

> Development plan of the Brantas river basin have started since 1959. A lot of water facilities including reservoirs were constructed in the projects.

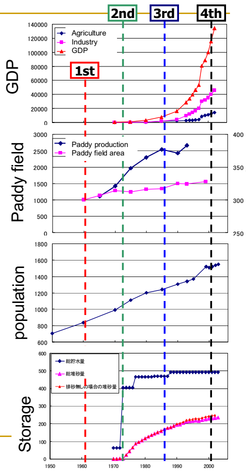


Location map of investigation area

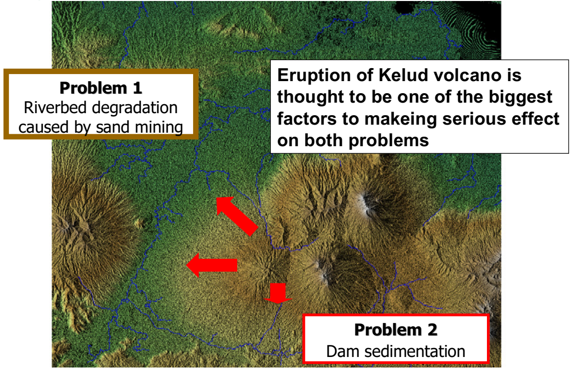
History of development in Brantas River Basin

There are 4 master plan executed in the Brantas River Basin

- > Time going, economic factors increasing
- > The master plans were effective. But another problem occurs
- > For example sedimentation in dam reservoirs and river bed degradation



Background of this study



Problem 1
Riverbed degradation caused by sand mining

Eruption of Kelud volcano is thought to be one of the biggest factors to makeing serious effect on both problems

Problem 2
Dam sedimentation

For the water resources management in the Brantas river basin, it is important to clarify the effect of volcano-crust for the river.

The purpose of this study

- To clarify the effect of Volcanic activities on sediment conditions in Brantas Rivers
- Authors carried out numerical analysis applied to Kelut volcano eruption on 1990.

Volcanic Activities of Kelud Volcano

> Kelud volcano (1,731m height) is one of the high level active volcano located in Java Island.

> It has 4 eruptions records since 1919.

> Almost all of the scale of eruptions were VEI 3

> In each event, following phenomenon also occurred:

1) Lahar due to Phreatic explosion.
2) Plinian with pylocrastic flow
3) Lahar due to the breach of crater lake

Table : scale of eruption of Mt. Kelud since 1919.

Year	Volume(10^6 m^3)	Number of deaths
1919	323	5110
1951	190	7
1966	90	283
1990	125	35

The latest eruption of active volcano ,Kelud

Jawa Pos , 21st of Nov. 2007

Jawa Pos , 5th of Nov. 2007

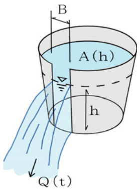
Numerical simulation carried out in this study

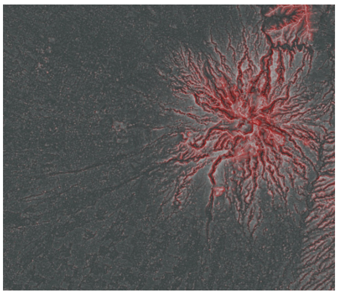
Considering the types of Kelud volcano eruption, we carried out following simulations to Kelut volcano eruption on 1990.

> Lahar due to crater wall collapsed type simulaiton(2-D analysis)
> Pyroclastic flow simiulation(2-D analysis)
> Pumice fall distribution calculation(1-D analysis)

Simulation model for lahar

This calculation assumes that crater wall collapse triggering lahars.





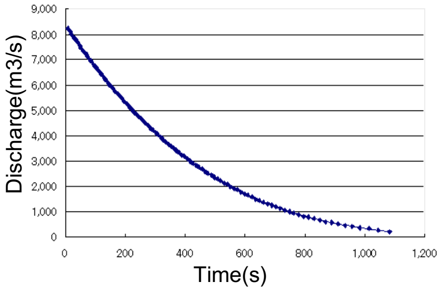
Red relief map around crater of Kelut volcano

Input of Hydrograph

We calculate the hydrograph according to the volume of crater lake on 1990 eruption.

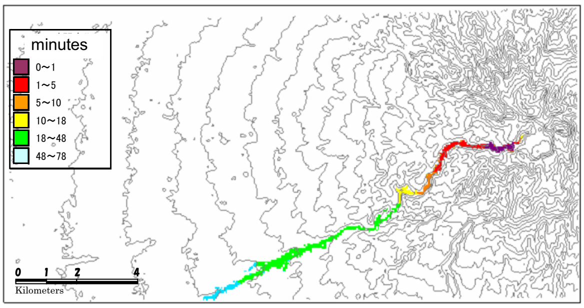
Total discharge of Water is about 4,000,000 m3

Sediment supplied by M.P.M formula

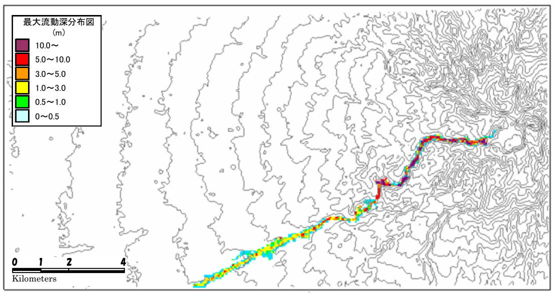


Relationship between time and discharge

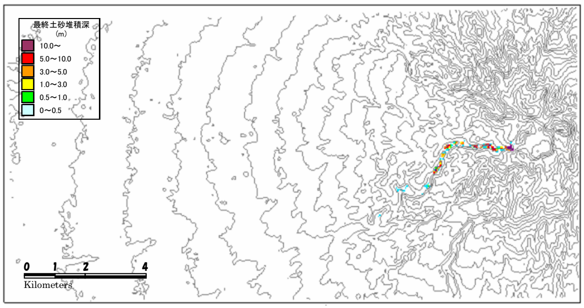
Results of lahar calculation



Arrival time distribution of Lahar



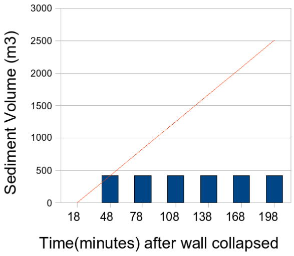
Distribution of depth of the flow



Distribution of sediment depth after lahar flow down

This figure shows sediment volume inflows into Brantas River within about 3 hours.

So the more time going, the more volume flows into Brantas River.



According to these figures, almost all of water and sediment from crater lake flows into Brantas River Basin. Total volume of water is about 4 million m3 in this case.

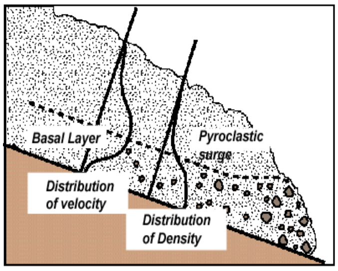
So, Lahar has serious effect on the conditions of Brantas River.

Simulation model for pyroclastic flow

Pyroclastic flow divided to two layers; Surge and main body.

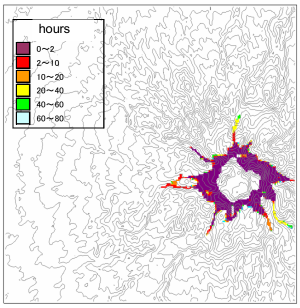
Main body is dragged to surge. So, it is important to know the behavior of main body.

We followed Yamashita & Miyamoto(1991)'s model in which the main body behavior is treated as the dry particle flow.

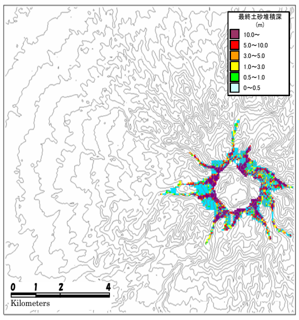


Schematic model of a pyroclastic flow

Result of calculation of pyroclastic flow



Distribution of arrival time of pyroclastic flow



Distribution of pyroclastic thickness of deposition

This results show Pyroclastic flow doesn't have serious effect on Brantas River in short term.

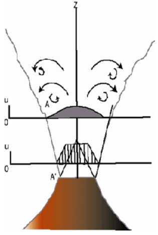
But pyroclastic flow supplies hillside area with a lot of unstable sediments.

So, In the long term, it becomes high potential to make debris flow or lahar generate as the secondary disasters.

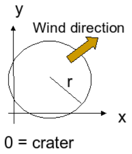
Numerical analysis model of pumice fall distribution

It is difficult to model behavior of pumice fall precisely, because pumice fall has complex factors to simulate.

We use the geometrical model following Miyamoto(1993).

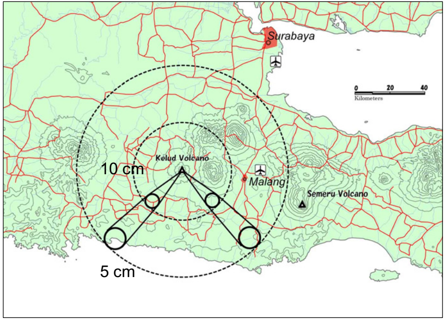


Schematic model of volcanic plume



Distribution of pumice fall is calculated by hight of plumes and wind direction.

Result of calculation of pumice fall distribution

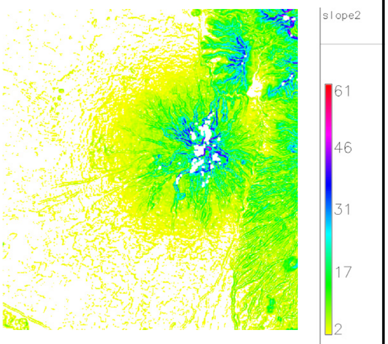


Distribution of pumice fall is determined by wind direction.
In Brantas River Basin, everywhere is possible to damage by pumice fall.

A lot of pumice fall does not directly fall in the Brantas River.

But After the heavy rainfall, pumice fall is possible to flow down, changing forms to concentrated flow.

Because gradient of hillside over a wide range on Kelud volcano is greater than 2 degree.



Distribution of gradient more than 2 degree about Keludvolcano

Summary and conclusion

- Lahar reach the main river course.
  Lahar is possible to make severe impact on the sediment conditions in Brantas river basin.

- Pyroclastic flow does not reach the main course.
  However unstable sediment on the mountain slope is increased, so that the sediment yield will be increased.

- Pumice fall reach the main river course. But in short term the effect on changing sediment condition in Brantas River Basin is not so large.
  But pumice fall yields unstable sediments in Brantas River Basin.

Summary and conclusion

- We can recognize the impact of eruptions on the river is not so big in short term.

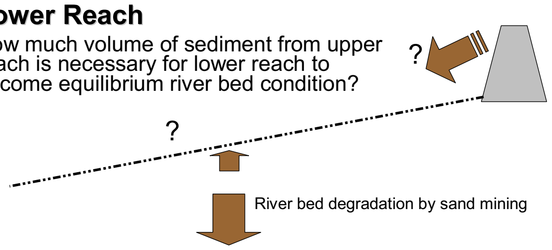
- But it is considered the potential of sediment movement is increased after eruptions.

- Because these sediment is easy to move if heavy rain falls.

Future studies of our plan

Lower Reach

How much volume of sediment from upper reach is necessary for lower reach to become equilibrium river bed condition?



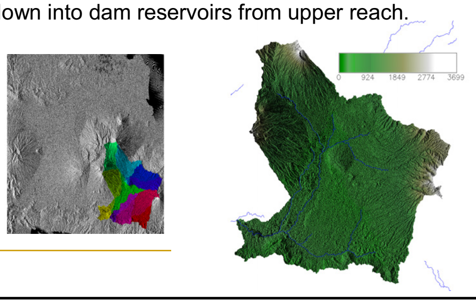
We have plans to execute simulation of the river bed variation;
case 1) in normal condition.
case 2) in volcanic activities took place.

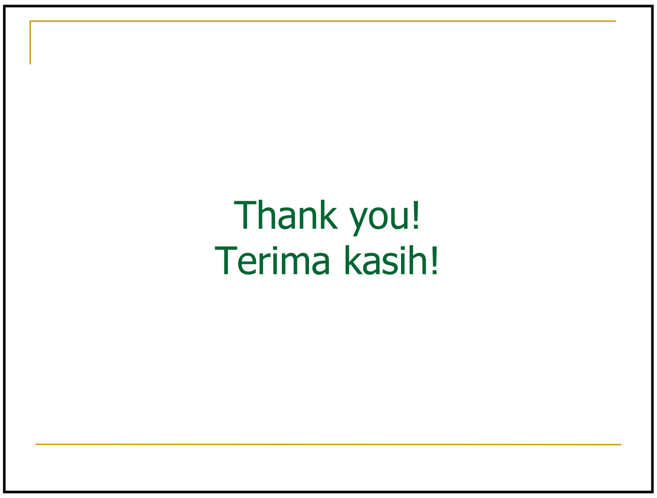
-> results of this presentation is preliminary studies for case 2)

Upper Reach

After the execution of the previous simulation, We estimate how much volume of sediment is necessary for lower reach.

Then we can consider how much volume is allowed to flow down into dam reservoirs from upper reach.





Thank you!
Terima kasih!

A Bed-Porosity Variation Model

- as a tool for integrated sediment management-

Prof. Masaharu Fujita

DPRI, Kyoto University

A Bed-Porosity Variation Model

- As a tool for integrated sediment management -

Masaharu FUJITA[1], Muhammad Sulaiman[2] and Daizo Tsutsumi[1]
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Keywords: bed variation, porosity, grain size distribution, sediment management, Talbot distribution,

As the void of bed material plays an important role in fluvial geomorphology, infiltration system in riverbeds and river ecosystem, a structural change of the void with bed variation is one of the concerned issues in river management as well as bed variation. Thus, a bed-porosity variation model is strongly required and it is expected that such a model contributes the analysis of those problems as a tool for integrated sediment management.

A flow chart of the presented numerical simulation of bed and porosity variation is shown in **Fig.1**. As the porosity is one of the variables in this model, we must solve the following equation as a continuity equation of sediment.

$$\frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)dz+\frac{1}{B}\frac{\partial Q_s}{\partial x}=0 \tag{1}$$

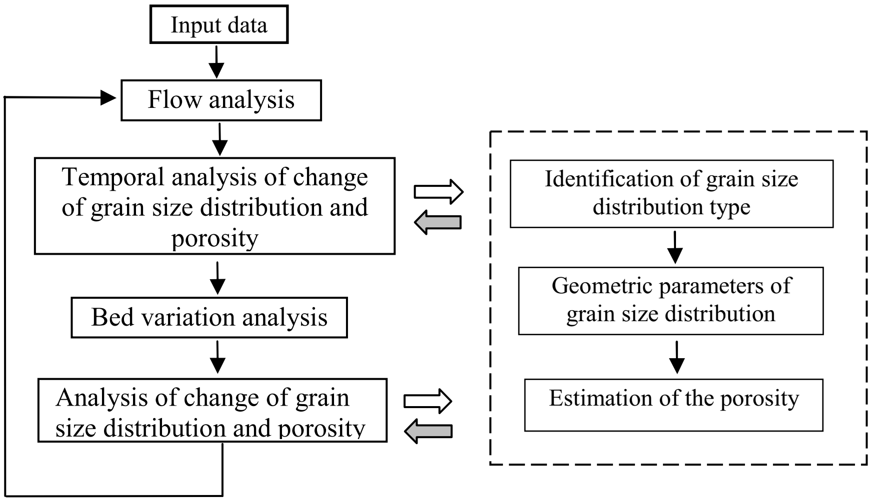


Fig. 1 Flow chart of the presented bed-porosity variation model

where λ = porosity of bed material, z = bed level, z_o = a reference level, Q_s = sediment discharge and B=channel width.

Porosity is dependent on the grain size distribution of bed material and its compaction degree. In this paper, the compaction degree is considered empirically and the porosity is assumed to be a function of geometric parameters of grain size distribution.

$$\lambda = f_n\left(\Pi_1, \Pi_2, \Pi_3, ...\right) \qquad (2)$$

where Π_1, Π_2, Π_3….= geometric parameters of grain size distribution.

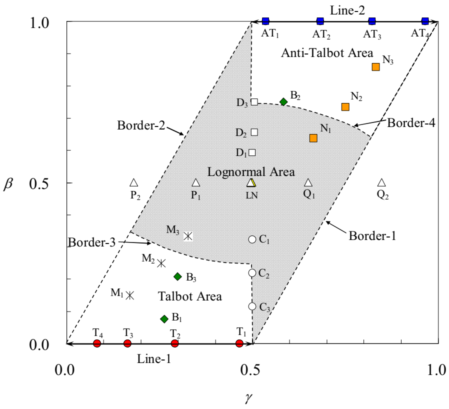


Fig.2 Diagram indicating Talbot, anti-Talbot and lognormal region

As we assume that the porosity is not constant depending only on the grain size distribution, the time differential term on porosity can not be neglected in Eq.(1). According to the previous exchange model between bed material and transported sediment such as Hirano's model, the change of grain size distribution in a time interval cannot be obtained without the change in bed elevation in the time interval. This means that Eq.(1) is an explicit equation. For this problem, we obtain temporally the change in the grain size distribution in the original mixing layer and then calculate the change in bed elevation using the temporal grain size distribution as shown in **Fig.1**.

There are some types of grain size distribution such as lognormal distribution and Talbot distribution. Therefore, we need a method for identifying the distribution type and obtaining the relation between the geometric parameters and the porosity for each type. For example, lognormal distribution has a parameter of Π_1=σ and Talbot distribution has two parameters of Π_1=d_{max}/d_{min}, Π_2=n_t, where σ=standard deviation of ln$d$, d_{max}=maximum grain size, d_{min}=minimum grain size and n_t=Talbot number.

A type of grain size distribution can be identified visually by the shape of grain size distribution and the probability density distribution. However, this visual identification method is not available for riverbed variation models. Thus, Sulaiman *et al.* (2007a) have introduced the geometric indices β and γ to identify the distribution type. The indices β and γ are defined as Eq.(3) and Eq.(4) respectively, designating the relative locations of the grain size d_{peak} for the peak probability density and the median grain size d_{50} between the minimum size d_{min} and the maximum size d_{max}.

$$\beta = \frac{\log d_{\text{max}} - \log d_{\text{peak}}}{\log d_{\text{max}} - \log d_{\text{min}}} \qquad (3) \qquad\qquad \gamma = \frac{\log d_{\text{max}} - \log d_{50}}{\log d_{\text{max}} - \log d_{\text{min}}} \qquad (4)$$

The indices of Talbot and anti-Talbot distributions are on Line-1 (β=0 and 0<γ<0.5) and Line-2 (β=1.0 and 0.5<γ<1.0) in **Fig.2**. The indices of lognormal distribution are plotted just on the center point (0.5, 0.5). The indices of the other distribution are plotted on the area of 0<β<1 and 0<γ<1, apart from Line-1, Line-2 and the center point. However, there is an area where no unimodal distribution exists. From a geometric analysis, an area where unimodal distribution exists is surrounded by Border-1, Border-2, β=0 and β=1.0 as shown in **Fig.2**.

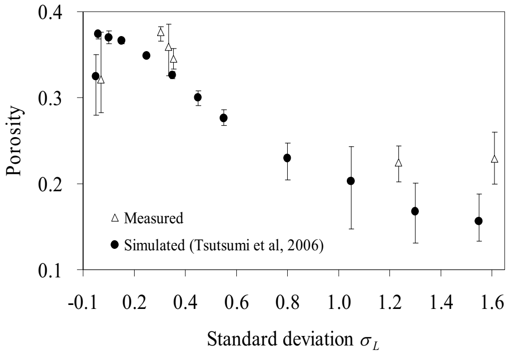


Fig. 3 Comparison between the measured porosity and the simulated one for lognormal distribution

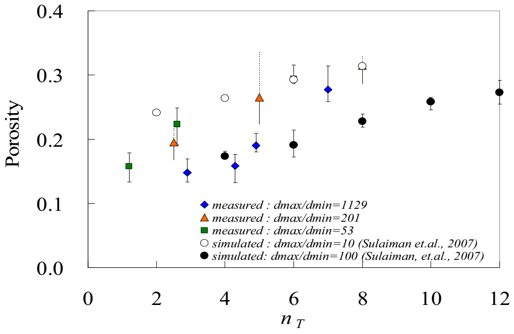


Fig.4 Comparison between the measured porosity and the simulated one for Talbot distribution

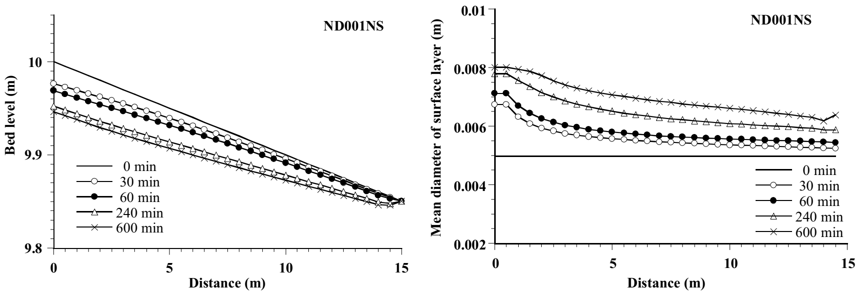
It seems reasonable that the grain size distribution type is identified with the distance to the point (γ, β) from Line-1, Line-2 or the center point. According to this criterion, the border line between Talbot distribution and lognormal distribution (Border-3) is written as Eq.(5) and the border line between anti-Talbot and lognormal distribution (Border-4) is expressed as Eq.(6). **Fig.2** shows the domain for lognormal, Talbot and anti-Talbot distributions.

Border-3: $\beta = (0.5-\gamma)^2 + 0.25$ (5) Border-4: $\beta = -(0.5-\gamma)^2 + 0.75$ (6)

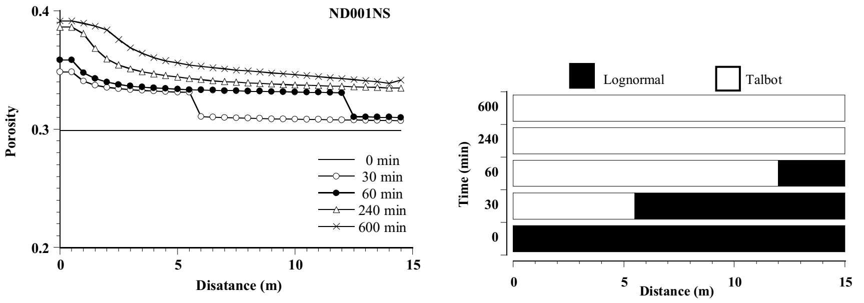
The porosity of various kind of grain size distribution can be obtained by means of a packing simulation model and an experimental method. As a result, the relation between the geometric parameter and the porosity is obtained as shown in **Fig.3** and **Fig.4** for lognormal distribution and Talbot distribution, respectively.

The presented bed-porosity variation model was applied to the bed variation on a channel with a length of 15m and a width of 0.5m. The initial channel slope is 0.01. The end of the channel is fixed. The initial bed material has a lognormal type of grain size distribution ranging from 0.1mm to 10mm. The water is supplied at a rate of 0.02m^3/s and no sediment is supplied. Under this condition, the maximum grain could not be transported. **Fig.5** (a), (b), (c) and (d) show the bed variation, the time and longitudinal variations of the mean grain size of surface layer and the porosity and the change in grain size distribution type. No sediment supply causes the bed degradation and the increase in porosity and mean grain size of the surface layer. Finally, the bed material had a Talbot type of grain size distribution.

The validity of this model has not been verified yet, but it is believed that this model has a good performance for the analysis of bed and porosity variation. It could be applied for the problems on bed variation and ecosystem in the downstream of dam.



(a) Bed variation (b) Mean diameter of surface layer



(c) Porosity of surface layer (d) Type of grain size distribution

Fig.5 Simulation result on bed and porosity variation

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[2] Tsutsumi, D., Fujita, M., and Sulaiman, M. (2006): Changes in the void ratio and void structure of riverbed material with particle size distribution. *River, Coastal and Estuarine Morphodynamics*, Vol. 2, Parker, G., Garcia, M.H., eds., Taylor & Francis, pp. 1059-1065.

A Bed-Porosity Variation Model

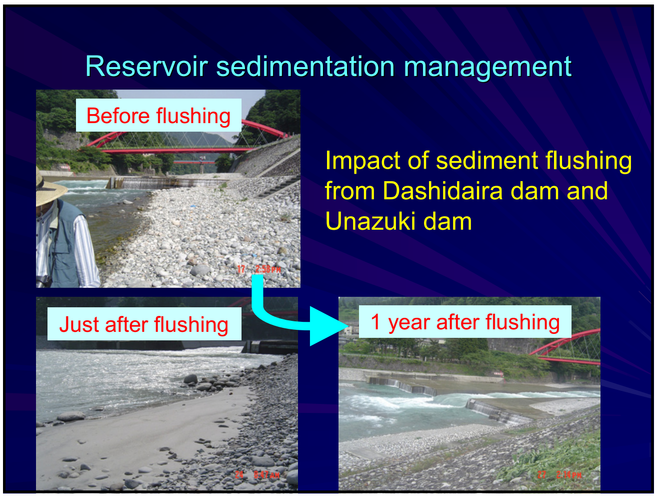
- as a tool for integrated sediment management-

Dr. Masaharu Fujita
Mr. Muhammad Sulaiman
Dr. Daizo Tsutsumi

DPRI, Kyoto University

Background

- **Targets of sediment management**
  - Disaster prevention
  - Reduction of bad influence of sediment on rivers
  - Effective utilization of sediment resources
  - Environment conservation
- **Tools**
  - Software …… bed variation models
  - Hardware ….. sabo dams, sediment flush gates, sediment bypass tunnel
- **Ecological aspects**
  - Habitat conservation
  - Disturbance to riverbeds
  - Void of bed material



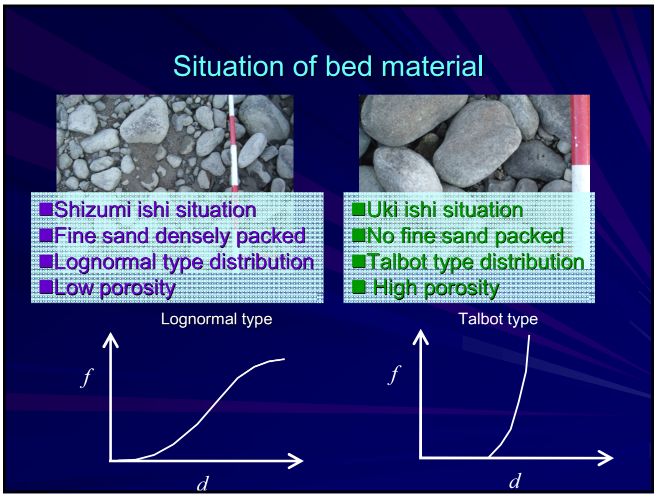
Reservoir sedimentation management

Before flushing

Impact of sediment flushing from Dashidaira dam and Unazuki dam

Just after flushing

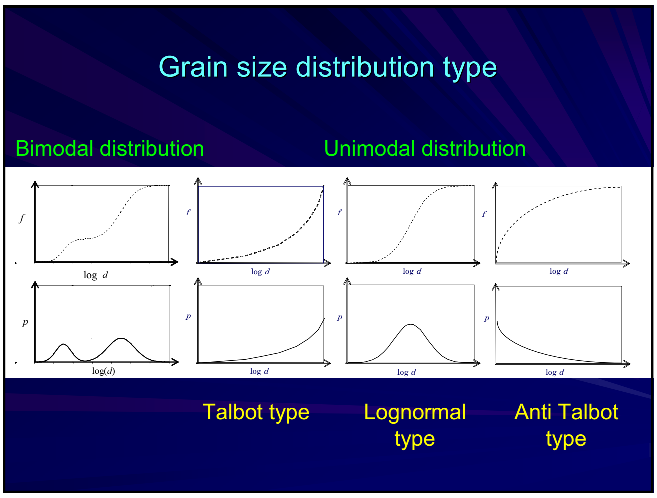
1 year after flushing



Situation of bed material

- Shizumi ishi situation
- Fine sand densely packed
- Lognormal type distribution
- Low porosity

- Uki ishi situation
- No fine sand packed
- Talbot type distribution
- High porosity



Grain size distribution type

Bimodal distribution

Unimodal distribution

Talbot type

Lognormal type

Anti Talbot type

Void of bed material

- **Porosity**
  - Bed variation
  - Infiltration system in riverbeds
- **Spaces among particles**
  - Habitat

A bed variation model providing the information on the changes in porosity and grain size distribution type of bed material

Basic equations

Continuity equation of water $\frac{\partial Bh}{\partial t}+\frac{\partial Q}{\partial x}=0$

Energy equation for flows $\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{1}{2}gBh^2+\frac{Q^2}{Bh}\right)=gBh\left(i_b-i_f\right)$

Continuity equation of sediment $\frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)dz+\frac{1}{B}\frac{\partial Q_s}{\partial x}=0$

Continuity equation of sediment with grain size d_j $\frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)p_j dz+\frac{1}{B}\frac{\partial Q_{sj}}{\partial x}=0$

B = channel width, h = water depth, Q = water discharge, t = time, x = distance in stream wise direction, λ = porosity of bed material, z = bed level, z_o = a reference level, Q_s = sediment discharge, g = gravity acceleration, i_b = bed slope, i_f = friction slope, j = grain size grade, p_j = mixing ratio of a grade j in bed material and Q_{sj} = sediment discharge of a grain size grade j

Previous bed variation model

λ=constant

Continuity equation of sediment

$$\frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)dz+\frac{1}{B}\frac{\partial Q_s}{\partial x}=0 \Rightarrow (1-\lambda)\frac{\partial z}{\partial t}+\frac{\partial q_S}{\partial x}=0$$

Continuity equation of sediment with grain size d_j

$$\frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)p_j dz+\frac{1}{B}\frac{\partial Q_{sj}}{\partial x}=0 \Rightarrow$$

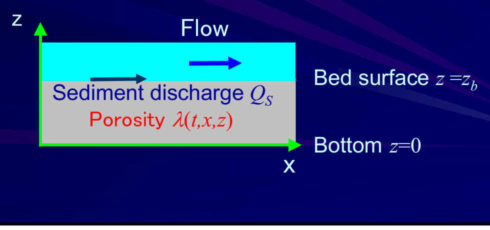
$$\left(\partial z/\partial t<0\right) \quad \frac{\partial f_j}{\partial t}=\frac{-1}{(1-\lambda)aB_s}\frac{\partial B_s q_{Sj}}{\partial x}-\frac{f_{j0}}{a}\frac{\partial z}{\partial t}$$

$$\left(\partial z/\partial t\geq 0\right) \quad \frac{\partial f_j}{\partial t}=\frac{-1}{(1-\lambda)aB_s}\frac{\partial B_s q_{Sj}}{\partial x}-\frac{f_j}{a}\frac{\partial z}{\partial t}$$

A proposed model

$\lambda\neq$constant

$$\frac{\partial}{\partial t}\left\{\int_0^{zb}(1-\lambda)dz\right\}+\frac{1}{B}\frac{\partial Q_S}{\partial x}=0 \qquad \frac{\partial}{\partial t}\int_{z_o}^{z}(1-\lambda)p_j dz+\frac{1}{B}\frac{\partial Q_{sj}}{\partial x}=0$$



Porosity estimation

- ■ Compaction degree
- ■ Grain size distribution

$$\lambda=f_n\left(\Pi_1,\Pi_2,\Pi_3,\ldots\ldots.\right)$$

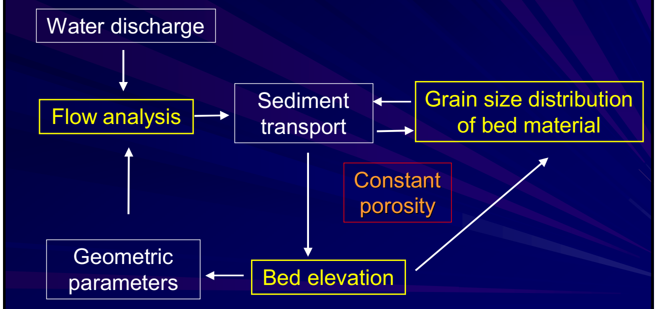
Π_1, Π_2, Π_3….= characteristic parameters of grain size distribution

Lognormal distribution: $\Pi_1=\sigma$

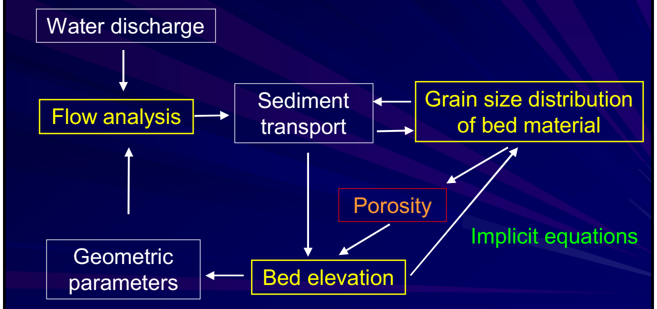
Talbot distribution: $\Pi_1=d_{\max}/d_{\min}$ $\Pi_2=n_T$

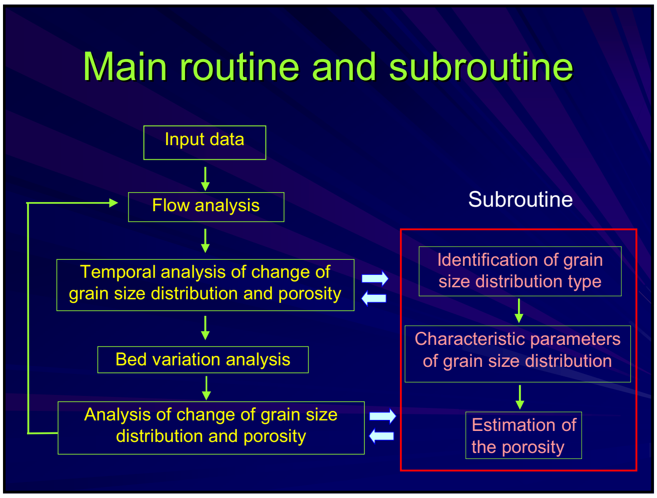
Particle packing simulation and measurement method

A bed variation model



A bed-porosity variation model





Main routine and subroutine

Input data

Flow analysis

Temporal analysis of change of grain size distribution and porosity

Bed variation analysis

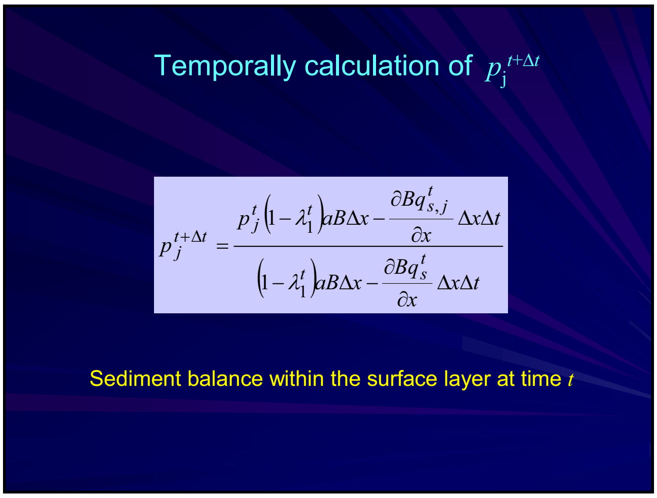
Analysis of change of grain size distribution and porosity

Subroutine

Identification of grain size distribution type

Characteristic parameters of grain size distribution

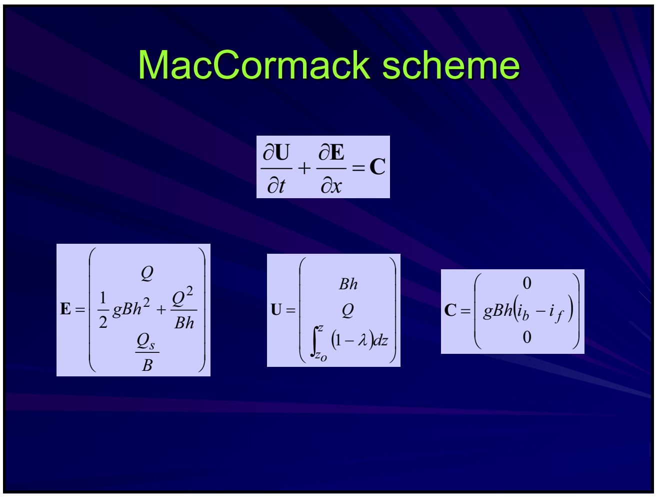
Estimation of the porosity



Temporally calculation of $p_{\mathrm{j}}^{t+\Delta t}$

$$p_j^{t+\Delta t} = \frac{p_j^t\left(1-\lambda_1^t\right)aB\Delta x - \dfrac{\partial Bq_{s,j}^t}{\partial x}\Delta x\Delta t}{\left(1-\lambda_1^t\right)aB\Delta x - \dfrac{\partial Bq_s^t}{\partial x}\Delta x\Delta t}$$

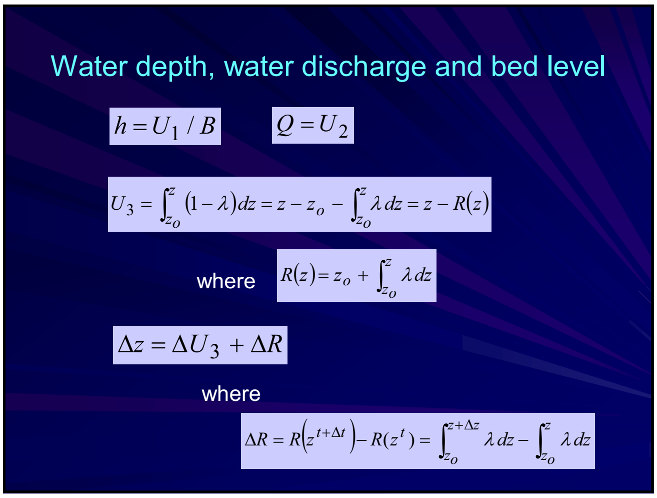
Sediment balance within the surface layer at time t



MacCormack scheme

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{E}}{\partial x} = \mathbf{C}$$

$$\mathbf{E} = \begin{pmatrix} Q \\ \frac{1}{2}gBh^2 + \frac{Q^2}{Bh} \\ \frac{Q_s}{B} \end{pmatrix} \qquad \mathbf{U} = \begin{pmatrix} Bh \\ Q \\ \int_{z_o}^{z}(1-\lambda)dz \end{pmatrix} \qquad \mathbf{C} = \begin{pmatrix} 0 \\ gBh\left(i_b - i_f\right) \\ 0 \end{pmatrix}$$



Water depth, water discharge and bed level

$$h = U_1 / B \qquad Q = U_2$$

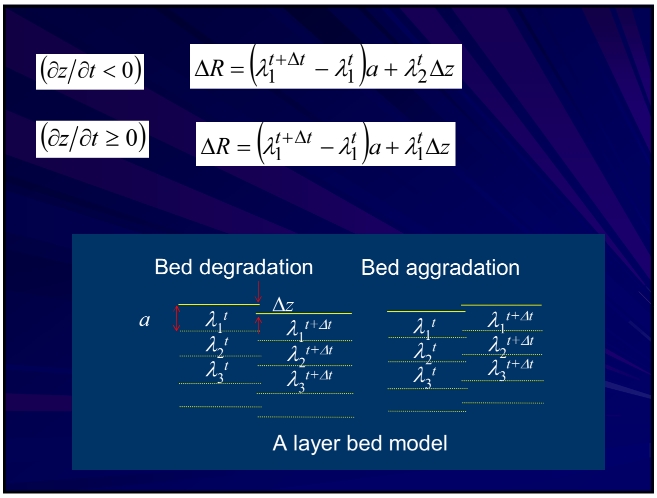
$$U_3 = \int_{z_o}^{z}(1-\lambda)dz = z - z_o - \int_{z_o}^{z}\lambda\, dz = z - R(z)$$

where $R(z) = z_o + \int_{z_o}^{z}\lambda\, dz$

$$\Delta z = \Delta U_3 + \Delta R$$

where

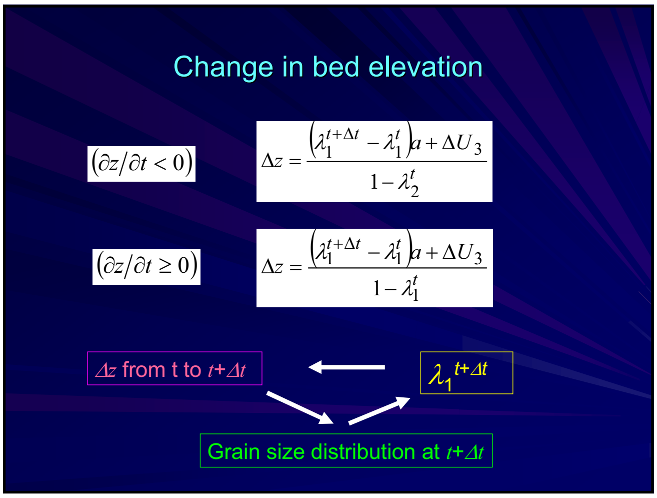
$$\Delta R = R\left(z^{t+\Delta t}\right) - R(z^t) = \int_{z_o}^{z+\Delta z}\lambda\, dz - \int_{z_o}^{z}\lambda\, dz$$



$(\partial z/\partial t < 0)$ $\quad \Delta R = \left(\lambda_1^{t+\Delta t} - \lambda_1^t\right)a + \lambda_2^t \Delta z$

$(\partial z/\partial t \geq 0)$ $\quad \Delta R = \left(\lambda_1^{t+\Delta t} - \lambda_1^t\right)a + \lambda_1^t \Delta z$

A layer bed model



Change in bed elevation

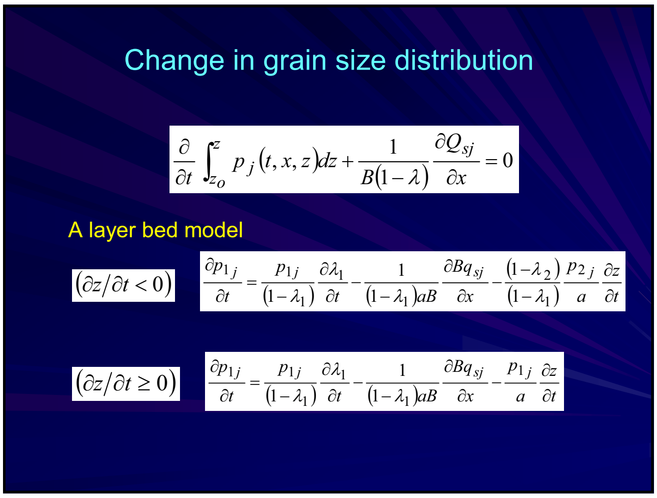
$(\partial z/\partial t < 0)$ $\quad \Delta z = \dfrac{\left(\lambda_1^{t+\Delta t} - \lambda_1^t\right)a + \Delta U_3}{1-\lambda_2^t}$

$(\partial z/\partial t \geq 0)$ $\quad \Delta z = \dfrac{\left(\lambda_1^{t+\Delta t} - \lambda_1^t\right)a + \Delta U_3}{1-\lambda_1^t}$

Δz from t to $t+\Delta t$

$\lambda_1^{t+\Delta t}$

Grain size distribution at $t+\Delta t$



Change in grain size distribution

$$\frac{\partial}{\partial t}\int_{z_o}^{z} p_j(t,x,z)dz + \frac{1}{B(1-\lambda)}\frac{\partial Q_{sj}}{\partial x} = 0$$

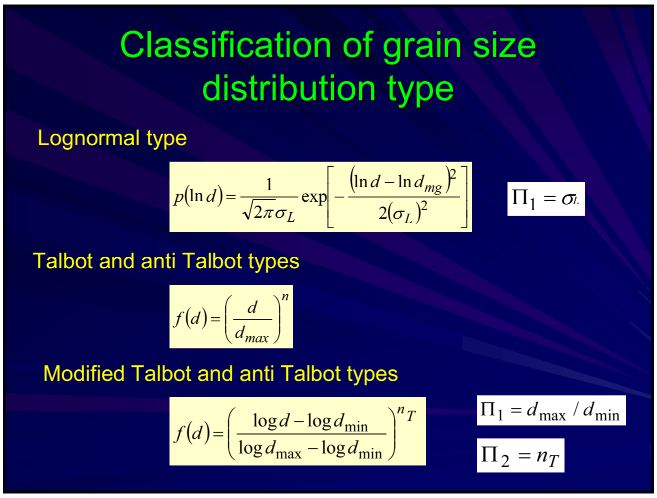
A layer bed model

$(\partial z/\partial t < 0)$

$$\frac{\partial p_{1j}}{\partial t} = \frac{p_{1j}}{(1-\lambda_1)}\frac{\partial \lambda_1}{\partial t} - \frac{1}{(1-\lambda_1)aB}\frac{\partial Bq_{sj}}{\partial x} - \frac{(1-\lambda_2)}{(1-\lambda_1)}\frac{p_{2j}}{a}\frac{\partial z}{\partial t}$$

$(\partial z/\partial t \geq 0)$

$$\frac{\partial p_{1j}}{\partial t} = \frac{p_{1j}}{(1-\lambda_1)}\frac{\partial \lambda_1}{\partial t} - \frac{1}{(1-\lambda_1)aB}\frac{\partial Bq_{sj}}{\partial x} - \frac{p_{1j}}{a}\frac{\partial z}{\partial t}$$



Classification of grain size distribution type

Lognormal type

$$p(\ln d) = \frac{1}{\sqrt{2\pi}\sigma_L}\exp\left[-\frac{(\ln d - \ln d_{mg})^2}{2(\sigma_L)^2}\right]$$

$\Pi_1 = \sigma_L$

Talbot and anti Talbot types

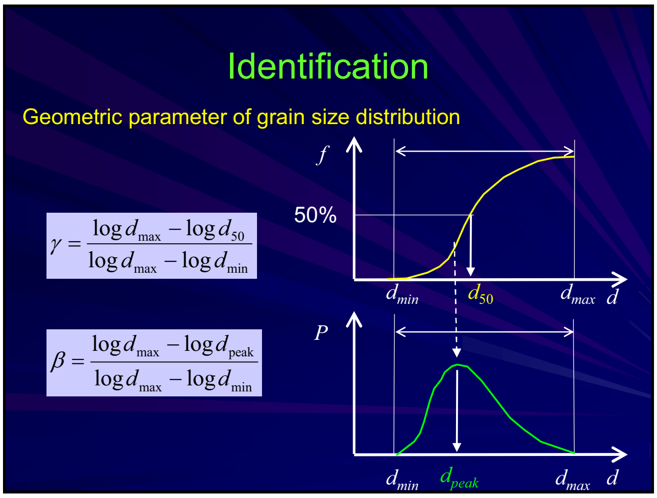
$$f(d) = \left(\frac{d}{d_{max}}\right)^n$$

Modified Talbot and anti Talbot types

$$f(d) = \left(\frac{\log d - \log d_{\min}}{\log d_{\max} - \log d_{\min}}\right)^{n_T}$$

$\Pi_1 = d_{\max} / d_{\min}$

$\Pi_2 = n_T$

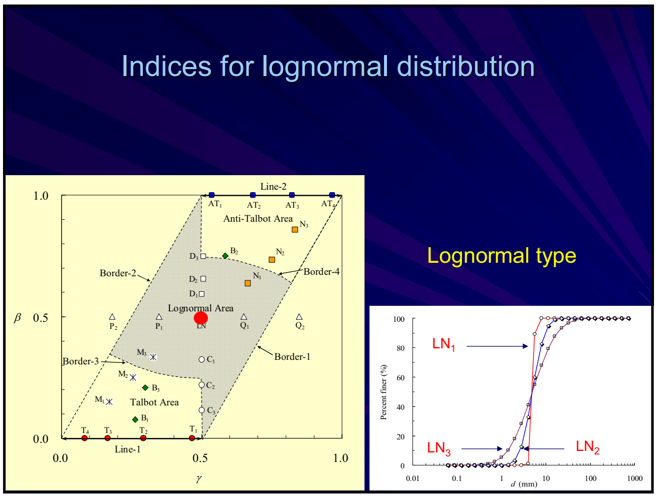


Identification

Geometric parameter of grain size distribution

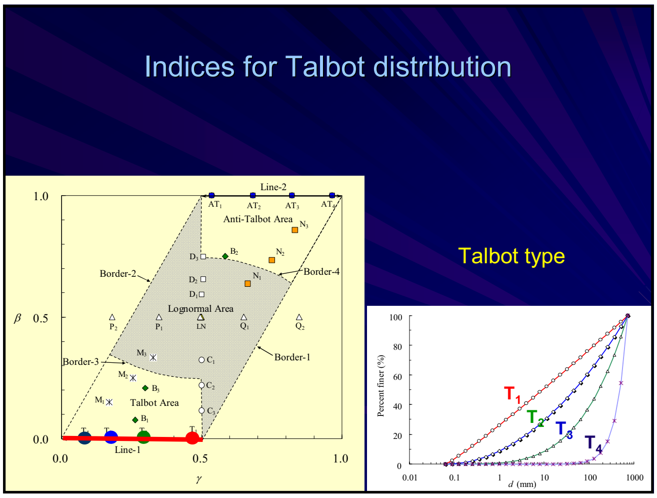
$$\gamma = \frac{\log d_{\max} - \log d_{50}}{\log d_{\max} - \log d_{\min}}$$

$$\beta = \frac{\log d_{\max} - \log d_{\text{peak}}}{\log d_{\max} - \log d_{\min}}$$



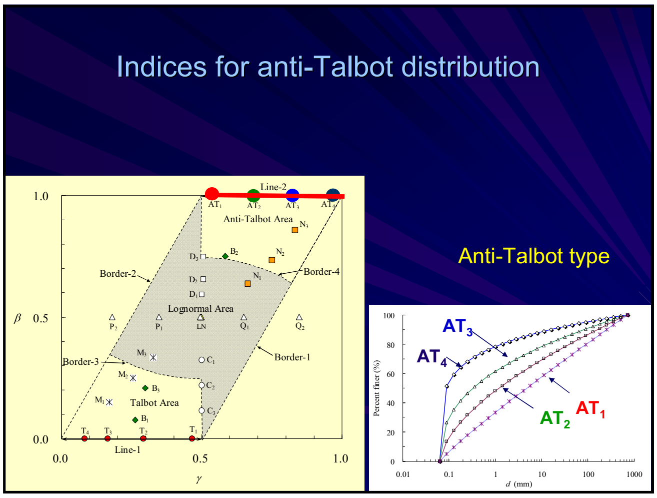
Indices for lognormal distribution

Lognormal type



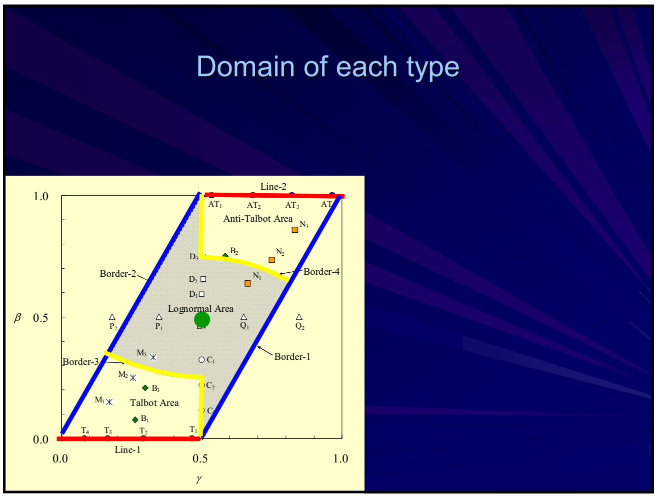
Indices for Talbot distribution

Talbot type

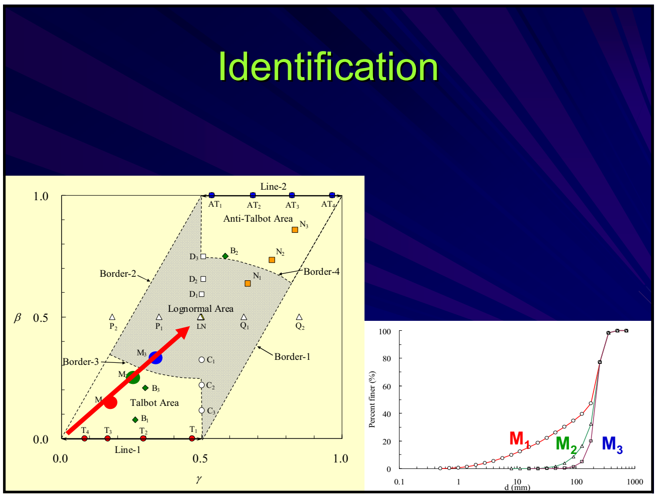


Indices for anti-Talbot distribution

Anti-Talbot type



Domain of each type



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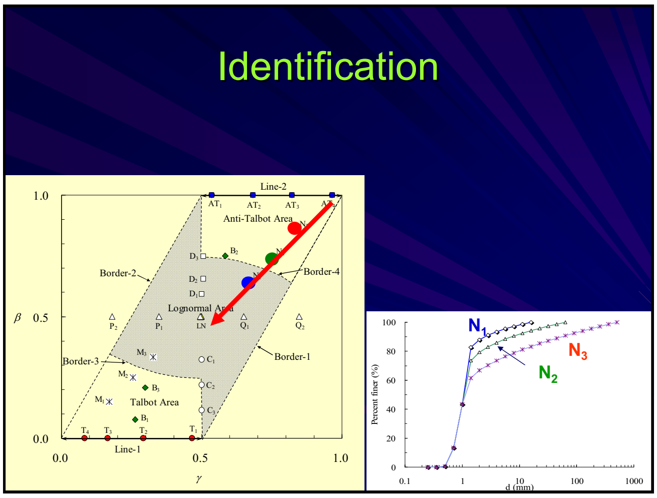

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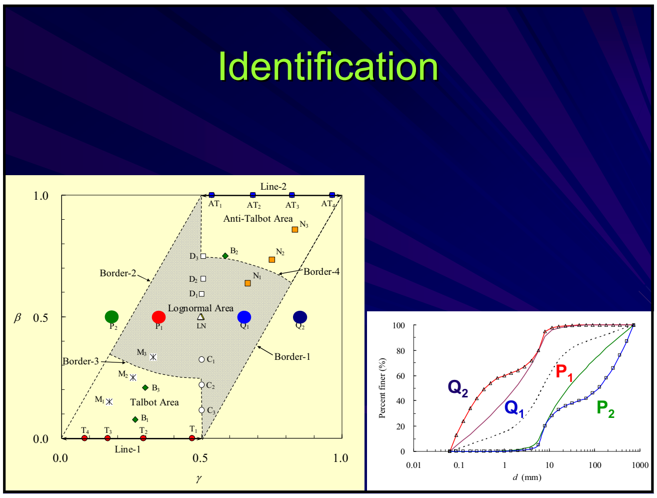

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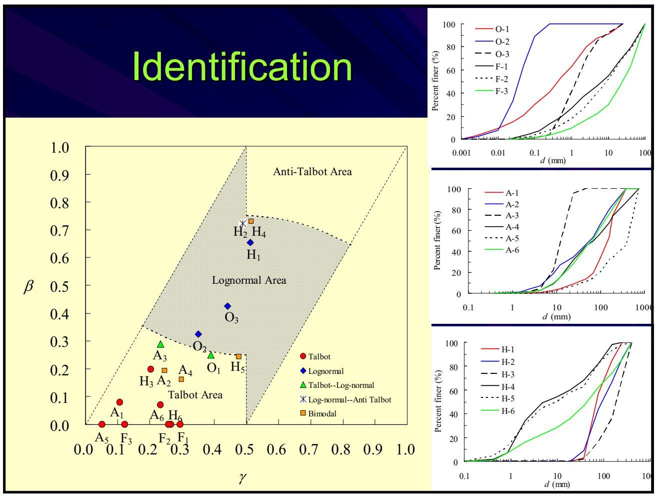

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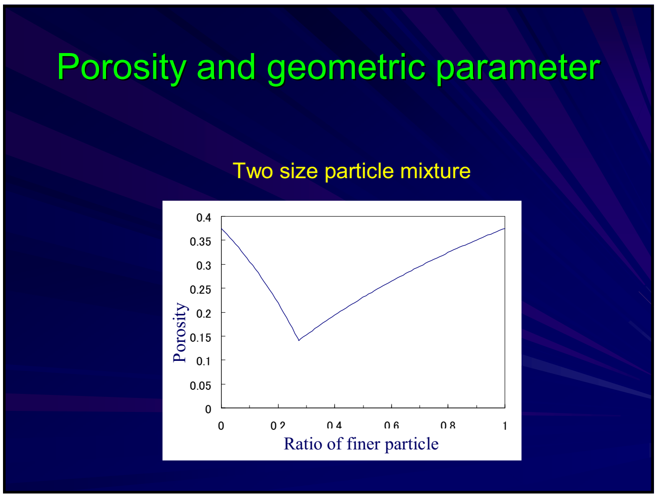
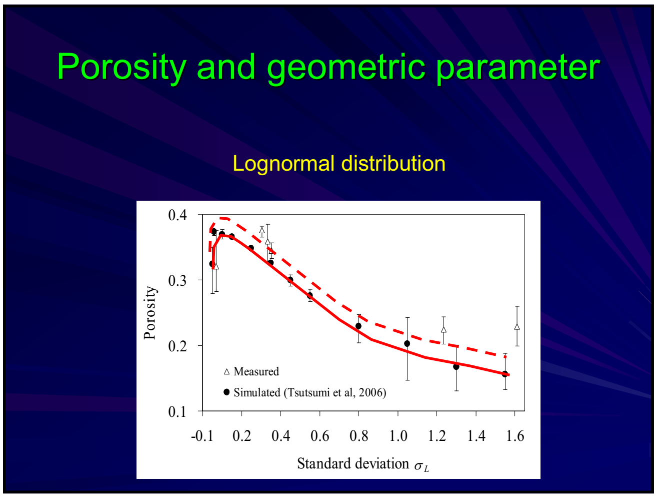


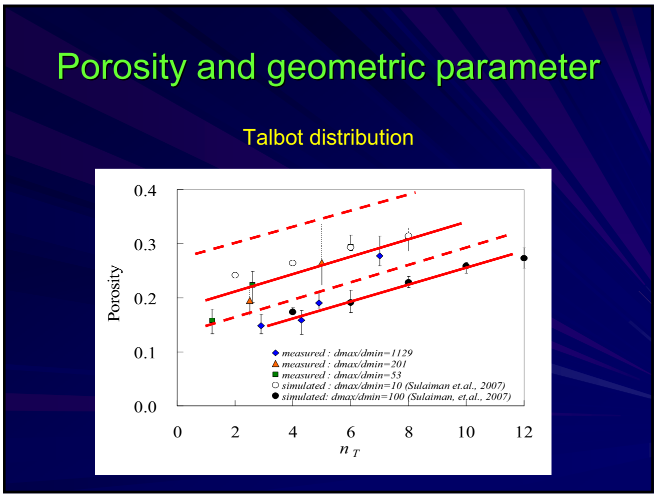
Porosity and geometric parameter

Two size particle mixture



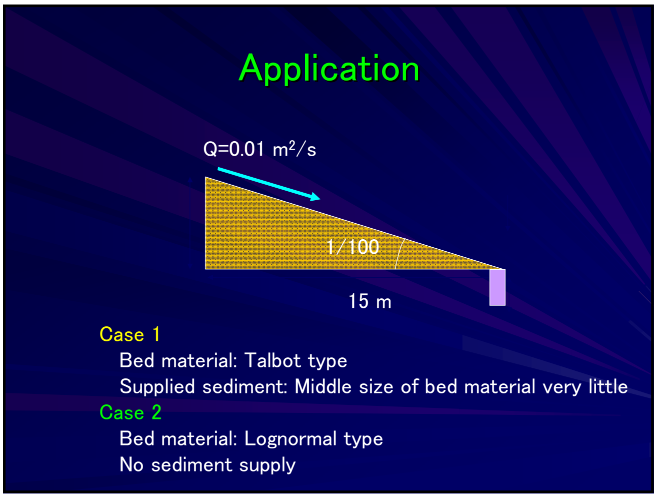
Porosity and geometric parameter

Lognormal distribution



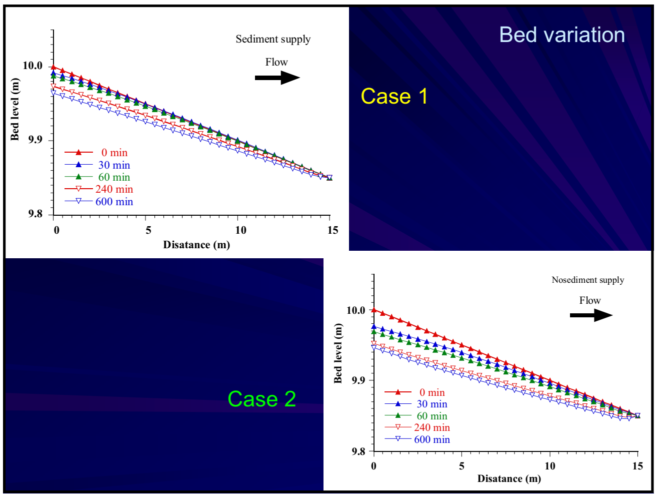
Porosity and geometric parameter

Talbot distribution



Application

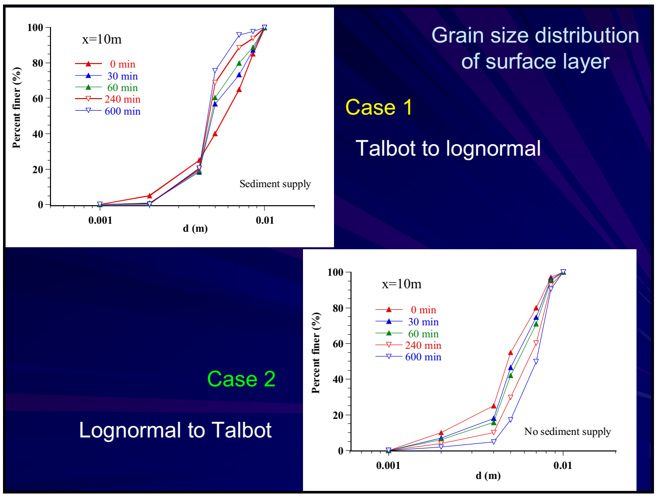
Case 1
Bed material: Talbot type
Supplied sediment: Middle size of bed material very little
Case 2
Bed material: Lognormal type
No sediment supply



Bed variation

Case 1

Case 2



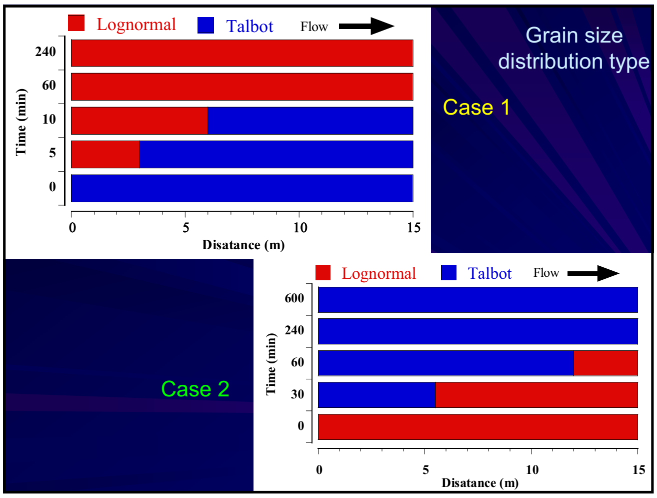
Grain size distribution of surface layer

Case 1

Talbot to lognormal

Case 2

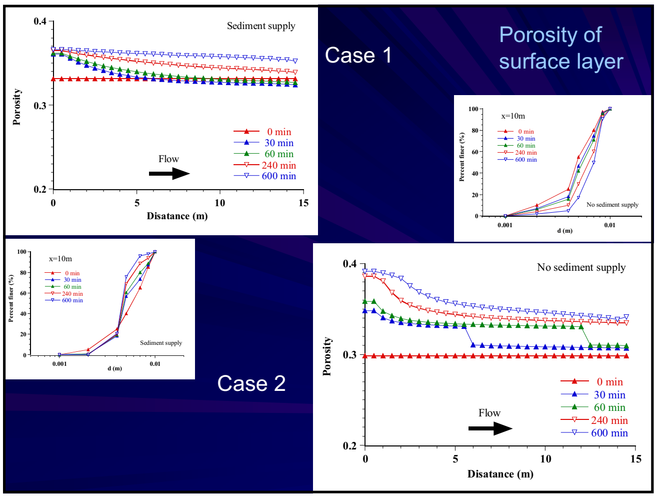
Lognormal to Talbot



Grain size distribution type

Case 1

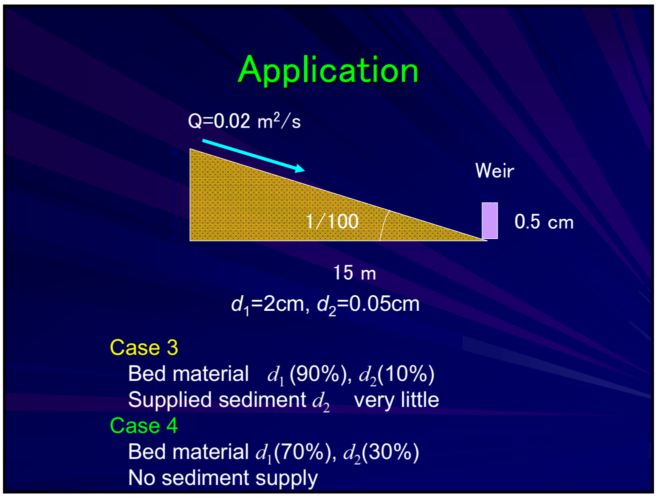
Case 2



Porosity of surface layer

Case 1

Case 2



Application

d_1=2cm, d_2=0.05cm

Case 3

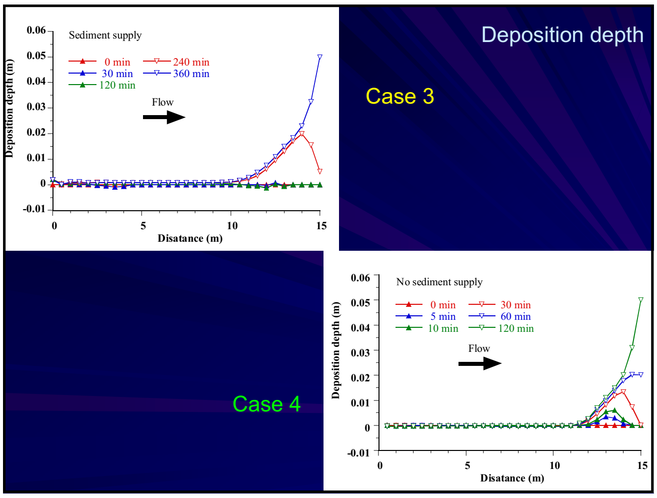
Bed material d_1 (90%), d_2(10%)

Supplied sediment d_2 very little

Case 4

Bed material d_1(70%), d_2(30%)

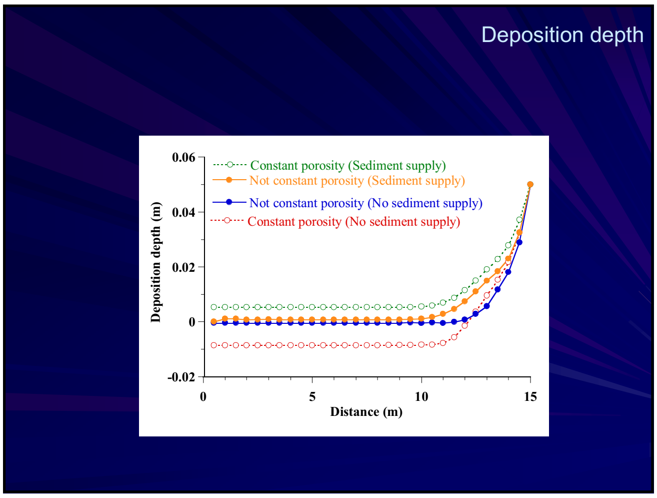
No sediment supply



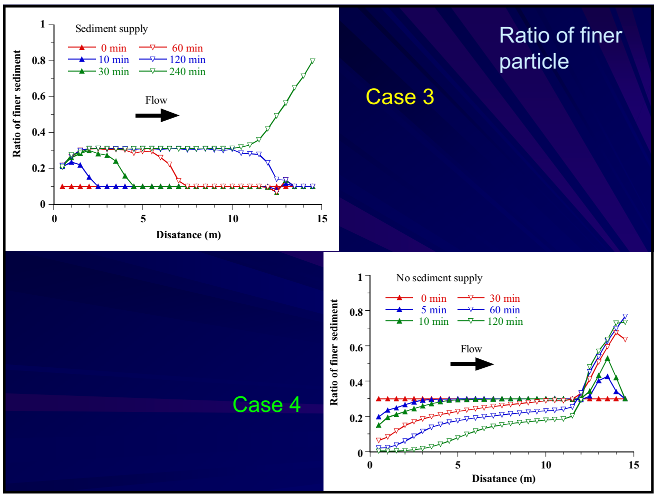
Deposition depth

Case 3

Case 4



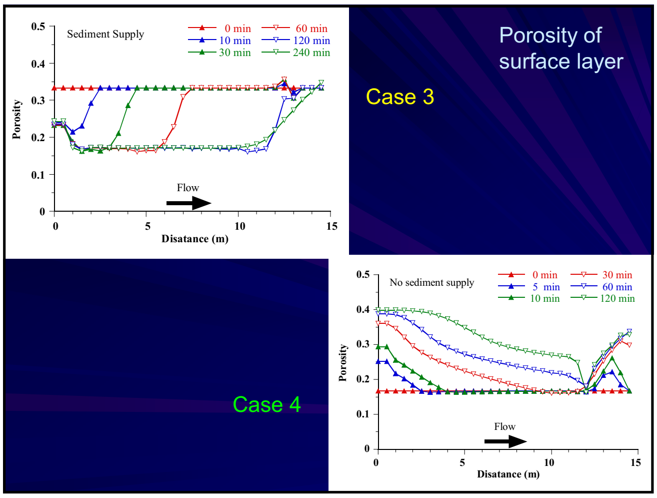
Deposition depth



Ratio of finer particle

Case 3

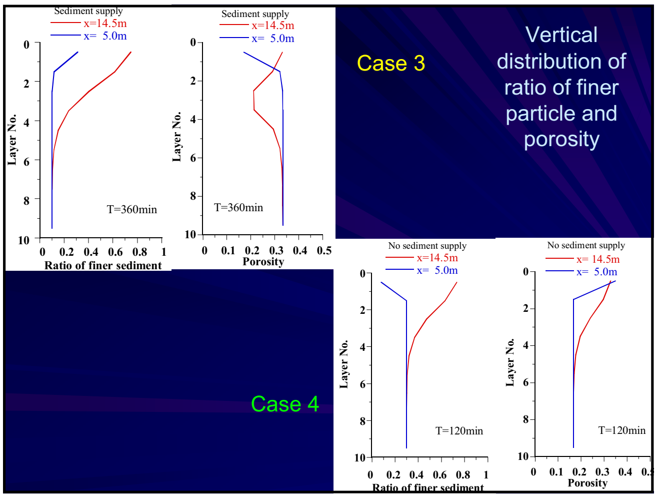
Case 4



Porosity of surface layer

Case 3

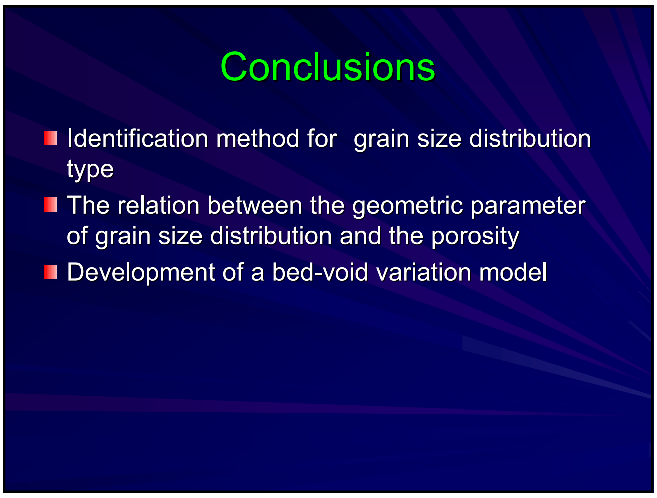
Case 4



Case 3

Vertical distribution of ratio of finer particle and porosity

Case 4



Conclusions

- Identification method for grain size distribution type
- The relation between the geometric parameter of grain size distribution and the porosity
- Development of a bed-void variation model

Reservoir Sediment Management Measures in Japan and those appropriate selection strategy

Dr. Tetsuya Sumi
Kyoto University

Reservoir Sediment Management Measures in Japan and those appropriate selection strategy

TETSUYA SUMI[1]

[1] *Associate Professor, Department of Civil and Earth Resources Engineering,*
Graduate School of Engineering, Kyoto University

The Japanese rivers are characterized by high sediment yield due to the topographical, geological and hydrological conditions. This has consequently caused sedimentation problems to many reservoirs constructed for water resource development or flood control purposes.

The necessity for the reservoir sediment management in Japan can be summarized in the following three points: 1) to prevent the siltation of intake facilities and aggradations of upstream river bed in order to secure the safety of dam and river channel, 2) to maintain the storage function of reservoirs, and realize sustainable water resources management for the next generation, and 3) to release sediment from dams with an aim to conduct comprehensive sediment management in a sediment routing system.

Sediment management approaches are largely classified into the following techniques: 1) to reduce sediment transported into reservoirs, 2) to bypass inflowing sediment and 3) to remove sediment accumulated in reservoirs. In Japan, in addition to conventional techniques such as excavation or dredging, sediment flushing and sediment bypass techniques are adopted at some dams: e.g. at Unazuki and Dashidaira dams in the Kurobe river, and at Miwa dam in the Tenryu river and Asahi dam in the Shingu river as shown in Figure 1, respectively. These dams practically using such techniques are focused on as advanced cases aiming for long life of dams. In addition to these dams, larger scale sediment bypass systems are now under studying at Sakuma and Akiba dams in the Tenryu river, and Yahagi dam.

The problems to promote such reservoir sediment management in future are 1)Priority evaluation of reservoirs where sediment management should be introduced, 2)Appropriate selection of reservoir sediment management strategies and 3)Development of efficient and environmental compatible sediment management technique. In order to decide priority and appropriate sediment management measures, Capacity-inflow ratio and Reservoir life indices are useful for guidance as shown in Figure 2. When the sediment management measures are selected, it is also necessary to consider those environmental influences in the downstream river and coastal areas both from positive and negative point of views.

In this paper, state of the art of reservoir sediment management measures in Japan and future challenges are discussed.

Keywords: Reservoir sediment management, sediment routing system, sediment bypassing, sediment flushing, environmental impact assessment, Tenryu river, Yahagi river

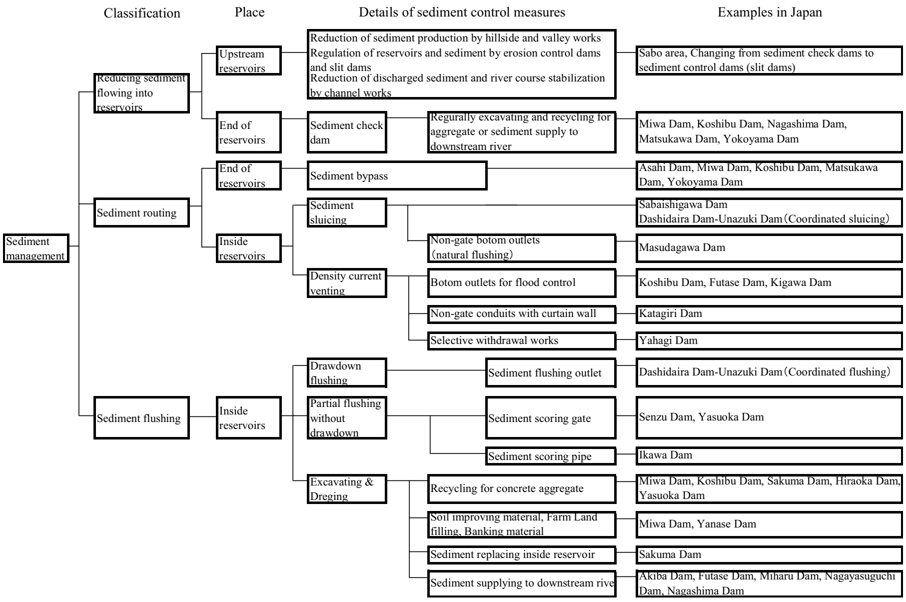


Figure 1. Classification of Reservoir Sedimentation management in Japan

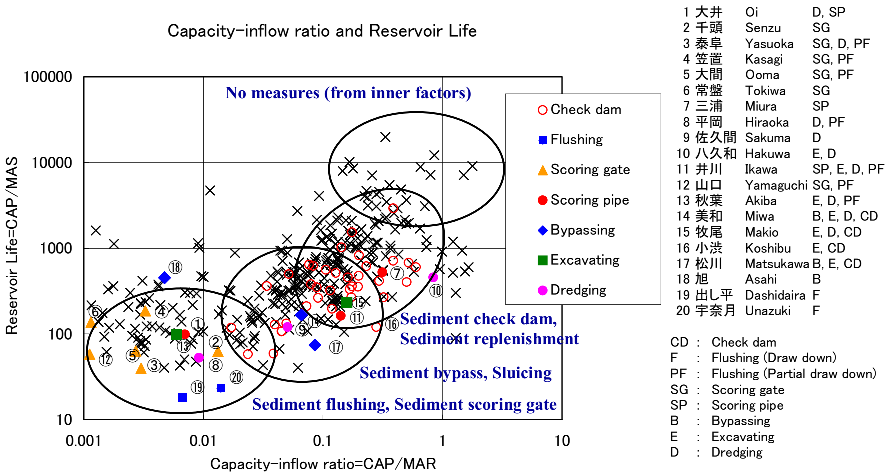
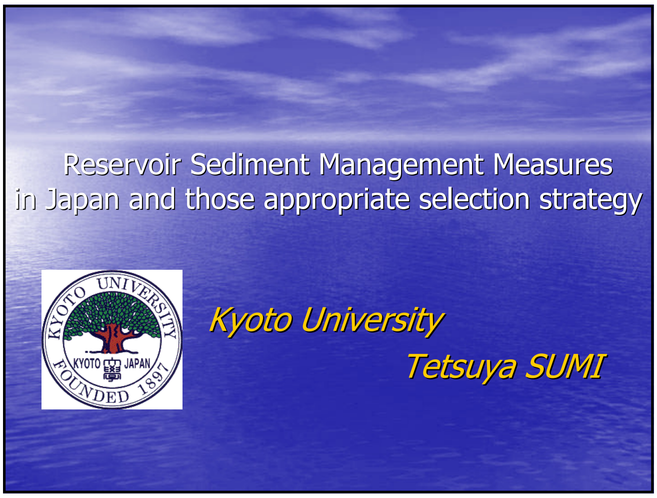


Figure 2. Appropriate selection of reservoir sediment management strategy

References

[1] T. Sumi, Baiyinbaoligao and S. Morita, *10th International Symposium on River Sedimentation, Moscow, CD-ROM*, (2007).

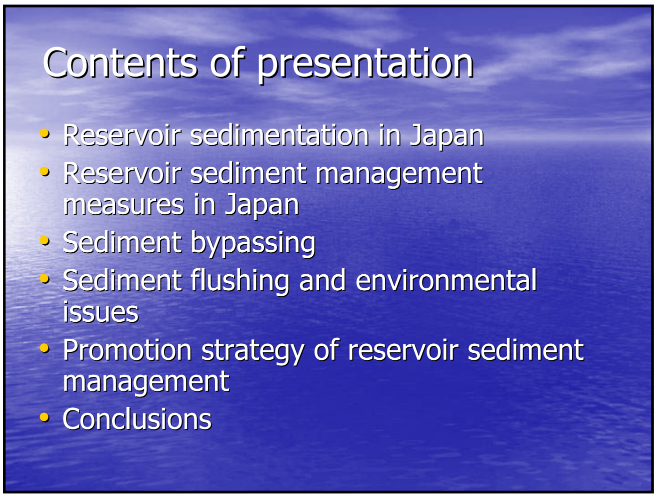
[2] T. Sumi and H. Kanazawa, *22nd International Congress on Large Dams, Barcelona, Q.85-R.16*, (2006).



Reservoir Sediment Management Measures in Japan and those appropriate selection strategy

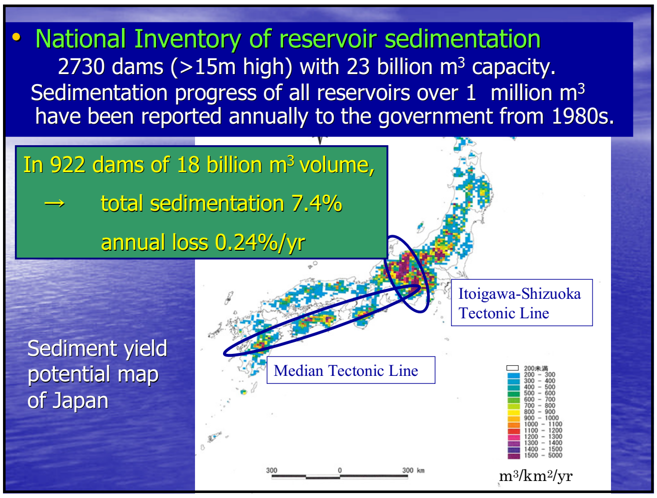
Kyoto University

Tetsuya SUMI



Contents of presentation

- Reservoir sedimentation in Japan
- Reservoir sediment management measures in Japan
- Sediment bypassing
- Sediment flushing and environmental issues
- Promotion strategy of reservoir sediment management
- Conclusions

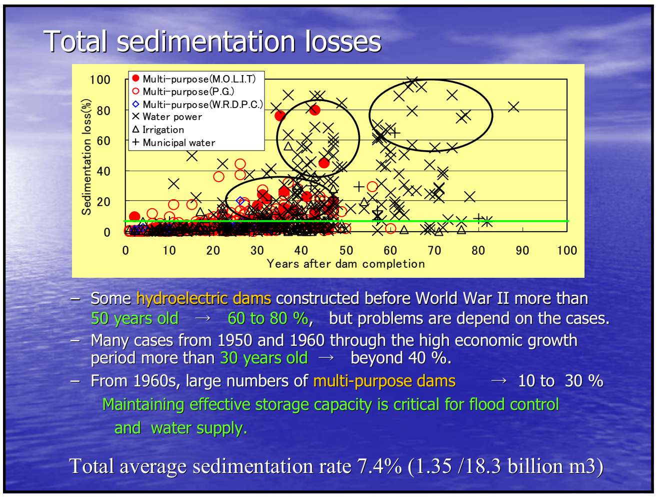


- National Inventory of reservoir sedimentation

2730 dams (>15m high) with 23 billion m^3 capacity.
Sedimentation progress of all reservoirs over 1 million m^3 have been reported annually to the government from 1980s.

In 922 dams of 18 billion m^3 volume,
→ total sedimentation 7.4%
annual loss 0.24%/yr

Sediment yield potential map of Japan

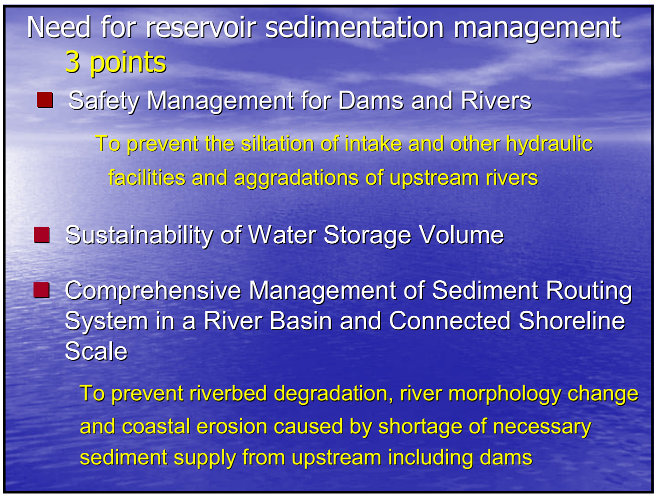


Total sedimentation losses

- Some hydroelectric dams constructed before World War II more than 50 years old → 60 to 80 %, but problems are depend on the cases.
- Many cases from 1950 and 1960 through the high economic growth period more than 30 years old → beyond 40 %.
- From 1960s, large numbers of multi-purpose dams → 10 to 30 %

Maintaining effective storage capacity is critical for flood control and water supply.

Total average sedimentation rate 7.4% (1.35 /18.3 billion m3)



Need for reservoir sedimentation management 3 points

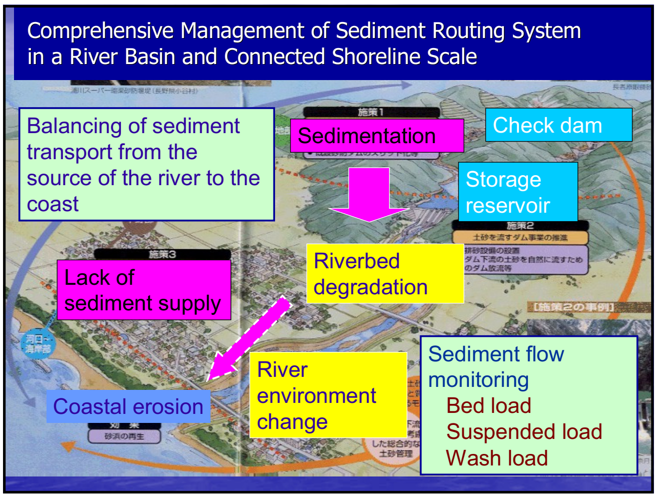
- Safety Management for Dams and Rivers

  To prevent the siltation of intake and other hydraulic facilities and aggradations of upstream rivers

- Sustainability of Water Storage Volume

- Comprehensive Management of Sediment Routing System in a River Basin and Connected Shoreline Scale

  To prevent riverbed degradation, river morphology change and coastal erosion caused by shortage of necessary sediment supply from upstream including dams



Comprehensive Management of Sediment Routing System in a River Basin and Connected Shoreline Scale

Balancing of sediment transport from the source of the river to the coast

Sedimentation

Check dam

Storage reservoir

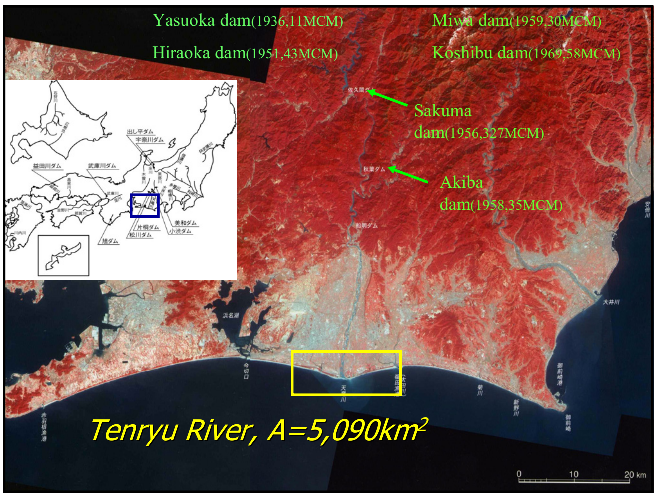
Riverbed degradation

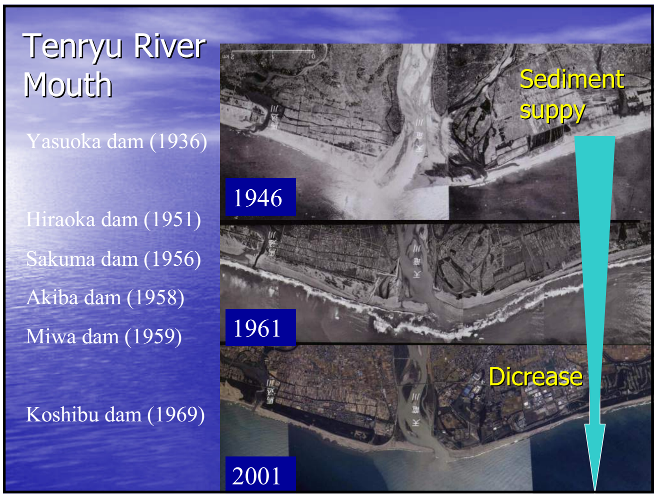
Lack of sediment supply

River environment change

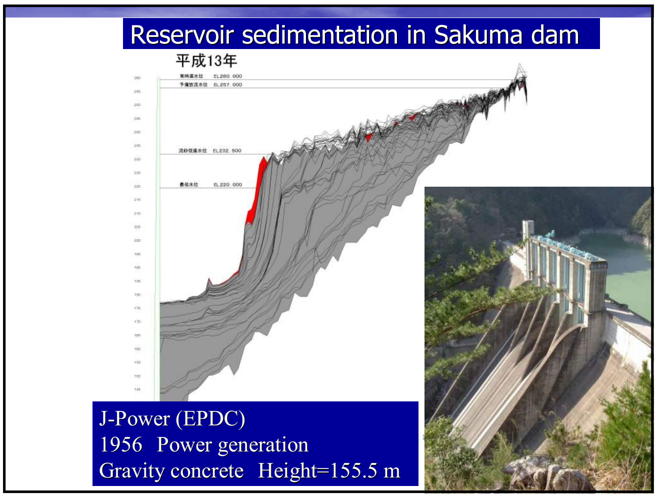
Coastal erosion

Sediment flow monitoring
- Bed load
- Suspended load
- Wash load



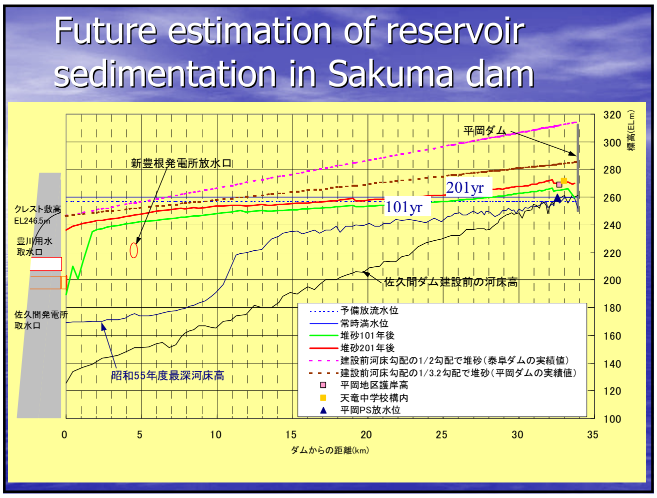


Tenryu River Mouth

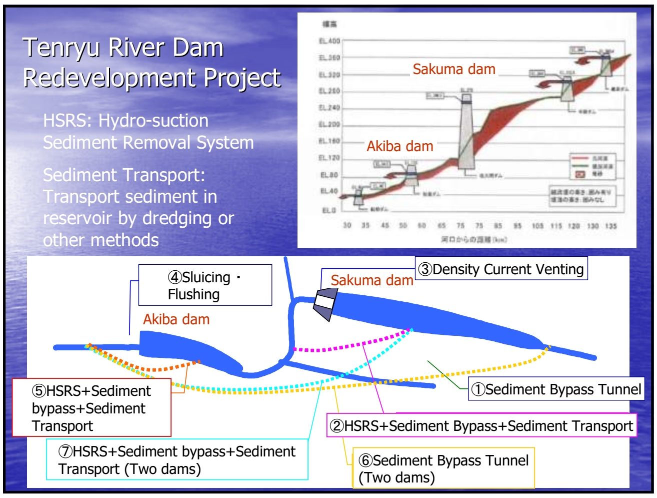


Reservoir sedimentation in Sakuma dam

J-Power (EPDC)
1956 Power generation
Gravity concrete Height=155.5 m



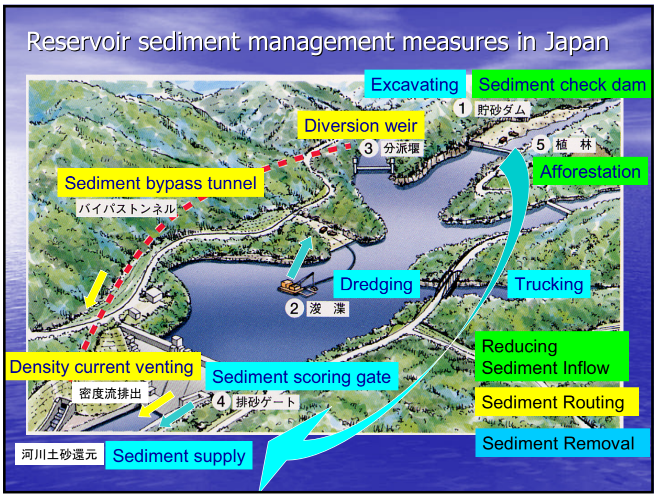
Future estimation of reservoir sedimentation in Sakuma dam



Tenryu River Dam Redevelopment Project

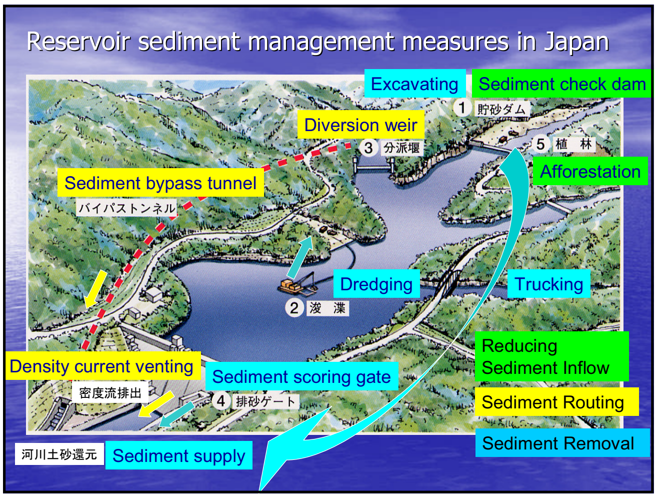
HSRS: Hydro-suction Sediment Removal System

Sediment Transport: Transport sediment in reservoir by dredging or other methods

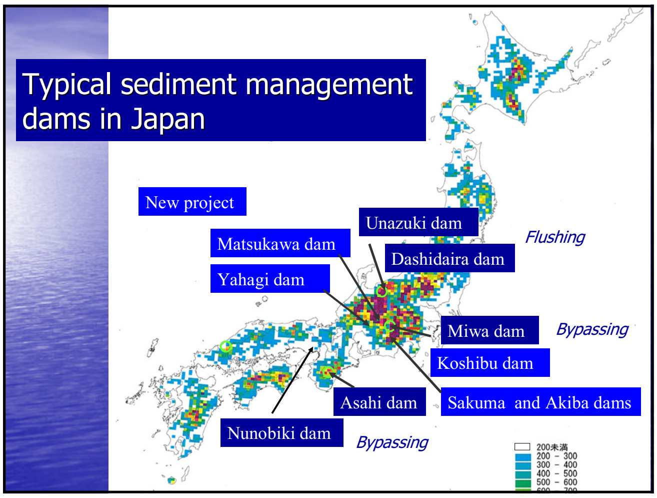


Reservoir sediment management measures in Japan

Reservoir sediment management measures in Japan



Typical sediment management dams in Japan

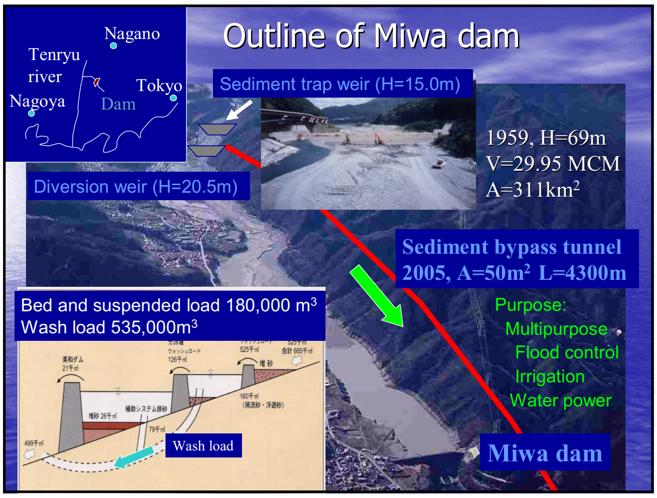


Sediment bypassing dams in the world

No	Name of Dam	Country	Tunnel Completion	Tunnel Shape	Tunnel Cross Section (B×H(m))	Tunnel Length (m)	General Slope (%)	Design Discharge (m^3/s)	Design Velocity (m/s)	Operation Frequency
1	Nunobiki	Japan	1908	Hood	2.9×2.9	258	1.3	39	-	-
2	Asahi	Japan	1998	Hood	3.8×3.8	2,350	2.9	140	11.4	13 times/yr
3	Miwa	Japan	2004	Horseshoe	2r = 7.8	4,300	1	300	10.8	-
4	Matsukawa	Japan	Under construction	Hood	5.2×5.2	1,417	4	200	15	-
5	Egshi	Switzerland	1976	Circular	r = 2.8	360	2.6	74	9	10days/yr
6	Palagnedra	Switzerland	1974	Horseshoe	2r = 6.2	1,800	2	110	9	2～5days/yr
7	Pfaffensprung	Switzerland	1922	Horseshoe	A= $21.0m^2$	280	3	220	10～15	～ 200days/yr
8	Rempen	Switzerland	1983	Horseshoe	3.5×3.3	450	4	80	～14	1～5days/yr
9	Runcahez	Switzerland	1961	Horseshoe	3.8×4.5	572	1.4	110	9	4days/yr

(Five bypass tunnels in Switzerland by Visher et al., 1997)

Outline of Miwa dam



1959, H=69m
V=29.95 MCM
A=$311km^2$

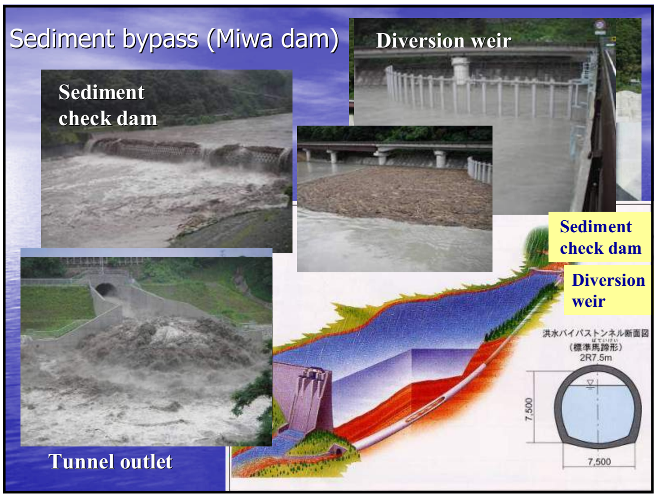
Sediment bypass tunnel
2005, A=$50m^2$ L=4300m

Bed and suspended load 180,000 m^3
Wash load 535,000m^3

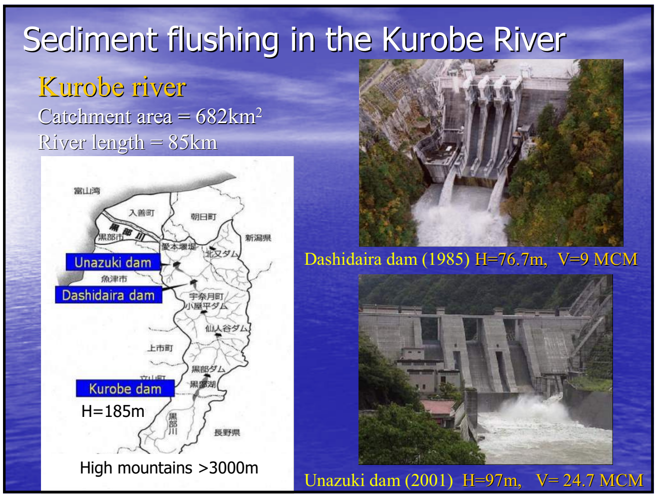
Purpose:
- Multipurpose
- Flood control
- Irrigation
- Water power

Miwa dam

Sediment bypass (Miwa dam)



Bypass operation in 2006



Sediment flushing in the Kurobe River

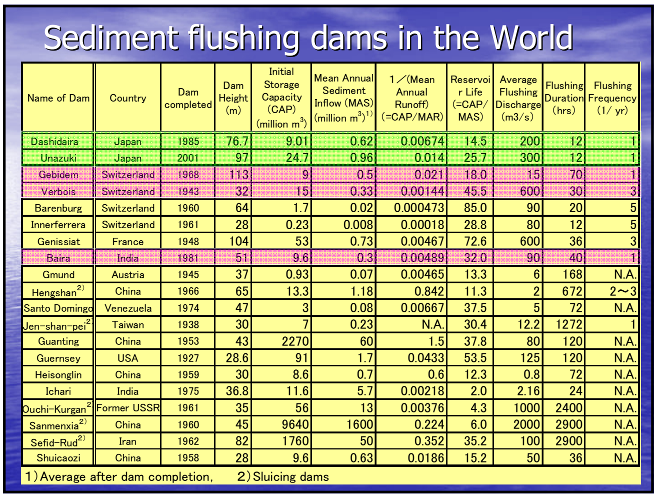
Kurobe river

Catchment area = 682km^2

River length = 85km

Dashidaira dam (1985) H=76.7m, V=9 MCM

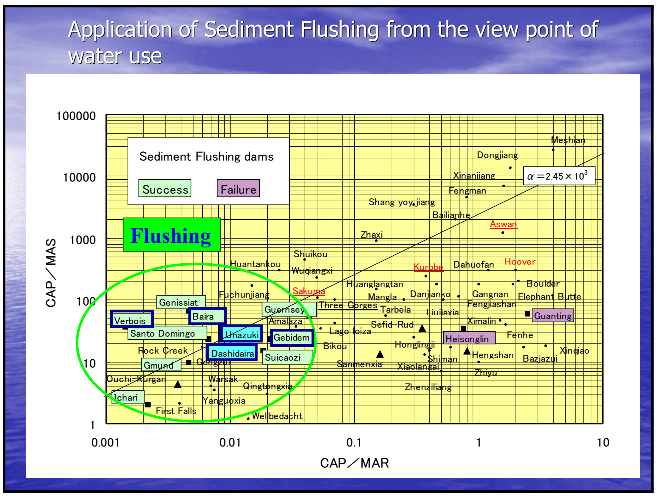
Unazuki dam (2001) H=97m, V= 24.7 MCM



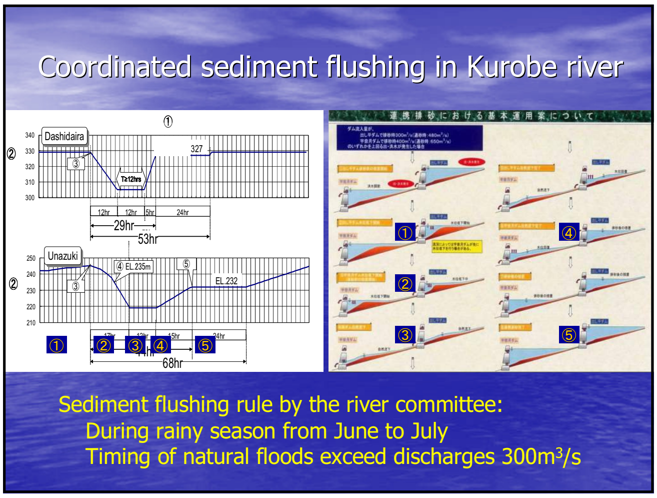
Sediment flushing dams in the World

Name of Dam	Country	Dam completed	Dam Height (m)	Initial Storage Capacity (CAP) (million m^3)	Mean Annual Sediment Inflow (MAS) (million m^3)$^{1)}$	1／(Mean Annual Runoff) (=CAP/MAR)	Reservoir Life (=CAP/MAS)	Average Flushing Discharge (m3/s)	Flushing Duration (hrs)	Flushing Frequency (1/ yr)
Dashidaira	Japan	1985	76.7	9.01	0.62	0.00674	14.5	200	12	1
Unazuki	Japan	2001	97	24.7	0.96	0.014	25.7	300	12	1
Gebidem	Switzerland	1968	113	9	0.5	0.021	18.0	15	70	1
Verbois	Switzerland	1943	32	15	0.33	0.00144	45.5	600	30	3
Barenburg	Switzerland	1960	64	1.7	0.02	0.000473	85.0	90	20	5
Innerferrera	Switzerland	1961	28	0.23	0.008	0.00018	28.8	80	12	5
Genissiat	France	1948	104	53	0.73	0.00467	72.6	600	36	3
Baira	India	1981	51	9.6	0.3	0.00489	32.0	90	40	1
Gmund	Austria	1945	37	0.93	0.07	0.00465	13.3	6	168	N.A.
Hengshan$^{2)}$	China	1966	65	13.3	1.18	0.842	11.3	2	672	2～3
Santo Domingo	Venezuela	1974	47	3	0.08	0.00667	37.5	5	72	N.A.
Jen-shan-pei$^{2)}$	Taiwan	1938	30	7	0.23	N.A.	30.4	12.2	1272	1
Guanting	China	1953	43	2270	60	1.5	37.8	80	120	N.A.
Guernsey	USA	1927	28.6	91	1.7	0.0433	53.5	125	120	N.A.
Heisonglin	China	1959	30	8.6	0.7	0.6	12.3	0.8	72	N.A.
Ichari	India	1975	36.8	11.6	5.7	0.00218	2.0	2.16	24	N.A.
Ouchi-Kurgan$^{2)}$	Former USSR	1961	35	56	13	0.00376	4.3	1000	2400	N.A.
Sanmenxia$^{2)}$	China	1960	45	9640	1600	0.224	6.0	2000	2900	N.A.
Sefid-Rud$^{2)}$	Iran	1962	82	1760	50	0.352	35.2	100	2900	N.A.
Shuicaozi	China	1958	28	9.6	0.63	0.0186	15.2	50	36	N.A.

1) Average after dam completion,　2) Sluicing dams



Application of Sediment Flushing from the view point of water use

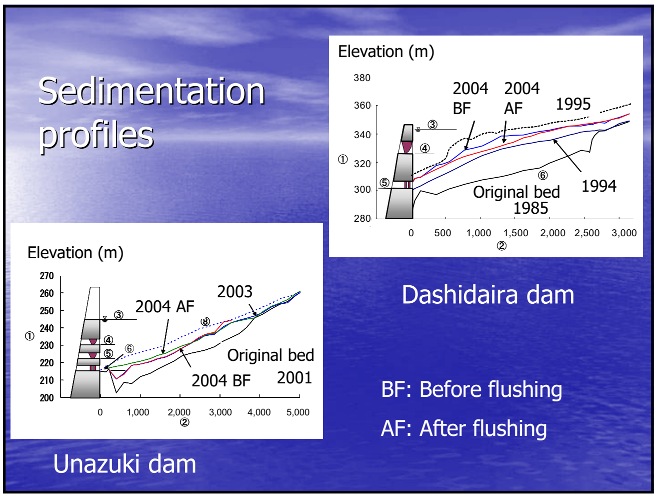


Coordinated sediment flushing in Kurobe river

Sediment flushing rule by the river committee:

During rainy season from June to July

Timing of natural floods exceed discharges 300m^3/s



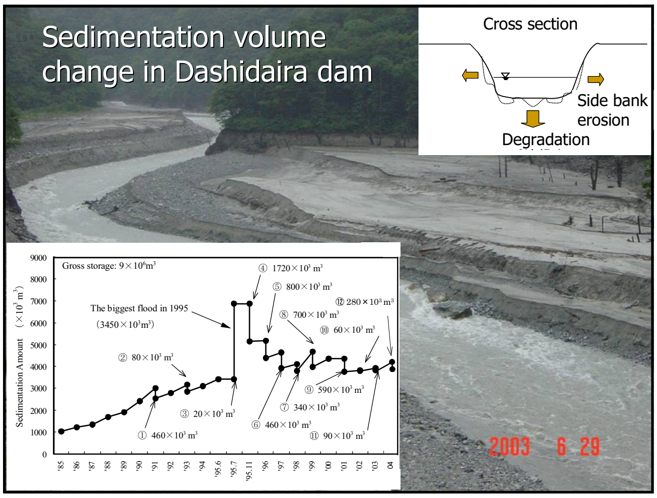
Sedimentation profiles

Dashidaira dam

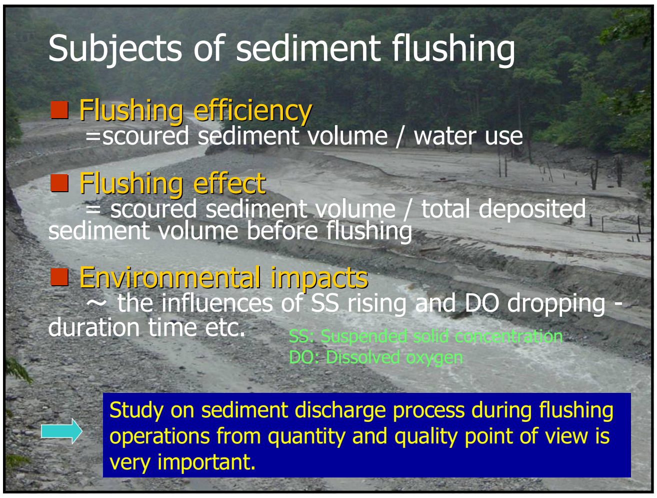
Unazuki dam

BF: Before flushing

AF: After flushing



Sedimentation volume change in Dashidaira dam

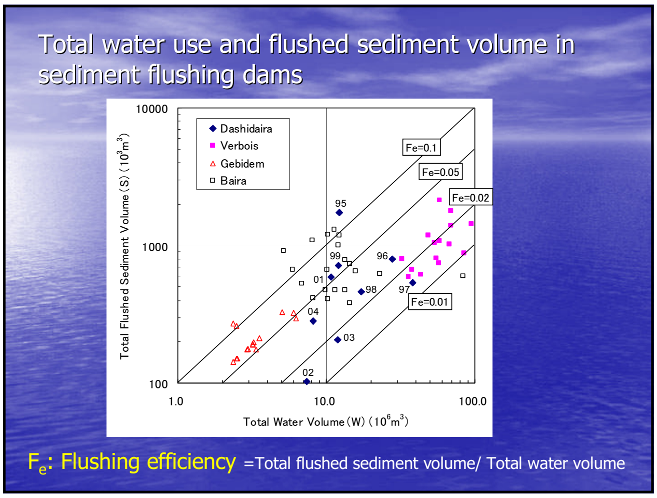


Subjects of sediment flushing

- **Flushing efficiency**
  =scoured sediment volume / water use
- **Flushing effect**
  = scoured sediment volume / total deposited sediment volume before flushing
- **Environmental impacts**
  ~ the influences of SS rising and DO dropping - duration time etc.

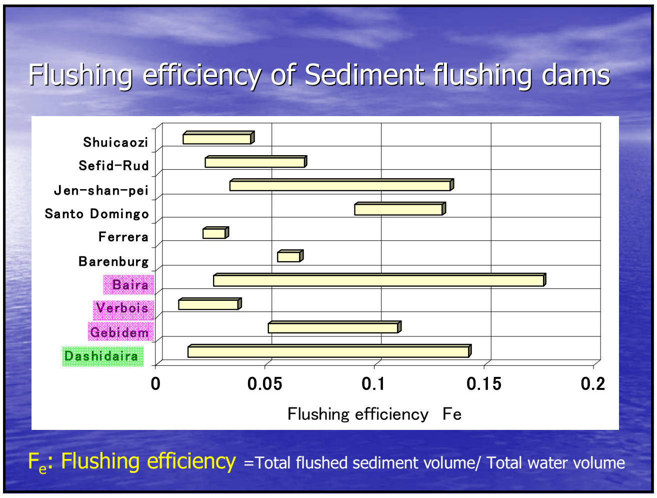
SS: Suspended solid concentration
DO: Dissolved oxygen

➡ Study on sediment discharge process during flushing operations from quantity and quality point of view is very important.



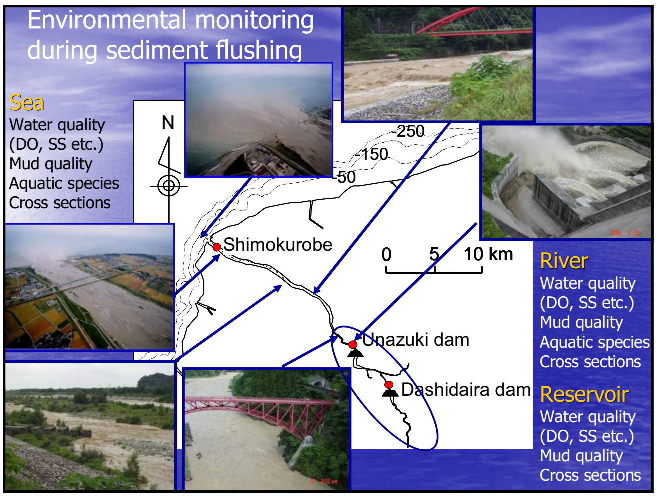
Total water use and flushed sediment volume in sediment flushing dams

F_e: Flushing efficiency =Total flushed sediment volume/ Total water volume



Flushing efficiency of Sediment flushing dams

F_e: Flushing efficiency =Total flushed sediment volume/ Total water volume

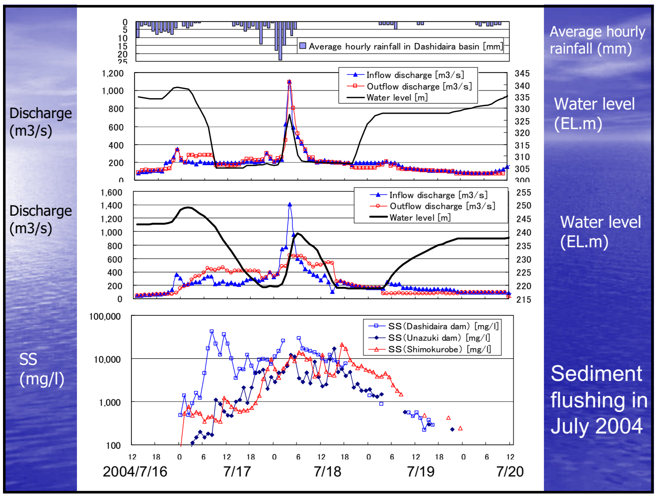


Environmental monitoring during sediment flushing

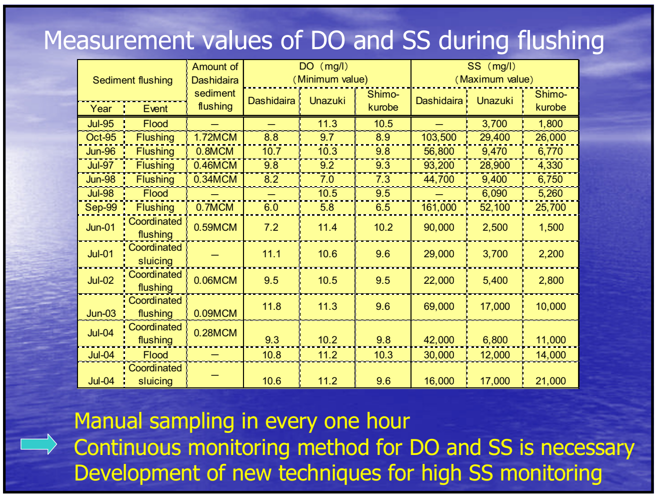
Sea
Water quality
(DO, SS etc.)
Mud quality
Aquatic species
Cross sections

River
Water quality
(DO, SS etc.)
Mud quality
Aquatic species
Cross sections

Reservoir
Water quality
(DO, SS etc.)
Mud quality
Cross sections



Sediment flushing in July 2004

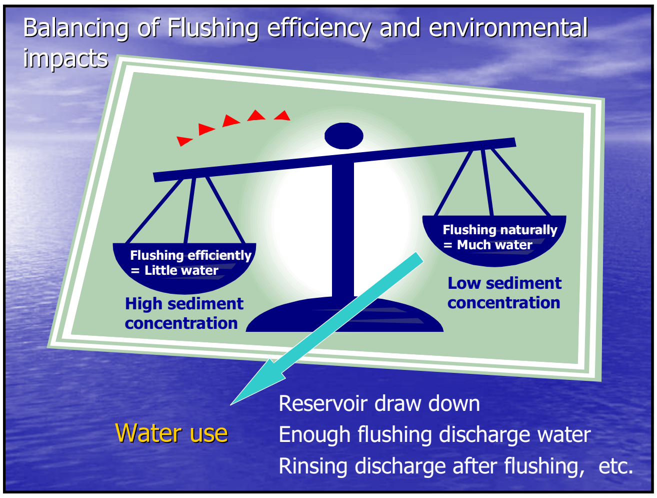


Measurement values of DO and SS during flushing

Sediment flushing		Amount of Dashidaira sediment flushing	DO (mg/l) (Minimum value)			SS (mg/l) (Maximum value)		
Year	Event		Dashidaira	Unazuki	Shimo-kurobe	Dashidaira	Unazuki	Shimo-kurobe
Jul-95	Flood	—	—	11.3	10.5	—	3,700	1,800
Oct-95	Flushing	1.72MCM	8.8	9.7	8.9	103,500	29,400	26,000
Jun-96	Flushing	0.8MCM	10.7	10.3	9.8	56,800	9,470	6,770
Jul-97	Flushing	0.46MCM	9.8	9.2	9.3	93,200	28,900	4,330
Jun-98	Flushing	0.34MCM	8.2	7.0	7.3	44,700	9,400	6,750
Jul-98	Flood	—	—	10.5	9.5	—	6,090	5,260
Sep-99	Flushing	0.7MCM	6.0	5.8	6.5	161,000	52,100	25,700
Jun-01	Coordinated flushing	0.59MCM	7.2	11.4	10.2	90,000	2,500	1,500
Jul-01	Coordinated sluicing	—	11.1	10.6	9.6	29,000	3,700	2,200
Jul-02	Coordinated flushing	0.06MCM	9.5	10.5	9.5	22,000	5,400	2,800
Jun-03	Coordinated flushing	0.09MCM	11.8	11.3	9.6	69,000	17,000	10,000
Jul-04	Coordinated flushing	0.28MCM	9.3	10.2	9.8	42,000	6,800	11,000
Jul-04	Flood	—	10.8	11.2	10.3	30,000	12,000	14,000
Jul-04	Coordinated sluicing	—	10.6	11.2	9.6	16,000	17,000	21,000

Manual sampling in every one hour

➡ Continuous monitoring method for DO and SS is necessary
Development of new techniques for high SS monitoring



Balancing of Flushing efficiency and environmental impacts

Water use

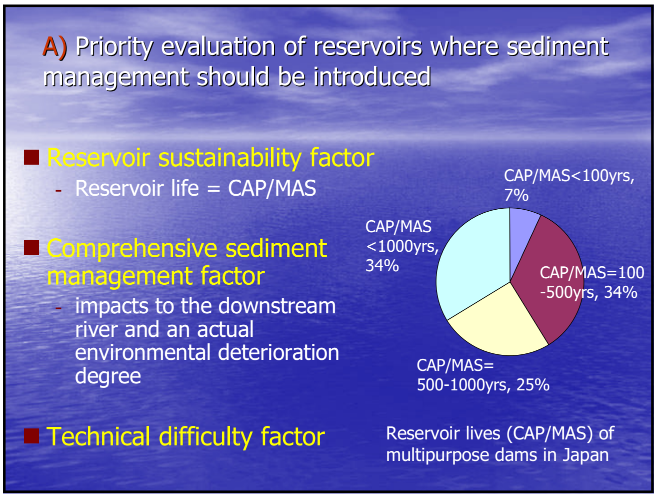
- Reservoir draw down
- Enough flushing discharge water
- Rinsing discharge after flushing, etc.

Promotion strategy of reservoir sediment management

A) Priority evaluation of reservoirs where sediment management should be introduced

B) Appropriate selection of reservoir sediment management strategy

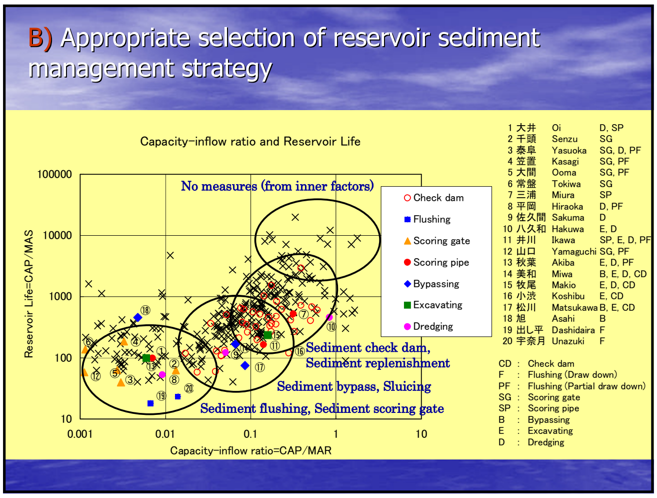
C) Development of efficient and environmentally compatible sediment management techniques



A) Priority evaluation of reservoirs where sediment management should be introduced

- Reservoir sustainability factor
  - Reservoir life = CAP/MAS
- Comprehensive sediment management factor
  - impacts to the downstream river and an actual environmental deterioration degree
- Technical difficulty factor

Reservoir lives (CAP/MAS) of multipurpose dams in Japan



B) Appropriate selection of reservoir sediment management strategy

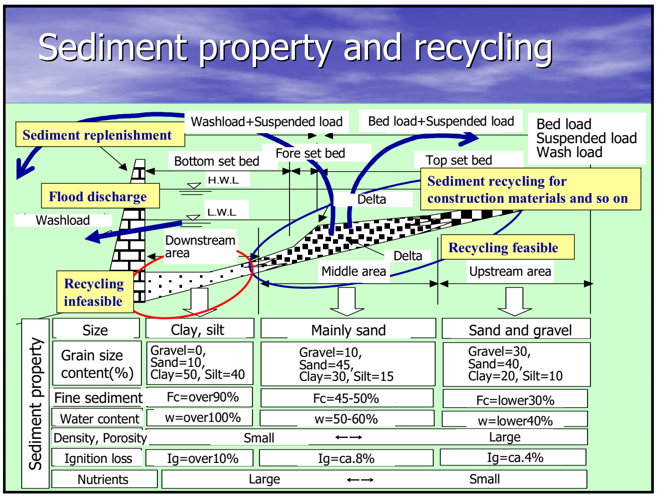
Capacity−inflow ratio and Reservoir Life

1	大井	Oi	D, SP
2	千頭	Senzu	SG
3	泰阜	Yasuoka	SG, D, PF
4	笠置	Kasagi	SG, PF
5	大間	Ooma	SG, PF
6	常盤	Tokiwa	SG
7	三浦	Miura	SP
8	平岡	Hiraoka	D, PF
9	佐久間	Sakuma	D
10	八久和	Hakuwa	E, D
11	井川	Ikawa	SP, E, D, PF
12	山口	Yamaguchi	SG, PF
13	秋葉	Akiba	E, D, PF
14	美和	Miwa	B, E, D, CD
15	牧尾	Makio	E, D, CD
16	小渋	Koshibu	E, CD
17	松川	Matsukawa	B, E, CD
18	旭	Asahi	B
19	出し平	Dashidaira	F
20	宇奈月	Unazuki	F

CD : Check dam
F : Flushing (Draw down)
PF : Flushing (Partial draw down)
SG : Scoring gate
SP : Scoring pipe
B : Bypassing
E : Excavating
D : Dredging

C) Development of efficient and environmentally compatible sediment management techniques

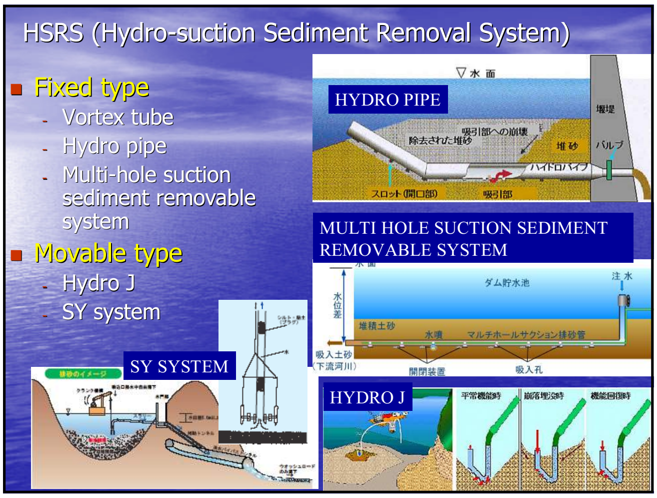
- "Take", "Transport" and "Discharge"
  - Sediment flushing/sluicing and sediment bypassing should be introduced more.
  - The sediment trucking and supply, and the Hydro-suction Sediment Removal System (HSRS) are needs to be improved furthermore and introduced as supplementary measures.



Sediment property and recycling

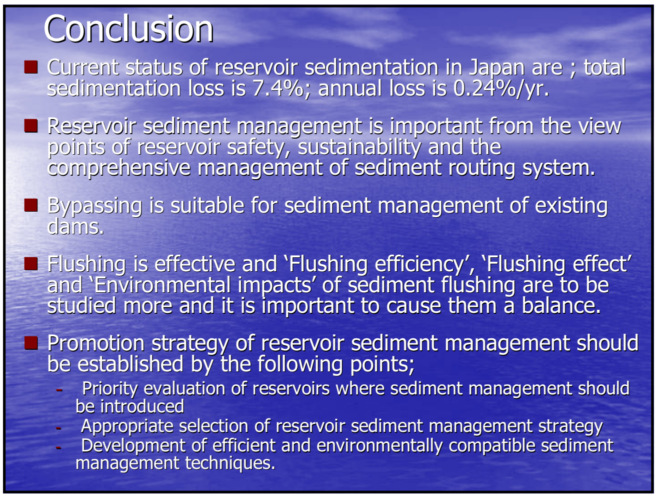
Sediment property

Size	Clay, silt	Mainly sand	Sand and gravel
Grain size content(%)	Gravel=0, Sand=10, Clay=50, Silt=40	Gravel=10, Sand=45, Clay=30, Silt=15	Gravel=30, Sand=40, Clay=20, Silt=10
Fine sediment	Fc=over90%	Fc=45-50%	Fc=lower30%
Water content	w=over100%	w=50-60%	w=lower40%
Density, Porosity	Small	←→	Large
Ignition loss	Ig=over10%	Ig=ca.8%	Ig=ca.4%
Nutrients	Large	←→	Small



HSRS (Hydro-suction Sediment Removal System)

- Fixed type
  - Vortex tube
  - Hydro pipe
  - Multi-hole suction sediment removable system
- Movable type
  - Hydro J
  - SY system



Conclusion

- Current status of reservoir sedimentation in Japan are ; total sedimentation loss is 7.4%; annual loss is 0.24%/yr.
- Reservoir sediment management is important from the view points of reservoir safety, sustainability and the comprehensive management of sediment routing system.
- Bypassing is suitable for sediment management of existing dams.
- Flushing is effective and ‘Flushing efficiency’, ‘Flushing effect’ and ‘Environmental impacts’ of sediment flushing are to be studied more and it is important to cause them a balance.
- Promotion strategy of reservoir sediment management should be established by the following points;
  - Priority evaluation of reservoirs where sediment management should be introduced
  - Appropriate selection of reservoir sediment management strategy
  - Development of efficient and environmentally compatible sediment management techniques.

Kurobe alluvial fan

Sediment discharge from Unazuki dam

Thank you for your attention!