Session 2

“Histories of Developments, Land Use Changing along the Brantas River Basin.”
Rainfall and Sediment runoff in the Lesti River Basin, Tributary of the Brantas River, Indonesia

Prof. Hajime Nakagawa
Disaster Prevention Research Institute,
Kyoto University
Rainfall and Sediment runoff in the Lesti River Bain, Tributary of the Brantas River, Indonesia

HAJIME NAKAGAWA1, YOSHIFUMI SATOTUKA2, SATORU OISHI3, YASUNORI MUT04, TAKEHIRO SAYAMA1, KAORU TAKARA1, andRAJI HARI SHARMA4

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4Graduate school of Engineering, Kyoto University

Intensive and continuous observations on sediment yield and transport are conducted in the Lesti River Basin (625 km²), a tributary of the Brantas River (11,800 km²), Indonesia (see Figure 1)[1]. This report presents the observation results of raindrop characteristics investigated with Micro Rain Radar (MRR), seasonal and inter-annual land cover change detected by remotely sensing, soil erosion measurements with staves installed at different land covers, and sediment turbidity measurements at the outlet of the Lesti River. Our motivation of these integrated observations is to understand all the processes from sediment yield to transport with the consideration of human impact such as cultivation, deforestation, and sand mining. By referring these observation data, we newly developed two models which can reproduce observed rainfall and sediment runoff processes by introducing the NDVI (Normalized Difference Vegetation Index) values that can express land cover changes [2].

Those models, named as “ST Model” and “RH Model”, respectively, are both in the kinematic wave runoff models and are rather similar. The important difference in those models comes from treatment of effects of NDVI on the erodibility of the topsoil. In the ST Model, erosion velocity of the topsoil, $D_r$ (kg/hr/m²), by the impacts of raindrops is expressed as;

$$D_r = \gamma K_e K_e = 56.48r$$  \hspace{1cm} (1)

where, $\gamma$=erodibility of the topsoil as shown in Fig. 2, $K_e$=coefficient of the erodibility (kg/J), $K_e$=impact energy of a raindrop (J/m²)[3], and $r$=rainfall intensity
On the other hand, in the “RH Model”, NDVI is not considered in evaluating the topsoil erosion by the rain drop impact, but is considered in the flow resistance, i.e., Manning’s roughness coefficient. This is because that when NDVI value is large, i.e., vegetation on the land-surface is very active, the flow resistance due to vegetation becomes large. The relationship between NDVI value and Manning’s roughness coefficient is established as:

\[ n = 0.0713 \exp(2.8p) \]  

where, \( n \) = Manning’s roughness coefficient (m\(^{-1/3}\)s), and \( p \) = NDVI value.

Figure 3 shows comparisons between calculated and observed long term water discharges and turbidity at Tawangrejeni from October 2004 to October 2006 in case of “ST Model”. Figure 4 shows comparisons between calculated and observed water discharge and turbidity at Tawangrejeni in the period from 0:00, Nov. 21, 2003 to 0:00, Nov. 24, 2003 in case of “RH Model”. Calculated water discharges and turbidities by using each model agree fairly well with observed data.

References

Fig. 4 Comparisons between calculated and observed water discharge and turbidity at Tawangrejeni in the period from 0:00, Nov. 21, 2003 to 0:00, Nov. 24, 2003


Rainfall and Sediment runoff in the Lesti River Basin, Tributary of the Brantas River, Indonesia

INTRODUCTION

SOEKISTIJONO, Aris HARNANTO and Fahmi HIDAYAT

Hajime NAKAGAWA1, Yoshifumi SATOFUKA2, Satoru OISHI3, Yasunori MUTO1, Takehiro SATYAMA1,Kaoru TAKARA4, and Raji Hari SHARMA4

1Disaster Prevention Research Institute, Kyoto University
2Graduate school of Agriculture, Kyoto University
3Interdisciplinary Graduate School of Medicine and Engineering, University of Yamanashi
4Graduate school of Engineering, Kyoto University

Brantas River Workshop in Malang
November 22-23, 2007
At Hotel Santika Malang

This project was done under the main theme of “System Modeling Approaches for Assessment of Interaction between Social Changes and Water Cycle” (Project Leader : Prof. Kaoru Takara, DPRI, Kyoto Univ.) and under the sub-theme of “Development of the Water Cycle Model in the Asian Monsoon Area” conducted under CREST (Core Research for Evolutional Science and Technology) Program by the Japan Science and Technology Agency (Period: 2001-2006)

Objectives

Recently, reservoir sedimentation becomes a big problem to flood control, water utility, and river environment. Sediment management in the basin is a very important matter. So that, we want
• to elucidate basin-scale rainfall and sediment runoff processes, and
• to consider the human impacts (agricultural activity) on the rainfall and sediment runoff phenomenon in the model.

Study Area and Hypothesis

• The Lesti River basin where the sediment yield due to eruption of Mt. Semeru is very active, was selected as a study area.
• We suppose that the main sediment source is from the slope surface erosion due to rain drop impact and surface flow, and riverbed erosion is not so important.
• Sand mining may effect a lot on the sediment yield but we neglect this effect due to difficulty of evaluation.

Methodology

We took following two actions;
• Understanding of the characteristics of the rainfall and sediment runoff by carrying out the observations on
  – characteristics of the topsoil erodibility due to rainfalls
  – characteristics of temporal and spatial distributions of turbidity in the river
  – characteristics of amount of rainfall, raindrops, and river water discharge, and
  – landuse and condition of land surface cover (by remote sensing technique)
• Modeling based on the observed data and information

Outline of Brantas River Basin

• Basin Area : 11,800 km² (25% of E. Java)
• Population (2003) : 11.5 million (43% of E. Java)
• Average Rainfall : 2,000 mm/year
• Water Potentials : 12 billion m³/year
• River Length : 320 km
• Active volcanoes : Mt. Kelud & Mt. Semeru
• Land Use (2004) :
  - paddy field : 39.0%
  - dry land : 12.0%
  - plantation : 22.0%
  - forest : 11.0%
  - settlements : 12.0%
  - others : 4.0%
Reservoir Sedimentation
Sengguruh Reservoir

Sengguruh Reservoir (Hydropower, Water Supply)
Annual Sediment Yield
2.26 × 10^6 m³/year

Reservoir Sedimentation
Sutami Reservoir

Sutami Reservoir (Flood Control, Hydropower, Irrigation, Water supply)

Lesti River Basin

Seasonal land-cover change in farmland
Oct 2003 (end of dry-season)
July 2005 (mid of dry-season)

Land use change

Deforestation in the last 5 years?
Land Cover Classification: Lesti River Basin

Seasonal land-cover change in farmland
Oct 2002
Feb 2003
Oct 2003
Dec 2003

Seasonal land-cover change in farmland
Oct 2004
Mar 2004
Mar 2005
Nov 2005
Seasonal variability of NDVI (Normalized Difference Vegetation Index)

NDVI value is the smallest at the beginning of the rainy season.

Vegetation activity: very low

A couple of month later

Vegetation activity: higher

NDVI value recovers very quickly just after getting rain

NDVI = (IR - R) / (IR + R)

(Green leaves absorb red- and blue- range wave length, and reflect infrared- range wave length)

NDVI value is the smallest at the beginning of the rainy season

Vegetation activity: very low

A couple of month later

Vegetation activity: higher

NDVI value recovers very quickly just after getting rain

Erosion + deposition velocity of the cultivated farmland is about three times bigger than that of the forest or tree crops farmland.

Erosion + deposition velocity has some negative co-relation with NDVI value.

Discharge and turbidity (SS) observation in Dec. 2003

Observations of flow discharge and turbidity

Observation of flow discharge using ADCP at Tawangregeni

Observation of spatial distribution of turbidity
Discharge and turbidity (SS) observation in Mar. 2005

- Padang (est.)
  - Q=2.2m^3/s
  - SS=1750mg/liter
  - Qs=13.9ton/h

- Genteng River
  - Genteng Up
    - Q=0.8m^3/s
    - SS=40mg/liter
    - Qs=0.1ton/h
  - Genteng Dn
    - Q=3m^3/s
    - SS=1300mg/liter
    - Qs=14.0ton/h

- Lesti Estuary (3/2)
  - Q=8.3m^3/s
  - SS=350mg/liter
  - Qs=10.5ton/h

- Tawangrejeni (est.)
  - Q=11.6m^3/s
  - SS=269mg/liter
  - Qs=11.2ton/h

- Genteng Estuary (3/2)
  - Q=3.3m^3/s
  - SS=65mg/liter
  - Qs=0.8ton/h

Harvest at the end of rainy season

Development of distributed rainfall and sediment runoff model “ST Model”

Rainfall-runoff model

- Surface flow
- Subsurface flow
- Matrix flow

250 X 250 Grid-cell
6101 cells

Rainfall-runoff simulation
Calibrated with this rainfall-runoff event (Lesti parameter set)

\( f = 0.35 \), thicker soil layer (4.0 m, Porosity 0.3) and smaller hydraulic conductivity (0.008 m/s) compared with that of the Yodo River basin, Japan

Rainfall-runoff simulation

Lesti parameter set (different rainfall event)
Rainfall-runoff simulation (two weeks)

Long term prediction (water discharge)

Rainfall-sediment-runoff model

Contiuity Equation of Sediment

\[
\frac{\partial (h,c)}{\partial t} + \frac{\partial (q,c)}{\partial x} = e(x,t)
\]

Surface flow
Subsurface flow
Matrix flow

DRF model
\[ e = DR + DF \]

DR : Soil detachment by raindrop impact
\[ DR = K \cdot KE \]

KE : the total kinetic energy of the net rainfall \([\text{J/m}^2]\)

\[ KE = 56.48 \cdot r \]

K : Soil detachability \([\text{kg/J}] = 0.002\)

DF : Soil detachment by runoff
\[ DF = \alpha (TC - c) h_0 \]

Consideration of the seasonal change of the landsurface erodibility

\[
\begin{align*}
DR &= K \cdot KE \\
DF &= \alpha (TC - c) h_0 \\
\end{align*}
\]
Cumulative sediment volume

Grain size distribution (slope)

Error comparison

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<tr>
<th>NDVI-n</th>
<th>Discharge RMSE</th>
<th>Turbidity RMSE</th>
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<tr>
<td>n=0.1</td>
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In case of NDVI-n, n is 0.1, 0.5, 0.8.
Conclusions

1. We carried out the various analyses of data obtained by field observations and remote sensing to understand the basin-wide rainfall and sediment runoff processes.
2. Sediment yield on the slope was found to happen due to heavy rainfall just beginning of the rainy season in the volcanic river basin such as the Lesti River basin.
3. At the beginning of rainy season, as the vegetation activity is low yet, a large amount of sediment were easily yielded by the raindrop shower, resulting in the high turbidity in the river.
4. The distributed rainfall and sediment runoff models, that are based on the erodibility variation due to landuse change, seasonal change of the vegetation, and raindrop impacts, were developed and long- and short-term predictions of sediment runoff phenomenon could be reproduced fairly well.
5. Model refinement and calibration of parameter set are necessary much more.

Expected effects in future

1. Highly accurate prediction for the inflow sediment volume into reservoirs may be possible.
2. Highly accurate prediction for the amount of sediment volume by erosion corresponding to the surface cover condition (human impact) with vegetation by using NDVI values from satellite image can be possible.
3. Suggestions to the farmers for the deliberate land use and development of agronomical technologies can be possible.

Thank you for your attention!
Watershed Management in Brantas river basin

*Mr. Eddy*

*Brantas Watershed Management Agency (BP-DAS Brantas), Ministry of Forestry*
VISION and MISSION

VISION
- As the land and forest information and services center for Watershed Management

MISSION
- Provide Watershed Management’s plan for stakeholders;
- Develop the model of Watershed Management;
- Develop the model system of Watershed Management’s Institution and Partnership;
- Watershed Management evaluation;
- Provide data and information about Watershed Management;
- Create an efficient and effective supporting system;

FUNDAMENTAL DUTY AND FUNCTION

FUNDAMENTAL DUTY
- Planning, Institution Development and Evaluation

FUNCTION
- Organize the Watershed Management’s Plan
- Organize and Present the Watershed Information
- Develop the Watershed Management’s Model
- Develop the Watershed Management’s Institution and Partnership
- Monitor and Evaluate the Watershed Management
- Organize the Administration and Internal Affair

JURISDICTION of BPDAS BRANTAS

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TOTAL | 13,528,333 | 12,636,497 | 924

AUTONOMIC SERVICE AREA (REGENCY / DISTRICT)

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TOTAL | 678,220 | 6,316,790 | 924

AUTONOMIC SERVICE AREA (CITY)

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TOTAL | 678,220 | 6,316,790 | 924
POTENCY, PROBLEMS AND SOLUTION

BRANTAS WATERSHED’S POTENCY

- Take place 34% from The East Java Province area
- 45% East Java’s resident live in Brantas Watershed area
- 30% agriculture area placed in Brantas Watershed
- Brantas Watershed’s state forest are 26%
- Own 8 (eight) dam for flood control
- Good infrastructures (road network, airport, port and telecommunication network)
- The central of education in East Java

ISSUE / PROBLEMS

LAND and HIDROLOGY

- Critical Land: 271,787 Ha in and outside forest zone which cause the decrease of rainfall percolation as the source of groundwater that enlarge the surface flow.
- Threat of flood disaster in Brantas watershed.
- High sedimentation in Karangkates Dam and Sengguruh Dam.

SOCIAL ECONOMY

- Crop cultivation at high oblique land
- People awareness for environment still lower
- Crop’s yield market system is not optimal
- Watershed autonomy is not set up yet (contribution between up and downstream).

Land and Forest Rehabilitation Activity

Cultivation
- People Forest
- People garden
- Re plantation:
  - Conservation Forest
  - Protection Forest
  - Production Forest
- Mangrove Forest
- The city green plantation

Multi Forestry Effort
- Fruit Plantation
- Bee Development
- Agro Forestry
- Village Seed Garden

Conservation Technique
- Controller DAM
- Defender DAM
- Gully Plug
- Diffusion Well
- Terrace Rehabilitation

Cultivation

Conservation Technique
Institution Development Activity

- Partnership Provisioning
- Farmer Training
- Workshop
- Dissemination
- Develop People Forest’s Model
- Develop Micro Watershed’s Model
- Develop Mangrove Forest’s Model
- Develop City Forest’s Model
- Worker Training

Training

- Watershed Management’s Monitoring and Evaluation
- River Current Observation Station’s Monitoring and Evaluation
- Land Use Monitoring and Evaluation
- Social Economic Monitoring and Evaluation
- Monitoring and Evaluation of Land Rehabilitation and Soil Conservation
- Monitoring and Evaluation of Land and Forest Rehabilitation
- Monitoring and Evaluation of The National Action of Land and Forest Rehabilitation (GERHAN)
- Natural Disaster Monitoring and Evaluation
- Forest and Land Rehabilitation Areal Model Activity
- Evaluation of Watershed’s Performance
- Data Base
- KUHRI / KUK-DAS Monitoring and Evaluation
- River Current Observation Station Development

River Current Observation Station

- Rainfall Gauge

Farmer Group Activity
### REALIZATION OF GERHAN'S CULTIVATION, 2003 -2004

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<th>No</th>
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<th>2005 (Ha)</th>
<th>2006 (Ha)</th>
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<td>18,330.99</td>
<td>7,860.00</td>
<td>31,478.89</td>
<td>103,279.60</td>
</tr>
</tbody>
</table>

### REALIZATION of GERHAN'S CONSERVATION TECHNIQUE, 2003-2007

<table>
<thead>
<tr>
<th>No</th>
<th>Watershed</th>
<th>2003 (Ha)</th>
<th>2004 (Ha)</th>
<th>2005 (Ha)</th>
<th>2006 (Ha)</th>
<th>2007 (Ha)</th>
<th>TOTAL (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BRANTAS</td>
<td>253</td>
<td>522</td>
<td>483</td>
<td>276</td>
<td>345</td>
<td>1,969</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>253</td>
<td>522</td>
<td>483</td>
<td>276</td>
<td>345</td>
<td>1,969</td>
</tr>
</tbody>
</table>

### Cultivation Plan of BPDAS Brantas, 2008

<table>
<thead>
<tr>
<th>No</th>
<th>Watershed</th>
<th>Pupus Forest (Ha)</th>
<th>Mangrove Forest (Ha)</th>
<th>City Green (Ha)</th>
<th>Re-plantation (Ha)</th>
<th>TOTAL (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BRANTAS</td>
<td>22,168.89</td>
<td>659.88</td>
<td>2,150.06</td>
<td>1,870.00</td>
<td>58,969.80</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>22,168.89</td>
<td>659.88</td>
<td>2,150.06</td>
<td>1,870.00</td>
<td>58,969.80</td>
</tr>
</tbody>
</table>

### Conservation Technique’s Plan of BPDAS Brantas, 2008

<table>
<thead>
<tr>
<th>No</th>
<th>DAS</th>
<th>Controller DAM (Ha)</th>
<th>Defender DAM (Ha)</th>
<th>Garly Plug (Ha)</th>
<th>Diffusion Well (Ha)</th>
<th>Pond (Ha)</th>
<th>TOTAL (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BRANTAS</td>
<td>49</td>
<td>990</td>
<td>990</td>
<td>2,215</td>
<td>-</td>
<td>3,554</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>49</td>
<td>990</td>
<td>990</td>
<td>2,215</td>
<td>-</td>
<td>3,554</td>
</tr>
</tbody>
</table>

---------- Thank You ----------
River Basin Development and Its Impact to Sediment Balance in the Basin Case Study:
the Brantas River Basin

Mr.Ir.Harianto, Indonesia
Jasa Tirta I Public Corporation
River Basin Development and Its Impact to Sediment Balance in the Basin  
Case Study: the Brantas River Basin Indonesia

by

Ir. Soekistijono, Dipl. HE  
Ir. Harianto, Dipl. HE

The Brantas River basin is located in East Java Province, Indonesia. This river is the second largest river in the Java Island having length of 320 km and catchment area of 11,800 km² that is about 25% of East Java’s area. Development in the basin commenced in 1960’s has resulted 8 reservoirs (Sengguruh, Sutami, Lahor, Wlingi, Lodoyo, Selorejo, Bening and Wonorejo), 4 river-improvement-schemes, four barrages, and three rubber dams. Although the development benefits have been realized as targeted including flood control of 50 years return period, providing irrigation water for 304,000 ha of irrigation area of which 83,000 ha can be secured from the mainstream, production of electricity of about 993 kWh/year, and provision of raw water for industries and municipal drinking water as much as 126,50 million m³/year and 280,68 million m³/year respectively etc, nowadays, the Brantas River basin faces serious sediment related issues that affect sustainable water resources management in the basin.

The unbalanced sediment flow among the upper reach, middle reach and lower reach occurs in the basin that caused by blocking of sediment flow by the dams and sabo facilities, erupted material of Mt. Kelud, and excessive sand mining in the river. These issues were not considered well during planning stage of the basin developments.

In the Brantas River basin, the deposition of sediment in the reservoirs is one of the major sediment issues. Because of a large amount of sediment inflow, the main reservoirs in the basin are rapidly losing their gross storage capacities, ranging from 30-90 percent of the originals gross storage capacities. In some smaller reservoirs such as Sengguruh, Wlingi and Lodoyo, their effective storage capacities were reduced to about 40 percent of original capacities. Most of those dams do not have facilities to remove deposited sediment in the reservoirs.

The other issues are effects of River Improvement Project which is still debateable and excessive sand mining activities in the river. As known that the discharge capacity in the Brantas River reduced due to riverbed aggradations caused by deposition of sediment from eruption of Mt. Kelud. Accordingly the river channel necessary for discharging the flood was proposed to be improved by dredging the river and heightening the existing levee. The Brantas Middle Reach River Improvement Project was proposed in the Second Master Plan in 1972. The project was implemented stage wise that consist of two phases i.e. 1) First Phase (1975-1985): improvement for 10-year flood and 2) Second Phase (1985-1994): improvement for 50-year flood. In the last 1980’s, riverbed degradation in the Brantas

1 Second International Workshop on Water and Sediment Management, Malang, November 22-23, 2007  
2 Director of Technical Affairs, Jasa Tirta I Public Corporation, Jl. Surabaya 2A Malang, 65115 Indonesia, email: mlg@jasatirta1.go.id, birolitbang@telkom.net
River became so remarkable that Watudakon Siphon cropped out from the riverbed and irrigation intake became rather difficult. Responding to these problems, Jatimlerek and Menturus rubber dams and new Watudakon Siphon were constructed under Second Phase Project.

Based on a study conducted in 1996 to investigate sand mining volume and number of workers in the Brantas Middle Reaches and the Porong River, it resulted that annual sand mining volume was estimated to be about 2.12 million m$^3$. In 2004, it was investigated that annual sand mining volume was estimated to be about 2.92 million m$^3$. This increasing was caused mainly by expanding utilization of pumping equipment. The annual sand mining volumes above are considered higher than the expected sediment inflows along the stretches. The Brantas River Morphological Studies conducted in 1992 under the Brantas River Rehabilitation Project estimated that the average annual local sediment inflows along the Brantas River upstream of Kertosono were 2,154,000; 1,831,000 and 1,615,000 m$^3$, respectively, in the first, second and third 5-year periods after the eruption of Mt. Kelud in 1990. According to the surveys conducted in 1991, 1996 and 1997, serious degradation was observed in all the reaches and the deepest degradation from 1996 to 1997 was about 4.5 m. Between 1991 and 2004, the average heights of riverbed degradation of the Brantas and Porong are 2.27 m and 1.95 m respectively. Continuous riverbed degradation has been causing serious bank collapse, destabilization and damage of river and relevant facilities such as rubber dam, bridge pier, weir, ground sill, revetment, water intake etc.

From the situation in the Brantas River basin as explained above, we can learn much that river basin development should be conducted in integrated and comprehensive manners. All aspects consist of technical, economic, social and environmental aspects etc should be taken into account comprehensively during the planning stage of water resources facility development.
Preface

- This presentation is mainly taken from the author’s experience in development and management of water resources in the Brantas River Basin.
- The experience shared in this presentation is not viewed from the academic perspective but is more aimed at improving the SIDCOM process of water resources development and management.

Facts of the Brantas River Basin

- Brantas is one of the strategic and important river systems in Indonesia.
- Functions as the most important source of water supply in East Java Province.

History of the Brantas River Basin Development

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Development Results in the Brantas River Basin

Workshop on Water and Sediment Management [Nov 22, 2007]

### Development Benefits

<table>
<thead>
<tr>
<th>Sector</th>
<th>Unit</th>
<th>1960</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Control</td>
<td>Inundated area</td>
<td>60,000 ha (annually)</td>
<td>None for the mainstream</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Cropping intensity</td>
<td>0.8 x annually</td>
<td>2.2 x annually</td>
</tr>
<tr>
<td>Power Generation</td>
<td>Million kWh/year</td>
<td>170</td>
<td>993</td>
</tr>
<tr>
<td>Bulkwater for Industry</td>
<td>Million m³/year</td>
<td>73</td>
<td>280.7</td>
</tr>
<tr>
<td>Bulkwater for Domestic</td>
<td>Million m³/year</td>
<td>50</td>
<td>126.5</td>
</tr>
</tbody>
</table>

### Water Use in the Basin

- **Electricity**: 993 M kWh/year
- **Irrigation**: 304.00 ha (83,000 ha from mainstream)
- **Bulkwater for Domestic Supply**: 280.68 M m³/year
- **Maintenance flow**: 204 M m³/year and flood control at 50 years return period = 60,000 ha
- **Fisheries**: 41 M m³/year

### Sediment Related Issues in the Basin

- The Brantas River basin faces serious sediment related issues that affect sustainable water resources management in the basin.
- The unbalanced sediment flow among reaches (upper, middle, lower) occurs in the basin that caused by:
  - Blocking of sediment flow by the dams and sabo facilities;
  - Erupted material of Mt. Kelud;
  - Excessive sand mining in the river.
- Although special care has been taken in the past to consider erosion-sedimentation, the recent land use change has led in the increase of erosion-sedimentation within the basin.

### Deposition of the Sediment

- Sutami Reservoir (completed in 1972), the main reservoir in the basin is rapidly losing their gross storage capacities, remains 50.93% of the originals gross storage capacities.
- In some smaller reservoirs such as Sengguruh, Wlingi and Lodo, their effective storage capacities were reduced to about 20-70 percent of original capacities.
- Most of those dams do not have facilities to remove deposited sediment in the reservoirs.
### Sediment Deposition

Wlingi Reservoir

### Transition of Reservoir Storage

<table>
<thead>
<tr>
<th>No.</th>
<th>Reservoir</th>
<th>Initial Capacity</th>
<th>Current Capacity</th>
<th>Rate of Sediment (mil m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sengguruh</td>
<td>19,7</td>
<td>21,5</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>Sutami</td>
<td>250.3</td>
<td>343.0</td>
<td>148.3</td>
</tr>
<tr>
<td>3</td>
<td>Lahvor</td>
<td>27.4</td>
<td>31.2</td>
<td>25.2</td>
</tr>
<tr>
<td>4</td>
<td>Wlingi</td>
<td>5.2</td>
<td>24.0</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>Lodingo</td>
<td>4.2</td>
<td>5.8</td>
<td>2.7</td>
</tr>
<tr>
<td>6</td>
<td>Sabangli</td>
<td>102.1</td>
<td>82.3</td>
<td>49.5</td>
</tr>
<tr>
<td>7</td>
<td>Bangun</td>
<td>28.4</td>
<td>32.9</td>
<td>20.2</td>
</tr>
<tr>
<td>8</td>
<td>Wetanir</td>
<td>99.4</td>
<td>111.6</td>
<td>99.5</td>
</tr>
</tbody>
</table>

### River Improvement Project

- In the past, discharge capacity in the Brantas River reduced due to riverbed aggradations caused by deposition of sediment from eruption of Mt. Kelud. Accordingly the river channel necessary for discharging the flood was proposed to be improved by dredging the river and heightening the existing levees.
- The Brantas Middle Reach River Improvement Project was proposed in the Second Master Plan in 1972. The project was implemented stage wise that consist of two phases
  - First Phase (1975-1985): 10-year flood
- In the last 1980’s, riverbed degradation in the Brantas River became so remarkable that Watudakon Siphon cropped out from the riverbed and irrigation intake became rather difficult. Responding to these problems, Jatimlerek and Menturus rubber dams and new Watudakon Siphon were constructed under Second Phase Project.

### Excessive Sand Mining

- Annual sand mining volume was estimated to be about 2.92 million m³ (2004). This increasing was caused mainly by expanding utilization of pumping equipment.
- The annual sand mining volumes above are considered higher than the expected sediment inflows along the stretches.
- The Brantas River Morphological Studies (1992) under estimated the average annual local sediment inflows along the Brantas River upstream of Kertosono:
  - First 5-year period Mt. Kelud eruption = 2,154,000 m³
  - Second 5-year after the eruption = 1,831,000 m³
  - Third 5-year after the eruption = 1,615,000 m³
- Between 1991 and 2004, the average heights of riverbed degradation of the Brantas and Porong are 2.27 m and 1.95 m respectively.
- Continuous riverbed degradation has been causing serious bank collapse, destabilization and damage of river and relevant facilities such as rubber dam, bridge pier, weir, ground silt, revetment, water intake etc.
Excessive Sand Mining

River Bed Degradation

Brantas River
Porong River

Degradation of riverbed in downstream section of Watudakon Siphon
Degradation of riverbed and exposed conduit (old Bangil Tak Siphon)

Collapse and Damage of Structures

Riverbed Profile of the Brantas River (1991-2006)

Collapse and Damage of Structures

Conclusion

- From the situation in the Brantas River basin as explained, we can learn much that river basin development should be conducted in integrated and comprehensive manners.
- All aspects consist of technical, economic, social and environmental aspects should be taken into account comprehensively.
## Technical:
- Loss of reservoir’s active storage due to sedimentation
- Water quantity management will endure problems due to the rapid erosion-sedimentation process
- Unbalanced sediment budget between the upper, middle and lower reaches

## Economic
- Hazard of floodings and landslide
- Externalities due loss of reservoir’s active storage

## Social
- Population pressure on water resources will deteriorate the resource itself

## Environmental
- Water quality degradation (including eutrophication at the reservoirs)
- Degradation of soil fertility leads into agriculture involution and higher use of fertilizers

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**THANK YOU**