ASSESSMENT MODEL OF WATER RESOURCE CONSERVATION MEASURES
Case Study at Upper Watershed of Sempor and Wadaslintang Dam

By: Sahid Susanto[1], Sigid Santosa[2] and Chandra Setyawan[3]

email: sahid.susanto@yahoo.com

A B S T R A C T

A quantitative assessment model for evaluating water resource conservation measures was created using system approach. The model contains three indicators: (i) basic performance indicators as the output reflecting the integrated effects, (ii) proxy indicator as the input reflecting the intervention of watershed through water resource conservation measures, and (iii) impact indicators reflecting the social and environment effects. The indicators are performed by scoring with applying weighting factors in each indicator. Range of the total score is 1-3. Hydrologic model of Mock is installed in the model to simulate the effects of water resource conservation measures. The model was applied in the degraded upper watershed of Sempor and Wadaslintang Dam located at Central Java. The watersheds are densely populated area and opening land for agricultural cultivation has been increasing. Using hydrologic data of 2000 to 2008, the result show that the model is sensitive enough to simulate the effects of water resource conservation measures applied in the two upper watersheds in the form of constructing check dams. They gave significantly effect in reducing surface run off coefficient (from 0.345 became 0.319 and from 0.46 became 0.34), sedimentation (from 0.134 became 1.2 and from 0.41 became 0.28 in million cumec) and increasing water resources availability (from 0.52 became 1.12 and from 1 became 1.3 in ratio of net inflow to rainfall) at upper watershed of Sempor and Wadaslintang Dam. The impact of the measures reflecting the social and environment was still not performed yet. Upper watershed of Sempor has total score of 2.0 means good and upper watershed of Wadaslintang has total score of 2.1 means good.

Key word: assessment model, system approach, degraded upper watershed of dam, water resources conservation measures

I. INTRODUCTION

The present environmental of watershed in Indonesia, particularly Java, are degrading. In case in the upper watershed of dam, through directorate general of water resources of the goverment of Indonesia has implement many water conservation measures programs, such as constructing of check dams, gully plugs, etc. but the rate of degradation is still exceed that of the programs, and an innovation assessment model for evaluating water resource conservation measures is still needed to ameliorate the situation, especially to conserve water resources at the upper watershed as a recharge area of dam.

[1] Professor at the Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta, Indonesia
[2] Staff member at Main Office of Serayu-Opak River Basin Development, Yogyakarta, Indonesia
[3] Staf member at the Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta, Indonesia

A quantitative assessment model for evaluating water resource conservation measures was created using system approach is proposed (Kodoatie, 2005). The aim of the study is directed to evaluate water resource conservation measures at the upper watersheds using a quantitative assessment model.

II. THE ASSESSMENT MODEL

2.1. The concept of the model

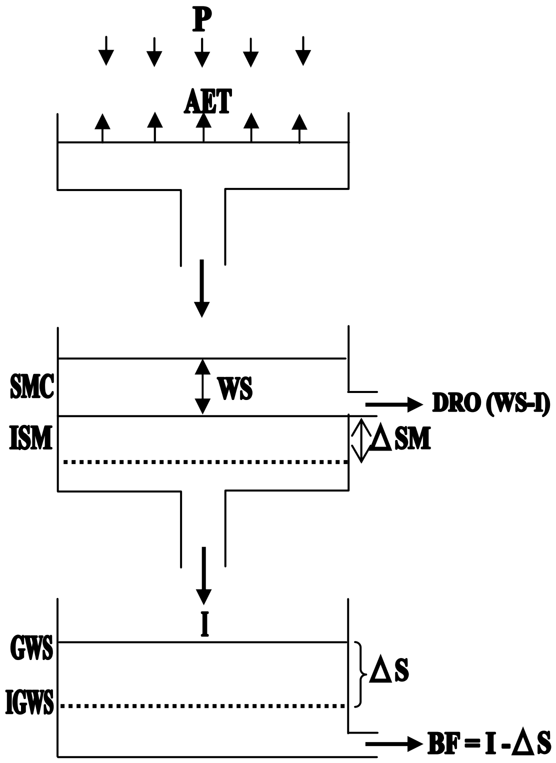
The basic principle of hydrologic system was applied to the watershed in the assessment model (Ponce, 1989). Those are input, process, output and impact. The model has two indicators: a) basic indicator and b) proxy indicator. Output of the watershed system is used as a basic indicator containing erosion and sedimentation, hydrology and water availability at the dam. Meanwhile input, process and impact are applied as a proxy indicator. The input and process has indicator of civil engineering and biological conservation measures, internal management performance and empowerment society. The impact has indicator of environmental and social and economic impact. All indicators are calculated in quantitative basis, and then they transfer to a scoring system with applying weighting factors in each indicator. The general condition of watershed is indicated from the calculated score (**Table 1**; Sukresno et al.,2004).

Table 1. Score of watershed condition

No	Condition of watershed	score
1	Very good	2,5 - 3
2	Good	2 - < 2,5
3	Average	1,5 - < 2
4	Bad	1 - < 1,5

2.2. Simulation of hydrologic processes

Mock hydrologic model of rainfall-discharge (Mock, 1973) is installed in the model to simulate the effect of water resource conservation measures on discharge (see **Figure 1**). Sedimentation from suspended load can be approached by using regression of discharge and suspended load. Bad load sedimentation is calculated using *Meyer-Peter and Muller's* method (Soemarto, 1999)



$AET = CF \times ETO$
$ER = P - AET$
$WS = ER - \Delta SM$
$ISM = SM_{I-1}$
$ISM_{FEB} = SM_{JAN}$
$IGWS = GWS_{I-1}$
$IGWS_{FEB} = GWS_{JAN}$
$I = C_W \times WS = C_D \times WS$
$GWS = 0,5 \times (1+K) \times I + K \times IGWS$
$Q_{BAS} = I - \Delta S = I - (GWS - IGWS)$
$Q_{TOT} = DRO + Q_{BSF}$

where :
P = rainfall (mm)
CF = crop factor
AET = actual evapotranspiration (mm)
ER = excess rainfall (mm)
DRO = direct runoff (mm)
WS = water surplus (mm)
ĀSM = change of soil moisture (mm)
SMC = soil moisture capacity (mm)
ISM = initial soil moisture (mm)
ĀS = change of ground water volume
IGWS = initial ground water storage
GWS = ground water storage
BF = base flow

Figure 1. Model Structure of Mock

III. RESULT AND DISCUSSION

3.1. Location of the study

The assessment model was applied in two degraded upper watersheds Sempor and Wadaslintang Dam located in the Serayu-Bogowonto river basin system, Central Java (**Figure 2**). The dams are multipurpose dam constructed for irrigation, electric power and drinking water. The area of upper watershed of Sempor dam is 41.8 km^2, meanwhile the upper watershed of Wadaslintang dam is 196 km^2.

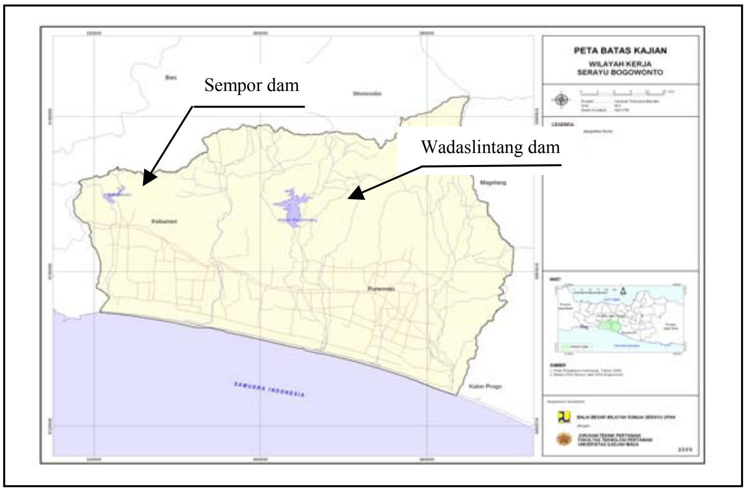


Figure 2. Location of Wadaslintang and Sempor Dam

Climatologically the watersheds fall in tropical monsoon climate. The condition of the watersheds are densely populated area and opening land for agricultural cultivation has been increasing. It causes erosion on the land and sedimentation to the dam.

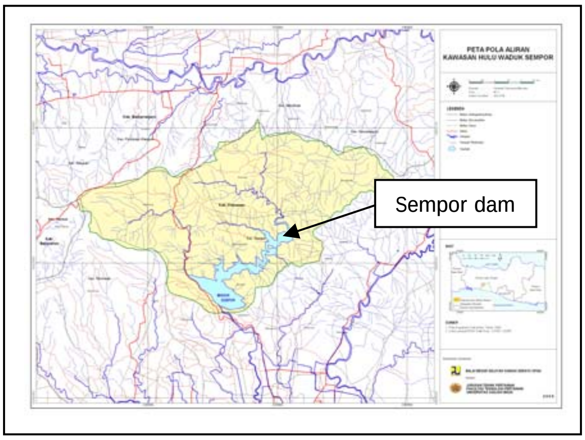


Fig.3. Upper Watershed of Sempor Dam

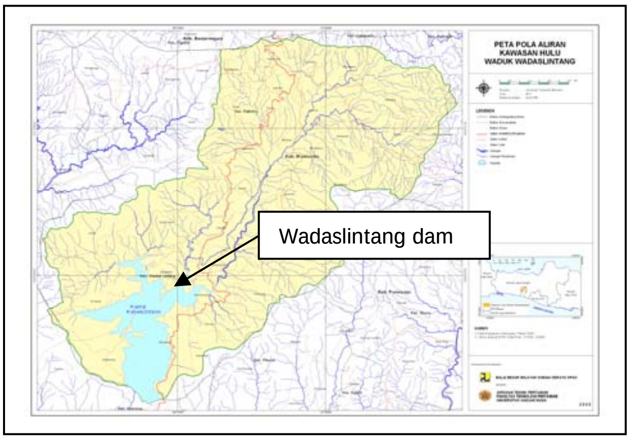


Fig.4. Upper Watershed of Wadaslintang Dam

3.2. Assessing water resource conservation measures

Table 2 and **Table 3** indicate the result of assessment model of the existing condition of watershed using scoring approach for the upper watershed of Sempor dam and Wadaslintang dam, respectively. Both from the two table shows that the model describes score value in each element. Score value of the output system of watershed is basically an integrated effect of input and process in the watershed (Asdak, 1995; Grigg, 1996). It is also as a basic indicator of watershed condition. Meanwhile, score values of impact give the effect of output of the watershed system.

Considering the condition of both two upper watersheds in the 1980^{th} was in degraded condition, it can be said that water resources conservation measures in the last 25 years, especially conducted Serayu-Opak Water Resources Main Office (Balai Besar Wilayah Sungai Serayu Opak, BBWS Serayu-Opak) has significantly effects in improving the upper watershed condition. This effect can be indicated in the present condition of the upper watershed with score values from the parameter output are mostly good. Meanwhile, score values from the process, especially for internal management gave mostly bad.

However, it can be shown from the table that the total score for the upper watershed of Sempor and Wadaslintang dam is 2.05 and 2.142, respectively. It means that both of upper watersheds in the present situation are in a position of good condition.

Table 2. Score value of the upper watershed of Sempor dam

No	Parameter	Unit	Weighting factor (%)	Year of Data	Average*	Category	Score	Score Value Each Element
1	2	3	4	5	6	7	8	9
A	Output							
1	Erosion loss	ton/ha/yr	**3**	1998	103.402	average	2	0.06
2	Sedimentation on the river	mm/yr	**3**	2004-2008	3.58	average	2	0.06
3	Sedimentation in the dam	mm/yr	**2**	1995-2004	2.5	average	2	0.04
4	Maximum discharge	$m^3/sec/km^2$	**3**	2000-2008	0.189	good	3	0.09
5	Minimum discharge	$m^3/sec/km^2$	**3**	2000-2008	0.0076	average	2	0.06
6	River regime coeffcient	-	**2**	2000-2008	26.991	good	3	0.06
7	Water storage availability = Rasio vol. aktual/vol.rancangan	million m^3/yr	**2**	2006-2008	0.4	bad	1	0.02
8	Water balance	million m^3/yr	**2**	2006-2008	Surplus	good	3	0.06
B	Input							
9	Sedimentation control on the river (Checkdam)	-	**13**	1998-2008	similar (4)	good	3	0.39
10	Gully Plug on tributaries	-	**8**	2008	similar (4)	good	3	0.24
11	Land: terraces, drainage canals	-	**10**	2006-2007	similar (2)	average	2	0.2
12	Replanting on stream bank	%	**5**	2008	23.75	bad	1	0.05
C	Process							
13	Permanent coverage index	%	**5**	2008	4.0	bad	1	0.05
14	Production of land coverage index	%	**5**	2008	89.35	bad	1	0.05
15	Data Base Manajemen Sistem	%	**2**	2008	< 50	bad	1	0.02
16	Manajemen Sistem of Monev of watershed	%	**2**	2008	50-80	Sedang	2	0.04
17	Human resources manajemen sistem	%	**2**	2008	< 50	bad	1	0.02
18	Internal watershed Monev system	%	**2**	2008	< 50	bad	1	0.02
19	Reporting watershed Monev system	%	**2**	2008	< 50	bad	1	0.02
20	Capacity building on conservation measures	%	**2.5**	2008	< 50	bad	1	0.025
21	Economic investment	%	**2.5**	2008	< 50	bad	1	0.025
D	Impact							
22	Land productivity	-	**5**	2007-2008	stable	average	2	0.1
23	Depth of soil solum	cm	**5**	2008	>80	good	3	0.15
24	Dependency of social income from land	%	**2.5**	2008	65	average	2	0.05
25	Population density	$person/km^2$	**2.5**	2003	± 900	bad	1	0.025
26	Social income	Rp/month	**2.5**	2008	<UMR	bad	1	0.025
27	Social instituition	-	**2.5**	2008	average	average	2	0.05
	Sum		100			-	53	**2.05**

***)** Source of data was collected from various report of Main Office of Serayu-Opak River Basin Development

Table 3. Score value of the upper watershed of Wadaslintang dam

No	Parameter	Unit	Weighting factor (%)	Year of Data Data	Average*	Category	Score	Score Value Each Element
A	Input							
1	Erosion loss	ton/ha/yr	**3**	1998	196.085	bad	1	0.03
2	Sedimentation on the river	mm/yr	**3**	2000-2008	1.77	good	3	0.09
3	Sedimentation in the dam	mm/yr	**2**	2004-2008	0.92355	good	3	0.06
4	Maximum discharge	$m^3/sec/km^2$	**3**	2000-2008	0.1987	good	3	0.09
5	Minimum discharge	$m^3/sec/km^2$	**3**	2000-2008	0.00678	average	2	0.06
6	River regime coeffcient	-	**2**	2000-2008	22.5862	good	3	0.06
7	Water storage availability = Rasio vol. aktual/vol.rancangan	million m^3/yr	**2**	2006-2008	0.566	Buruk	1	0.02
8	Water balance	million m^3/yr	**2**	2006-2008	Surplus	good	3	0.06
B	Input							
9	Sedimentation control on the river (Checkdam)	-	**13**	2007	similar (4)	good	3	0.39
10	Gully Plug on tributaries	-	**8**	2008-2009	similar (4)	good	3	0.24
11	Land: terraces, drainage canals	-	**10**	2006-2007	similar (2)	average	2	0.2
12	Replanting on streambank	%	**5**	2006-2008	81.09	good	3	0.15
C	Process							
13	Permanent coverage index	%	**5**	2008	8.5	bad	1	0.05
14	production of land coverage index	%	**5**	2008	78.0385	bad	1	0.05
15	Data Base Manajemen Sistem	%	**2**	2008	< 50	bad	1	0.02
16	Manajemen Sistem of Monev of watershed	%	**2**	2008	50-80	average	2	0.04
17	Human resources manajemen sistem	%	**2**	2008	< 50	bad	1	0.02
18	Internal watershed Monev system	%	**2**	2008	< 50	bad	1	0.02
19	Reporting watershed Monev system	%	**2**	2008	< 50	bad	1	0.02
20	Capacity building on conservation measures	%	**2.5**	2008	< 50	bad	1	0.025
21	Economic investment	%	**2.5**	2008	< 50	bad	1	0.025
D	Impact							
22	Land produktivity	-	**5**	2007-2008	stable	average	2	0.1
23	Depth of soil solum	cm	**5**	2008	>80	good	3	0.15
24	Dependency of social income from land	%	**2.5**	2008	76.92	bad	2	0.05
25	Population density	person/km^2	**2.5**	2003	± 685	bad	1	0.025
26	Social income	Rp/month	**2.5**	2008	<UMR	bad	1	0.025
27	Social instituition	-	**2.5**	2008	Cukup	average	2	0.05
	Sum		100				57	**2.142**

***)** Source of data was collected from various report of Main Office of Serayu-Opak River Basin Development

3.3. **Simulated discharge**

Hydrologic model of Mock was used to simulate discharge of the effects of water resource conservation measures at both two the upper watersheds conducted by BBWS Serayu-Opak during about the last 25 year has been significant.

For that reason, hydrologic data of 1982 and 2000 was used to calibrate the model in the upper watersheds of Sempor and wadaslintang dam (**Fig. 5** and **Fig. 6**). The Calibration process was conducted by trial and error. **Table 4** shows the optimal parameter of the model from the calibration process.

Tabel 4. The optimal parameter of the model from the calibration process

Parameter	unit	Simbol	Sempor DAM*	Wadaslintang DAM
			Optimal parameter	Optimal parameter
1. Area of watershed	km^2	A	44.158	192.53
2. Infiltration coefficient in rainy season	-	WIC	0.5	0.27
3. Infiltration coefficient in dry season	-	DIC	0.5	0.4
4. Initial soil moisture	(mm)	ISM	100	50
5. Soil moisture capacity	(mm)	SMC	100	140
6. Initial groundwater storage	(mm)	IGWS	1490.661	1990
7. Groundwater recession constant	-	K	0.995	0.995

* Using hydrologic data from Endah, 2005

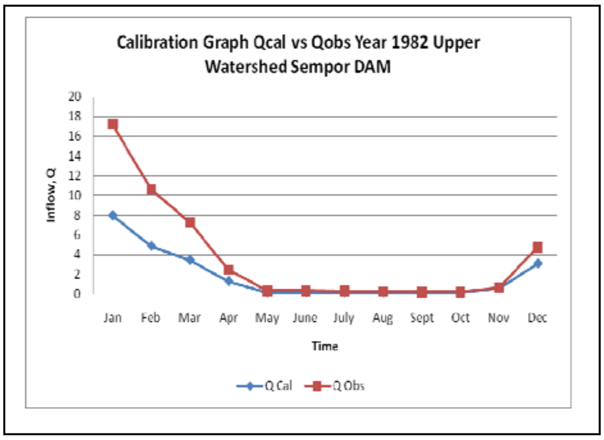


Fig. 5 Calibration Model Upper Watershed of Sempor Dam

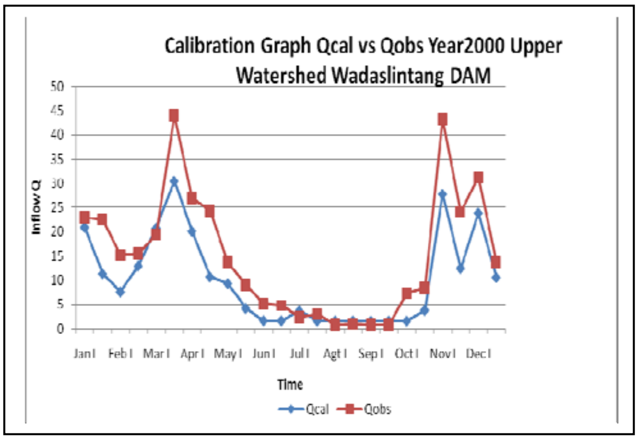


Fig. 6 Calibration Model Upper Watershed of Wadaslintang Dam

The results show that correlation coefficient (R) and volumetric error (%) for upper watershed of Sempor dam is 0.98265 and 0.02 respectively. For upper watershed of Wadaslintang dam is 0.94000 (R) and 0.32 %, respectively. They indicate that the model is sensitive enough to simulate the effects of water resource conservation measures applied in the two upper watersheds in the form of constructing check dams.

The model then was applied to simulate water discharge using data from the year of 2000 to 2008. The results are presented in **Figure 7** (a) to (d). All simulated discharge show that they represent of the typical discharge in the tropical monsoon climate. The monthly discharge in a year full cycles shows that in the rainy season (October/November-April/May), the discharge flows to the water storage of the dam, then the discharge change drastically when the dry season came (April/May-October/November). In the peak month of dry season (July and August) the discharge is always zero.

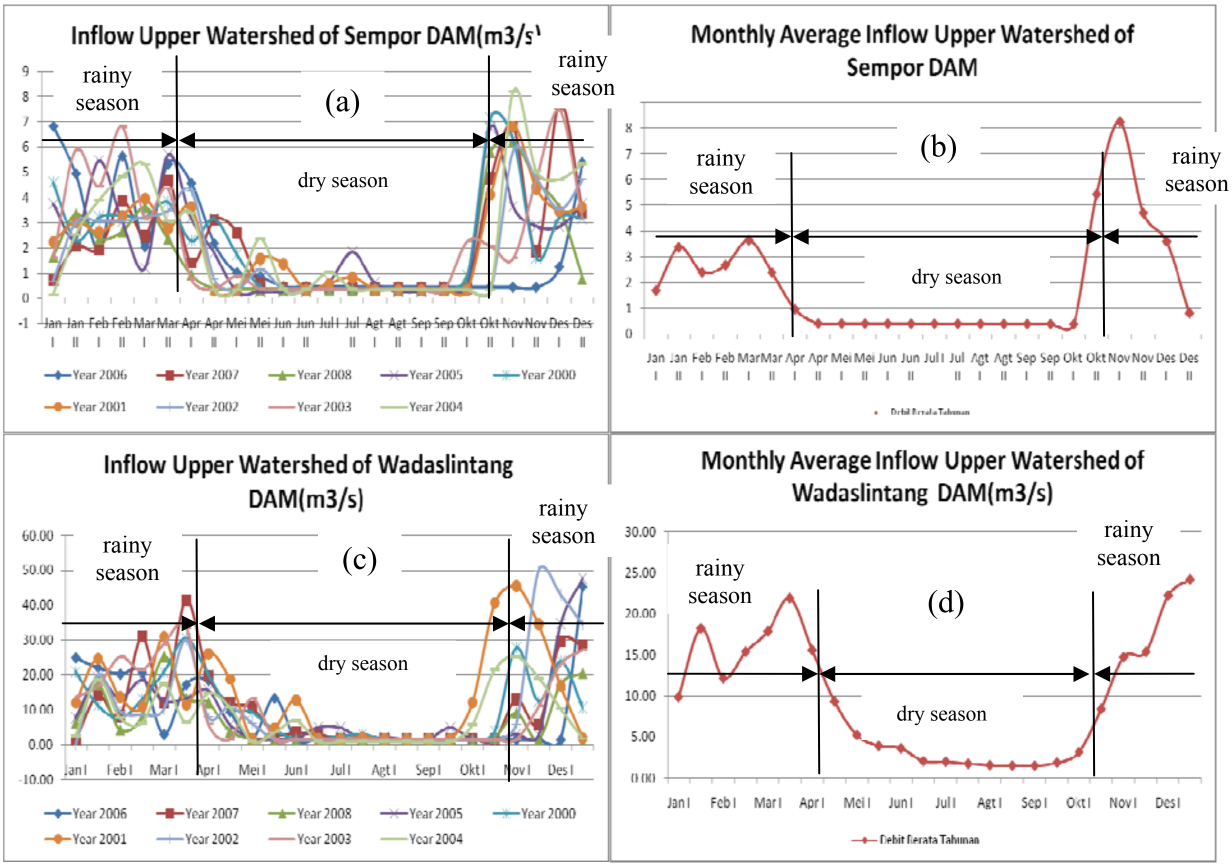


Fig. 7. Simulated discharge (2000-2008) and its average from the upper watershed of Sempor dam (a) and (b) and Wadaslintang dam (c) and (d)

3.4. Discharge inflow, runoff coefficient and sedimentation

Based on the simulated discharge, calculation of discharge inflow, runoff coefficient and sedimentation was calculated. **Fig. 8** presents the average ratio of rainfall and simulation discharge inflow (2000-2008) at the two upper watersheds study. The regression line, both for discharge from upper watershed of Sempor dam and Wadaslintang dam gives increasing trend during eight years.

Calculation result of the average runoff coefficient (2000-2008) is presented in **Fig. 9.** During eight years simulation gives the regression line with decreasing trend. The same trend also happens for sedimentation **(Fig. 10).**

The trend lines as mentioned above indicate that water resources conservation measures through constructing small, medium and large size of sedimentation control at some tributaries in the upper watershed of the dams have significant impact in increasing discharge inflow to the water storage of the dams, decreasing runoff coefficient and sedimentation flowing to the dams (**Fig. 11**)

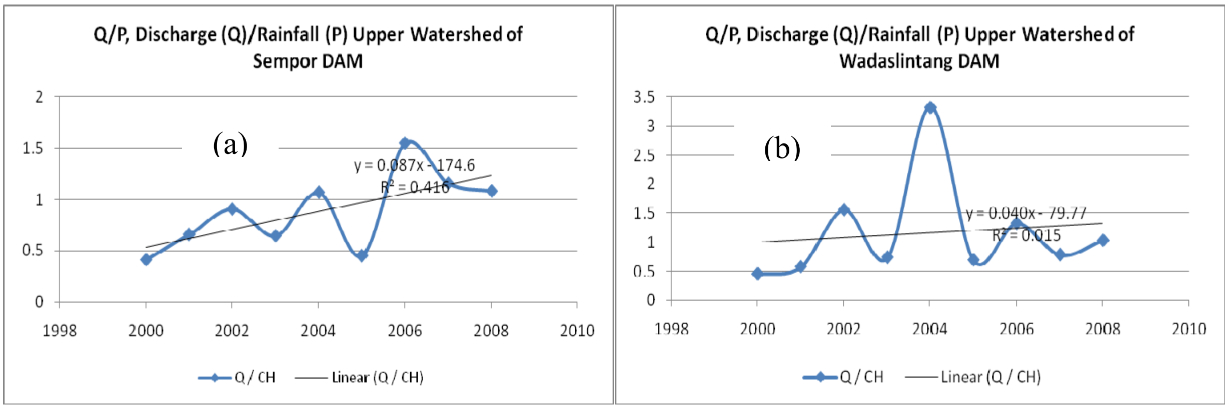


Fig. 8. Average ratio of discharge and rainfall at the upper watershed
(a) Sempor dam (b) Wadaslintang dam

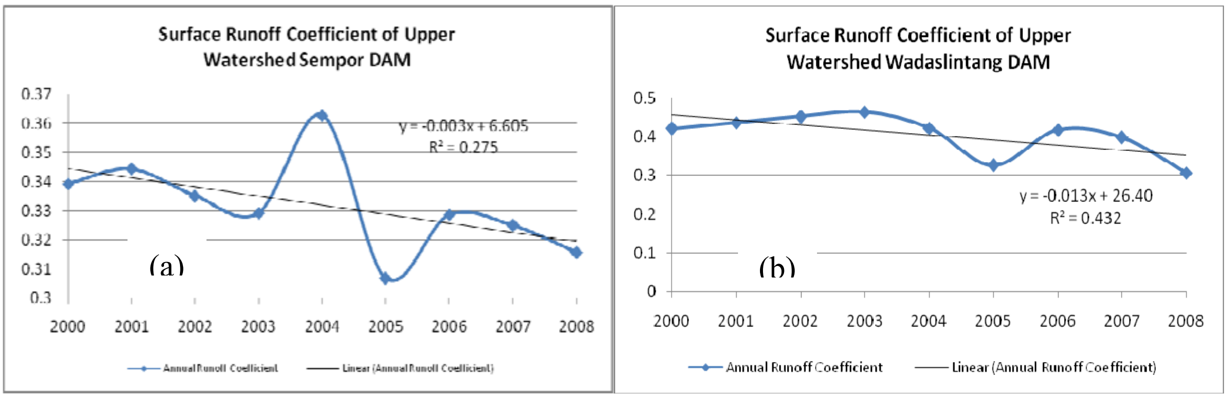


Fig. 9. Surface runoff coeficient at the upper watershed
(a) Sempor dam (b) Wadaslintang dam

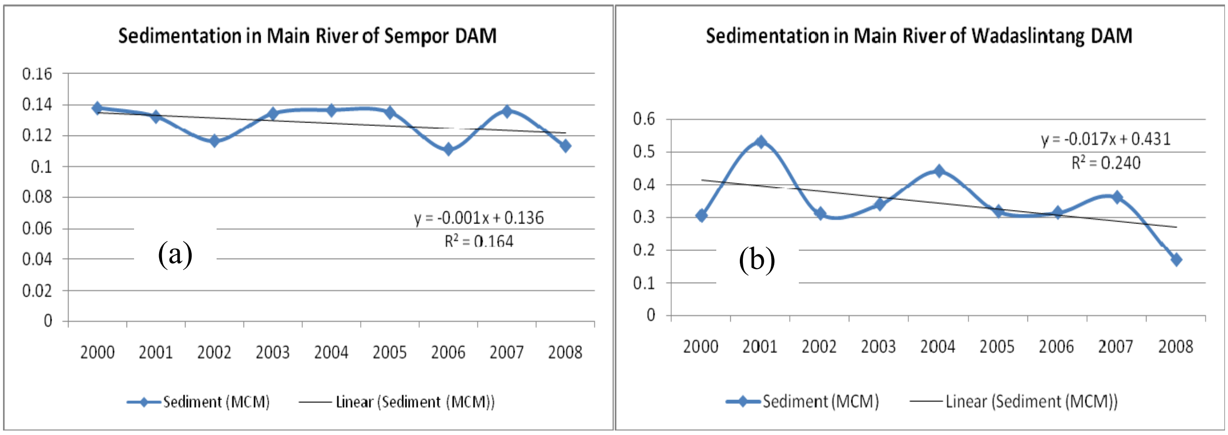


Fig.10. Sedimentation from the upper watershed
(a) Sempor dam (b) Wadaslintang dam

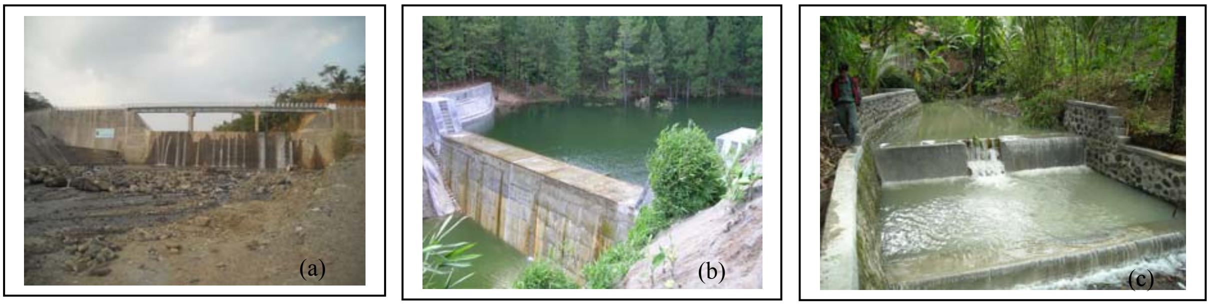


Fig. 11. Examples of contructing large, medium and small size of sedimention control built at some tributaries in the upper watershed of the dams

(a) Large size of sedimention control built at the upper watershed of Wadaslintang dam
(b) Medium size of sedimention control built at the upper watershed of Sempor dam
(c) Small size of sedimention control built at the upper watershed of Sempor dam

The simulation result of decreasing sedimentation inflow flowing to the dams as mentioned above are significantly in line with trend of decreasing sedimentation in the dam which was collected using echo sounding method conducted by Serayu-Opak Water Resource Office (*Balai Besar Wilayah Sungai Serayu-Opak*). In the Sempor dam, average sedimentation rate flowing to the dam in 1982 to 1994 was 0.19 million m^3/year decreasing became 0.11 million m^3/year in 1994 to 2004. In Wadaslintang dam, it was 1.9 million m^3/year in 1993-2004 became 0.711 million m^3/year in 2004-2008.

IV. SUMMARY AND CONCLUSION

4.1. Summary

The proposed quantitative assessment model for evaluating water resource conservation measures has been applied to evaluate the condition of two upper watersheds of Sempor and Wadaslintang dam, located in Central Java. The model contains three indicators: (i) basic performance indicators as the output reflecting the integrated effects, (ii) proxy indicator as the input reflecting the intervention of watershed through water resource conservation measures, and (iii) impact indicators reflecting the social and environment effects. The indicators are performed by scoring with applying weighting factors in each indicator. Range of the total score is 1-3.

Hydrologic model of Mock is installed in the model to simulate the effects of water resource conservation measures. The model proved that water resources conservation measures in the last 25 years, has significantly effects in improving the upper watershed condition. They gave significantly effect in reducing surface run off coefficient (from 0.345 became 0.319 and from 0.46 became 0.34), sedimentation (from 0.134 became 1.2 and from 0.41 became 0.28 in million cumec) and increasing water resources availability (from 0.52 became 1.12 and from 1 became 1.3 in ratio of net inflow to rainfall) at upper watershed of Sempor and Wadaslintang Dam. The impact of the measures reflecting the social and environment was still not performed yet. Both of the upper watersheds of Sempor and Wadaslintang have total score of 2.0 and 2.1, respectively. It means that the watershed is in good condition.

4.2. Conclusion

1. Application of the proposed quantitative assessment model at the upper watershed of Sempor and Wadaslintang Dam proved that the model was sensitive enough for evaluating water resource conservation measures at the watersheds. The assessment shows that water resources conservation measures in the last 25 years has significantly effects in improving the upper watershed condition. This effect can be indicated in the present condition of the upper watershed with score values from the parameter output are

mostly good. Total score for the upper watershed of Sempor and Wadaslintang dam is 2.05 and 2.142, respectively.

2. Discharge simulated by Mock hydrologic model show that change in discharge inflow, runoff coefficient and sedimentation flowing to the dams revealed the effect of water resources conservation measures through constructing small, medium and large size of sedimentation control at some tributaries.

4.3. Recommendations

Various programs of water resources conservation measure through building small, medium and large size of sedimentation control at tributaries should be continuously constructed. In order to make more area of permanent land cover, however, the program should be mixed with biological approach.

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