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Analysis of Surface Water Balance at Marmoyo Sub-Watershed, East Java, Indonesia

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ABSTRACT

This paper studied the potency of surface water at Marmoyo sub-watershed. Marmoyo sub-watershed was located at Jombang regency, East Java-Indonesia. The methodology consisted of analysis potency of surface water, nowadays demand and prediction for the year of 2030, and surface water balance. Result was used as a consideration of water resource management in this watershed.

Key Words: potency, surface water, water balance.

INTRODUCTION

Droughts inflict considerable economic and social damage worldwide [1]. That frequent and irregular occurrence has been a prime reason for the planning and construction of water resources infrastructure intended to increase the reliability of water supply in drought-prone areas. The understanding of drought recurrence, duration, and severity is of vital important to water supply because droughts exacerbate the scarcity of natural water sources. The two key variables in regional water planning such as instrumental records of stream flow and precipitation would be extracted information about the probabilistic nature and recurrence of droughts.

An urgent problem of hydrology and hydrogeology is the revaluation of current resources of surface and ground water in the context of present-day climate changes [2]. Studying spatial and temporal regularities in river run off formation in large river basins makes it possible to reveal the major relationships between water balance elements, the specific features of groundwater and surface water recharge and the formation of their natural resources under both existing and anticipated changes to climate its main elements (precipitation, river runoff, evaporation).

Much of water resources system analysis technology used today was initiated by the Harvard Water Project [3] and was motivated by institutional needs for tools for water resources infrastructure project evaluation and operation. As many countries have recently tried to adopt water sector reforms, it has become clear that there is a need for integrated mechanisms to (1) develop consensus to address conflicts and define the administrative goals of water policy and (2) promote desirable behavior of water users through regulation.

The correct management of water resources requires the maintaining of environmental-economic balance, under which the damage inflicted on natural objects and their resources is compensated for by water-environmental investments from the funds desired from water use [4]. The implementation of such

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management regime is hampered by the uncertainty of many factors that affect the decision-making and create the risk of ineffective investments of management efficiency requires studying the relationships between water quality indices, water use characteristics, and the volumes and direction of investments.

MATERIALS AND METHODS

This study was carried out at Marmoyo sub-watershed. Thesub-watershed was located at Jombang regency, East Java Province, Indonesia. Map of location was as Figure 1.

Figure 1. Map of Jombang Regency

The steps of this study were consisted of 1) collecting data hydrology; 2) field observation; 3) analysis of potency surface water nowadays and in coming year; 4) analysis of any water supplies nowadays and the prediction at the year of 2030; 5) analysis demand and supply surface water; and (6) analysis of potency of surface water balance. Surface water was included average area rainfall, evapotranspiration, and river flow.

Thiessen method (for analysis area rainfall supply):

$$P = \frac{P_1 A_1 + P_2 A_2 + \ldots + P_n A_n}{A_1 + A_2 + \ldots + A_n} = \frac{\sum_{i=1}^{n} Pi.Ai}{\sum_{i=1}^{n} Ai} \quad (1)$$

P_1, P_2, …., P_n = rainfall depth at rainfall station of 1, 2, …,. A_1, A_2, … A_n = area number of polygon: 1, 2, …, n. and n = number of rainfall station

Method of F.J. Mock (for analysis potency surface water) [5]

1. Limited Evapotranspiration

   $\square S \quad = P - ET_p$ (2)

   $E/ET_p = (m/20) \,.\, (18 - n)$ (3)

   $E \quad = Et_p \,.\, (m/20) \,.\, (18\text{-}h)\, ET_t$ (4)

   $ET_a \quad = ET_p - E$ (5)

2. Water Balance

   $WS \quad = P - SS\,(\square S\,)$ (6)

   $SS \quad = SMC_n - SMC_{n-1}$ (7)

$SMC_n = SMC_{n-1} + P_1$ (8)

3. Sub surface water balance

$dV_n = V_n - V_{n-1}\ WS$ (9)

$I = i\ .\ WS\ dV_n$ (10)

$V_n = 1/2\ .\ (1 + k)\ .\ I + k\ .\ V_{n-1}$ (11)

4. Surface flow

$R_o = BF + DR_o$ (12)

$BF = I - dV_n$ (13)

$DR_o = WS - I$ (14)

Note :

□S = netto rainfall depth (mm)

P = rainfall depth (mm)

ET_p = potential evapotranspiration (mm)

ET_a = limited evapotranspiration (mm)

WS = water surplus (mm)

SS = percentage groundwater (mm)

SMC = soil moisture (mm)

dV = change of percentage groundwater (mm)

V = percentage groundwater (mm)

I = infiltration rate (mm/s)

i = infiltration coefficient (<1)

k = recession coefficient of groundwater (<1)

DR_o = direct flow (mm)

BF = groundwater flow (mm)

R_o = surface flow (mm)

n = number of day in a month

m = percentage area uncovered by vegetation (0 < m < 50 %)

RESULTS AND DISCUSSION

The parameters of water balance at Marmoyo sub-watershed was included total water supply and demand. There were 4 conditions water balance due to five years period. There were 4 scenarios at the year of 2010, 2015. 2020. 2025. Each scenario based on dependable discharge with probability of 50% (average, scenario-1), 70% (scenario-2), 80% (scenario-3), and 90% (scenario-4). Results showed that water balance at the year of 2030 = 113.00 million m^3/year (scenario-1), 110.36 million m^3/year (scenario-2), 108.73 million m^3/year (scenario-3), and 106.08 million m^3/year (scenario-4). The whole result was described as Table 1.

Table 1 water balance at Marmoyo sub-watershed in the year of 2030

	Volume (million m^3)												
Compo-nent	**Jan**	**Feb**	**Mar**	**Apr**	**Mei**	**Jub**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**yearly**
outlet flow													
$Q_{raverage}$	33,306	28,156	29,204	20,895	16,110	10,972	7,854	5,852	5,463	5,463	7,908	13,538	184,72
$Q_{70\%}$	31,850	25,911	24,280	17,519	12,669	8,752	6,255	4,606	3,334	3,364	5,368	10,245	154,15
$Q_{80\%}$	29,287	24,771	20,347	17,391	12,299	8,351	6,087	4,435	3,233	2,696	3,585	8,105	140,59
$Q_{90\%}$	28,454	24,517	19,157	15,709	10,770	7,791	5,679	4,140	3,018	2,220	2,881	6,614	130,95
Total Supply	29,29	24,77	20,35	17,39	12,30	8,35	6,09	4,44	3,23	2,70	3,58	8,11	140,59
Domestic	0,29	0,26	0,29	0,28	0,29	0,28	0,29	0,29	0,28	0,29	0,28	0,29	3,42
Irrigation	3,71	3,74	3,82	2,11	2,42	2,93	2,17	1,66	2,66	2,23	1,57	2,03	31,06
Total demand	4,01	4,00	4,11	2,39	2,71	3,21	2,46	1,95	2,94	2,52	1,85	2,32	34,47
water balance	25,28	20,77	16,24	15,00	9,58	5,14	3,63	2,49	0,30	0,17	1,73	5,78	106,11

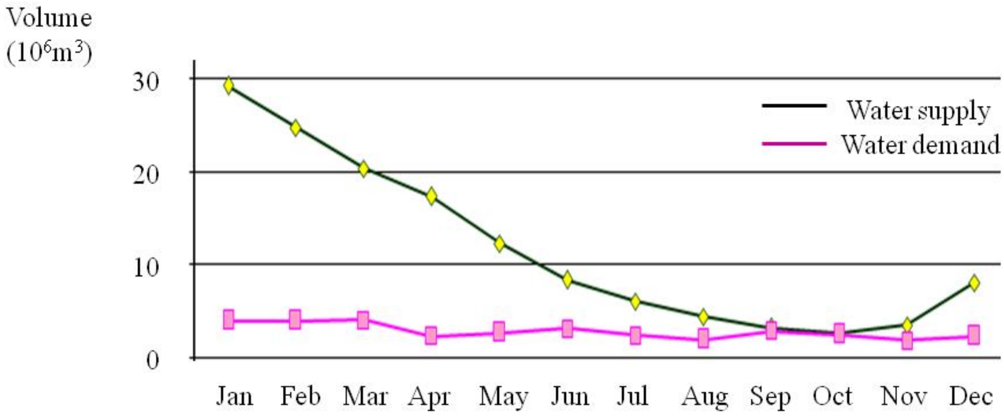

Figure 2. Water balance at Marmoyo watershed in the year of 2030

Conclusion

Potency of water supply at Marmoyo watershed was 183.646 million m^3/year. It included 119.63 million m^3/year of rainfall supply. Prediction total water demand at the year of 2030: 27.585 million m^3/year (scenario-1); 30.231 million m^3/year (scenario-2); 31.858 million m^3/year (scenario-3); 34.504 million m^3/year (scenario-4).

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