SYNERGIZING DIGITAL-BASED TECHNOLOGY AND MANAGEMENT IN WATER BALANCE CALCULATION AS DECISION SUPPORT SYSTEM FOR RIVER BASIN MANAGEMENT-STUDY AT UPPER CITARUM WATERSHED IN BANDUNG GREATER AREA

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ABSTRACT

Most of the water needs for households and industries in Bandung Greater Area (including agriculture, plantation, fishery) is supplied by Upper Citarum Watershed. Water balance analysis is absolutely necessary to respond to water needs that continues to increase simultaneously and to avoid water scarcity as well. Water balance analysis is very important to help the government to organize and plan water allocation for the fulfillment of households and industry needs. The study is conducted in the Upper Citarum Watershed that crosses the City of Bandung, Regency of Bandung, Regency of West Bandung, Regency of Sumedang and City of Cimahi, in 2016. The combination of calculation by manual and with DSS-Ribasim method is applied to attain the water balance value. The results exhibits that the DSS-Ribasim calculation shows the Q_{80} *mainstay discharge which means that the water requirement for household, city and industry is fulfilled well. Nevertheless, the water requirement for drinking water company (PDAM) in Regency of West Bandung, is only fulfilled by 55.7%. Meanwhile, the result of manual calculation shows that there is no shortage of water supply in general, but there is a deficit for PDAM in Upper Citarum Watershed which influences water supply for the City of Bandung, Regency of Bandung, Regency of West Bandung and City of Cimahi. The synergy of these calculation is expected to give an important contribution for the governments in Bandung Greater Area to improve their public sector performance management in organizing water allocation and avoiding water scarcity.*

Keyword: Digital-Based Technology, Water Value, Water Balance, Upper Citarum Watershed, Bandung Greater Area.

INTRODUCTION

Water covers 70% earth’s surface, but fresh water that is necessary for human life and industrial use, is just 2.5% and two-thirds of that is in the form of glacier. This small amount of fresh water causes about 1.1 billion people worldwide lack access to water and 2.7 billion people find water scarce for at least one month of the year (WWF, 2017). According to JP Morgan (2008) and 2030 Water Resource Group (2009) research, there is water scarcity that have major impact on public and private sectors. The 2030 Group concludes that by 2030, assuming an average annual growth of 2%, if no efficiency gains are realized, there will be 2.800 billion m^3 water shortage that affect domestic, industrial and agriculture needs.

As the population and industry grow, the demand of water continues to increase. Cities cannot be sustainable without ensuring reliable access to safe drinking water and adequate sanitation. World Water Assessment Programme (2009) mentions that almost all major cities in the world face the crisis of water in 2010. Yamashita (2012) states that the increase of water demand for industrial and domestic needs in Tokyo caused the government developed waterworks from surface water in remote areas. Nevertheless, according to Alimah and Putro (2014), the use of Citarum Watershed is dominated by households.

Upper Citarum Watershed which is part of Citarum watershed, covers Bandung city, Bandung Regency, West Bandung Regency, Sumedang Regency and Cimahi city where these areas are dominated by residential, agricultural and industrial areas. In this study, these areas called Bandung Greater Area. Bandung Greater Area community are highly depending on upper Citarum watershed and most of the water necessity is supplied from Citarum Watershed. Unfortunately, there has never been any research on water balance that calculate how much water supplied by Citarum Watershed to fulfil domestic, industrial and agriculture demand in Bandung Greater Area.

Therefore, in order to maintain the sustainability of water fulfillment for domestic, industrial and agriculture needs, this study is needed to calculate the need and availability. The result of this study can support government policy in terms of planning and managing water allocation for community needs in Bandung Greater Area. The water balance analysis can be used as a basis analysis to develop policy for Citarum Watershed to prevent water scarcity problem and the fulfillment of water supply for Bandung Greater Area.

LITERATURE REVIEW

Water Scarcity

Physical Water Scarcity

Water scarcity refers to the volumetric abundance or lack thereof, of water supply. This is typically calculated as a ratio of human water consumption to available water supply in a given area. Water scarcity is a physical, objective reality that can be measured consistently across regions and over time (Schulte, 2014). Water scarcity involves water shortage, water stress or deficits and water crisis. The relatively new concept of water stress is difficulty in obtaining sources of fresh water for use during a period of time; it may result in further depletion and deterioration of available water resources. Water shortages may be caused by climate change, such as altered weather-patterns (including droughts or floods), increased pollution and increased human demand and overuse of water (WWF, 2013). The term water crisis labels a situation where the available potable, unpolluted water within a region is less than that region's demand (Hinrichsen, 2008). Two converging phenomena drive water scarcity: Growing freshwater use and depletion of usable freshwater resources (Chance, 2011).

Water scarcity can be resulted by two mechanisms: (1) Physical (absolute) water scarcity and (2) Economic water scarcity. Physical water scarcity results from inadequate natural water resources to supply a region's demand and economic water scarcity results from poor management of the sufficient available water resources. According to the United Nations Development Programme, the latter is found more often to be the cause of countries or regions experiencing water scarcity, as most countries or regions have enough water to meet household, industrial, agricultural and environmental needs, but lack the means to provide it in an accessible manner.

Economic Water Scarcity

Many countries and governments aim to reduce water scarcity. The UN recognizes the importance of reducing the number of people without sustainable access to clean water and sanitation. The Millennium Development Goals within the United Nations Millennium Declaration aimed by 2015 to "halve the proportion of people who are unable to reach or to afford safe drinking water". Around one fifth of the world's population currently live in regions affected by physical water scarcity, where there is inadequate water resources to meet a country's or regional demand, including the water needed to fulfil the demand of ecosystems to function effectively. Arid regions frequently suffer from physical water scarcity. It also occurs where water seems abundant but where resources are over-committed, such as when there is over development of hydraulic infrastructure for irrigation. Symptoms of physical water scarcity include environmental degradation and declining groundwater as well as other forms of exploitation or overuse.

Economic water scarcity is caused by a lack of investment in infrastructure or technology to draw water from rivers, aquifers or other water sources or insufficient human capacity to satisfy the demand for water. One quarter of the world's population is affected by economic water scarcity. Economic water scarcity includes a lack of infrastructure, causing the people without reliable access to water to have to travel long distances to fetch water, that is often contaminated from rivers for domestic and agricultural uses.

Water Balance

Water balance will explain about the relation between inflow and outflow of water in certain area for a given period of water circulation. Water balance is the difference between the amount of water available (on the surface) and the water needed in a given period of time. Water balance can also refer to the ways in which an organism maintains water in dry or hot conditions. It is often discussed in reference to plants or arthropods, which have a variety of water retention mechanisms, including a lipid waxy coating that has limited permeability. This water requirement can be considered as DMI requirement (domestic, municipal and industrial). The simplest from of water balance equation is as follows:

$$P=Q+E+/-\Delta S \qquad (1)$$

P: Precipitation
Q: Runoff
E: Evaporation
ΔS: The storage in the soil, aquifers or reservoirs

In water balance analysis, it is often useful to divide water flows into ‘green’ and ‘blue’ water. ‘Blue’ water is the surface and groundwater that is available for irrigation urban and industrial use and environmental flows. ‘Green’ water is water that has been stored in the soil and that evaporates into the atmosphere. The source of 'green' water is rainfall or 'blue' water has been used for irrigation.

Water balance analysis can be used to: (1) Assess the current status and trends in water resource availability in an area over a specific period of time and (2) Strengthen water management decision-making, by assessing and improving the validity of visions, scenarios and strategies. Water balance estimates are often presented as being precise. In fact, there is always uncertainly, arising from inadequate data capture networks, measurement errors and the complex spatial and temporal heterogeneity that characterises hydrological processes. Consequently, uncertainty analysis is an important part of water balance estimation as is quality control of information before used.

When the data sources are imprecise, it is often possible to omit components that do not affect changes. For example, it is possible to omit storage from an annual water balance if year-on-year storage changes (such as reservoirs) are negligible. Some common problems that occur when water balance estimations are made include:

1. Temporal and spatial boundaries are not defined;
2. The quality of input data is poor;
3. Double counting of water flows when water flows within an area added to water flow exiting area;
4. Inappropriate extrapolation of field level information to a larger scale. Many hydrological relationships are scale dependent (e.g. runoff as a proportion of rainfall is almost always higher at smaller spatial and temporal scales);
5. Intuition (often based on popular myths) is used rather than good quality information;
6. The storage term(s) of the water balance is omitted;
7. Political or other pressures result in unreliable estimates that have been manipulated.

METHODOLOGY

Time and Location of Research

The researched location is Upper Citarum Watershed that crosses Bandung City, Bandung Regency, West Bandung Regency, Sumedang Regency and Cimahi City area throughout 2016. The followings are the rivers that flow along the Citarum Watershed (Table 1):

Table 1
WATER DISTRICT IN UPPER CITARUM WATERSHED

No	Water District	Area (km^2)
1	Citarik	245.55
2	Saguling	431.61
3	Kedaleman/Cirasa	306.81
4	Cisangkuy	190.05
5	Cikapundung	32.8
6	Cekungan Bandung	336.34
7	Patrol-Ciwidey	74.76
8	Tegal Luar-Cikeruh	72.24
	Upper Citarum watershed	1689.93

Source and Technique of Data Collection

Data collection techniques in this study is related to the tools or instruments to obtain data. Data are collected based facts according to the type of data used. The primary data are collected by performing interview and field observation while the secondary data are collected by analysing various sources, especially data from Balai Besar Wilayah Sungai (BBWS) Citarum (Figure 1).

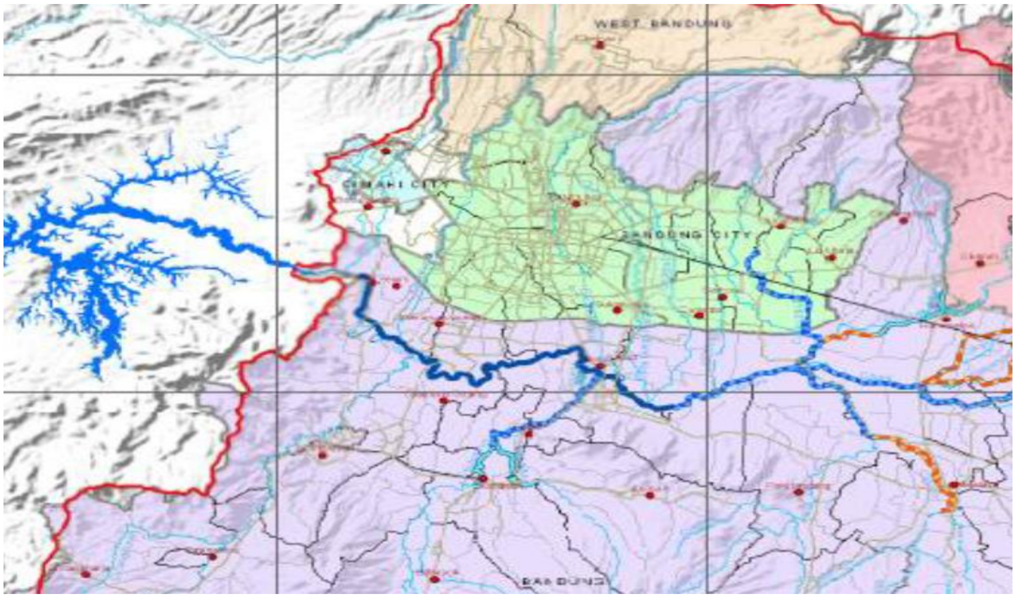

FIGURE 1
RESEARCHED LOCATION (JICA, 2010)

Water Allocation Simulation

The water allocation simulation model can answer the question that often arise in the development of water resources such as:

1. Alternative and potential evaluation of water resource development:
   a. How to develop water supply and irrigation networks without causing water shortage and harm other water users in an area with fluctuation water availability like Citarum watershed.
   b. Conflict of interest possibility between water users (for irrigation, hydropower plant, raw water and others) that may happen in the future.
   c. Comparison of hydropower plant and water discharge potential with or without reservoir.
2. Waterworks development and management assessment:
   a. Determining reservoir development effectiveness to fulfill water needs in various sectors;
   b. Determining the reservoir dimension that meet water demand.

This simulation model should be able to calculate and simulate the unique and important characteristics of Citarum Watershed, especially the availability of water, water requirements, the operation of the water system and the alternative solution and also provide easy data entry and well-presented output with alternative solutions that are easily evaluated. In this simulation, there are two important things, they are the condition of the water system stated in the water system scheme and planned alternative water resources development.

Water System Scheme

This scheme is developed to give the picture about hydrological water system, complete with water structures and its carrier. The water system scheme consists of nodes represent water resource, water requirement and infrastructure and branches represent river, canal, tunnel or pipe. The nodes consist of three types, which are:

1. Ordinary node as an element in the water system that does not control the water flow. These nodes can be either an inflow node, terminal node, confluence node, run-of-river node, dummy node or district drainage node.
2. Activity node as water requirement node can be either public water supply node, low flow node, irrigation node, fishpond node, district extraction node or loss flow node.
3. Control node as irrigation structure that control water system, can be either a reservoir or dam.

Water District

To illustrate the scheme properly, delineation is conducted for watershed and water districts. Water district is the smallest natural area that bounded by water infrastructure in river or natural boundary such as stream, which is then used to illustrate the area of the scheme for this study. This water district represents:

1. The smallest hydrological unit that covers water demand and supply
2. Have the same capabilities with watershed to response rain and flow
3. A complementary unit in managing and balancing water resource

The division of water district size is based on the detail of the region that needed to be analyzed and the location of water infrastructure and water supply on the river. Each water district has certain characteristic which can generally classified into three parts: (1) Upper water district; (2) middle water district; (3) lower water district. Upper water district acts as water catchment area and water reservoir and needs to be protected. As inflow node, the analysis also considering rain run-off relationship. The middle water district area is more complex because it is the production and utilization area, characterized by the existence of agriculture, raw water production and so on. The lower water district area is the utilization, disposal, irrigation, fishpond and urban areas that have water allocation issues, estuary coastal management and seawater intrusion.

Water Balance Calculation

The water balance calculation and analysis of the Upper Citarum Watershed are done with digital-based technology and management, which are: (1) DSS-Ribasim by provide complex data inputs from water availability and demand fluctuation in each water system location and (2) Calculating the amount of water discharge inflow and outflow on each river or channel in the scheme with Microsoft Excel using average data as input. The manual calculation result will then enrich the result from DSS-Ribasim and give different perspective.

DSS-Ribasim

Decision making on water management policy at the national, river basin or polder level is a complex matter. A policy maker or river basin authority may want to reduce flood risk or improve water quality. The decision on what to do is ultimatedly political, but in order to make well founded decisions, information on the water system is required. The decision makers may not be water managers or many different disciplines are required or they may want to involve other stakeholders. In all these cases information needs to be shared and needs to be processed in such as way that the information facilitates the decision making process. A tool that makes this possible is a Decision Support System or DSS (TU Delft).

Decision Support System River Basin Simulation (DSS-Ribasim) is a decision support system on water resource management. DSS-Ribasim is a generic model to simulate water districts behavior under various hydrological conditions, water demands and existing water infrastructures (Giupponi, 2011). This tool is a comprehensive, integrated and flexible simulator that connects the hydrological input from certain location and various water activities. This model was inspired by the MITSIM in United States and developed by Delft University of Technology in Netherland since 1985. This model has been used in more than 20 countries in the world. This study used various hydrological conditions such as wet, normal and dry conditions throughout the year to calculate and analyze water balance and impact of the strategy to improve water availability.

Manual Calculation

The results of the water balance calculation are shown separately and sequentially from Upper Citarum to Lower Citarum river followed by its streams. Manual calculation used average water discharge Q_{80} and Q_{95} inflow and outflow on each river or channel in the scheme. The amout of water discharge are calculated with Microsoft Excel.

RESULTS

DSS-Ribasim Results

To analyse and calculate water balance in various hydrological conditions and the impact of the strategy to improve water availability, the simulation is conducted in wet, normal and dry conditions. The scenario is conducted in water infrastructure on wet condition (maximum), normal condition and dry condition (minimum). The result of water balance in Upper Citarum watershed is shown in Table 2. Meanwhile, DSS-Ribasim result shows the mainstay water discharge on each river segment and the fulfillment of water demand. Q_{80} of mainstay water discharge on each river segment is shown in Figure 2.

Table 2
WATER BALANCE

Balance Component	m^3/s	Million m^3/year
Average supply	95.242	3,003.57
Irrigation	19.679	620.60

Table 2
WATER BALANCE

Domestic, municipal, industrial	2.935	92.26
River treatment	10.98	346.26
Remainder (surplus)	61.649	1,944.16

In general, the water balance shows surplus in rainy season (October-May) with about 65%, but there is deficit of water supply in dry season (June-September) and the river treatment is difficult to realize. PDAM Bandung (municipal water treatment) relies on Cisangkuy river and experiences water shortage, so it is necessary to get supply from Cilaki river and Cibatarua river. DSS-Ribasim using Q_{80} mainstay water discharge results show the fulfillment percentage of domestic, municipal and industrial (DMI) demand as follows.

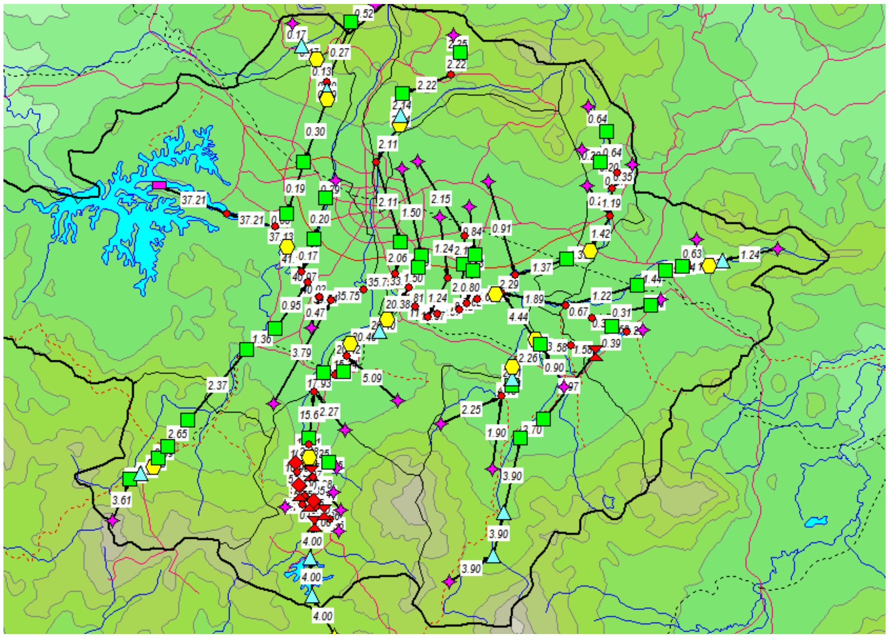

FIGURE 2
AVERAGE WATER DISCHARGE IN UPPER CITARUM WATERSHED (BP DAS CITARUM-CILIWUNG, 2009)

Table 3
FULFILLMENT OF WATER DEMAND FOR DMI

No.	Water Demand	Demand (m^3/s)	Deficit (m^3/s)	Fulfillment (%)	
				Volume(m^3)	Time (s)
1	PDAM Bandung city 4 m^3/s	4.005	0.000	100	100
2	PDAM Bandung city 1.6 m^3/s	1.602	0.802	50	50
3	PDAM Bandung city 0.1 m^3/s	0.100	0.000	100	100
4	PDAM Bandung Regency 3.5 m^3/s	3.505	2.061	41	33
5	PDAM Bandung Regency 0.5 m^3/s	0.501	0.000	100	100
6	PDAM Bandung Regency 0.2 m^3/s	0.200	0.000	100	100
7	PDAM Cimahi city 0.4 m^3/s	0.401	0.038	91	33
8	PDAM West Bandung Regency 0.3 m^3/s	0.300	0.133	56	0
9	Industry 16 m^3/s	16.022	0.000	100	100
10	PT Panafil (Industry) 70 l/s	0.070	0.000	100	100

Table 3
FULFILLMENT OF WATER DEMAND FOR DMI

11	Banjaran Pameungpeuk (Industry) 106 l/s	0.106	0.000	100	100
12	Saguling 4 m^3/s	4.005	0.000	100	100
	Total	**31.718**	**3.034**	**90.4**	**81.1**

The Table 3 shows that in general all DMI water demand can be fulfilled except for PDAM West Bandung Regency which only 56% fulfilled because of the limited water discharge from Cimeta river as main source. It is necessary to get additional supply from Cimahi river. PDAM Bandung city also experienced a considerable water shortage, but it can be solved by constructing Sentosa water reservoir and inter basin transfer from Cilaki and Cibatarua river. The result of water demand fulfillment for irrigation area is shown in Table 4. This table shows that in general most of irrigation area water demand is fulfilled except in Sudiplak, Malang and Lagadar and Mandalasari irrigation area. It should be considered that some of these irrigation area lands have been transformed into settlements area.

Table 4
FULFILLMENT OF WATER DEMAND FOR IRRIGATION AREA

No.	**Water Demand**	**Demand (m^3/s)**	**Deficit (m^3/s)**	**Fulfillment (%)**	
				Volume (m^3)	**Time (s)**
1	Ciherang 2,460 ha	2,93	0	100	100
2	Wanir 2,098 ha	2.42	0.72	70.4	50
3	Wangisagara 1,697 ha	1.96	0.92	53.2	16.7
4	Cirasea 3,052 ha	3.52	0.89	74.6	50
5	Ciyasana 1,189 ha	1.37	1.06	22.4	0
6	Lembang 191 ha	0.22	0.08	63.2	50
7	Cikareumbi 63 ha	0.07	0.03	63	50
8	Ciregol 115 ha	0.13	0.05	63.2	50
9	Sukasari 232 ha	0.27	0.27	0	0
10	Panyocokan 476 ha	0.55	0.09	83.9	75
11	Depok 580 ha	0.67	0.67	0	0
12	Panundaan 232 ha	0.27	0.04	83.9	75
13	Leuwikuya 2,573 ha	2.96	1.28	56.7	16.7
14	Soreang 1,120 ha	1.29	0.61	52.9	16.7
15	BBkan Jampang 449 ha	0.52	0.08	83.9	75
16	Rancabuaya 763 ha	0.88	0.14	84	75
17	Kiangroke 63 ha	0.07	0.00	100	100
18	Cibatubeureum 70 ha	0.08	0.00	100	100
19	Panyadap 1,079 ha	1.24	0.70	43.6	8.3
20	Rancakasumba 430 ha	0.50	0.10	80.6	66.7
21	Cangkuang 403 ha	0.46	0.15	67.5	50
22	Cicalengka 267 ha	0.31	0.11	63.3	50
23	Mandalasari 1.159 ha	1.34	1.34	0	0
24	Muncang 152 ha	0.18	0.18	0	0
25	Kujangsari 147 ha	0.17	0.17	0	0
26	Cibeunying Ciateul 149 ha	0.17	0.17	0	0
27	Cijanggel 391 ha	0.45	0.02	95.6	75
28	Bongkok 170 ha	0.20	0.00	98.5	83.3
29	Malang dan Lagadar 750 ha	0.86	0.68	21.1	8.3
30	Nanjung 360 ha	0.42	0.27	35.4	0
31	Sudiplak 210 ha	0.24	0.19	21.1	0
32	Sukapura dan Buahbatu 287 ha	0.33	0.33	0	0
33	Ranjeng 150 ha	0.17	0.15	11	8.3

Table 4
FULFILLMENT OF WATER DEMAND FOR IRRIGATION AREA

34	Rancalili 398 ha	0.46	0.41	10.9	8.3
35	Cikalong 145 ha	0.17	0.00	100	100
	Total	**27.73**	**11.89**	**57.1**	**38.8**

Manual Calculation Results

The results of the water balance calculation using Microsoft Excel are shown separately and sequentially from Upper Citarum to Lower Citarum river followed by its streams.

Cisarea River

Cirasea river has Q_{80} with 2.25 m^3/s and Q_{95} with 1.58 m^3/s, it has 2 streams orde 3 which are Cikoneng and Cigarugag rivers with respectively Q_{80} with 1.90 m^3/s and 0.89 m^3/s and Q_{95} with 1.32 m^3/s and 0.68 m^3/s. It supplies water for Cirasea irrigation area and PDAM Bandung Regency. There is also Cibodas water reservoir that has the capacity of 317.96 m^3. Figure 3 shows the example of manual calculation result for Cisarea river.

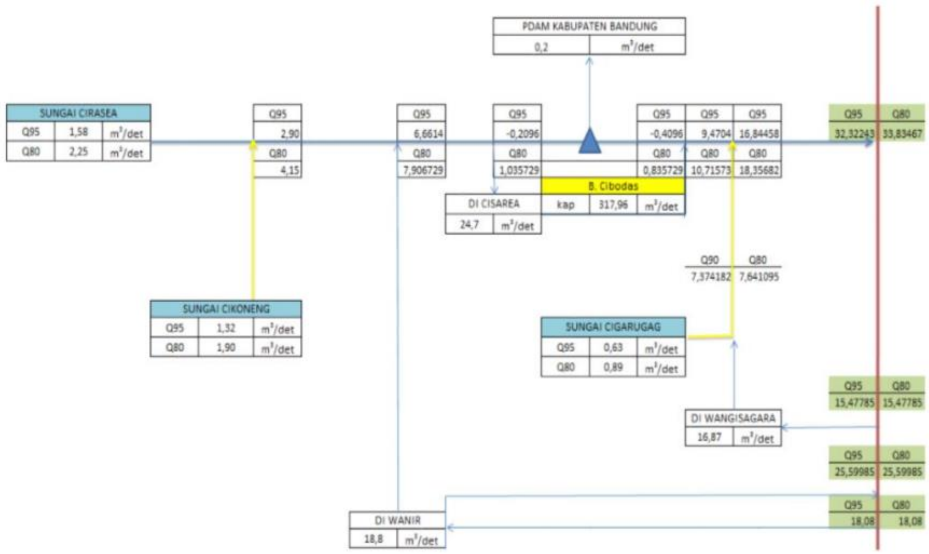

FIGURE 3
CISAREA RIVER SCHEME (BP DAS CITARUM-CILIWUNG, 2009)

Citarik River

Citarik river has Q_{80} with 2.25 m^3/s and Q_{95} with 1.58 m^3/s, it has 3 streams orde 3 which are Cimulu, Cikaloge and Cimanggung rivers that supply water for Cangkuang, Cicalengka, Mandalasari, Ciyasana and Panyadap irrigation area and PDAM Bandung Regency. There is also one reservoir namely Citarik reservoir.

Cikeruh River

Cikeruh river has Q_{80} with 0.54 m^3/s and Q_{95} with 0.39 m^3/s, it has 5 streams orde 3 which are Cibanjaran, Cinambo, Cipariuk, Cibeusi and Cisaranten rivers that supply water for Sukasari, Muncang and Depok irrigation area and PDAM Bandung Regency.

Cipamokolan, Cidurian and Cicadas River

Cipamokolan river has Q_{80} with 0.85 m^3/s and Q_{95} with 0.63 m^3/s, Cidurian river has Q_{80} with 2.16 m^3/s and Q_{95} with 1.6 m^3/s and Cicadas river has Q_{80} with 1.24 m^3/s and Q_{95} with 0.93 m^3/s that supply water for Ranjeng, Rancacili, Buahbatu and Kujangsari irrigation area.

Cikapundung River

Cikapundung river has Q_{80} with 2.25 m^3/s and Q_{95} with 1.95 m^3/s, it has 2 streams orde 3 which are Cikapundung Kolot and Kali Gemuruh rivers that supply water for Cikareumbi, Lembang and Ciregol irrigation area, PLTA Tirtawening and PDAM Bandung city. There is also one reservoir namely Cikapundung reservoir.

Cisangkuy River

Cisangkuy river has Q_{80} with 6.36 m^3/s and Q_{95} with 4.06 m^3/s, it has 8 streams orde 3 which are Cinyiruan, Cisarua, Cikalong, Cilaki, Cigeureuh and Citalugtug rivers that supply water for Cikalong, COS Gantung, Cilaki, Cibatu Bereum, Cimedal, Ciherang, Kiangroke irrigation area, PLTA Plengan, PLTA Cikalong, PLTA Lamajan, PDAM Bandung Regency and PDAM Bandung city. There is also two reservoir namely Sentosa and Cibintinu reservoir.

Cigondewah and Cibolerang River

Cigondewah river has Q_{80} with 3.79 m^3/s and Q_{95} with 2.99 m^3/s and Cibolerang river has Q_{80} with 0.47 m^3/s and Q_{95} with 0.4 m^3/s that supply water for Soreang irrigation area while Cibintinu river work as outlet for that irrigation area.

Ciwidey River

Ciwidey river has Q_{80} with 3.61 m^3/s and Q_{95} with 3.01 m^3/s, it has 3 streams orde 3 which are Ciinjuk, Cikawung and Cibodas rivers that supply water for Babakan Jampang, Rancabuaya, Panundaan, Leuwikuya and Soreang irrigation area and PDAM Bandung Regency. There is also one reservoir namely Ciwidey reservoir.

Cibeureum River

Cibeureum river has Q_{80} with 0.29 m^3/s and Q_{95} with 0.27 m^3/s that supply water for Nanjung and Sudiplak irrigation area while Citarum river work as outlet for that irrigation area.

Cimahi River

Cimahi river has Q_{80} with 0.52 m^3/s and Q_{95} with 0.49 m^3/s, it has 1 streams orde 3 which is Cimeta river that supply water for Cijanggel, Bongkok, Malang and Lagadar irrigation area and PDAM West Bandung Regency. There is also two reservoir namely Sukawana and Cimeta reservoir.

DISCUSSION

Citarum Watershed is the biggest watershed in West Java and plays an important role in supplying water for West Java and Jakarta. Citarum has 269 km length and area of 6.614 km^2 or about 22% of West Java area. Citarum watershed is divided into three parts which are Upper Citarum watershed, Middle Citarum watershed and Lower Citarum watershed (BBWS Citarum, 2010). The rainfall intensity in Upper Citarum watershed is strongly influenced by the topography. The annual rainfall varies from 1,966 to 2,600 mm. The rainy season start from November to April and the rainfall intensity can reach 300 mm. Based on Schmidt-Fergusson's Climate Classification, Citarum watershed climate classification is C and Am (tropical monsoon) according to Köppen Climate Classification System and B2 according to Olderman Classification (BPDAS, 2009). The benefits of the Upper Citarum watershed for society and industry are:

Support Water Security

Communities and industries use water from Citarum for daily use and agricultural such as paddy fields, vegetables and so on. The industries use water in production and cooling process. There are 484 industries and 75% of them are textile industry that require a lot of water.

Support Energy Security

Citarum watershed is the source of three largest reservoirs in West Java which are Saguling reservoir with volume of 982 million m^3, Cirata reservoir volume of with 2,165 million m^3 and Jatiluhur with volume of 3,000 million m^3. Those reservoirs and the other reservoirs produce 1,400 MW for PLTA (hydropower plant) which supplies electricity for Java and Bali (Fulazzaky, 2014).

Support Food Security

Water from Citarum watershed is utilized to support food security by irrigating agricultural area (especially around Pantura) through irrigation canal with total about 300,000 hectares. Citarum watershed also a source of raw water with 5,5 billion m^3/year for large cities such as Bandung and Jakarta and other area around Citarum watershed (Parikesit et al., 2005).

Agricultural, Technical and Vocational Education

Water from Citarum watershed is not only essential for agriculture, but also can be used as a media to educate people on technical and vocational activities. At the end, this will have an impact on poverty alleviation and rural development, which finally resulted on sustainable economic development (Chamel & Hartl, 2011; MoFED, 2006).

As an addition, technological advancements which are implemented in the Citarum watershed can spur economic development in West Java industry and agriculture. The technological progress can cause the lowering of the cost of production. Moreover, by improving the efficiency with which existing products are produced, new technologies can open up the possibility of increasing output and, assuming that markets are available, taking advantage of previously unexploited increasing returns to scale (The World Bank, 2008).

Upper Citarum Watershed has 26,022 ha critical area which encounter degradation of water resources conservation function. The other issues happened in Upper Citarum watershed is floods caused by:

1. Forest conversion that remove natural forest to meet other land needs, such as plantations and agriculture.
2. Unplanned development of settlements area on forestland.
3. Uncontrolled cropping pattern.
4. Groundwater exploitation that also caused land subsidence.
5. Water pollution from domestic, industrial and agriculture waste.
6. Erosion in Upper Citarum watershed that increase sedimentation in middle and lower area.

CONCLUSION

This study synergizes simulation and manual calculation to calculate water balance in Upper Citarum watershed. This result is very beneficial for the government of Bandung Greater Area as an information to be considered for decision making to manage and distribute water to meet domestic, industrial and agriculture needs as well as to avoid water scarcity in all area.

The conclusion of water balance in Upper Citarum watershed from DSS-Ribasim analysis is shown in Table 5. In general, the water balance shows surplus in rainy season (October-May) with about 65%, but there is deficit of water supply in dry season (June-September) and the river treatment is difficult to realize. PDAM Bandung relies on Cisangkuy river and experiences water shortage, so it is necessary to get supply from Cilaki river and Cibatarua river. Water demand for domestic, municipal and industrial is well supplied except PDAM West Bandung Regency which fulfil about 55.7% because of the limited discharge of Cimeta river so it is necessary to get supply from Cimahi river. Most irrigation water needs are supplied, except Sudiplak, Malang and Lagadar and Mandalasari irrigation area. It is necessary to improve the canal efficiency, water infrastructure and operation and maintenance service to solve this issue.

Table 5
WATER BALANCE

Balance Component	m^3/s	Million m^3/year
Average supply	95.242	3,003.57
Irrigation	19.679	620.60
Domestic, municipal, industrial	2.935	92.26
River treatment	10.98	346.26
Remainder (surplus)	61.649	1,944.16

Meanwhile, the conclusion from manual calculation with Microsoft Excel is that there is no water shortage for every demand site in all water allocation schemes. The accuracy of the calculation on each segment is very hard to obtained, especially for calculating reservoir performance in the scheme while it should involve the influence of the elevation and volume curves and also the reservoir gate operation which is very difficult to calculate manually. Water discharge and water demand fluctuation in irrigation area as input in water allocation scheme are also cannot be applied in this method. The water inflow and outflow are 60% and 40% sequentially and the water usage is 1 litre/second/ha with the assumption of relatively fixed irrigation development and 3 times a year cropping pattern. In this current condition on PDAM in Upper Citarum watershed, there is deficit in Bandung city (-11.19 m^3/s), Bandung Regency (-4.37 m^3/s), West Bandung Regency (-1.56 m^3/s) and Cimahi city (-4.12 m^3/s). Those demands are served by PDAM in Sukawana, Ciwidey, Cisangkuy, Citarum, Cisarea, Cikeruh, Citarik, Cikapundung, Cimeta and Saguling.

RECOMMENDATION

The research results serve an essential contribution for the government in Bandung Greater Area (the government of City of Bandung, Regency of Bandung, Regency of West Bandung and City of Cimahi) to improve the public sector performance management by which the agency of development planning, spatial planning, environmental service, water resources and other related agencies from each city and regency government cooperate and coordinate each other to organize water allocation for the fulfillment of households and industry needs and to avoide water scarcity in the Bandung Greater Area as well. In order to do that, the government in Bandung Greater Area needs to: (1) Build water infrastructure due to the water balance deficit in dry season and reduce or even solves water shortage in some PDAMs and (2) build drainage canal due to the water balance surplus for up to 65% in rainy season. Moreover, the research result can also be used as a basis for the government to prevent flood and distribute water for irrigation equally.

Finally, it should be remembered that Citarum not only has significance in water supply (physical entity) for industry, household and agriculture, but it must also be understood that Citarum has a major role as a socio-cultural tool, such as education and recreation media. Therefore, the Agency of Environmental Service and the Agency of Water Resources should also cooperate with the Agency of Tourism and the Agency of Education in managing the Citarum.

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