Effects of population and land-use change on water balance in DKI Jakarta

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Abstract. The raw water balance of DKI Jakarta consists of the needs and availability of raw water in DKI Jakarta. The population growth and land-use changes through the year 2030 led the demand for water to increase every year. The aims of this research are to identify and to evaluate the population of land-use changes that affect raw water needs in DKI Jakarta. Data analysis was carried out by processing and calculating from data that had been obtained based on the reference year (2010). Population growth and land conversion in 2010, it will form a change in land-use in 2030 affected to raw water balance in DKI Jakarta. Cisadane and Citarum Rivers, rain harvest and reverse osmosis becomes an alternative water resource to increase the availability of raw water. The amount of raw water deficit after the application of this strategy was reduced by 37.3% from 9661,536 l/s in 2010 to 3604,931 l in 2030. For eliminating the deficit of raw water required additional alternative water resources other forms of Ciawi Reservoir and IPA Buaran III.

1. Introduction
Water is the main natural resource needed by all living things. For humans, water resources are a basic necessity to support life and become a basic necessity in the country's economic development. The existence of water resources both in terms of quantity and quality has headed towards a critical direction and has become a world problem [1]. Raw water needs in the water balance are divided into two components, namely water needs for HUI (household, urban and industrial) and irrigation water needs [2]. Indonesia which is located in the tropics area, has a sufficient level of water availability. However, the available water in DKI Jakarta as the capital city of Indonesia is not sufficient due to changes in water use patterns. Based on the population census conducted by the Central Bureau of Statistics in 2010, it was found that the total population of DKI Jakarta was 9,640,400 people. This amount is certainly a burden on services that must be provided by the DKI Jakarta provincial government. The imbalance in the raw water balance in DKI Jakarta occurs due to an increase in raw water demand, which is not matched by sufficient water availability. Green open space that functions as a water catchment area has been converted into housing, industrial areas and other sectors. This conversion of function causes a reduction in the water catchment area [3].
Based on this information, the aim of this research was to evaluate DKI Jakarta’s water balance in 2030 based on a comparison between the supply and demand of raw water. Raw water needs are seen from population and land-used based on the arrangement of regional spatial plan of DKI Jakarta 2030. The supply of raw water is seen from the production capacity of PAM Jaya. Apart from that, the potential water resources in DKI Jakarta, such as the Cisadane and Citarum Rivers, Rain harvesting and reverse osmosis can determine the best strategy to comply with the balance of raw water in DKI Jakarta. Water balance is a balance of water input and output in a place in a certain period, so the amount of water is excess (surplus) or lack (deficit) [4]. In addition, it also is to simulate the potential of water resources around DKI Jakarta in the form of the Cisadane and Citarum River potentials; rain harvest, and reverse osmosis to comply with the supply of raw water. Determine water resources management strategies was based on the potential of water resources around the DKI Jakarta area to comply with the water balance in DKI Jakarta by 2030.

Indonesia has water reserves of 3,221 billion m³/year, or the country with the fifth-largest water reserves in the world. From this potential, 691.3 billion m³/year can be utilized. A total of 175.1 billion m³/year has been used for domestic, urban, industrial and irrigation purposes. About 80.5% of 17.5 billion m³/year or 141 billion m³/year is used for irrigation water needs, 6.4 billion m³/year for domestic and urban water needs, 27.7 billion m³/year is used for industrial needs [5]. DKI Jakarta as the capital city of Indonesia is a magnet for Indonesians to live in. DKI Jakarta is crossed by 13 large rivers and several small rivers as well as 40 lakes spread across 5 urban areas. This surface water has the potential to support the lives of residents of DKI Jakarta. DKI Jakarta has a clean water supply from the Batu Laut Reservoir authority of 81% for drinking water, 14% from PDAM (Indonesian regional water utility company) in Tangerang, and 5% from Kali Krukut (a tributary) located in DKI Jakarta [6].

The DKI Jakarta Provincial Government through PAM Jaya provides clean water through its two partners, comprising PT Pam Lyonaise Jaya and PT Aetra Air Jakarta. Most of the raw water used comes from Batu Laut Reservoir located in Purwakarta. There are six Water Treatment Plant (WTP) currently operating, comprising WTP Pejompongan I with a capacity of 2200 l/s, WTP Pejompongan II with a capacity of 3800 l/s, WTP Cilandak 400 l/s, and WTP Taman Kota 200 l/s for the western part. Based on the results of measurements and records carried out by water company operators, in January 2014 the volume of water distributed was 45,820,855 m³ but only 25,086,449 m³ were sold or distributed. There are 20,734,406 m³ of the water volume lost [7].

2. Materials and Methods

2.1 Materials

The data needed to project DKI Jakarta’s water balance include population data, population density, population rate, maps of the arrangement of the regional spatial plan, map of distribution area of PAM Jaya in DKI Jakarta, number of each non-domestic sector, raw water production capacity, river management patterns, number of households, and regency area. Population data and population rate were used to project population condition in 2030. The maps of the arrangement of the regional spatial plan were used as material for land-use analysis. The map of distribution area of PAM Jaya was used as a reference for water balance projections. Raw water production capacity data was used as reference data for projections. The river management patterns, the number of households, and the area of the regency were used to calculate and project the water resources potential strategies. Generally, this research is divided into the stage of data collection, comparison and the stage of modeling the strategies to meet the raw water needs.

2.2 Methods

The data analysis was carried out by processing and calculating the data obtained based on the reference year in 2010. With the population growth and land conversion from 2010, land-use changes have occurred in 2030 which will affect the DKI Jakarta’s raw water balance. The calculation of the number of raw water needs was seen from the population as domestic needs, and the number of non-domestic sectors to determine the amount of non-domestic needs. The area of each sector was obtained
from the arrangement of the regional spatial plan of DKI Jakarta in 2010 and 2030. The availability of raw water was obtained from the volume of raw water production that enters area of DKI Jakarta. The value of DKI Jakarta’s water balance was obtained by comparing the total value of raw water needs and the availability of raw water so that it can be seen that the raw water in DKI Jakarta is in a surplus or deficit condition.

Quantitatively, the water balance illustrates the principle that over a period of time the total water input equals the total water output added changes in storage. The value of changes in reserve water can be either positive or negative. The concept of water balance basically shows the balance between the amount of water that enters, the water available, and what leaves a certain system. In general, the water balance equation is formulated by [8].

\[ I = O \pm \Delta S \] (1)

where, \( I \) is Inflow, \( O \) is Outflow, \( \Delta S \) is Change in storage

3. Result and discussion

3.1 Population projection

According to data on the population of DKI Jakarta for 2010 to 2015 in Table 1, the population rate for 2016 to 2030 can be determined. The projected population rate used the geometric method by developing three scenarios of the basic rate data used, namely the minimum rate of 1.02%, the rate a maximum of 1.41% and an average rate of 1.15%. In this research, the District of Kepulauan Seribu was not included in the research area. Based on these data of the Central Bureau of Statistics, it projected that the population rate in DKI Jakarta for 2010 to 2014 is 1.11%. Thus, the population rate used to
project the population of DKI Jakarta is almost close to projection rate of the Central Bureau of Statistics, an average rate of 1.15%.

Table 1. Population in DKI Jakarta 2010-2015

| Year | Population (people) | Population growth rate (%/year) |
|------|---------------------|-------------------------------|
| 2010 | 9,640,400           | 1.34                          |
| 2011 | 9,752,100           | 1.16                          |
| 2012 | 9,862,100           | 1.13                          |
| 2013 | 9,969,900           | 1.09                          |
| 2014 | 10,075,300          | 1.06                          |
| 2015 | 10,177,900          | 1.02                          |

Source: The Central Bureau of Statistics of DKI Jakarta [9]

3.2 Projection of DKI Jakarta’s population in 2030

In projecting DKI Jakarta’s domestic raw water needs, the data required was the population of DKI Jakarta in the research base year (2010). By utilizing the geometric method, the population of DKI Jakarta can be projected until 2030. DKI Jakarta is included in the metropolitan city because it has a population of more than 1,000,000 people each year. Therefore, the standard water requirement used is 150 l/person/day. Based on the calculation results, there are three scenarios for the projection of the population based on the population rate. The used scenario is a scenario with an average population rate because it is close to the population rate used by the Central Bureau of Statistics. The population of DKI Jakarta has increased every year with an average increase of 2-3% per year. The Central Bureau of Statistics has projected the population of each province until 2035. In its report, DKI Jakarta has a population of 11,310,000 people in 2030. There is a difference in the projected population of DKI Jakarta, which is based on the calculation results in 2030 that the population of DKI Jakarta is 11,837,120 people. The difference in 527,120 people occurs due to differences in the population rate used in the projection.

3.3 Population density of DKI Jakarta

The increase in population that continues until 2030 involves the increase in population density. This can be seen from the population density projection graph in Figure 3. Based on the projection, until 2030, the highest population density will be still in West Jakarta, amounting to 23,217 people/km².
high population density is due to the expanding number of settlements. The annual increase in population density ranges from 200 to 500 people/km².

![Figure 3. Population density projection of DKI Jakarta](image)

### 3.4 Land-use change in DKI Jakarta

#### Table 2. Differences in Area per Sector in 2010 and 2030

| Year | Sector                  | Area (ha) | Area (km²) |
|------|-------------------------|-----------|------------|
| 2010 | Settlement              | 30,710.00 | 307.10     |
|      | Green open space        | 10,217.39 | 102.17     |
|      | Office, trade, and industrial | 24,324.80 | 243.25     |
| 2010 | **Total**               | **65,363.00** | **653.63** |
| 2030 | Settlement              | 39,196.70 | 391.97     |
|      | Green open space        | 9,325.06  | 93.25      |
|      | Office, trade, and industrial | 16,545.56 | 165.46     |
| 2030 | **Government area**     | **295.68** | **2.96**   |
| 2030 | **Total**               | **65,363.00** | **653.63** |

As the center of economic development, land in DKI Jakarta is also dominated by office, trade and industrial land. Economic growth which is only centered in one city resulted DKI Jakarta having 24,325 ha of office, trade and industrial land in 2010. In 2030 according to the arrangement of regional space plan of DKI Jakarta in 2030, the area of office, trade and industrial land will decrease to 16,546 ha. The decrease in the amount of land by 31.9% according to Table 2 was occurred because in the 2010 the arrangement of regional space plan, the mapping of office, trade and industrial areas were still one with the government area. Meanwhile in 2030, the mapping was more detailed and there was a division with
government areas. The government land area according to the arrangement of regional space plan in 2030, is 296 ha.

3.5 The demand of raw water in DKI Jakarta

Based on population data for the base year (2010-2014), a projection of domestic water demand can be carried out until 2030. The calculation of domestic water needs for megapolitan areas is 150 l/person/day. Based on the projection results of domestic water demand, Central Jakarta has the smallest population, with an average of around 975,264 people with an average domestic water demand of 1,694 l/s. The highest domestic water demand is in East Jakarta with an average number of 5,229 l/s with an average population of 3,009,932 people. In 2012, there was a decrease in the amount of domestic water demand by 7 l/s. This occurs due to a decrease in population based on the calculation of the Central Bureau of Statistics DKI Jakarta. In 2013 the population increased so that the number of domestic water needs also increased. Thus, it can be seen that there is a directly proportional relation between population and domestic water demand.

Meanwhile, non-domestic water needs have different water demand standards depending on the type of activities. In this research, DKI Jakarta’s non-domestic water needs are divided into several types of activities. Water leakage or water loss is the main problem in water distribution faced by PAM Jaya [10]. The amount of water leakage or loss becomes the responsibility of PAM Jaya and includes raw water needs. So that there is an increase in the amount of raw water to overcome the water loss. The water that has been produced and is lost before it reaches the consumers namely non-revenue water (NRW). Based on the projection, the amount of water leakage or loss will continue to decline until 2030 by 14.20% compared to 2010 at 46.36%.

![Flow rate (l/s) vs. year](image)

**Figure 4.** Domestic water needs projection of DKI Jakarta in 2010-2030.
3.6 Supply of raw water in DKI Jakarta

According to the projection results of supply water for the DKI Jakarta area, there is a change in the total of supply water in DKI Jakarta each year, as shown in Figure 7. This occurs because of water leakage in the pipeline distribution system. Changes in weather and climate are also one of the causes of changes in water supply from the Jatiluhur Reservoir. In 2030, the production capacity will be 16,269 l/s, increasing 2,233 l/s from 2010. The increase in water production capacity by PT Aetra and PT PALYJA, there has been a decrease in the number of purchases of processed water from PDAM Tirta Kerja Rahaja. In 2010, total purchases of processed poured water amounted to 2,875 l/s and decreased by 785 l/s to 2,090 l/s in 2030.
3.7 Water Balance in DKI Jakarta

By projecting the amount of raw water balance for DKI Jakarta from 2010 to 2030, it can provide an overview of the raw water balance in DKI Jakarta which can be the basis for realizing the DKI Jakarta arrangement of regional space plan in 2030. Based on the results of the calculation of the DKI Jakarta raw water balance projection, it is known that DKI Jakarta has experienced water shortages since 2010. This occurs due to an increase in population yearly resulting in an increase in the demand for raw water. The population growth has a very big share because almost 87% of the raw water needs in DKI Jakarta come from domestic water needs. The increase in the availability of raw water cannot meet the demand for raw water which also increases every year. This increasing amount of water deficit is also influenced by the rate of leakage of raw water distribution pipes. Changes in the balance of raw water each year occur due to changes in the supply of raw water. From 2011 the deficit in raw water has decreased until 2018 arounded 8,654.73 l/s. In 2030, the deficit in DKI Jakarta’s raw water balance will reach 10,007.6 l/s, assuming a leakage rate of 14%. Based on calculations, water balance of DKI Jakarta can be calculated using the equation $y = -44.32x - 9357.2$ with a coefficient of determination ($R^2$) of 0.1125.
3.8 Water Resources Management Strategies

In this research, strategies were calculated to reduce the deficit so that the balance of raw water balance in DKI Jakarta can be maintained. There are three alternatives water resources in this research, such as the potential of the Cisadane and Citarum Rivers, rain harvest, and reverse osmosis. In conducting the analysis, raw water balance projection data was used as initial raw water demand data which was used to find the raw water balance projection after obtaining raw water supply from the three alternative water sources.

3.8.1. Potential of Cisadane and Citarum Rivers. The calculation of the river’s ability as a new water resource to supply raw water for DKI Jakarta is the strategy to increase the amount of raw water. This addition will affect the projected amount of raw water balance for DKI Jakarta. The additional water supply from this potential river alternative is managed by PAM Jaya so that it is included in the planning for additional production capacity. The strategy to increase the supply of raw water from the Citarum River, which is located in the western part of DKI Jakarta, is precisely channeled through the Western Tarum Channel. Meanwhile, the strategy for the availability of raw water from the Cisadane river is in the eastern part of DKI Jakarta. The total additional of raw water using this river’s potential alternative is 5,631 l/s in 2030. For the Ciliwung River, its utilization is still in the feasibility study stage. Later the Ciliwung reservoir can produce a minimum of 2,000-3,000 l/s of raw water in the rainy season. This raw water storage is also useful to reduce the potential for flooding in the DKI Jakarta area.

Table 3. Total Additional of raw water using the alternative of potential rivers.

| Year | Western Additional production capacity (l/s) | Eastern Additional production capacity (l/s) | Total of Additional production capacity (l/s) | Western Additional processed bulk water capacity (l/s) | Eastern Additional processed bulk water capacity (l/s) | Total of Additional processed bulk water capacity (l/s) | Total addition (l/s) |
|------|---------------------------------------------|---------------------------------------------|-----------------------------------------------|--------------------------------------------|-----------------------------------------------|------------------------------------------------|-------------------|
| 2010 | 0                                           | 0                                           | 0                                             | 0                                          | 0                                             | 0                                              | 0                 |
| 2011 | 0                                           | 0                                           | 0                                             | 0                                          | 0                                             | 0                                              | 0                 |
| 2012 | 0                                           | 0                                           | 0                                             | 0                                          | 0                                             | 0                                              | 0                 |
| 2013 | 0                                           | 0                                           | 0                                             | 0                                          | 0                                             | 0                                              | 0                 |

Figure 9. Comparison of water balance in DKI Jakarta.
### Table 4. Additional Production Capacity

| Year | Additional production capacity (l/s) | Total of additional production capacity (l/s) | Additional processed bulk water capacity (l/s) | Total of additional processed bulk water capacity (l/s) | Total addition (l/s) |
|------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------------------------------------|---------------------|
| 2014 | 274                                 | 0                                             | 0                                             | 0                                                      | 274                 |
| 2015 | 957                                 | 0                                             | 280                                           | 0                                                      | 1237                |
| 2016 | 1231                                | 0                                             | 1600                                          | 0                                                      | 1600                |
| 2017 | 1231                                | 0                                             | 2500                                          | 700                                                    | 3200                |
| 2018 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2019 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2020 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2021 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2022 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2023 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2024 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2025 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2026 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2027 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2028 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2029 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |
| 2030 | 1231                                | 0                                             | 3400                                          | 1000                                                   | 4400                |

3.8.2. **Rain Harvest.** Based on the calculation, it’s known that on average there are 10% luxury households of the total settlements in South Jakarta each year. The projection results show that in one year (the experimental year 2014) there are ± 137 rainy days. Assuming each household uses two storage tanks, each measuring 1,050 liters can produce 0.009 l/s for one household. The standard water requirement per person is 150 l/day, assuming there are six residents in a household so that in one day it takes 900 liters of raw water. The projection results of raw water availability using alternative rain harvest can be seen in Table 4.

**Table 4. Supply of raw water projection using the alternative of rain harvest**

| Year | Supply of water (l/s) | Total of households | Total raw water using rain harvest (l/s) |
|------|-----------------------|---------------------|-----------------------------------------|
| 2010 | 48,955                | 442.42              |
| 2011 | 49,037                | 443.16              |
| 2012 | 50,477                | 456.17              |
| 2013 | 51,226                | 462.95              |
| 2014 | 51,372                | 464.26              |
| 2015 | 53,307                | 481.75              |
### Table 5. Supply of raw water projection using the alternative of reverse osmosis

| Year | Houses | Pump capacity | Total of raw water |
|------|--------|---------------|--------------------|
|      |        | (gallon/day)  | (l/day)            | (l/s)              |
| 2010 | 43722  | 15            | 285                | 144.221            |
| 2011 | 44201  | 15            | 285                | 145.802            |
| 2012 | 44858  | 15            | 285                | 147.969            |
| 2013 | 45414  | 15            | 285                | 151.563            |
| 2014 | 45947  | 15            | 285                | 153.478            |
| 2015 | 46528  | 15            | 285                | 153.478            |

#### 3.8.3. Reverse osmosis

Reverse osmosis (RO) is an alternative for the availability of raw water using brackish water or salt water as the main material for distillation. In this research, the RO strategy is applied to housing in the North Jakarta area. The selection of this area is because North Jakarta is the regency that is the closest to the sea. Most of the population consumes water from PAM Jaya. Alternative distillation with an RO system uses a pump as a means of applying pressure so that water can pass through the osmosis membrane. The assumption used in this research is that there are 10% of housing each year that use the RO system. In a day, this system produces 15 gallons or 285 liters for each household. The standard water requirement per person is 150 l/day, assuming there are six residents in a household, so that in a day, 900 l of raw water is needed. Based on the calculation of water availability projections utilizing an alternative RO system, it can be seen that the amount of raw water produced in 2030 is 181,508 l/s. The projection results of raw water availability using RO alternatives can be seen in Table 5.
Year | Houses | Pump capacity | Total of raw water |
|-----|--------|---------------|-------------------|
|     |        | (gallon/day) | (l/day) | (l/s) |
| 2016 | 47095  | 15            | 285      | 155.346 |
| 2017 | 47661  | 15            | 285      | 157.215 |
| 2018 | 48228  | 15            | 285      | 159.084 |
| 2019 | 48794  | 15            | 285      | 160.952 |
| 2020 | 49361  | 15            | 285      | 162.821 |
| 2021 | 49927  | 15            | 285      | 164.690 |
| 2022 | 50494  | 15            | 285      | 166.558 |
| 2023 | 51060  | 15            | 285      | 168.427 |
| 2024 | 51627  | 15            | 285      | 170.296 |
| 2025 | 52193  | 15            | 285      | 172.164 |
| 2026 | 52760  | 15            | 285      | 174.033 |
| 2027 | 53326  | 15            | 285      | 175.902 |
| 2028 | 53893  | 15            | 285      | 177.770 |
| 2029 | 54459  | 15            | 285      | 179.639 |
| 2030 | 55026  | 15            | 285      | 181.508 |

Based on these three strategies, DKI Jakarta’s raw water balance is measured. The demand of raw water used is the water deficit from the raw water balance using the existing supply of raw water without any additions. For the supply of raw water, the calculation of the raw water balance uses the existing supply raw water plus the implementation of the three alternative water resources strategies. The calculation of water balance can be seen in Table 6. Based on the projection, it can be seen that by adding the three alternative water resources strategies, there will be a significant reduction in the raw water deficit. The strategies of implementing alternative water resources was carried out in areas with potential only, if these are carried out in a wider area or the entire DKI Jakarta area can apply it, it can be projected that there will be no more raw water deficit in DKI Jakarta.

Table 6. Raw water balance with the addition of 3 alternative water resources strategies

| Year | The demand of raw water (l/s) | Rain Harvesting (l/s) | Reverse Osmosis (l/s) | Upgrade PAM (l/s) | Supply of raw water (l/s) | Water balance (l/s) |
|------|-------------------------------|-----------------------|----------------------|------------------|--------------------------|---------------------|
| 2010 | 10248.177                     | 442.420               | 144.221              | 0                | 586.640                  | -9661.536           |
| 2011 | 10677.322                     | 443.162               | 145.802              | 0                | 588.964                  | -10088.358          |
| 2012 | 10038.235                     | 456.173               | 147.969              | 0                | 604.142                  | -9434.093           |
| 2013 | 9415.142                      | 462.945               | 149.804              | 0                | 612.750                  | -8802.392           |
| 2014 | 9173.644                      | 464.262               | 151.563              | 274.000          | 889.825                  | -8283.819           |
| 2015 | 8789.459                      | 481.751               | 153.478              | 1237.000         | 1872.229                 | -6917.230           |
| 2016 | 8534.376                      | 488.981               | 155.346              | 2831.000         | 3475.328                 | -5059.048           |
| 2017 | 8597.787                      | 496.211               | 157.215              | 4431.000         | 5084.426                 | -3513.361           |
| 2018 | 8484.735                      | 503.441               | 159.084              | 5631.000         | 6293.525                 | -2191.210           |
Based on the results of these calculations, there is still a water balance deficit until 2030. This is in accordance with the water balance projection carried out by PAM Jaya. According to PAM Jaya in 2030 there will still be a deficit of raw water. To overcome this condition, in addition to increasing water production from the Jatiluhur Reservoir, PAM Jaya will also build additional alternative sources of raw water from the Ciawi Reservoir and water treatment plant (WTP) of Buaran III. These alternatives were started in 2016. If these two alternatives have been active, there will be a raw water surplus starting in 2022. The total raw water surplus in 2030 will reach 895,069 l/s.

**Figure 10.** Raw water balance with the addition of 3 alternative water resources strategies.

**Table 7.** Projection of raw water balance with additional Ciawi Reservoir and WTP of Buaran III

| Year | Ciawi Reservoir | WTP Buaran III | Total supply of raw water | Total demand of raw water | Water balance |
|------|-----------------|----------------|---------------------------|----------------------------|---------------|
| 2020 |                 |                |                           |                            |               |
| 2021 |                 |                |                           |                            |               |
| 2022 |                 |                |                           |                            |               |
| 2023 |                 |                |                           |                            |               |
| 2024 |                 |                |                           |                            |               |
| 2025 |                 |                |                           |                            |               |
| 2026 |                 |                |                           |                            |               |
| 2027 |                 |                |                           |                            |               |
| 2028 |                 |                |                           |                            |               |
| 2029 |                 |                |                           |                            |               |
| 2030 |                 |                |                           |                            |               |
| Year | Demand (l/s) | Supply (l/s) | Water Balance (l/s) |
|------|--------------|--------------|---------------------|
| 2016 | 500          | 0            | 509.048             |
| 2017 | 500          | 0            | 3513.361            |
| 2018 | 750          | 0            | 2191.210            |
| 2019 | 1500         | 0            | 2351.425            |
| 2020 | 2500         | 0            | 4090.724            |
| 2021 | 3500         | 1000         | 4311.849            |
| 2022 | 4500         | 2000         | 4361.919            |
| 2023 | 4500         | 2000         | 4115.970            |
| 2024 | 4500         | 2000         | 4052.022            |
| 2025 | 4500         | 2000         | 3985.145            |
| 2026 | 4500         | 2000         | 3915.242            |
| 2027 | 4500         | 2000         | 3842.357            |
| 2028 | 4500         | 2000         | 3766.436            |
| 2029 | 4500         | 2000         | 3687.315            |
| 2030 | 4500         | 2000         | 3604.931            |

**Figure 11.** Water balance in DKI Jakarta using strategy 2

4. **Conclusions**

The calculation of DKI Jakarta’s water balance projections from 2010 to 2030, it can be concluded that the increase in population and changes in land-use every year increases the demand for raw water. If there is no strategy (existing condition), DKI Jakarta’s water balance will experience a deficit from 2010 to 2030. By adding three alternatives water resources strategies, there will be a significant reduction in the raw water deficit but the raw water balance still shows a deficit figure. By adding the alternatives strategies of additional raw water sources from the Ciawi Reservoir and WTP of Buaran III, there will be a raw water surplus in 2030 reaching 895,069 l/s.
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