The impact of water conservation using sedrainpond and infiltration wells on surface water quantities: a case study of the Pakopen micro watershed, Semarang District, Central Java, Indonesia

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Abstract. Due to the increasing amounts of surface runoff and land degradation in watersheds, mitigation efforts need to be taken by adopting water conservation technologies to reduce flooding and surface runoff. The purpose of this research is to study the impact of sedrainpond (SDP) and infiltration well technology procurement on surface water in order to mitigate flood disasters downstream. The method approach is carried out by measuring the field discharge, collecting rainfall data and analysing the data using ArcView GIS and Microsoft Excel. The measured discharge in the study was 1170.9 L/s. The study applies 1819 units of SDP technologies with a diameter of 1 m, a depth of 2.5 m and a total storage volume of 3573.11 m^3, and 340 units of infiltration wells with a diameter of 1 m, a depth of 2 m and a total storage volume of 533.65 m^3. For scenario 1, where the water contained in the well is drained in one day, the flood discharge can be reduced to 986 L/s, along with a flow rate decrease of 184.9 L/s (15.79%). While for scenario 2, where the water contained in the well is drained in two days, the flood discharge can be reduced to 1001.6 L/s with a flow rate decrease of 184.9 L/s (14.46%).

1 Introduction

Water is one of the most important sources of life for all living beings [1]. Current water levels are uncertain because of excess water during the rainy season and a lack of water during the dry season. This is due to increased land degradation in watersheds, as a result of land changes by communities due to increasing land development. Therefore, it is a challenge [2] to conserve soil and water as a disaster mitigation effort. Disaster mitigation is carried out in anticipation of floods and droughts, so the application of technology has an important role [3] to reduce the risk of a disaster. The technology of sedrainpond (SDP) [4], as an appropriate technology built on paddy fields belonging to farmers, does not only serve as soil conservation but also functions as water conservation, including infiltration wells built in yardlands [5]. SDP technology and infiltration wells can trim the flood discharge or

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reduce surface water. Both these appropriate technologies are applied to different locations (in paddy fields and in settlements). Both of these technologies are viewed from a significant and measurable storage capacity but have not been combined as rainwater catchments, in order to reduce flood discharge or surface flow. The purpose of this research is to study the impact of SDP technology development and infiltration wells on surface water in order to mitigate flood disasters downstream.

2 Material and methods

2.1 Research area

The study site is located at the Pakopen micro watershed, Semarang District, Central Java Province, Indonesia. Geographically, the Pakopen micro watershed is located at the coordinates of 7 ° 11'17.03 "S - 110 ° 23'16.32" E. The area of Pakopen micro watershed is ~260.85 hectares, comprising Pakopen village with an area of 59.07 hectares, Munding village with an area of 181.39 hectares, Sidomukti village with an area of 4.85 hectares and Duren village with an area of 15.53 hectares.

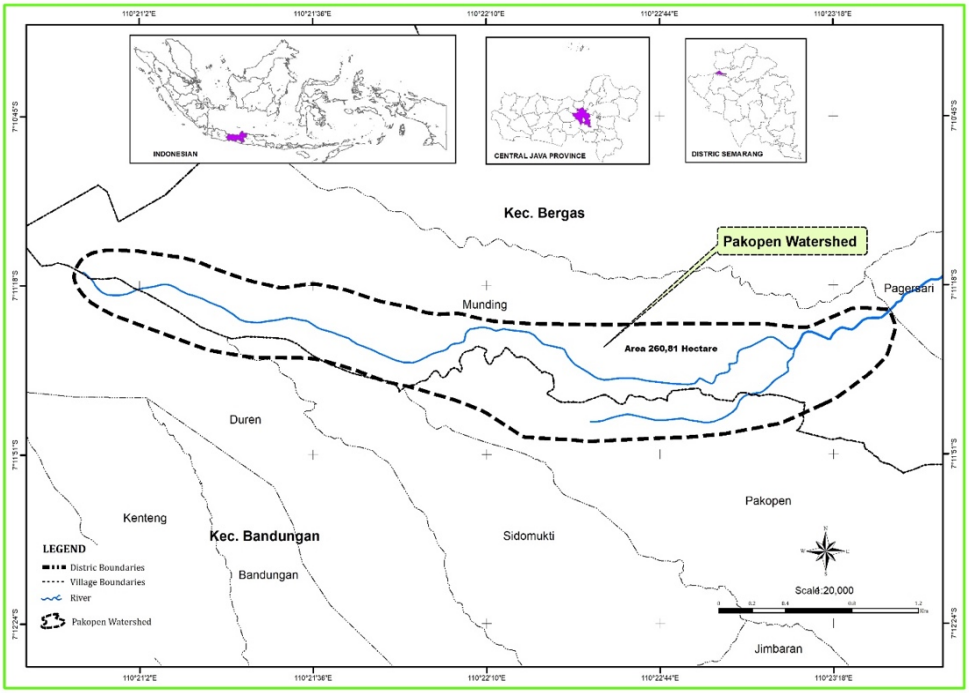

Fig. 1. Location map of discharge measurement.

2.2 Method

The river flow is measured using a current meter. The location map is created using the ArcView GIS program. All data are analysed using Microsoft Excel. The stages in the data analysis process are calculating the flow volume of the watershed based on monthly rainfall data and calculating the flow volume after conservation using SDP and infiltration wells.

2.3 Hydrology observations and measurements

Observations were made for the water level, water discharge and rainfall to obtain the data used as the basis for determining the runoff coefficient. The observation of the water level is based on rain conditions in the field. There are five water surface data obtained, namely, on April 17, 2017, April 20, 2017, April 21, 2017, April 23, 2017, and April 26, 2017.

The peak of the water level on April 17, 2017 is 12 cm occurring at 18.00, on April 20, 2017 is 16.2 cm occurring at 14:40, on 21 April 2017 is 8.2 cm occurring at 15:20, on 23 April 2017 is 11.8 cm occurring at 18.00 and at 26 April 2017 is 18.6 cm occurring at 14:40. The results can be seen in Figures 2 to 6.

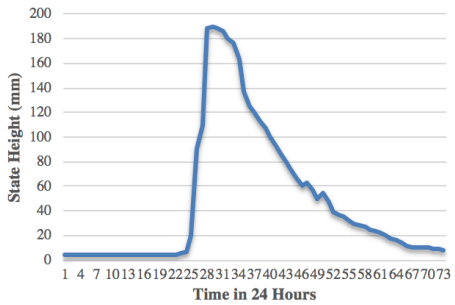

Fig. 2. Stage hydrograph for 17 April, 2017.

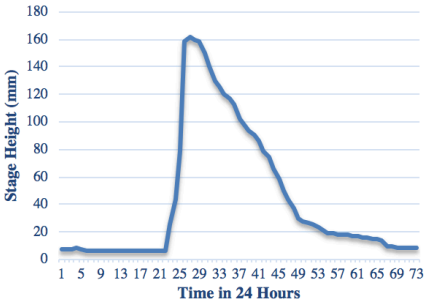

Fig.3. Stage hydrograph for 20 April, 2017.

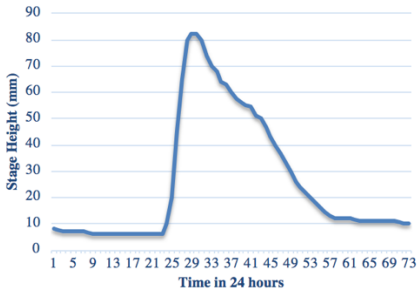

Fig. 4. Stage hydrograph for 21 April, 2017.

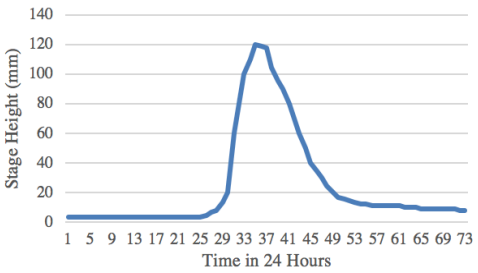

Fig. 5. Stage hydrograph for 23 April, 2017.

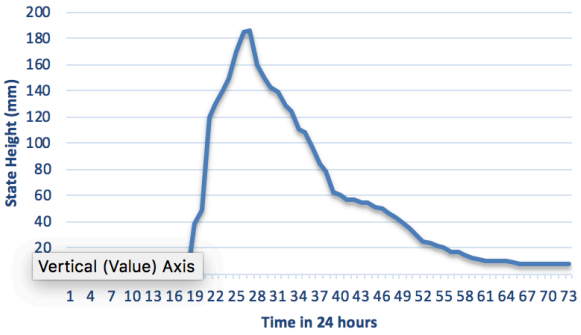

Fig.6. Stage hydrograph for 26 April, 2017.

3 Results and discussions

3.1 Results

Field measurements and calculations are used to derive results from the impact of the conservation of infiltration wells and SDP on surface water in the Pakepon micro watershed and to compare water levels, flow rates and runoff coefficients prior to conservation and after conservation.

3.1.1 Discharge rating curve

A discharge rating curve gives the relationship curve between the water flow and the water level. From the calculation with a water level value of 7 cm, a discharge value of 50 L/s was obtained, with a water level value of 20 cm, a discharge value of 220 L/s was obtained, with a water level value of 44 cm, a discharge rate of 300 L/s was obtained, with a water level value of 8 cm, a discharge value of 60 L/s was obtained, with a water level value of 39 cm, a discharge value of 250 L/s was obtained, with a water level value of 10 cm, a discharge value of 80 L/s was obtained. A squared radiant (R^2) of 0.9437 cm was found, so it can be concluded there is a good relationship between the discharge and the water level because the squared radiant (R^2) is close to 1. The comparison between the calculated discharge flow and the measured water surface level can be seen in the Table 1 and Figure 1:

Table 1. Measured water level and flow.

	Location I					
H (cm)	7	20	44	8	39	10
Q (L/s)	50	220	300	60	250	80

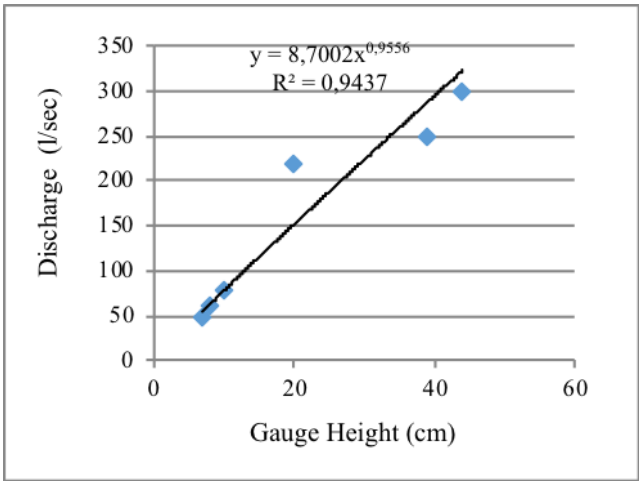

Fig.7. Discharge rating curve of the Pakepon micro-watershed.

From the calculation result, we obtain the equation of a curve, as shown below:

$$Q = 8.7\,H^{0.9556} \quad (1)$$

where
Q = Discharge flow (m^3/s)
H = Water surface level (m)

3.1.2 Discharge hydrograph

A discharge hydrograph, also known simply as a hydrograph, is a graph of the relationship between the discharge and the time that is converted using a rating curve. Observations were made on April 17, April 20, April 21, April 23 and April 26. The peak of the discharge that occurred on April 17, 2017 was 1302.9 L/s at 15:40, on 20 April 2017 was 1111.2 L/s at 15:00, on 21 April 2017 was 573.0 L/s at 15:00, on 23 April 2017 was 837.4 L/s at 17:40 and on 26 April 2017 was 1283.1 L/s at 14:40. The results can be seen in Figures 8 to 12.

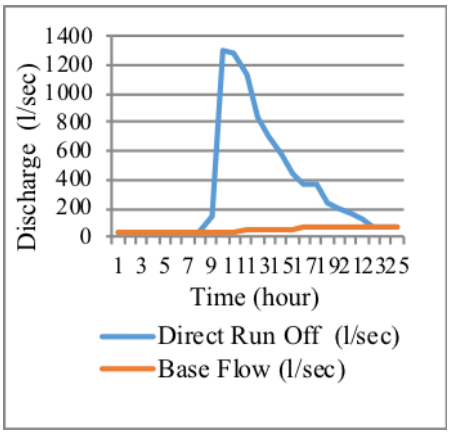

Fig. 8. Discharge hydrograph for April 17th.

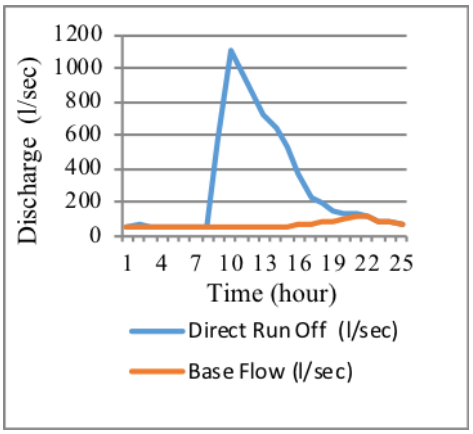

Fig. 9. Discharge hydrograph for April 20th.

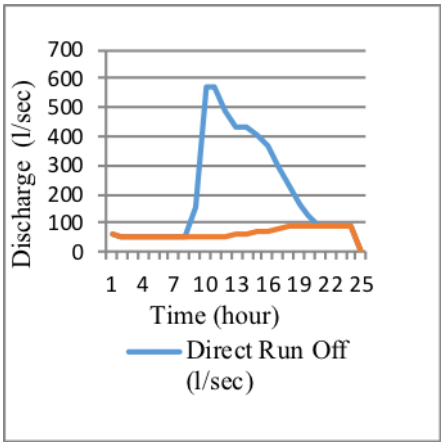

Fig. 10. Discharge hydrograph for April 21st.

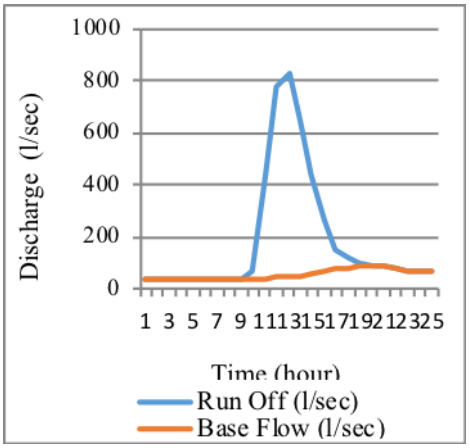

Fig. 11. Discharge hydrograph for April 23rd.

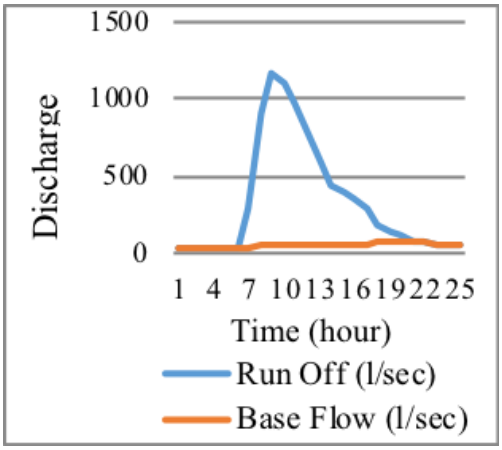

Fig.12. Discharge hydrograph for April 26th.

3.1.3 Conservation technology performance (SDP and infiltration wells)

Within one year, the volume of rain in the Pakepon micro watershed, with an area of 260.85 hectares, is 6476887 m^3. The Pakepon micro watershed area applies 1189 SDP technologies with a 1 m diameter and a 2.5 m depth, and an absorption well of 340 pieces with a diameter of 1 m and a depth of 2 m. The total SDP deposit volume is 3573.11 m^3, while the volume of the absorption well is 533657 m^3.

In the rainy season (November-April), the total volume of runoff prior to conservation is 2720184 m^3, which can broken down into November with 314722 m^3, December with 562797 m^3, January with 483808 m^3, February with 360387 m^3, March with 398648 m^3 and April with 599823 m^3. In the dry season (May-October), the total volume of runoff prior to conservation was 344342 m^3, which can be broken down to May with 234499 m^3, June with 62944 m^3, July with 12342 m^3, August with 6171 m^3, September with 9874 m^3 and October with 18513 m^3.

The calculation of runoff volume after conservation uses two scenarios. Scenario 1 is a condition when the water that is accommodated by the SDP and infiltration wells runs out in one day. Scenario 2 is a condition when the water that is accommodated by the SDP and infiltration wells runs out in two days.

From the calculation results for scenario 1, the total volume of runoff after conservation is 2579929 m^3. In the rainy season (November-April), the total volume of runoff after conservation is 2309507 m^3, with details: in November of 273,654 m^3, December at 468,341 m^3, January of 397,566 m^3, February at 294,679 m^3, March at 337,046 m^3, and April amounted to 538,221 m^3. In the dry season (May-October), the total volume of runoff after conservation was 270,420 m^3, with details: in May of 197,538 m^3, June of 54,731 m^3, July 4,128 m^3, 2,064 m^3 in August, 5,767 m^3 in September, October of 6,193 m^3. Within one year, the decrease in runoff volume was 484,599 m^3 (15.81%).

Table 2. Comparison of rainfall volume, runoff volume before conservation and runoff volume after conservation for scenario 1 .

Month	Rain Fall Volume (m^3)	Run Off Volume Before (m^3)	Run Off Volume After (m^3)
January	1.022.529	483.808	397.566
February	761.680	360.387	294.679
March	842.543	398.648	337.046
April	1.267.727	599.823	538.221
May	495.614	234.499	197.538
June	133.033	62.944	54.731
July	26.085	12.342	4.128
August	13.042	6.171	2.064
September	20.868	9.874	5.767
October	39.127	18.513	6.193
November	665.166	314.722	273.654
December	1.189.473	562.797	468.341
Total	6.476.887	3.064.528	2.579.929
Average	539.740,58	255.377,33	214.994,08

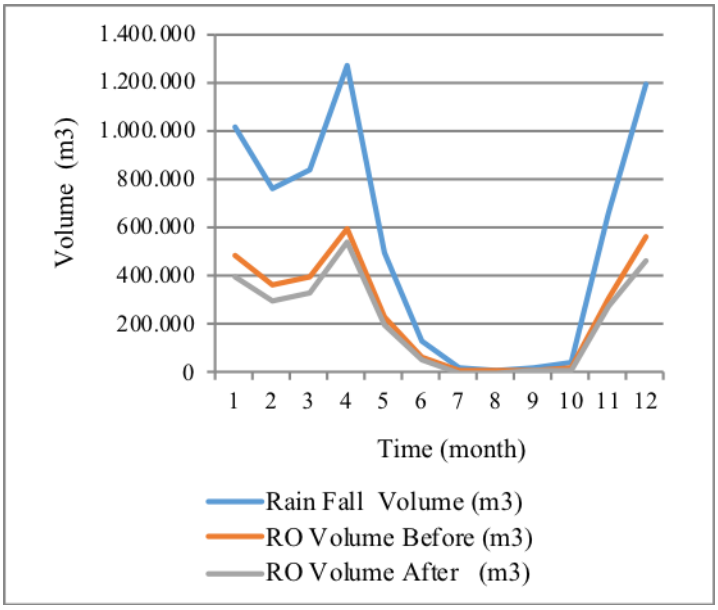

Fig.13. Plot of the comparison of rainfall volume, runoff volume before conservation and runoff volume after conservation scenario 1 .

From the calculation results with scenario 2, the total volume of run off after conservation was 2682598 m^3. In the rainy season (November-April), the total volume of runoff after conservation was 2412177 m^3, which can be broken down monthly for November at 273654 m^3, December at 501195 m^3, January at 430420 m^3, February at

319320 m^3, March at 349367 m^3 and April amounted to 538,221 m^3. In the dry season (May-October), the total volume of runoff after conservation was 270421 m^3, with details: in May of 197,538 m^3, June at 54,731 m^3, July 4,128 m^3, 2,064 m^3 in August, 5,767 m^3 in September, October of 6,193 m^3. Within one year, the decrease in runoff volume was 381390 m^3 (12.46%).

Table 3. Comparison of rainfall volume, run off volume before conservation and run off volume after conservation for scenario 2.

Month	Rain Fall Volume (m^3)	RO Volume Before (m^3)	RO Volume After (m^3)
January	1.022.529	483.808	430.420
February	761.680	360.387	319.320
March	842.543	398.648	349.367
April	1.267.727	599.823	538.221
May	495.614	234.499	197.538
June	133.033	62.944	54.731
July	26.085	12.342	4.128
August	13.042	6.171	2.064
September	20.868	9.874	5.767
October	39.127	18.513	6.193
November	665.166	314.722	273.654
December	1.189.473	562.797	501.195
Total	6.476.887	3.064.528	2.682.598
Average	539.740,58	255.377,33	223.549,83

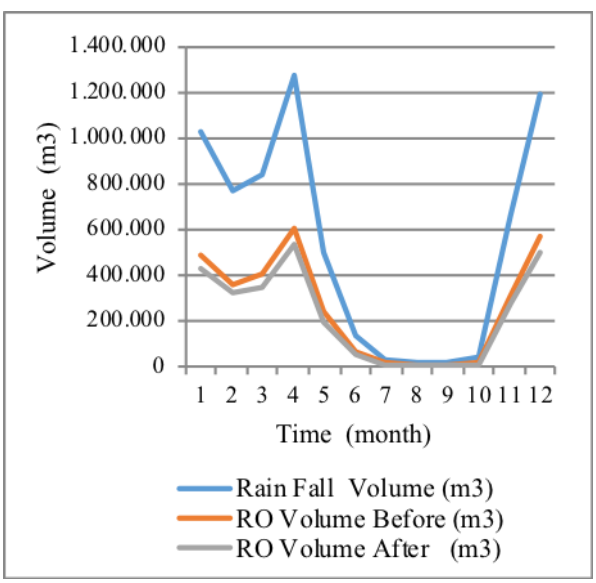

Fig. 14. Plot of the comparison of rainfall volume, runoff volume before conservation and runoff volume after conservation scenario 2 .

The runoff coefficient is calculated based on the comparison between volume runoff and the amount of rainfall at that time. The result of the coefficient of runoff before conservation is presented in Table 4.

Table 4. Runoff coefficient calculation results .

	Date of Rain					Average
	April 17th	April 20th	April 21st	April 23rd	April 26th	
Rainfall (mm)	29	19	10	10	25	18,6
Watershed rain volume (m^3)	75.646	49.561	26.085	26.085	65.212	48517,96
Measurement volume (m^3)	27.417	26.048	12.328	13.171	32.618	22316,54
Runoff coefficient	0,36	0,53	0,47	0,50	0,50	0,47

In the rainy season (November-April), the total flow before conservation is 1041.4 L/s, with a break down in November of 121.4 L/s, December at 210.1 L/s, January at 180, 6 L/s, February at 149.0 L/s, March at 148.8 L/s, and April at 231.4 L/s. In the dry season (May-October), the total flow rate before conservation is 129.5 L/s with details: in May of 87.6 L/s, June at 24.3 L/s, July 4, 6 L/s, August 2.3 L/s, September at 3.8 L/s and October at 6.9 L/s.

The calculation of discharge after conservation uses two scenarios. Scenario 1 is a condition when the water that is accommodated by the SDP and absorber wells runs out in one day. Scenario 2 is a condition when the water that is accommodated by the SDP and absorption wells runs out in two days.

3.2 Discussion

From the calculation of scenario 1, the total flow rate is 986 L/s. In the rainy season (November-April), the total discharge flow after conservation is 884.16 L/s, with details: in November of 105.58 L/s, December at 174.86 liters/sec, January at 148.43 liter/second, February at 121.81 liter/second, March at 125.84 liter/second, and April at 207.65 liter/second. In the dry season (May-October), the total discharge flow after conservation is 101.72 liters/sec, with details: in May of 73.75 liters/sec, June of 21.12 liters/sec, July 1, 54 liters/second, August 0.77 liter/second, September at 2.22 liters/sec, and October at 2.31 liters/sec. Within one year, a decrease of the flow rate of 184.9 liters/second or 15.79% was obtained.

Table 5. Comparison of discharge value of rainfall, before conservation and after conservation scenario 1

Month	Discharge Rain Fall (l/s)	Discharge Before (l/s)	Discharge After (l/s)
January	381,77	180,6	148,43
February	284,38	149,0	121,81
March	314,57	148,8	125,84
April	473,32	231,4	207,65
May	185,04	87,6	73,75
June	49,67	24,3	21,12
July	9,74	4,6	1,54
August	4,87	2,3	0,77
September	7,79	3,8	2,22
October	14,61	6,9	2,31
November	248,34	121,4	105,58
December	444,10	210,1	174,86
Total	2.418,19	1.170,9	986

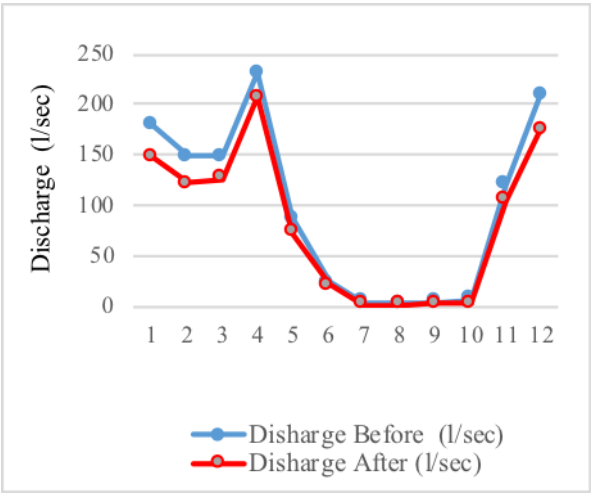

Fig. 15. Comparison of discharge value before conservation and after conservation for scenario 1.

In the calculation of scenario 2, the total flow rate is 1001.6 L/s. In the rainy season (November-April), total discharge flow after conservation is 828.4 liters/sec, with details: in November of 10.5 liters/sec, December at 187.1 liters/sec, January at 160.7 liters/second, February amounted to 132 liters/sec, March at 130.4 liters/sec, and April amounted to 207.6 liters/sec. In the dry season (May-October), the total discharge flow after conservation is 101.7 l/sec, with details: in May of 73.8 liters/sec, June at 21.1 liters/sec, July 1, 5 liters/second, August 0.8 liter/second, September at 2.2 liter/second, and October at 2.3 liter/second. Within one year, the flow rate decreased by 184.9 liters/second or 14.46%.

Table 6. Comparison of discharge value of rainfall, before conservation and after conservation for scenario 2.

Month	Discharge Rain Fall (l/s)	Discharge Before (l/s)	Discharge After (l/s)
January	381,77	180,6	160,7
February	284,38	149,0	132,0
March	314,57	148,8	130,4
April	473,32	231,4	207,6
May	185,04	87,6	73,8
June	49,67	24,3	21,1
July	9,74	4,6	1,5
August	4,87	2,3	0,8
September	7,79	3,8	2,2
October	14,61	6,9	2,3
November	248,34	121,4	10,5
December	444,10	210,1	187,1
Total	2.418,19	1.170,9	1.001,6

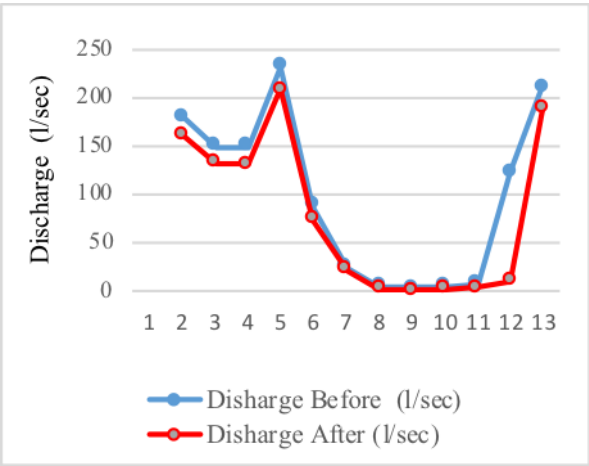

Fig. 16. Comparison of discharge value before conservation and after conservation for scenario 2.

4 Conclusions

Based on the analysis of the micro sub-watershed of Pakepon, the conclusions are:

1. The measured (prior to conservation) flow rate on the Pakepon micro watershed of 260.85 hectares in total for one year is 1,170.9 L/s with an average of 97.6 L/s.
2. Conservation is achieved with the development of SDP technology (Sedrainpond) and infiltration wells. SDP installed a number of 1819 units, with the average diameter of 1 m, 2.5 m deep and a total storage volume of 3573.11 m^3. While the infiltration wells

installed a number of 340 units with an average diameter of 1 m, 2 m deep and a total storage volume of 533.65 m^3.

3. Total flow rate after conservation with scenario 1 calculation is 986 liters/sec with an average of 82.2 liters/sec. In the rainy season (November-April), total flow discharge after conservation is 884.16 liter/sec. In the dry season (May-October), the total flow rate after conservation is 101.72 liters/sec. Within one year, a decrease of the flow rate of 184.9 liters/second or 15.79% was obtained.
4. Total flow discharge after conservation with scenario 2 calculation is 1001,6 liter/second. In the rainy season (November-April), total discharge flow after conservation is 828.4 liters/sec. In the dry season (May-October), the total discharge flow after conservation is 101.7 liters/sec. Within one year, the flow rate decreased by 184.9 liters/second or 14.46%.
5. So based on the calculation result with scenarios 1 and 2, it is better to calculate with scenario 1 because it got the discharge flow value after the conservation is smaller, with the ratio of 1.33%.

Acknowledgments

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