Water Availability Study using NRECA Model (Embun Sei Fatimah North Kalimantan Case Study)

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Abstract. Analysis of water availability is very much needed for the management of water resources, for example the construction of a reservoir in a certain area. To analyze the availability of water, it can be done from observational discharge data, but if the discharge data is not available, then using the runoff rain model. One model is NRECA. In this paper, a study was conducted on the availability of water in the reservoir area in Nunukan, North Kalimantan. Construction of reservoirs in the area to meet the needs of clean water in the area. The model used is NRECA. From the calculation results obtained by the availability of water with a probability of occurrence of 90% between 0.001 m³/s - 0.012 m³/s.

Key Words: NRECA, rainfall, discharge, evapotranspiration.

1. Introduction
Faster population growth causes the need for cleaner greater. Therefore, in an area to meet the needs of clean water, it is necessary to manage and develop the existing water resources in the area. This happened in the Nunukan area, North Kalimantan. In the Nunukan area to meet its clean water needs, it is planning to build a reservoir in the area. To plan the construction of a reservoir, it is necessary to study the availability of water at the reservoir site.

The availability of water in a watershed is usually determined based on the recording of discharge data at a presumptive and continuous water level, in Indonesia in general the continuous and long data are rain data. Seeing these conditions, we need a rain-discharge model that can simulate rain and climate data to become discharge data (Novianti, R., 2000). Some methods of calculating the transformation of rain data into a debit are Mock modeling, NRECA, Tank Model etc.

Researchers will conduct research on the prediction of mainstay discharge at the watershed in the construction site of the Sei fatimah Nunukan North Kalimantan reservoir using the NRECA Model.

2. Data, Methodology, and Variables
2.1 Research Data
The data used in this study are rain data, kimatologi data, topographic data. Rain data are used in 2004-2015 from Class IV Climatology Station Nunukan. Climatology data is used to calculate evapotranspiration.
2.2 Methodology
The stages in this study include calculating regional average rainfall, calculating the volume of rainwater with a rational method, calculating reliable rainfall with 3 methods, namely methods based on year, second, based on month, third based on modification. Calculate the mainstay discharge with the NRECA method.

3. Result and Discussion
Monthly flow into the reservoir can be calculated by the Rational Method, this method has been developed by the Irrigation Research Center since 1992. This Rational Method directly calculates the volume of rain water so that the results of the calculation of the volume of water in the rainy season in the Embi Sei Fatimah plan can be seen in table 1.

| No | Year | Volume (m$^3$) | Tahun | Volume (m$^3$) | Probability |
|----|------|----------------|-------|----------------|-------------|
| 1  | 2004 | 195559.50      | 2015  | 70546.77       | 91.7%       |
| 2  | 2005 | 348648.75      | 2005  | 70999.14       | 83.3%       |
| 3  | 2006 | 246762.23      | 2006  | 73419.60       | 75.0%       |
| 4  | 2007 | 326973.75      | 2004  | 95885.10       | 66.7%       |
| 5  | 2008 | 356184.00      | 2013  | 96419.58       | 58.3%       |
| 6  | 2009 | 300479.25      | 2012  | 128125.77      | 50.0%       |
| 7  | 2010 | 330008.25      | 2011  | 138744.99      | 41.7%       |
| 8  | 2011 | 397570.50      | 2014  | 140760.77      | 33.3%       |
| 9  | 2012 | 371484.00      | 2007  | 142000.58      | 25.0%       |
| 10 | 2013 | 298069.50      | 2008  | 154383.12      | 16.7%       |
| 11 | 2014 | 330301.50      | 2010  | 156721.47      | 8.3%        |
| 12 | 2015 | 260520.75      | 2009  | 158921.36      | 0.0%        |

Average 313546.83 Q80% 71967.32 80.00%

Source: Calculation

NRECA is a lumped conceptual rainfall-runoff model developed by National Rural Electric Cooperative Association to estimate hydrological conditions for small hydroelectric projects.

From the climatology data obtained from Class IV Climatology Station Nunukan from 2010 to 2014, Evapotranspiration Method of Penman Monteith can be calculated, the results of the evapotranspiration calculation can be seen in Table 2.

| No | Month  | 2010 | 2011 | 2012 | 2013 | 2014 |
|----|--------|------|------|------|------|------|
| 1  | January| 4.03 | 3.74 | 3.47 | 3.58 | 3.69 |
| 2  | February| 5.45 | 3.82 | 4.04 | 3.96 | 4.77 |
| 3  | March  | 5.65 | 3.68 | 4.01 | 4.80 | 5.33 |
| 4  | April  | 4.98 | 4.42 | 4.70 | 4.03 | 5.17 |
| 5  | May    | 4.38 | 3.80 | 4.44 | 3.75 | 4.71 |
| 6  | June   | 4.26 | 3.62 | 4.02 | 3.53 | 3.87 |
| 7  | July   | 3.89 | 4.05 | 4.08 | 3.40 | 3.96 |
| 8  | August | 4.38 | 4.09 | 4.67 | 3.61 | 4.27 |
| 9  | September| 4.09 | 4.15 | 4.15 | 3.98 | 4.35 |
| 10 | October| 3.93 | 4.29 | 4.46 | 3.66 | 4.29 |
| 11 | November| 3.92 | 3.68 | 4.01 | 3.65 | 4.35 |
| 12 | December| 3.59 | 3.57 | 3.80 | 3.72 | 3.66 |

Source: Calculation
The mainstay rainfall calculation based on the base year method is calculated from monthly rainfall data which is summed up by rainfall into annual rainfall then sorted from the largest to the smallest value then the percentage of occurrence is calculated. From the calculation results obtained that the mainstay rainfall based on a base year with a percentage occurred 90% or close to occur in 2004. The calculation of the mainstay rain based on the base year can be seen in the table below.

Table 3. Calculation of Mainstay Rain Based on Years (mm)

| Year  | Annual Rainfall (mm) | Basic Year | Annual Rainfall (mm) | Probability % |
|-------|-----------------------|------------|-----------------------|---------------|
| 2004  | 1533.8                | 2011       | 3118.2                | 7.69          |
| 2005  | 2734.5                | 2012       | 2913.6                | 15.38         |
| 2006  | 1935.39               | 2008       | 2793.6                | 23.08         |
| 2007  | 2564.5                | 2005       | 2734.5                | 30.77         |
| 2008  | 2793.6                | 2014       | 2590.6                | 38.46         |
| 2009  | 2356.7                | 2010       | 2588.3                | 46.15         |
| 2010  | 2588.3                | 2007       | 2564.5                | 53.85         |
| 2011  | 3118.2                | 2009       | 2356.7                | 61.54         |
| 2012  | 2913.6                | 2013       | 2337.8                | 69.23         |
| 2013  | 2337.8                | 2015       | 2043.3                | 76.92         |
| 2014  | 2590.6                | 2006       | 1935.4                | 84.62         |
| 2015  | 2043.3                | 2004       | 1533.8                | 92.31         |

Source: Calculation

The calculation of the mainstay rain based on the base month is almost the same as the base year but the rain data used is monthly rainfall data so that 90% of the rainfall will be obtained each month. Rain data is sorted from large to small then the percentage of occurrence is calculated from small to large. From the calculation the mainstay rain calculation will be obtained based on the following base month.

Table 4. Calculation of Mainstay Rain Based on month (mm)

| No | Jan | Feb | Mar | Apr | May | Jun | July | August | Sep | Oct | Nov | Des | P (%)  |
|----|-----|-----|-----|-----|-----|-----|------|--------|-----|-----|-----|-----|--------|
| 1  | 250.8 | 258.6 | 293.5 | 404.8 | 491.2 | 377.5 | 439.0 | 446.2 | 378.9 | 346.5 | 288.1 | 316.6 | 7.7     |
| 2  | 248.6 | 215.8 | 216.9 | 390.0 | 392.1 | 335.2 | 402.3 | 422.4 | 372.6 | 337.8 | 280.4 | 279.5 | 15.4    |
| 3  | 244.9 | 197.0 | 166.4 | 325.2 | 388.0 | 318.3 | 328.0 | 354.8 | 258.9 | 241.3 | 264.4 | 276.5 | 23.1    |
| 4  | 197.4 | 154.5 | 156.0 | 312.7 | 358.7 | 254.1 | 327.6 | 343.4 | 241.7 | 223.8 | 253.5 | 221.6 | 30.8    |
| 5  | 171.5 | 140.4 | 133.6 | 210.5 | 346.0 | 241.6 | 311.9 | 312.5 | 217.2 | 208.7 | 201.2 | 180.3 | 38.5    |
| 6  | 151.1 | 139.1 | 112.9 | 174.1 | 329.7 | 237.2 | 282.6 | 305.0 | 200.8 | 206.2 | 179.1 | 151.0 | 46.2    |
| 7  | 147.5 | 128.3 | 110.2 | 149.1 | 244.9 | 215.7 | 239.4 | 267.0 | 187.9 | 191.5 | 178.1 | 145.1 | 53.8    |
| 8  | 146.4 | 119.1 | 96.5  | 143.2 | 178.3 | 210.2 | 233.7 | 203.0 | 181.8 | 134.8 | 136.0 | 129.6 | 61.5    |
| 9  | 132.9 | 71.2  | 87.8  | 141.9 | 174.6 | 202.6 | 203.4 | 195.5 | 166.9 | 132.9 | 121.6 | 119.3 | 69.2    |
| 10  | 118.6 | 52.4  | 87.7  | 99.0  | 165.1 | 173.3 | 174.5 | 190.3 | 159.1 | 121.0 | 100.0 | 89.9  | 76.9    |
| 11  | 99.3  | 45.0  | 74.4  | 89.8  | 157.6 | 134.7 | 168.8 | 153.8 | 149.4 | 110.2 | 66.9  | 73.5  | 84.6    |
| 12  | 67.5  | 18.7  | 25.9  | 82.7  | 146.1 | 116.5 | 132.0 | 125.2 | 117.3 | 99.8  | 61.6  | 56.5  | 92.3    |

90%: 77.0 26.6 40.4 84.8 149.6 122.0 143.0 133.8 126.9 102.9 63.2 61.6 90
80%: 110.9 49.4 82.4 95.3 162.1 157.9 172.2 175.7 155.2 116.7 86.8 83.3 80

Source: Calculation

The mainstay of rain calculation when using rainfall data based on the base year of the rain characteristics is different from the pattern of rainfall characteristics that occur on average in the Nunukan region, whereas when using the base month the rainfall is very small, so the rainfall modification is needed so that the rainfall characteristics approach characteristics of the average rainfall that occurs in Nunukan.
In the mainstay discharge calculation the NRECA method used for the calculation is the mainstay rainfall modification and also the evapotranspiration calculation and also other input data needed.

From the figure 2, the smallest mainstay discharge occurs in March, while for large discharges occur in July and August.

4. Conclusion
From the above calculation analysis, the availability of water contained in the location of the Sei Fatimah reservoir, with a probability of 90%, between 0.01 m$^3$/s to 0.012 m$^3$/s. Low mainstay discharge occurs in March and high in July and August.

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References
[1] Jiang T, Chen Y D, Xu C yu, Chen X, Chen X and Singh V P 2007 Comparison of hydrological impacts of climate change simulated by six hydrological models in the Dongjiang Basin, South China J. Hydrol. 336 316–33
[2] Krista Westerbeek-Vopicka, 2009, Sediment Assessment of Stormwater Retention Ponds within the Urban Environment of Calgary, Canada, Water Qual. Res. J. Can. Volume 44, No. 1, 81-91.
[3] Febrinasti Alia, M. Baitullah Al Amin, Citra Indriyati, Bimo Brata Adhitya, 2019, Evaluating the Technical Feasibility of Retention Basins for Flood Control in Palembang City, Science and Technology Indonesia, Vol. 4, No. 2, 40-51.

[4] Waldemar MIODUSZEWSKI, 2012, Small Water Reservoirs – their function and Construction, Journal of Water and Land Development, No. 17 (VII-XII), 45-52.

[5] Quentin B. Travis and Larry W. Mays, 2008, Optimizing Retention Basin Network, Journal of Water Resources Planning and Management, Vol. 134, No. 5.

[6] Narayanan Kannan, Jaehak Jeong, Jeff Arnold, Roger Glick, Leila Gosselink, Raghavan Srinivasan, 2014, Hydrologic Modelling of Detention Pond, International Journal of Research in Engineering and Technology, Vol. 03, Issue: 02, 657-662.

[7] E. Gaborit, D. Muschalla, B. Vallet, P.A. Vanrolleghem and F. Anctil, 2013, Improving the performance of stormwater detention basins by real-time control using rainfall forecasts, Urban water Journal, Vol. 10, No. 4, 230-246.

[8] Lubos Jurik, Dusan Huska, Klaudia Halaszova, Anna Bandlerova, 2015, Small Water Reservoirs-Sources of Water or Problems?, Journal of Ecological Engineering, Vol. 16, No. 4, pages 22-28.

[9] Colleta Tundu, Michael James Tumbare, and Jean-Marie Kileshye Onema, 2018, Sedimentation and Its Impacts/Effects on River System and Reservoir Water Quality: case Study of Mazowe Catchment, Zimbabwe, Proc. IAHS, 377, 57-66.

[10] Crawford D N H and Thurin S M 1981 Hydrologic estimates for small hydroelectric projects

[11] Reichl F and Hack J 2017 Derivation of flow duration curves to estimate hydropower generation potential in data-scarce regions Water (Switzerland)

[12] Darina Vassova, 2013, Comparison of Rainfall-Runoff Models for Design Discharge Assessment in a Small Ungauged Catchment, Soil & Water Res, Vol, 8, No.1, 26-33.

[13] Fernanda Pereira Souza, Maria Elisa Leite Costa and Sergio Koide, 2019, Hydrological Modelling and Evaluation of Detention Ponds to Improve Urban Drainage System and Water Quality, Water, Vol. 11, No. 8.

[14] Md. Sharif Imam Ibn Amir, Mohammad Masud Kamal Khan, Mohammad Golam Rasul, Raj H. Sarma, and Fatema Akram, 2013, Automatic Multi-Objective Calibration of a Rainfall Runoff Model for the Fitzroy Basin, Queensland, Australia, International Journal of Environmental Science and Development, Vol. 4, No. 3, 311-315.

[15] Andrea Gioia, 2016, Reservoir Routing on Double-Peak Design Flood, Water, 2016, Vol. 8.

[16] Pavel Kovar, Michaela Hrabalikova, Martin Neruda, Roman Neruda, Jan Srejber, Andrea Jelinkova and Hana Bacinova, 2015, Choosing an Appropriate Hydrological Model for Rainfall-Runoff Extremes in Small Catchmwrns, Soil & Water Res., Vol. 10. 137-146.

[17] Jin Kang Du, Dapeng Zheng, Youpeng Xu, Shunfu Hu, Chongyu Xu, 2016, Evaluating functions of reservoirs' storage capacities and locations on daily peak attenuation for Ganjiang River Basin using Xinanjiang Model, Chinese Geographical Science, Vol. 26, Issue 6, pp 789-802.

[18] Alcamo J, Döll P, Henrichs T, Kaspar F, Lehner B, Rösch T, Siebert S: Global estimates of water withdrawals and availability under current and future “business-as-usual” conditions. Hydrol. Sci. J., 48(3), 339–348, 2003. doi:10.1623/hysj.48.3.339.45278

[19] Putra LA: Analysis of the Effectiveness of Ciawi Reservoir Using SWAT Model as an Effort of Flood Control of Ciliwung Watershed. Master thesis, Department of Civil and Environmental Engineering, Faculty of Agricultural Technology, IPB University, Bogor, Indonesia, 2015. [in Indonesian]

[20] Susanto A, Kerami D, Deliyanto B, Pramuhadi G: Analysis of the needs of reservoirs and reservoirs for flood control and sustainable water supply (case study of Upper Ciliwung River Basin). Research Report of Inter-University Cooperation, 424/Regional and City Planning, Regional and City Planning Studies Program, Faculty of Mathematics and Natural Sciences, Open University, Jakarta, Indonesia, 2013. [in Indonesian]
[21] Kesuma RP, Wahyudi AH, Suyanto: Application of mock method, NRECA, tank model, and rainrun in Trani Dam, Wonotoro, Sudangan, and Walikan. eJournal Civil Engineering Matrix, 1(4), 472–479, 2013. [in Indonesian]

[22] Crawford NH, Thurin SM: Hydrologic estimates for small hydroelectric projects: NRECA Small Decentralized Hydropower (SDH) Program. National Rural Electric Cooperative Association, Washington DC, USA, 1981.

[23] Mulya H, Hadirahardja J, Kodoatie R: Water resources management strategies on non-groundwater basin (non-cat) small islands (study case: Batam Island). Int. Ref. J. Eng. Sci., 2(7), 14–22, 2013.

[24] Sucaka B, Hadiani R, Wahyudi AH: Reliability analysis of mock method with rain data 5, 10, 15 daily and 1 monthly. e-Journal Civil Engineering Matrix, 1(4), 480–487, 2013. [in Indonesian]

[25] Ciliwung-Cisadane River Basin Agency: Pattern of Water Resources Management. Ciliwung-Cisadane River Basin Agency, Jakarta, Indonesia, pp. 1–195, 2014. [in Indonesian]

[26] Limantara LM: Reliability performance of Tambak Pocok small dam, Bangkalan of Indonesia. Asian J. Nat. Appl. Sci., 1(2), 5–14, 2012