# DEVELOPMENT OF WATERSHED ASSESSMENT PROCEDURE: A NEW APPROACH

*by* Heri Sulistiyono

**International Journal of Civil Engineering and Technology (IJCIET)**
Volume 9, Issue 1, January 2018, pp. 550–561, Article ID: IJCIET_09_01_055
Available online at http://http://iaeme.com/Home/issue/IJCIET?Volume=9&Issue=1
ISSN Print: 0976-6308 and ISSN Online: 0976-6316



# DEVELOPMENT OF WATERSHED ASSESSMENT PROCEDURE: A NEW APPROACH

**Supardi**
BWS-NT1, Department of Public Works and Public Housing - 83125, NTB, Indonesia

**H. Sulistiyono**
Faculty of Engineering, University of Mataram - 83125, NTB, Indonesia

**ABSTRACT**

*Watershed management is required to maintain the quality and quantity of water resources. Recently, the indication of change in watershed quality has become a global concern. A better procedure is necessary for watershed assessments. This study observed the downward trend in watershed's quality in the proposed procedure through four following parameters: a) average of annual discharge, b) the coefficient of flow regime, c) the coefficient of annual runoff and d) the value of the water availability index every year. A regression technique was modified in this study to obtain a more sensible prediction of future watershed quality. The technique developed in this study was demonstrated to assess the degradation of watershed quality in Lombok Island. Hydrological data from 1994 to 2016 was used in this study. The results showed that the new modified technique of regression was reasonable to be applied. Moreover, it was found that the average of river discharge decreases by 4% per year, the coefficient of river regime increases by 9% annually, the Coefficient of runoff increases 9% annually and the Index of Water Availability decreases by 4% every year.*

**Key words**: Discharge, Index of Water Availability, Runoff Coefficient, River Regime Coefficient, Modified Regression, Watershed Management.

**Cite this Article:** Supardi and H. Sulistiyono, Development of Watershed Assessment Procedure: A New Approach, International Journal of Civil Engineering and Technology, 9(1), 2018, pp. 550–561.
http://iaeme.com/Home/issue/IJCIET?Volume=9&Issue=1

## 1. INTRODUCTION

Watershed can receive, store, and drain rainwater that falls on it through the tributaries along with its mother river to the estuary. Much of life depends on the quantity and quality of water resources in the watershed. Humans play an important and dominant role in maintaining the quality of a watershed.

The main problems in the watershed include erosion, land degradation, drought, flooding, and degradation of river water quality as water resources. Destruction of upstream watershed area is one of the factors that degradation watershed quality. In his study, McDonald et al (2016) mentioned that 309 big cities around the world have been affected by the impact of degraded watersheds. Although many watershed modeling has been conducted, yet until now, the scientific understanding of the watershed degradation model is still limited. In watershed modeling, several important parameters can be used to evaluate the watershed quality status. In this paper, these following parameters: the Average of Annual Discharge, the Coefficient of the flow regime, the Annual Runoff Coefficient and the Index of Water Availability are used in the watershed quality evaluation. According to the Research and Development Center for Watershed Management Technology (Anonymous, 2017), the average discharge is the most important information for water resources managers, as it can provide a picture of potential water availability in the waterhed. The Coefficient of the flow regime is the ratio between the maximum discharge (Q max) and the minimum discharge (Q min) in the river. This coefficient is useful to understand the maximum fluctuation of river flow. The high value of fluctuation indicates a damage of watershed in term of incapability to hold water in the watershed (Suyono 1999). The Annual Runoff Coefficient is a comparison between annual flow thickness (Q, mm) and annual rain thickness (P, mm) in a watershed. This value gives an overview of the excess of annual rainfall that transformed into annual runoff in the watershed. Similar to the coefficient of the flow regime, the high value of the annual runoff coefficient indicates a damage of watershed in term of incapability to hold water in the watershed. The Index of Water Availability is a ratio between the average of annual water availability and the total population. This value indicates the capability of watershed to provide water to supply the residential water demand (Sulistiyono, 2010).

According to Sri Harto (2000), the amount of surface flow can be estimated using the parameters of watershed. The parameters are (a) the area and shape of the watershed, (b) the type of topography and (c) the type of land use. Land use influence is expressed by the coefficient of surface flow (C). This coefficient is the ratio between surface flow and rainfall. The value of this coefficient ranges from 0 - 1. A larger value of C indicates a more damage of watershed hydrological status.

Next in this study, a regression method is used to estimate the future hydrological status of watershed. Many researchers take the advantage of this method in the various studies, as regression is an easy statistical tool that is able to give satisfied results. (Ardana, 2015, Sutapa, 2006; Larson et al., 2004; Roman et al., 2012; Sulistiyono and Lye, 2012; Sulistiyono and Lye, 2014; Sulistiyono et al., 2015). A linear regression method will only give results based on a linear equation; therefore the result obtained has a weakness, such as a zero value in the prediction result. According to some researchers, the form of asymptotic situations is more acceptable than the form of symptotic situations to avoid a zero value in the prediction result (Kowalik and Walega, 2015; Hawkins et al., 2015). Therefore in this study, the regression method was modified to be able to give asymptotic prediction of the future

## 2. METHODOLOGY

The proposed procedure of watershed assessment is shown in Figure 1.

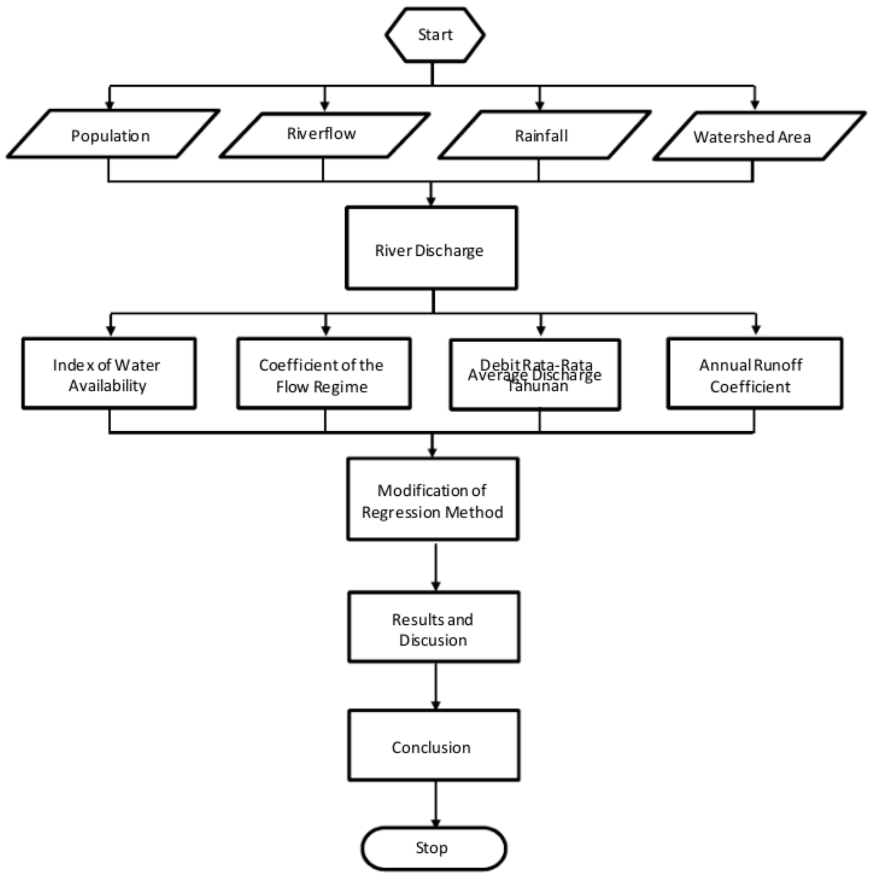


**Figure 1** A New Assessment Procedure

River discharge is the volume of water moving past a cross-section of a stream or river over a set period of time (Suyono, 1999, and Sri Harto, 2000). In Figure 1, river discharge is affected by the amount of population, river flow, rainfall, and watershed. Therefore, discharge defines the shape, size and course of the stream and is tied to water quality and habitat. In undeveloped watersheds, soil type, vegetation, and slope all play a role in how fast and how much water reaches a stream. In watersheds with high human impacts, water flow might be depleted by withdrawals for irrigation, domestic or industrial purposes. Drastically altering landscapes in a watershed, such as with development, can also change flow regimes, causing faster runoff with storm events and higher peak flows due to increased areas of impervious surface. These altered flows can negatively affect an entire ecosystem by upsetting habitats and organisms dependent on natural flow rates. Tracking stream flow measurements over a period of time can give us baseline information about the stream's natural flow rate. In water resources study, hydrological models are common tools for estimating daily time series of stream flow. Calibration and verification are necessary to obtain the predicted model parameters (Sulistiyono, 1999; Rahmanadi and Sulistiyono, 2018).

Parameters considered in the proposed procedure are:

***a) The Average of Annual Discharge (Q)***

In this study, the average of annual discharge was obtained from the recording of Automatic Water Level Recorder (AWLR) or based on other discharge calculations, such as the Mock Model (Sulistiyono, 1999) and the Nreca Model (Sulistiyono, 2013).

***b) Coefficient of the Flow Regime (KRA)***

The coefficient of flow regime is obtained as a ratio between the highest monthly discharge and the lowest monthly discharge. The calculation can be solved by using Equation 1 as shown below.

$$KRA = \frac{Q\max}{Q\min} \qquad (1)$$

with :

$Q_{max}$ : the highest monthly discharge ($m^3$/sec)

$Q_{min}$ : the lowest monthly discharge ($m^3$/sec)

***c) Annual Runoff Coefficient (C)***

The annual runoff coefficient is calculated based on the average of annual discharge ($m^3$/sec) divided by average of annual rainfall (mm/yr) that falling on the watershed ($km^2$). The annual runoff coefficient can be expressed in Eq. 2 below:

$$C = \frac{k \; x \; Q}{CH \quad x \; A} \qquad (2)$$

with :

C : annual runoff coefficient

*k* : conversion factor = 365x86400 (sec),

A : watershed area (ha),

Q : average of annual discharge ($m^3$/sec),

CH : average of annual rainfall (mm/yr).

***d) Index of Water Availability (IKA)***

The index of water availability (IKA) is calculated using the Equation 3:

$$IKA = \frac{Qa}{Pt} \qquad (3)$$

with :

IKA : index of water availability ($m^3$/capita/yr)

Q : average of annual discharge ($m^3$/sec)

Pt : population (persons)

The discharge data used in the analysis of water availability is the monthly or daily streamflow data. The number of data has to be adequate for statistical analysis. The discharge data is the observed data at the automatic water level recorder (AWLR). If the debit data is inadequate or even unavailable, the discharge can be simulated using the Mock or the Nreca models based on the rainfall data and the potential evapotranspiration in the area of interest.

***e. Modification of Regression***

Generally, the simple linear regression is as expressed in Eq 4.

$$\hat{y} = a + bx \quad (4)$$

with :

$\hat{y}$ : dependent variables

$a$ : constant

$b$ : coefficient of independent variables

$x$ : independent variables

Equation (4) will produce a straight line result. In accordance with the opinion of some experts that the decrease in watershed status will not reach zero (the line equation will not intersect with the x-axis or y-axis), therefore the equation of simple linear regression should be modified to form an asymptotic line. In this study, a modification of the regression equation is conducted by a transformation of dependent variable (X) using a natural logarithmic function. Thus, Equation (4) can be developed into equation (5) as follows:

$$\hat{y} = a + b(\ln(x)) \quad (5)$$

with :

$\hat{y}$ : dependent variables

$a$ : constant

$b$ : coefficient of independent variables

$ln$ : natural logarithmic function

$x$ : independent variables

Equation (5) can be solved after the values of a and b were obtained. In this case, the value of b is obtained before the value of a. The value of b is calculated by using the least squares in Equation 6 as follows:

$$b = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} \quad (6)$$

with :

$b$ : coefficient of independent variables

$x_i$ : independent variables of x

$\bar{x}$ : average of independent variables of x

$y_i$ : dependent variables of y

$\bar{y}$ : average of dependent variables of y

After the value of b is obtained, then the value of a can be calculated by using the substitution equation in Eq. 7 as follows:

$$a = \bar{y} - bx \quad (7)$$

with :

$a$ : constant

$\bar{y}$ : average of dependent variables of y

$b$ : coefficient of independent variables

$x$ : independent variables

## 3. CASE STUDY

To understand the illustration of watershed assessment procedure, we applied this study procedure in three watersheds in the Lombok Island, namely: Jangkok Watershed, Belimbing Watershed and Sidutan Watershed.

The locations of the three watersheds are shown in Figure 2 below.

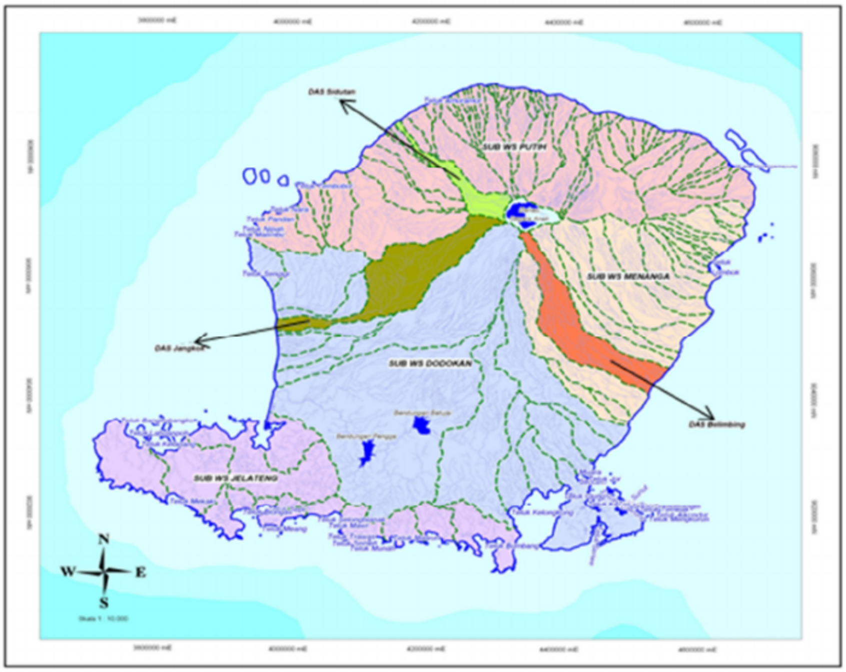


**Figure 2** Locations of the Jangkok Watershed, the Belimbing Watershed and the Sidutan Watershed

Figure 2 shows the Belimbing watershed with an area of 91.47 $km^2$ located in the East Lombok Regency. The Jangkok watershed with an area of 168.73 $km^2$ is located in the West Lombok and Mataram, and the Sidutan watershed with an area of 48.93 $km^2$ located in the North Lombok Regency.

## 4. RESULTS AND DISCUSSION

The watershed status are analyzed using hydrological data from 1994 to 2016. From the analysis, it is known that there is a trend of decrease in the hydrological status of the watersheds. Next, the future hydrological status of watershed can be estimated using the modified regression based on the trend. In this study, the hydrological status of watershed in 2025 is estimated.

The results of watershed parameter analysis are presented in Table 1.

**Table 1** Q, KRA, C and IKA from 1994-2016

| No | Year | Q ($m^3/dt$) | KRA | C | IKA ($m^3$/capita/yr) |
|---|---|---|---|---|---|
| 1 | 1994 | 1.8 | 4.3 | 0.19 | 12 |
| 2 | 1995 | 1.66 | 5.8 | 0.18 | 11.7 |
| 3 | 1996 | 1.53 | 6.1 | 0.19 | 11.5 |
| 4 | 1997 | 1.5 | 7.2 | 0.22 | 10.6 |
| 5 | 1998 | 1.34 | 8.7 | 0.24 | 10.5 |
| 6 | 1999 | 1.3 | 9.5 | 0.28 | 10 |
| 7 | 2000 | 1.3 | 9.84 | 0.31 | 9.6 |
| 8 | 2001 | 1.18 | 10.8 | 0.34 | 9 |
| 9 | 2002 | 1.21 | 11.1 | 0.33 | 8.3 |
| 10 | 2003 | 1.12 | 12.2 | 0.4 | 7.5 |
| 11 | 2004 | 1.1 | 13.8 | 0.42 | 7.1 |
| 12 | 2005 | 1.13 | 14.61 | 0.4 | 7.494 |
| 13 | 2006 | 0.95 | 15.2 | 0.45 | 7 |
| 14 | 2007 | 0.97 | 15.4 | 0.48 | 6.5 |
| 15 | 2008 | 0.99 | 16.6 | 0.49 | 6.1 |
| 16 | 2009 | 0.95 | 16.8 | 0.5 | 5.8 |
| 17 | 2010 | 0.88 | 17.84 | 0.48 | 5.814 |
| 18 | 2011 | 0.89 | 18 | 0.52 | 5.6 |
| 19 | 2012 | 0.82 | 19 | 0.55 | 5.5 |
| 20 | 2013 | 0.77 | 20 | 0.54 | 5 |
| 21 | 2014 | 0.8 | 20.1 | 0.59 | 4.4 |
| 22 | 2015 | 0.75 | 20.61 | 0.58 | 4.483 |
| 23 | 2016 | 0.7 | 20.62 | 0.6 | 4.5 |

Table 1 shows a decrease in the average of annual discharge of Lombok's rivers by 5%. This decreases indicates the occurrence of potency of water scarcity in the future. With this rate of decrease, the average flow of rivers in Lombok by 2016 is 0.70 $m^3$/sec. A decrease in the average of annual discharge indicates an increase in the surface flow and a decrease in the base flow. The decrease in the average of annual discharge of rivers in Lombok is in line with the average increase in KRA every year; therefore, the average KRA becomes 20.62 in 2016. As the value of KRA in 2016 is larger than 20, the watershed status in Lombok Island is categorized as critical. Moreover, KRA in 2016 was 210% larger than KRA in 2000. This indicates a significant increase in the potential floods and droughts from 2000 to 2016. In addition, there is an increase in C by 9% every year. By 2016, the average of C is 0.60. It is larger than 0,5 and is categorized as bad watershed status as 60% of rainfall on the watershed will transformed into runoff. IKA in 2016 is 4.50 $m^3$/capita/year. This value is 46.876% smaller than IKA in 2000. It indicates that there is a potential decrease about 2.93% every year in water availability.

Next from the results of the analysis, the modified regression model was developed using the transformation of natural logarithmic functions. The modified regression models were obtained as follows:

Modified regression equation for the Average of Annual Discharge as expressed in Equatiom 8.

$$Q = -0.361*\ln(x) + 1.9241 \qquad (8)$$

with :

$Q$ : the Average of Annual Discharge

$ln$ : natural logarithmic function

$x$ : the number of data

Modified regression equation for the Coefficient of the Flow Regime as expressed in Equation 9.

$KRA = 6.0748*\ln(x) + 0.1138$ (9)

with :

*KRA*: the Coefficient of the Flow Regime

*ln* : natural logarithmic function

*x* : the number of data

Modified regression equation for the Annual Runoff Coefficient as expressed in Equation 10.

$C = 0.1575*\ln(x) + 0.0501$ (10)

with :

*C* : the Annual Runoff Coefficient

*ln* : natural logarithmic function

*x* : the number of data

Modified regression equation for the Index of Water Availability as expressed in Equation 11.

$IKA = -2.873*\ln(x) + 14.099$ (11)

with :

*IKA*: the Index of Water Availability

*ln* : natural logarithmic function

*x* : the number of data

Using a modified regression equation, the average of annual discharge in 2025 is estimated to be 0.67 $m^3$/s. This value is only a half of the average of annual discharge in 2000, which is 1.3 $m^3$/s. As the population in Lombok is growing, the watershed will not be able to provide adequate water supply. The discharge rate up to 2025 is shown in Figure 3 below.

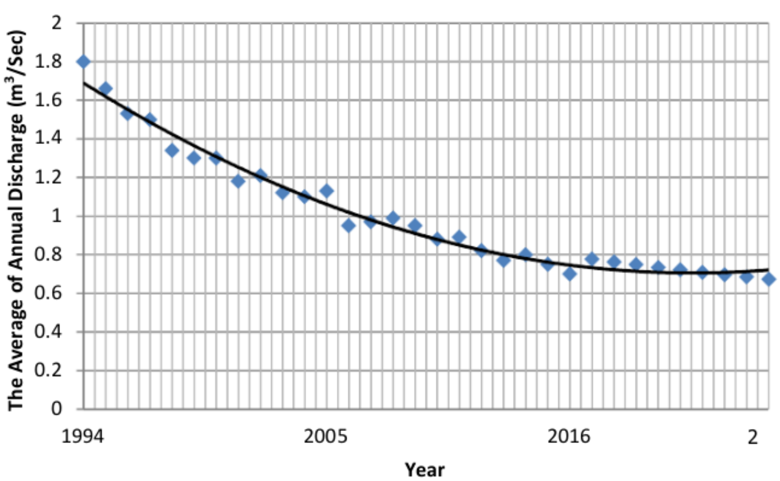


**Figure 3** The Estimated Average of Annual Discharge until 2025

The value of KRA in 2025 is predicted to increase to 22.5. It means that the quality of the watershed is getting worse in the future. The magnitude of floods is getting large. Graphically, the KRA values up to 2025 is shown in Figure 4.

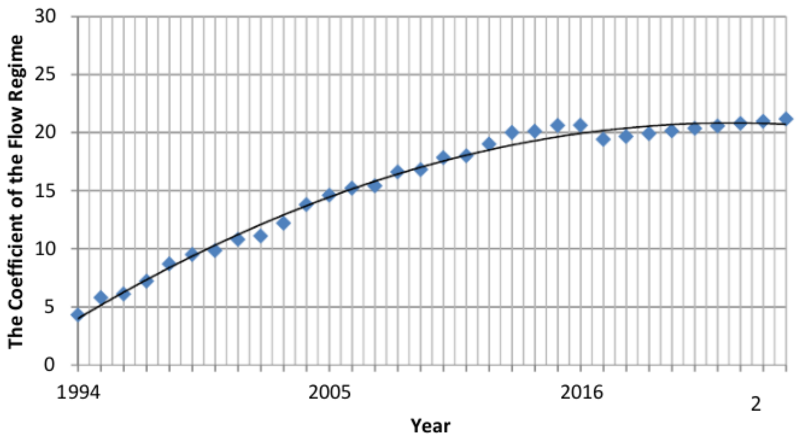


**Figure 4** Estimated KRA values up to 2025

The value of C in 2025 is estimated to increase to 0.60. This means that 60% of the falling rainfall in the watershed will turn into surface runoff. This indicates that the quality of the watersheds is very poor, as the watershed cannot hold or store rainfall to ground water. Graphically, the approximate value of C to 2025 is shown in Figure 5 below.

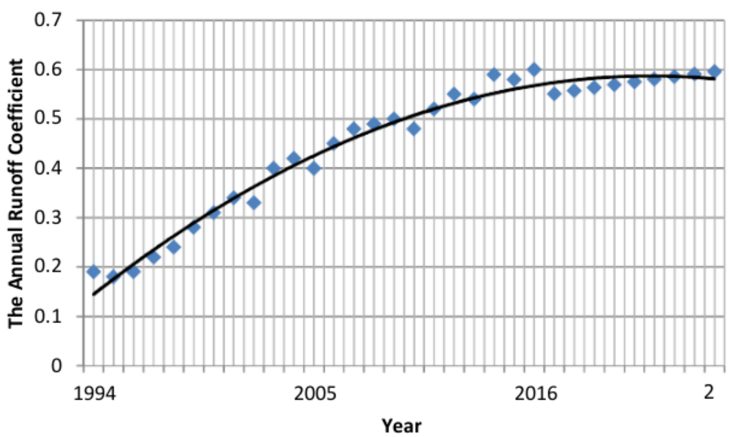


**Figure 5** Estimated KRA values up to 2025

Next, the index of water availability in 2025 is estimated to decrease to 4500 $m^3$/capita/year. By assuming that every person needs 100 lt/day, then every person needs 36500 lt/yr or 36500 $m^3$/capita/year. It means that the water availability in the watershed is very less. In 2025, the water is only enough for people, not for other else. Graphically, IKA values until 2025 is shown in Figure 6.

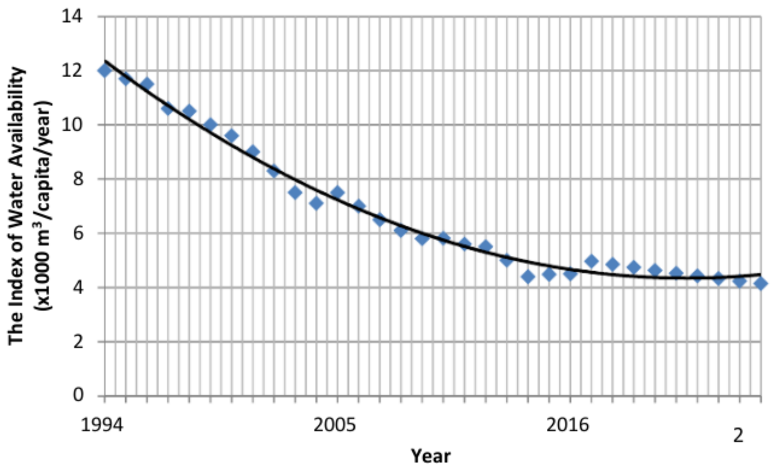


**Figure 6** Estimated IKA values up to 2025

## 5. CONCLUSION

To ensure the sustainability of watershed quality, watersheds have to be reassessed every certain periods. Moreover, procedures of assessments also have to be reviewed in accordance with new conditions, such as climate change. Therefore, it is expected to have a procedure of watershed assessment that can assess recent and predict future statuses of watershed. From the study, it can be concluded that:

This study has successfully developed a new procedure for assessing watershed status. The proposed procedure involves 4 (four) watershed parameters and 1 (one) modified regression. From the case study, the result shows that the proposed procedure can be reasonably applied.

There will be a significant decrease in the average of annual discharge, Q in the future that may cause watersheds unable to provide sufficient water availability. It is estimated that the Flow Coefficient (KRA) increases in the future. It indicates that the magnitude of floods is larger and potentially damaging to environments. The value of the annual runoff coefficient is also estimated to increase in the future. This shows that the function of watershed to store water from rainfall will be reduced in the future. In 2025, it is estimated that 60% of the rainfall will transform into runoff. The value of The Index of Water Availability is also estimated to significantly decrease in the future. In 2025, the value of IKA is estimated to 4500 m3/capita/yr.It indicates that watershed can only provide water for people to live, but cannot provide water for anything else.

Taking into account the estimated parameters in the future, it is understood that the watershed status in WS Lombok is at a critical level. Conservation efforts are needed to improve watershed functions, especially to improve the ability to provide adequate water availability and to enhance the ability to detent floods.

## 6. ACKNOWLEDGEMENTS

The authors thank BWS-NT1, Department of Public Works and Public Housing for providing runoff, climatic and rainfall data.

## REFERENCES

[1] Anonymous, 2017. Monev Technology Transfer with Minimal Data (*Alih Teknologi Monev Dengan Data Minimal*). Research Institute and Technology Development of Watershed Management. http://balitekdas.org/fasilitas/spas

[2] Ardana,P., 2014. Application of Regression Models in the Transformation of Rainfall-Runoff Data. Case Study: Tukad Jogading Watershed. (*Aplikasi Model Regresi Dalam Pengalihragaman Hujan Limpasan Terkait Dengan Pembangkitan Data Debit. Studi Kasus: DAS Tukad Jogading*). https://www.researchgate.net/publication/281422758_Aplikasi_Model_Regresi_Dalam_Pengalihragaman_Hujan_Limpasan_Terkait_Dengan_Pembangkitan_Data_Debit_Studi_Kasus_DAS_Tukad_Jogading

[3] Hawkins, R., H., Ward, T., J., Grillone, G., D'Asaro, F., 2015. Standard Asymptotic Response and Expected Runoff from Curve Number Theory. Watershed Management Symposium 2015. ASCE. http://ascelibrary.org/doi/abs/10.1061/9780784479322.017

[4] Kowalik, T. and Walega, A., 2015. Estimation of CN Parameter for Small Agricultural Watersheds Using Asymptotic Functions. Water 2015, 7, 939-955; doi: 10.3390/w7030939. ISSN 2073-4441. www.mdpi.com/journal/water

[5] Larson, S.J., Crawford, C.G. and Gilliom, R.J., 2004. Development and Application of Watershed Regressions for Pesticides (WARP) for Estimating Atrazine Concentration Distributions in Streams. USGS Publication. https://pubs.usgs.gov/wri/wri034047/wrir034047.pdf

[6] McDonald, R., Weber, K., Padowski, J., dan Shemie, D., 2016. Estimating watershed degradation over the last century and its impact on water-treatment costs for the world's large cities. Proceeding of the National Academy of Sciences of the U S A. 2016 Aug 9; 113(32): 9117–9122. Published online 2016 Jul 25. doi: 10.1073/pnas.1605354113. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4987831/

[7] Roman, D.C., Vogel, R.M., Schwarz, G.E., 2012. Regional regression models of watershed suspended-sediment discharge for the eastern United States. Journal of Hydrology. Elsevier. https://doi.org/10.1016/j.jhydrol.2012.09.011

[8] Rahmanadi, L. and Sulistiyono, H., 2018. Hybrid Technique between Design of Experiments and Artificial Neural Networks for Rainfall-Runoff Model Calibration Method. International Journal of Civil Engineering and Technology, 9(1), 2018, pp. 11-21. http://iaeme.com/Home/issue/IJCIET?Volume=9&Issue=1

[9] Sri Harto Br, 2000. Hydrology (*Hidrologi*). Naviri, Yogyakarta.

[10] Sutapa, I.W., 2006. Study of Influence and Relationship of Variable Form of Watershed to Synthetic Unit Hydrograph Parameters (*Studi Pengaruh Dan Hubungan Variabel Bentuk Das Terhadap Parameter Hidrograf Satuan Sintetik*). Jurnal SMARTek, Vol. 4, No. 4, Nopember 2006: 224 – 232. http://jurnal.untad.ac.id/jurnal/index.php/SMARTEK/article/viewFile/442/379

[11] Sulistiyono, H., 1999. Rainfall-Runoff Model Calibration Using Experimental Designs and Response Surface Methodology. Master of Engineering Thesis. Memorial University of Newfoundland, Canada.

[12] Sulistiyono, H., 2010. A spreadsheet based water balance model for the Reak River basin, Lombok, Indonesia. Proceedings, Annual Conference - Canadian Society for Civil Engineering. https://www.researchgate.net/publication/291148045_A_Spreadsheet_Based_Water_Balance_Model_for_the_Reak_River_Basin_Lombok_Indonesia

[13] Sulistiyono, H. And Lye, L.M., 2012. A proposed downscaling model for climate change studies. Proceedings, Annual Conference - Canadian Society for Civil Engineering. https://www.researchgate.net/profile/Heri_Sulistiyono3/publication/288973765_A_proposed_downscaling_model_for_climate_change_studies/links/569e4a7d08ae82c7c2961de0.pdf

[14] Sulistiyono, H., 2013. Potential Impacts of Climate Change On Water Resources in Lombok, Indonesia. Doctoral Thesis. Memorial University of Newfoundland. http://research.library.mun.ca/11491/

[15] Sulistiyono, H. And Lye, L.M., 2014. Estimating design temperatures in Arctic environments: A new approach. 2014 Oceans - St. John's, OCEANS 2014. http://ieeexplore.ieee.org/document/7002975/?reload=true

[16] Sulistiyono, H., Khan, F., Lye, L., Yang, M., 2015. A risk-based approach to developing design temperatures for vessels operating in low temperature environments. Ocean Engineering. 0029-8018/& 2015 Elsevier Ltd. All rights reserved. http://dx.doi.org/10.1016/j.oceaneng.2015.08.040.

[17] K. Rajkumar, P. Thavamani, Chandresh Dwivedi and PankajRegar, An Eco-Friendly Rubber-Textile Composites For Construction Of Rubber Dam To Use In Watersheds Application, Volume 5, Issue 2, February (2014), pp. 128-137, International Journal of Advanced Research in Engineering and Technology.

[18] Thanappan Subash, Kushnappa B.K, Dhanasekaran A and Afiya A, Changes on Physio-Chemical Properties of Soil in Agricultural Land in Ambo-Guder Watershed, Ambo, Ethiopia – A Case Study. International Journal of Civil Engineering and Technology, 8(5), 2017, pp. 667–675.

[19] SS.Asadi, N.Vijay Kumar, K. Rajyalakshmi and M. Satish Kumar, Designee of Water Harvesting Structures for Water Resources Management: A Model Study from Chelila Watershed, Bhutan, International Journal of Mechanical Engineering and Technology 8(10), 2017, pp. 666–679

[20] Suyono, 1999. Criticism of the Watershed (*Kekritisan Daerah Aliran Sungai*). Training Material for Water Resources Inventory and Evaluation Force IV. Faculty of Geography UGM, Yogyakarta.

# DEVELOPMENT OF WATERSHED ASSESSMENT PROCEDURE: A NEW APPROACH

ORIGINALITY REPORT

| 4% | 7% | 4% | 8% |
| --- | --- | --- | --- |
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

4%

★ Submitted to Pennsylvania State System of Higher Education

Student Paper

| | | | |
| --- | --- | --- | --- |
| Exclude quotes | On | Exclude matches | < 3% |
| Exclude bibliography | On | | |

# DEVELOPMENT OF WATERSHED ASSESSMENT PROCEDURE: A NEW APPROACH

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

**Instructor**

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12