

# IJAER-Model Wate

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## **Model of Water Resources Sustainability: Mining Void Water Utilization in Coal Mining (Case Study at PT. Adaro Indonesia, South Borneo, Indonesia)**

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### **ABSTRACT**

Surface coal mining may disrupts the carrying capacity of water, hence the sustainability of water resources during mining operations and post-mining depends on environmental services of mining void. This research was designed to study the environmental costs and benefits of mining void water (general term of pit lake in Indonesia) in PT. Adaro Indonesia on site Tanjung, Kabupaten Tabalong, South Borneo, Indonesia to understand the factors influencing mining sustainability through utilization of mining void or mining pit, and to develop a model for water resources sustainability in coal mining. The main factor influencing mining sustainability is the void water quality. pH is the key factor which determines how mining void water may be used. Water utilization is based on the demands of the surrounding community, and

includes drinking water, fish farming, and land farming. Calculations on the environmental services provided by mining void water for tourism, drinking water supply, and fish farming in PT. Adaro Indonesia shows an Extended NPV of Rp 7.124.884.062.739.430 ( $\pm$  USD 593, 740, 338, 561.62) and B/C ratio of 8, 25.

#### 4 INTRODUCTION

Surface mining in coal mining causes void (ex-pit mining hole). This lead to ground water depletion because of opened soil layers causing loss of vegetation along with carrying capacity of water. Void caused by surface mining allowed storing of run-off water which gives potential environmental service in coal mining water sustainability. However, acid mine drainage (AMD) potential requires mining void water quality to be studied and assessed. As coal stockpile decreases along with post-mining, economic potential valuation of water and environmental service potential formed is necessary to assess mining sustainability. Sustainability concept roots to first thermodynamic principal and refer to natural system capacity to survive effectively through energy usage and waste generation minimalise entrophy (Jepson, 2001).

Conventional benefit and cost model in coal mining reckon financial cost benefit but not including mining void water environmental service cost benefit. For sustainability to be part of economic calculation and matter decision process, ecological and environment value need to be integrated into pricing policy in analysing the advisability of the activity (Djayadinigrat, 2000). Therefore a further approach of economic valuation from mining void water environmental service is needed. Conventional benefit cost (NPV) that calculates financial benefit and cost has been developed by Munangsih into extended NPV that reckon in external environmental cost benefit (Munasinghe, 1992). The purpose of this study is to find out the factors influencing raw water source sustainability from utilization of mining void water, benefit and cost component of mining void water environmental service value for various water utilization, and construct the model of extended benefit and cost related to water resource sustainability in coal mining.

#### 3 METHODOLOGY / EXPERIMENTAL

This study is an exploratory research in which conducted by collecting datas on mining site in Kabupaten Balangan and Kabupaten Tabalong, South Borneo. Data collection is done by surveying, field observation, questionnaire distribution, and focus group discussion. Population and samples in this study are PT. Adaro Indonesia and the surrounding mining site community.

The following table shows the roots of water resource sustainability model designed in this research.

**Table 1** Roots of Water Resource Sustainability Model

| Economic Model / Equation  | Subject  |
|--|--|
| <p><i>Cash Flow Income (Financial)</i></p> $Benefit\ Cost = NPV = \sum_{t=0}^T \frac{(B_t - C_d)}{(1+r)^t} = \sum_{t=0}^T \frac{CF_t}{(1+r)^t}$                  | <p>Indonesian coal mining calculate <b>Direct Benefit Cost</b>, (Ditjen Minerba, PTBA 2009, Rudeno,1998)</p> |
| <p>In condition that natural resource and stable environment includes external environment benefit cost (Munasinghe (1992) in Suparmoko, (2004))</p>             |  |
| $Extended\ Benefit\ Cost = \sum_{t=0}^T \frac{(B_d + B_e)}{(1+r)^t} - \sum_{t=0}^T \frac{(C_d + C_p + C_e)}{(1+r)^t} = \sum_{t=0}^T \frac{(B_s - C_d)}{(1+r)^t}$ | <p>Input component of coal depletion and NSW mining (Munasinghe (1992) in Suparmoko, (2007))</p>             |

Extended model of benefit and cost of water resource sustainability in coal mining is designed based on the following steps:

1. Practice of benefit and cost analysis of sustainable coal mining should identify positive and negative externalities of coal mining impact towards mining void water environmental service value as raw water source during mining operation and post-mining.
2. Do an internalisation of external impact into benefit and cost model of water resource sustainability analysis by including financial and external community benefit and cost that arise because of the presence of mining void water environmental service as raw water source during mining, and benefit and cost of utilization of mining void water in post-mining.
3. Present value concept is used in calculating financial benefit and cost, environmental benefit and cost, community benefit and cost, and environmental service benefit and cost of mining void water as raw water source during coal mining and post-mining.
4. Net value calculation of coal mining environment sustainability, both benefit and cost flow, is done using present value concept.

On utilization of mining void water, obtained benefit will then input into conventional benefit and cost model that is needed to construct the model of water resource sustainability (extended NPVea). If the value generated by using the constructed model shows extended NPVea greater than 0 (extended NPVea > 0), then water resource in coal mining is sustainable.

### 3. RESULT

Focus group discussion with public figures of surrounding mining site community, the community leaders, and housewives resulted in wishes of mining void water utilization as drinking water source and farming irrigation. Void water presence is necessary to community living around mining area such as farmers and planters. Social study toward Ring 1 Village (village located around mining area), PT. Adaro Indonesia, shows that mining void water can be utilized other than as raw water source, which are tourism and hydropower. Table 2 below shows the crosstab result from the distributed questionnaire.

**Table 2** Crosstab Result from 80 Respondents

|                       |                                | Wishes towards PT. Adaro Indonesia related to Mining Void Presence & Utilization |   |                  |   | %    |
|-----------------------|--------------------------------|--|---|------------------|---|------|
|                       |                                | Daily water distribution   | Proper life, Clean air and water, good relationship | Fish-farming Aid | Farming training, disease treatment, planting spacing |      |
| Main Job / Profession | Farmer/planter                 | 6  | 3   | 3                | 2   | 17.5 |
|                       | Employee of PT Adaro Indonesia | 6  | 3   | 3                | 2   | 17.5 |
|                       | Entrepreneur                   | 6  | 3   | 3                | 2   | 17.5 |
|                       | Civil worker                   | 6  | 3   | 3                | 2   | 17.5 |
| %                     |                                | 30   | 15  | 15               | 10  | 70   |

Model of Water Resource Sustainability of Mining Void Water Environmental Service Benefit and Cost in Coal Mining is constructed as the following,

$$\text{Extended NPVav} = \sum_{t=0}^n \frac{(B_d + B_{id})}{(1+r)^t} - \sum_{t=0}^n \frac{(C_d + C_{id})}{(1+r)^t} = \sum_{t=0}^n \frac{(B_{av} - C_{av})}{(1+r)^t}$$

CF = cash flow

B<sub>d</sub> = direct benefit of mining void water utilization

B<sub>id</sub> = indirect benefit of mining void water utilization

C<sub>d</sub> = direct cost of mining void water utilization

C<sub>id</sub> = indirect cost of mining void water utilization

B<sub>av</sub> = total benefit of mining void water utilization

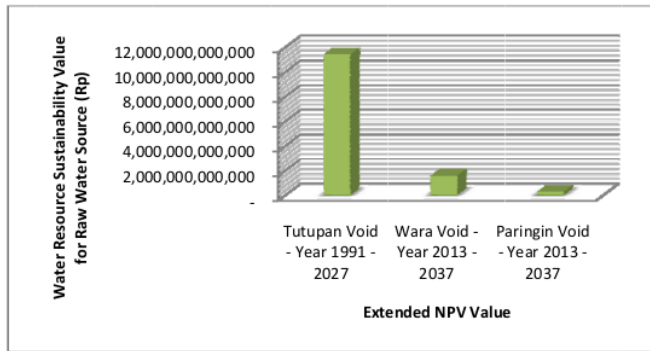
- $C_{av}$  = total cost of mining void water utilization
- $B_{av}$  = direct benefit of mining void water
- $r$  = interest rate
- $t$  = year 0 to T
- $\Sigma$  = sum

**Table 3** Benefit and Cost of Mining Void Water Utilization of Existing Void on 3 Blocks (Paringin, Wara, Tutupan) in PT. Adaro Indonesia with and without Technology Intervention

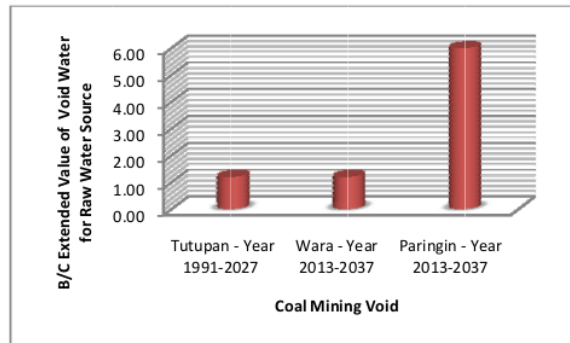
| No | Void Water Utilization | Benefit Component |                  | Cost Component |               |  |
|----|------------------------|-------------------|------------------|----------------|---------------|--|
| 1  | Raw water source       |                   |                  |                |               | Technology intervention (water treatment)        |
|    | Paringin               | Direct benefit    |                  | Direct cost    |               |  |
|    | Wara                   | Direct benefit    |                  | Direct cost    |               |  |
|    | Tutupan                | Direct benefit    |                  | Direct cost    |               |  |
| 2  | Tourism                |                   |                  |                |               | Natural attenuation (no technology intervention) |
|    | Paringin               | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |
|    | Wara                   | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |
|    | Tutupan                | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |
| 3  | Fish farming           |                   |                  |                |               | Natural attenuation (no technology intervention) |
|    | Paringin               | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |
|    | Wara                   | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |
|    | Tutupan                | Direct benefit    | Indirect Benefit | Direct cost    | Indirect cost |  |

Since year 2008, PT Adaro Indonesia is the only coal mining company in Indonesia that has been utilizing mining void water as raw water source. Drinking water procurement programme by PT Adaro Indonesia had received and award in 2009. Mining void water utilization as raw water source has been a benefit to the surrounding community on Kabupaten Balangan with raw water–drinking water distributed reaching 156 m<sup>3</sup>/day. Internal company needs of raw water–drinking water also utilizing mining void water, reaching 120 m<sup>3</sup>/day, that is currently derived from water treatment plant on void T300 at Tutupan. Based on the calculation using

developed model of water resource sustainability, benefit and cost of water resource sustainability of mining void water utilization as raw water source in PT Adaro Indonesia coal mining is found. Time span used is 1991 – 2027. It is shown that extended net present value of water resource sustainability by utilizing mining void water as raw water source in PT Adaro Indonesia coal mining reaches Rp 11.437.090.559.371 (± USD 953, 090, 880) at Tutupan Block with total benefit of Rp 68.622.543.356.228 (± USD 5, 718, 545, 280) and total cost of Rp 57.185.452.796.856 (± USD 4, 765, 454, 400).



**Figure 1** Graphic of Benefit and Cost of Water Resource Sustainability for Raw Water Source at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia

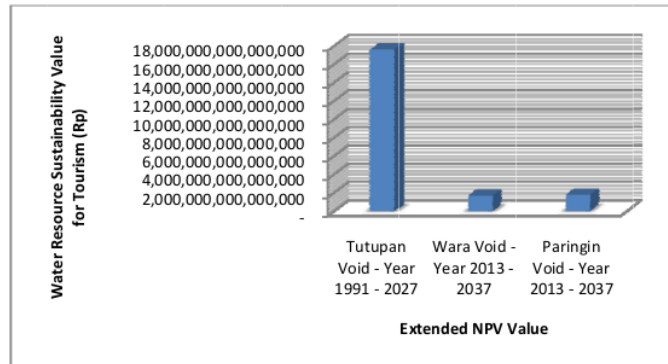


**Figure 2** Graphic of Benefit and Cost Extended Value of Void Water for Raw Water Source at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia

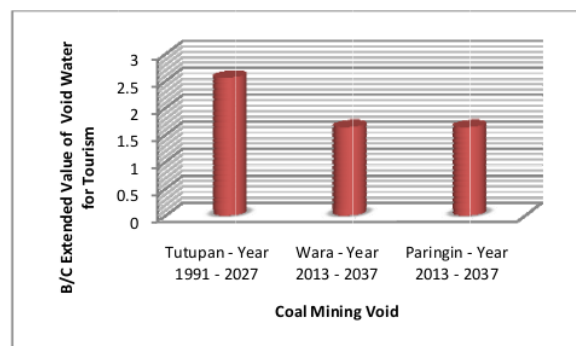
Benefit and cost of water resource sustainability of mining void water utilization as tourism in PT Adaro Indonesia coal mining with time span used 1991 – 2027 in



calculation shows that extended net present value of water resource sustainability by utilizing mining void water as tourism reaches Rp 17.600.505.621.890.900 (± USD 1, 466, 708, 801, 824) at Tutupan Block with total benefit of Rp 45.029.676.664.556.400 (± USD 3, 752, 473, 055, 380) and total cost of Rp 27.429.171.042.665.500 (± USD 2, 285, 764, 253, 555).



**Figure 3** Graphic of Benefit and Cost of Water Resource Sustainability for Tourism at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia

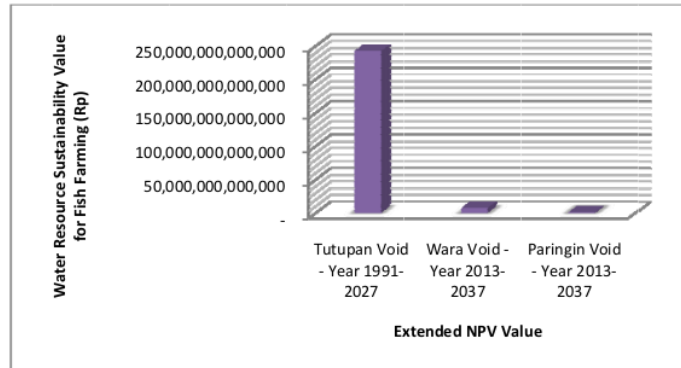


**Figure 4** Graphic of Benefit and Cost Extended Value of Void Water for Tourism at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia

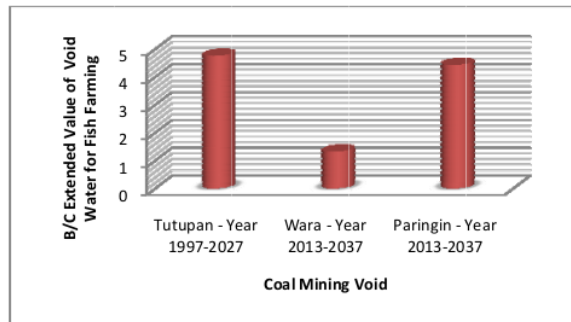
Researches on freshwater fish and shrimp farming has been done by local university and Limnology Research Center. Abundant amount of water in mining void is a big potential in development of fish resources conservation and freshwater fish farming. Based on the calculation using developed model of water resource



sustainability, benefit and cost of water resource sustainability of mining void water utilization as fish farming with time span used is 1991 – 2027, it is shown that extended net present value of water resource sustainability reaches Rp 242.240.940.506.683 (± USD 20, 186, 745, 042) at Tutupan Block with total benefit of Rp 1.152.813.336.210.730 (± USD 96, 067, 778, 018) and total cost of Rp 910.572.395.704.045 (± USD 75, 881, 032, 975).



**Figure 5** Graphic of Benefit and Cost of Water Resource Sustainability for Fish Farming at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia



**Figure 6** Graphic of Benefit and Cost Extended Value of Void Water for Fish Farming at Tutupan, Wara, and Paringin Block, PT. Adaro Indonesia

Interest rate used in each calculation of water resource sustainability benefit and cost extended net present value of mining void utilization is 7% and inflation rate of 8%.

**4. DISCUSSION**

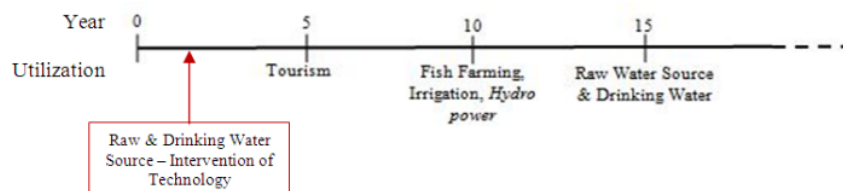
Tutupan void has the most beneficial environmental service cost because of its large mining area where it is the biggest site in PT Adaro Indonesia coal mining. Mining void water volume for each existing void in PT Adaro Indonesia can be seen on the Table 4 below.

**Table 4** Total Volume of Mining Void Water at PT Adaro Indonesia

| Area     | Void         | Min. Elevation | Max. Elevation | Total Volume (m <sup>3</sup> ) |
|----------|--------------|----------------|----------------|--------------------------------|
| Tutupan  | Hill 11      | -20            | 119            | 40.615.641                     |
|          | T300         | 33             | 103            | 3.802.868                      |
| Wara     | Pit Slovenia | 55             | 90             | 1.861.220                      |
| Paringin | Ex-Pit PRG   | 30             | 87             | 5.434.305                      |

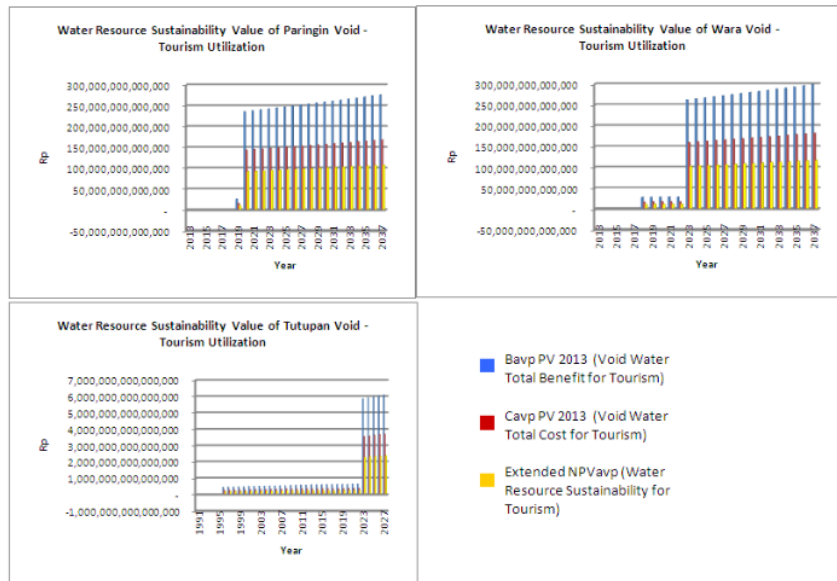
pH level is the water quality key factor that allows its utilization. Reclamation action, including mining void water utilization, should be based on an increase in the pH and decrease the salinity (Martinez-Pagan, *et al.*, 2011). Water utilization suggested based on social study are drinking water, fish farming, and land farming irrigation. Based on void years and natural pH stabilisation possibility, environmental service of mining void water according to time span of utilization from 5 year to 15 year after water filling sequentially are (1) tourism (2) fish farming (3) irrigation (4) hydropower and (5) drinking water source. The utilization as fish farming is a typical functions of ecological and socio-economical factor as in Central German lignite mining district (Schultze *et al.*, 2009) while the major use of the pit lake (mining void) is for recreational purposes or tourism (Linke & Schiffer (2002) in Schultze *et al.*, (2009)).

Calculating environmental benefit and cost of mining void water utilization reckon in that void formation in mining means groundwater depletion (relatively small amount) in mining area; run-off water will then fill mining void formed with relatively greater volume of water than groundwater depletion occurred. Furthermore, mining void water formed has the possibility to be utilized directly despite acid condition with intervention of technology, as in this study at PT Adaro Indonesia.



**Figure 7** Mining Void Utilization According to Time

Mining void water is a subsided water in mining in which the water qualities are different with different time of subsidence, situation, and utilization (Liang-Ji *et al.*, 2007). The figure above shows that with natural attenuation, mining void can be utilized in the fifth year of its presence for tourism with an average extended net present value for three mining void area of Rp 7.036.802.170.523.070 ( $\pm$  USD 586, 400, 000, 000). Figure below shows the increasing benefit cost of mining void utilization for tourism based on calculation result of total benefit, total cost, and extended net present value of void for each void block.



**Figure 8** Graphic of Total Benefit, Total Cost, and Extended NPV of Void Utilization for Tourism for Each Void Block at PT Adaro Indonesia

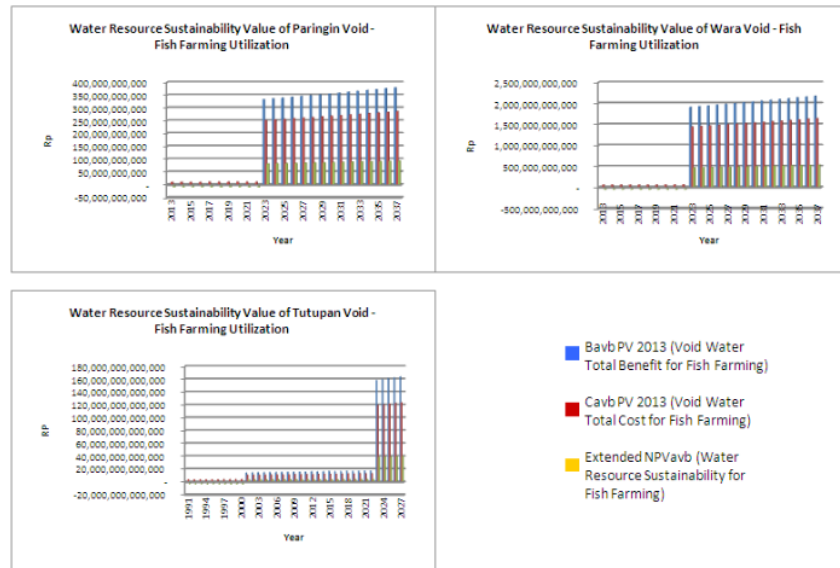
Utilization of mining void on tourism sector resulted the biggest extended net present value with B/C value is the smallest. This is because tourism can be done in the fifth year of mining void age, therefore it has the longest time of utilization hence resulted in great value of extended net present value. Tourism sector has small B/C value because the benefit from utilizing mining void as tourism is obtained based on the value of visits and activities. Benefit and cost of tourism management is calculated with transfer benefit of Lake Toba tourism management benefit and cost year 2011, with benefit value of Rp 2.058.696, - and cost value of Rp 1.253.880, -. Figure below show existing voids in PT Adaro Indonesia which indicates its high potential in

tourism sector such as water sport center, recreation center, and floating restaurant or lake-view restaurant.



**Figure 9** Existing Void in PT. Adaro Indonesia (Clockwise from Top-left: Hill 11 (Tutupan), T300 (Tutupan), Pit Slovenia (Wara), Ex-Pit PRG (Paringin))

In the tenth year of its presence, mining void water can be utilized as freshwater fish farming area with an average extended net present value for three mining void area of Rp 83.643.491.328.027 ( $\pm$  USD 6, 970, 290, 944). The tilapia fish is assumed on the calculation based on field survey that suggested tilapia fish is the most beneficial economic value in limited area, with selling price and fish farming management cost used are Rp 22.000, - and Rp 16.613, - respectively. Figure below shows the increasing benefit cost of mining void utilization for fish farming based on calculation result of total benefit, total cost, and extended net present value of void for each void block.

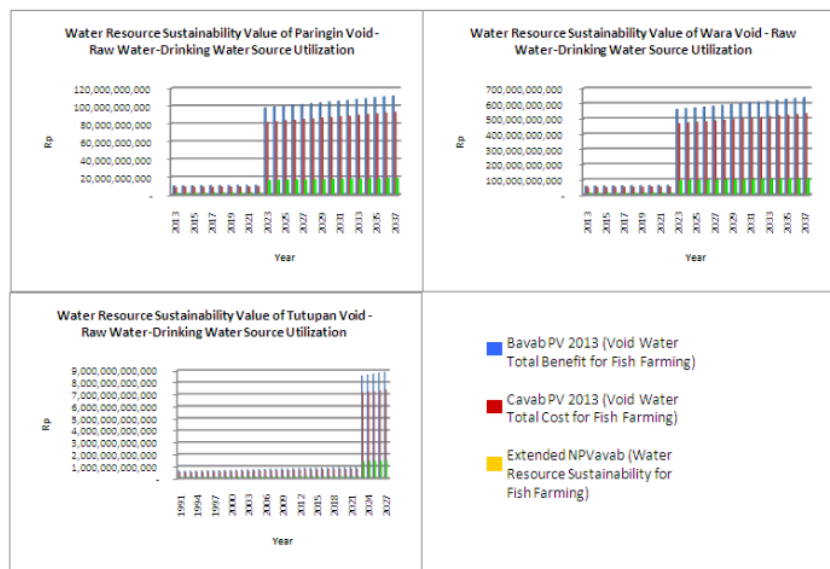


**Figure 10** Graphic of Total Benefit, Total Cost, and Extended NPV of Void Utilization for Fish Farming for Each Void Block at PT Adaro Indonesia

Beside freshwater fish farming, mining void water can also be utilized as irrigation water for plantations such as rubber that is the largest plantation existed in South Borneo beside palm oil. The use of mining void water as irrigation water will take use of great volume of water. Hence, the run off of water in mining area is an important issue for filling the mining void and stabilise the water balance for the sustainability of mining void utilization as an attempt of sustaining water resource in coal mining for the sustainability of the coal mining itself.

Mining void as water reservoir has the potential to be utilized as micro-hydro power plant. According to intense rainfall on rainy season and minimum run-off debit on Tutupan Area reaching 276, 36 m<sup>3</sup>/sec, mining void water can be used as hydropower. In South Borneo, there are more than 9 micro-hydro power plant alongside Hulu Sungai Utara and Hulu Sungai Selatan. The main problem of micro-hydro power plant in South Borneo is the insufficient debit and water volume to generate power. Since mining void water tend to have stable debit because of its reservoir-characteristic, micro-hydro power plant built utilizing mining void water will have longer time and more effective power generation. With total volume of Void Hill 11 at Tutupan of 40.615.641 m<sup>3</sup> on its maximum elevation, the run-off debit will maintain the volume of mining void in normal rainy weather within one week.

Mining void water can be utilized as raw water source for household needs and drinking water in the 15th year of its presence with an average extended net present value for three mining void area of Rp 4.438.400.888.338 ( $\pm$  USD 369, 866, 740). The utilization as raw water source and drinking water resulted the least benefit because it has great cost on the water treatment plant. However, benefit from mining void water utilization as raw water and drinking water source can be obtained from the first year of mining void presence because of technology intervention that is water treatment plant. The price of raw water and water treatment by PAM Kabupaten Tabalong used in calculation are Rp 3.000, - and Rp 2.500, - respectively. Figure below shows the increasing benefit cost of mining void utilization for raw water source based on calculation result of total benefit, total cost, and extended net present value of void for each void block.



**Figure 11** Graphic of Total Benefit, Total Cost, and Extended NPV of Void Utilization for Raw Water-Drinking Water Source for Each Void Block at PT Adaro Indonesia

Mining wastewater in PT Adaro Indonesia is treated using series of settling pond, and the water quality of treated wastewater complied with Environment Minister Decree No. 113 Year 2003. Whereas surface water quality is complied with national water quality standard, Presidential Decree No. 82 Year 2001.





**Figure 12** Direct Utilization of Mining Void Water as Drinking Water with Intervention of Technology

## 5. CONCLUSION

Based on social study in coal mining site and surroundings, mining void water utilization suggested are drinking water, fish farming, and land farming irrigation. According to void years and natural pH stabilisation possibility, environmental service of mining void water in accordance with time span of utilization from 5 year to 15 year after water filling sequentially are (1) tourism (2) fish farming (3) irrigation (4) hydropower and (5) drinking water source. However, the use of technology allows mining void water to be utilized as drinking water – raw water source in the first year of mining void presence. This study shows that mining void has beneficial value with calculations on void water environmental service as tourism, drinking-raw water source, and fish farming in PT. Adaro Indonesia shows Extended NPV of Rp 7.124.884.062.739.430 ( $\pm$  USD 593, 740, 338, 561.62) and B/C ratio of 8, 25. Extended NPV resulted greater than 0 (extended NPV > 0), which means water resource in coal mining, in this study is PT Adaro Indonesia coal mining, is sustainable. The model of water resource sustainability found is

$$\text{Extended NPV}_{av} = \sum_{t=0}^n \frac{(B_d + B_{id})}{(1+r)^t} - \sum_{t=0}^n \frac{(C_d + C_{id})}{(1+r)^t} = \sum_{t=0}^n \frac{(B_{av} - C_{av})}{(1+r)^t}$$

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