Clean Water Network Planning in Ba’engas Village, Labang Sub-District, Bangkalan Regency, Indonesia

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Abstract. Access to clean water supply systems have not been fully available to all people, especially those living in rural areas. Ba’engas Village, located in Labang Sub-District, Bangkalan Regency, has not possessed clean water facilities to fulfil its people’s needs. The elevation difference and the distance of about 9 km between water resources causing difficulties in water provision. This research discusses clean water network planning in Ba’engas Village by utilizing the Pocong River, at a rate of 3,236 l/sec. The objective of this research is to investigate the provision of water availability for consumption up to the year 2035, simulate clean water networks and find out its results, and calculate planned budget. The modelling and simulation of clean water networks are developed utilizing WaterCAD V.8.i software. This research employs three alternatives, with different numbers of pumps and tanks each. The result of clean water projection is a rate of 4,936 l/sec. Based on the simulation results, alternative 1 was chosen, using 1 pump and 1 tank, according to the permitted planning criteria of speed between 0.1–2.5 m/sec, head loss gradient from 0 to 15 m/km, and pressure from 0.5 to 8 atm. The cost for clean water network planning with alternative 1 is estimated IDR 8,021,618,000.

1. Introduction
Water becomes one of the primary needs for survival. As such, the provision of clean water plays a very important role to improve their quality of living. Based on data obtained from the Regional Drinking Water Company (PDAM, Perusahaan Daerah Air Minum) of Bangkalan Regency, many villages have not yet obtained clean water services, particularly those located in inland or peripheral areas. One of the efforts taken to resolve this issue is by creating a good plan for clean water networks, making use of distribution system of pipe networks.

Ba’engas Village is one of the villages located in Labang Sub-District, Bangkalan Regency. This village suffers from the lack of clean water facilities, resolving by utilizing Pocong River, with discharge level of 3.236 l/sec. Distant location of the water source as well as difference in elevation with low-lying residential areas complicate water provision. Thus, this study discusses an effective planning for clean water networks to solve the problems at the study location, by considering the utilization of pumps and tanks. Pumps are utilized to increase water pressure and elevate water from a low elevation region to a higher elevation area; meanwhile, tanks function to store water for distribution to the service area or residential locations.
The aim of this study is to investigate clean water provision for the residents of Ba’engas village up to the year 2035, simulate clean water network planning for the study location, and to calculate the size of the Planned Budget (RAB, Rencana Anggaran Biaya) for building clean water networks in Ba’engas Village in Labang Sub-District, Bangkalan Regency.

This study will benefit in providing inputs or information to the Regional Drinking Water Company of Bangkalan Regency to improve services and the provision of clean water, developing planning of clean water networks for residents of Ba’engas Village in Labang Sub-District of Bangkalan Regency, and adding further insights to the field of clean water network planning.

2. Materials and Methods

The location of the study area, Ba’engas Village in Labang Sub-District, Bangkalan Regency, is depicted in Figure3. The village is located in the southern part of Bangkalan Regency at elevations ranging from 20 to 50 m above sea level and geographically positioned between 112° and 113° BT and between 6° and 7° LS, bordered by these administrative regions of:

- North : Bringin Village
- South : West Sukolilo Village
- East : Bunajih Village
- West : Morkepek Village

The required supporting analytic data for the pipe network system in this planning study cover:
- Data of water availability, utilizing the discharge flow of Pocong River;
- Data of population, comprising the number of residents of Ba’engas Village spreading out among 6 hamlets; and
- Data of topography, consisting of the elevation data for water sources, locations of pump, placement of the tank bases, and the targeted areas or regions served.

The steps involved in the data processing for the completion of this planning study are as follows:
- Collecting primary and secondary data consisting of technical and other supporting data used in the analysis of clean water network systems
- Processing the population and amount of service data
- Calculating clean water needs
- Establishing the planned networks at service up to the year 2035
- Calculating the Planned Budget for building the plans

2.1. Major Losses

Fluid flowing into the pipe will experience shear stress and the velocity gradient across the field due to the kinematic viscosity. The shear stress will cause power loss during drainage (Triatmodjo II, 1993: 25). Shear stress occurs at the pipe wall becomes the main cause of energy loss in a flow line (major losses); in addition, this stress depends on the type of pipe. High loss equation by major press Hazen – Williams (Webber 1971:121) is as follows:

\[ H_f = \frac{k}{Q^{1.85}} \]  \hspace{1cm} (1)

\[ k = \frac{10,675 \cdot L}{C_{bw}^{1.85} \cdot D^{4.87}} \]  \hspace{1cm} (2)

with:

- \( H_f \) = height major loss press (m)
- \( k \) = coefficient of pipe characteristics
Q = flow in pipe (m³/sec)
D = diameter of pipe (m)
L = length of pipe (m)
Chw = Hazen - Williams roughness coefficient

**Table 1. Coefficient Characteristics of Pipe According to Hazen – Williams**

| Nilai Chw | Type of Pipes                        |
|-----------|-------------------------------------|
| 140       | extremely smooth pipe               |
| 130       | smooth pipes, cement, cast iron new |
| 120       | new welded steel pipe               |
| 110       | new riveted steel pipe              |
| 100       | old cast iron pipes                |
| 95        | old riveted steel pipe              |
| 60-80     | the old pipe                        |

Sources: Triatmodjo II, 1993: 51

2.2. Minor Losses

Various contributors of minor losses include: sudden narrowing or widening of pipes, bends, joints, and the presence of valves in pipes.

If a pipeline consists of pipes of different sizes connected to the same diameter, the pipe is in a series relationship, leading to several high losses (Priyantoro, 1991: 49)

![Figure 1. Series Pipe Line: Dake (1958 : 78)](image)

Equation of series pipe continuity:
Q = Q1 = Q2 with:
Q = total discharge on installed pipeline (m³/sec)
Q1, Q2 = discharge in pipes 1 and 2 (m³/sec)
Total pressure loss in pipes installed in series (Triatmodjo, 1996: 74):
H = hl1 + hl2
with:
H = total loss of press on the pipe installed in series (m)
hl1, hl2 = loss of pressure per pipe (m)

2.3. Criteria for Clean Water Pipes

Plumbing network planning must meet certain criteria in accordance with the existing standards. The criteria for pipelines are presented in the following table:

**Table 2. Criteria of Pipelines**

| Criteria | Alteration |
|----------|------------|
|          |            |
| Criteria                      | Alteration                                                                 |
|-------------------------------|-----------------------------------------------------------------------------|
| 1. Velocity                   | - Speed less than 0.3 m/sec                                                 |
| (0.1 - 2.5 m/sec)             | a. Reduced pipe diameter                                                   |
|                               | b. Added pump                                                               |
|                               | c. Higher upstream pipe elevation (adjusted in the field)                   |
|                               | - Speed of more than 4.5 m/sec                                              |
|                               | a. Enlarged diameter                                                        |
|                               | b. Higher elevation in the upstream pipe compared to the downstream pipe    |
| 2. Headloss Gradient          | - Head loss Gradient of more than 15 m / km                                |
| (0 – 15 m/km)                 | a. Enlarged pipe diameter                                                   |
|                               | b. Larger upstream pipe elevation compared to the downstream pipe           |
| 3. Pressure                   | - Pressure of less than 0.5 atm                                             |
| (0.5 – 8 atm)                 | a. Enlarged diameter of the pipe is enlarged                                |
|                               | b. Added pump                                                               |
|                               | c. Installed second pipe at the top, part or all of the length of the pipe  |
|                               | - Pressure of more than 8 atm                                               |
|                               | a. Reduced pipe diameter                                                    |
|                               | b. Established press release building                                       |
|                               | - Pressure Reducer Valve (PRV) Installation                                |

Source: Minister of Public Works Regulation on the Implementation of SPAM Development, 2007

2.4. Budget plan (RAB)

RAB is an estimated cost before the building or project is carried out. The basic calculation of the RAB is principally obtained from the sum of all volumes from each type of work which is available at each unit price.

3. Results and Discussion

The projection of the population growth of Ba’engas Village was calculated using three methods of projection, Arithmetic Method, Geometric Method, and Exponential Method. The projection of the population in this study was conducted up to 20 years in the future.

![Figure 2. Administrative Map of Bangkalan Regency](image)

The planning for the next 20 years was adjusted in accordance to the SPAM (Sistem Penyediaan Air Minum, Drinking Water Supply System) planning criteria. According to the composition of primary plans for SPAM development, there is a criterion stipulating between 15-20 years in the planning horizon portion. To determine which method should be best employed to project the size of the population from the three methods of projection above, the appropriateness was tested using...
statistical testing using standard deviations and correlation coefficients. From the results of the conducted appropriateness testing for the projection methods, arithmetic method was selected as the projection method measuring the population growth. Arithmetic method was selected because it has the smallest standard deviation values. Meanwhile, the resulting correlation coefficient values were nearly equal; and thus, the selection only used the standard deviation appropriateness testing. The calculation results for the three methods of projection as well as the test of appropriateness for the standard deviations are presented in Table 3.

Table 3. Results of Standard Deviations

| Method    | Hamlet         |          |          |
|-----------|----------------|----------|----------|
|           | Sogah          | T. Agung | Ba'engas |
| Arithmetic| 47,532          | 117,103  | 69,6028  |
| Geometric | 55,486          | 135,853  | 80,6434  |
| Exponential| 55,997        | 137,047  | 81,3453  |

| Method    | Hamlet         |          |          |
|-----------|----------------|----------|----------|
|           | Tengginah      | Kolpoh   | Pangloros|
| Arithmetic| 50,661          | 82,482   | 34,947   |
| Geometric | 58,648          | 97,439   | 41,214   |
| Exponential| 59,155        | 98,416   | 41,623   |

Source: Calculation Results

After calculating the projections for the population, the projection of average water needs for the people of Ba’engas Village was afterwards calculated, with the assumption of water needs of 60 liters/person/day (SPAM, 2007, p.59).

The results of calculated projections for the average clean water needs of Ba’engas Village residents in 2035 are presented in Table 4. The table informs the total average clean water needs for Ba’engas Village population in 2035 will be 4.936 l/sec. This total average clean water needs used in the planning is modeled and simulated using the WaterCAD V.8.i software. The modeling and simulation for the planning of clean water networks used three alternative plans.

Alternative 1 utilizes 1 pump and 1 tank; alternative 2 utilizes 2 pumps and 2 tanks; and alternative 3 utilizes 3 pumps and 2 tanks.

Table 4. Projection of Clean Water Needs

| No | Hamlet | Unit | Year |
|----|--------|------|------|
| 1  | Sogah  | kl/s | 0.580|
| 2  | T. Agung| kl/s | 1.473|
| 3  | Ba'engas| kl/s | 0.881|
| 4  | Tengginah| kl/s | 0.644|
| 5  | Kolpoh | kl/s | 0.952|
| 6  | Pangloros| kl/s | 0.407|
|    | Total   |      | 4.936|

Source: Calculation Results

For this modeling and simulation of clean water networks, alternative 1 was opted because the simulation results for this alternative satisfied the permitted planning criteria for the planned networks comprising speed, head loss gradient, and pressure. The planning criteria for the planned pipe networks refer to the Regulation of the Public Works Minister PU on SPAM development, which
states that the criteria for the parameter of speed is between 0.1 to 2.5 m/sec, the parameter of head loss gradient is from 0 to 15 m/km, and the parameter of pressure is from 0.5 to 8 atm (SPAM, 2007, p.55).

In the modeling and simulation, the pump components used in the planning with alternative 1 are rotodynamic pumps of the centrifugal type with the pump catalog number of 65 x 50 B2 – 5 3.7 (Sularso & Tahara, 2000:p.53). The calculation of pump selection specification was adjusted with the calculation of rotodynamic pumps of the centrifugal type specifications as well as with pump selection flowchart. The scheme of clean water network planning with alternative 1 is illustrated in Figure 4. The pump is simulated for 24 hours with a discharge capacity of 7 l/sec and a pump head of size 24.79 m. The time operating pattern is arranged so that the pumps are turned off and on automatically or by leveling.

![Figure 3. Scheme of Clean Water Network](image)

The modeling and simulation of the tank components were conducted within a period of 24 hours with the tanks designed to never be in an empty or full state (leveling). From the simulation of the tanks, the resulting tank dimension was found to store water volume of 36,000 liters. The design of the tanks for this clean water network planning stipulates tanks with dimensions of 4 m in length, 3 m in width, and 3 m in height.

The results of modeling and simulation with pipes of HDPE material are presented in Table 5. The following results offer pipe simulation at 8 AM, as the peak hour of water usage.

| Pipe No. | Diameter (inch) | Speed (m/s) | Head loss Gradient (m/km) |
|----------|----------------|-------------|--------------------------|
| P-1      | 8              | 0.23        | 0.30                     |
| P-2      | 8              | 0.23        | 0.30                     |
| P-3      | 8              | 0.23        | 0.30                     |
| P-4      | 8              | 0.23        | 0.30                     |
| P-5      | 8              | 0.23        | 0.30                     |
| P-6      | 6              | 0.32        | 0.81                     |

Table 5. Results of Pipe Simulation at 8 AM
### Table 1: Pipe Information

| Pipe No. | Diameter (inch) | Speed (m/s) | Head loss Gradient (m/km) | Pipe No. | Diameter (inch) | Speed (m/s) | Head loss Gradient (m/km) |
|----------|----------------|-------------|---------------------------|----------|----------------|-------------|---------------------------|
| P-7      | 8              | 0.23        | 0.30                      | P-23     | 6              | 0.21        | 0.35                      |
| P-8      | 8              | 0.23        | 0.30                      | P-24     | 4              | 0.39        | 1.80                      |
| P-9      | 8              | 0.23        | 0.30                      | P-25     | 4              | 0.27        | 0.91                      |
| P-10     | 8              | 0.23        | 0.30                      | P-26     | 3              | 0.29        | 1.44                      |
| P-11     | 8              | 0.23        | 0.30                      | P-27     | 3              | 0.19        | 0.67                      |
| P-12     | 8              | 0.23        | 0.30                      | P-28     | 3              | 0.31        | 1.67                      |
| P-13     | 8              | 0.23        | 0.30                      | P-29     | 3              | 0.13        | 0.34                      |
| P-14     | 8              | 0.23        | 0.30                      | P-30     | 3              | 0.21        | 0.81                      |
| P-15     | 8              | 0.23        | 0.30                      | P-31     | 3              | 0.48        | 3.74                      |
| P-16     | 8              | 0.23        | 0.30                      |          |                |             |                           |

Source: Calculation Results

As informed by the previous table, the speed and head loss gradient have met the permitted planning criteria, the speed parameter ranging from 0.1 to 2.5 m/sec and the parameter of head loss gradient ranging from 0 to 5 m/km.

From the results of modeling and simulation of junction points, it was found that the pressure value meets the permitted criteria for pipe network planning, ranging from 0.5 to 8 atm. The results of simulated junction points are presented in Table 6.

#### Table 6. Results of Junction Simulation at 8 AM

| Label | Demand (L/s) | Pressure (atm) | Notes | Label | Demand (L/s) | Pressure (atm) | Notes |
|-------|--------------|----------------|-------|-------|--------------|----------------|-------|
| J-1   | 0            | 2.28           | Satisfactory | J-16  | 0            | 0.96           | Satisfactory |
| J-2   | 0            | 2.25           | Satisfactory | J-17  | 0            | 0.81           | Satisfactory |
| J-3   | 0            | 2.22           | Satisfactory | J-18  | 0            | 0.65           | Satisfactory |
| J-4   | 0            | 2.19           | Satisfactory | J-19  | 0            | 0.67           | Satisfactory |
| J-5   | 0            | 2.16           | Satisfactory | J-20  | 0            | 0.76           | Satisfactory |
| J-6   | 0            | 2.13           | Satisfactory | J-21  | 0            | 0.94           | Satisfactory |
| J-7   | 0            | 2.10           | Satisfactory | J-22  | 0            | 1.12           | Satisfactory |
| J-8   | 0            | 2.07           | Satisfactory | J-23  | 0            | 0.86           | Satisfactory |
| J-9   | 0            | 2.04           | Satisfactory | J-24  | 0            | 1.31           | Satisfactory |
| J-10  | 0            | 2.01           | Satisfactory | J-25  | 0.86         | 1.02           | Satisfactory |
| J-11  | 0            | 1.98           | Satisfactory | J-26  | 1.41         | 0.69           | Satisfactory |
| J-12  | 0            | 1.95           | Satisfactory | J-27  | 0.60         | 1.03           | Satisfactory |
| J-13  | 0            | 1.93           | Satisfactory | J-28  | 0.96         | 1.31           | Satisfactory |
| J-14  | 0            | 1.59           | Satisfactory | J-29  | 2.19         | 1.02           | Satisfactory |
| J-15  | 0            | 1.27           | Satisfactory |       |              |                |       |

Source: Calculation Results

The calculation of the Planned Budget refers to the Analysis of Labor Unit Costs of the Department of Public Works and Public Housing and Development in 2016 and the list of standard units for building materials, equipment, and labor costs for Bangkalan Regency in 2017. The formula used to calculate the Planned Budget consists of multiplying the work volume by the price of the work unit.
In calculating the construction budget, there are three differentiated kinds of analysis for the materials, labor, and work unit price (Ibrahim, 1993, p.138). The recapitulated results of the calculated Planned Budget are presented in Table 7.

Table 7. Planned Budget

| Description     | Price for Alternative 1 (IDR) |
|-----------------|------------------------------|
| Pipe Work       | 6,982,466,700.44             |
| Pump Work       | 141,385,417.17               |
| Tank Work       | 168,527,672.84               |
| Total           | 7,292,379,790.45             |
| Tax             | 729,237,979.04               |
| Total + Tax     | 8,021,617,769.49             |
| Rounding        | 8,021,618,000.00             |

Source: Calculation Results

4. Conclusion

Based on the results of the analysis carried out in this planning study, the conclusions of the study are as follows:
1. The projected average clean water needs for Ba’engas Village in Labang Sub-District, Bangkalan Regency in 2035 is 4.936 l/sec.
2. The results of modeling and simulation of the clean water network planning with alternative 1 show that the parameters of speed, head loss gradient, and pressure meet the standard planning criteria.
3. The Planned Budget needed for the development of clean water networks in Ba’engas Village in Labang Sub-District, Bangkalan Regency is IDR 8,021,618,000.00.

The suggestions based on the discussed results of this planning study are as follows:
1. The local government of Ba’engas Village in Labang Sub-District, Bangkalan Regency is encouraged to realize the proposed plans for clean water networks by establishing facilities to provide clean water which sufficiently meets the needs of its residents.
2. The local communities is encouraged to cooperate in developing, maintaining, and operating clean water networks in order to supply and meet their clean water needs on daily basis improving the quality of living.

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