INTRODUCTION

West Papua Province is a new province with a relatively low economic level due to inadequate road access. Many areas are isolated, which hampers the distribution of goods and services. One isolated area is the Kaimana Regency with Fakfak Regency. Therefore, to open regional isolation and improve the local community's economy, it is necessary to plan a road in the Inari – Bofuwer segment as an infrastructure that can connect the two areas.

Road planning consists of geometric road planning based on Tata Cara Perencanaan Geometrik Jalan Antar Kota No. 38 Tahun 1997, road pavement thickness planning using the 2017 Bina Marga method, and road drainage planning based on Perencanaan Sistem Drainase Jalan Tahun 2006.

The geometric design of the road for horizontal alignment obtained 13 Spiral-Circle-Spiral bends and 5 Spiral-Spiral bends. In contrast, the vertical alignment consists of 13 concave curves and 13 convex curves. The road pavement uses Burda or Burtu with a thickness of LPA Class A 250 mm, LPA Class B 110 mm, and a soil stabilization layer 150 mm. The planned road drainage channel is in the form of a trapezoid with a width of 0.4 – 0.6 meters and a height of 0.85 – 1.15 meters.

**Keywords:** 2017 bina marga, perencanaan sistem drainase jalan tahun 2006, road planning, tata cara perencanaan geometrik jalan antar kota no. 38 tahun 1997, west papua province.

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**Abstract**

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**Keywords:** 2017 bina marga, perencanaan sistem drainase jalan tahun 2006, road planning, tata cara perencanaan geometrik jalan antar kota no. 38 tahun 1997, west papua province.
This research identifies the existing problem, namely the absence of infrastructure that can connect Kaimana Regency with Fakfak Regency, so it is necessary to plan a road to open regional isolation and increase community economic growth.

Furthermore, a literature study is carried out, which is the stage of collecting references, both from books, regulations, or guidelines, and research that has been done previously.

The next step is to collect the data needed in this study, namely topographic maps, data LHR, data CBR, and data rainfall which is secondary data.

After obtaining all the required data, then data analysis is carried out for road planning in the Inari – Bofuwer segment, which is divided into the following sub-chapters:

A. Road Planning

1. Road Classification by Function

There are four groups of roads according to their function as follows [5]:

a. Arterial Road

Public roads that serve the main transportation with high average speed, long-distance travel, and access roads are limited.

b. Collector Road

Public roads that serve the collectors’ transportation with moderate average speed, medium-distance travel, and entrances are limited.

c. Local Road

Public roads that serve the local transportation with a low average speed, short distance travel, and access roads are not limited.

d. Environmental Road

Public roads that serve the environmental transportation with a low average speed and short distance travel.

2. Road Classification by Road Class

Table 1 road class classification

| Function   | Class | Heaviest Axle Load |
|------------|-------|--------------------|
| Arterial   | I     | > 10               |
|            | II    | 10                 |
|            | III A | 8                  |
| Collector  | III A | 8                  |
|            | III B | 8                  |
| Local      | III C | 8                  |

3. Road Classification According to Road Terrain

Table 2 road terrain classification

| Terrain Type | Notation | Terrain Slope (%) |
|--------------|----------|-------------------|
| Plain        | D        | < 3               |
| Rolling      | B        | 3 – 25            |
| Mountainous  | G        | > 25              |

4. Cross Section

a. Traffic Lane

The width of the lane and road shoulder according to the VLHR is shown in Table 3 below.

Table 3 lane width and road shoulder

| Lane         | Shoulder Width Width (m) | Shoulder Width Width (m) | Shoulder Width Width (m) | Shoulder Width Width (m) |
|--------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Arterial     | I                         | 1.5                      | 1.5                      | 1.5                      |
| Collector    | III A, III B             | 2                        | 2                        | 2                        |
| Local        | III C                    | 2.5                      | 2.5                      | 2.5                      |

5. Sight Distance

Sight distance is the distance required by the driver while driving to know the surrounding conditions, and if there is a hazard, it can be avoided [6], [7]. There are two groups of sight distance, namely:

a. Stopping Sight Distance

$$d_s = \frac{0.278 \times V_R \times T}{\sqrt{f \times L}}$$

Information:

- \(V_R\) = design speed (km/hour)
- \(T\) = response time, 2.5 seconds
- \(f\) = coefficient of friction along the pavement
- length asphalt, 0.35 – 0.55
- \(L\) = ramp (%)  

b. Overtaking Sight Distance

$$d_o = d_1 + d_2 + \frac{d_3}{2} + d_4$$

Information:

- \(d_1\) = distance traveled during response time (m)
- \(d_2\) = distance covered during overtaking until back to the original lane (m)
d_3 = distance between the vehicle that precedes with vehicles coming from the direction of opposite after the preceding process is complete (m)
d_4 = distance traveled by the vehicle coming from the opposite direction (m)
T_1 = time, 2.12 + 0.026 V_R (seconds)
T_2 = time the vehicle is in the opponent's lane, 6.56 + 0.048 V_R (seconds)
a = average acceleration, 2.052 + 0.0036 V_R (km/hour/second)
m = speed difference of the design vehicle the one that precedes and the vehicle that preceded, 10 – 15 km/hour

Table 5 value of d_i

| V_R (km/hour) | d_i (m) |
|---------------|---------|
| 50 – 65       | 30      |
| 65 – 80       | 55      |
| 80 – 95       | 75      |
| 95 – 110      | 90      |

Source: Direktorat Jenderal Bina Marga (1997)

B. Road Geometric Planning

1. Planning Parameters

a. Design Vehicle

Table 6 design vehicle size

| Design Vehicle Category | Height | Width | Length | Front | Back | Ls | Minimum | Maximum | Bulge Radius (cm) |
|-------------------------|--------|-------|--------|-------|------|----|---------|---------|------------------|
| Small Vehicle           | 30     | 130   | 210    | 580   | 90   | 420| 730     | 1410    |                  |
| Medium Vehicle          | 410    | 260   | 1210   | 400   | 150  | 740| 1280    | 1410    |                  |
| Big Vehicle             | 410    | 200   | 200    | 1320  | 90   | 740| 1410    | 1410    |                  |

Source: Direktorat Jenderal Bina Marga (1997)

b. Design Speed

Table 7 design speed classification

| Function   | Design Speed (km/hour) |
|------------|------------------------|
|            | Plain | Rolling | Mountainous |
| Arterial   | 70 – 120 | 60 – 80 | 40 – 70 |
| Collector  | 60 – 90 | 50 – 60 | 30 – 50 |
| Local      | 40 – 70 | 30 – 50 | 20 – 30 |

Source: Direktorat Jenderal Bina Marga (1997)

2. Horizontal Alignment

Horizontal alignment, also known as road alignment, is a projection of the road axis on a horizontal plane consisting of straight lines connected by curved lines [6]. Several components must be considered in planning a horizontal alignment, namely:

a. Bend

The superelevation and the centrifugal force are determined as follows:

i. Out of town roads:
   \[ e_{\text{max}} = 10\% \text{, } V_R > 30 \text{ km/hour} \]
   \[ 8\% \text{, } V_R = 30 \text{ km/hour} \]

ii. City roads: \( e_{\text{max}} = 6\% \)

iii. Centrifugal force \( f \) = 0.14 – 0.24 for asphalt

The magnitude of the superelevation and the centrifugal force affect the horizontal bending radius, which can be obtained using the following equation.

\[ R_{\text{min}} = \frac{V^2}{3.6 \times e_{\text{max}}} \] (6)

The transition arc length (L_s) is used as the largest of the three following values.

i. Maximum travel time on the transition curve
   \[ L_s = \frac{T^2}{1.6} \] (7)

ii. Anticipating centrifugal force
   \[ L_s = \left( \frac{0.622 \times \frac{V^2}{9.8}}{T^2} \right) - \left( \frac{2.727 \times \frac{V^2}{9.8 \times e_{\text{max}}}}{T^2} \right) \] (8)

iii. Level of attainment of slope change
   \[ L_s = \left( \frac{e_{\text{max}} - e_c}{T} \right) V_R \] (9)

Information:

\( T = \) travel time on the transition curve, 3 seconds
\( V_R = \) design speed (km/hour)
\( e = \) superelevation
\( C = \) change in acceleration, 1 – 3 m/s^3
\( R = \) radius of bend (m)
\( e_{\text{max}} = \) maximum superelevation
\( e_c = \) normal superelevation, 2 – 4%
\( r_c = \) level of achievement of slope change across the road

\[ r_{\text{max}} = 0.035 \text{ m/m/sec, } \text{V}_R < 70 \text{ km/hour} \]
\[ r_{\text{max}} = 0.025 \text{ m/m/sec, } \text{V}_R > 80 \text{ km/hour} \]

b. Horizontal Curved Shape

The planning of the horizontal curved shape is carried out according to the flow chart shown in Figure 2 below.

Figure 2 Flowchart of the selection of horizontal curved shapes according to Bina Marga 1997.

(Source: Sulistiono, Djoko)

The equations used in planning the horizontal curved shape are as follows.
\[ L = \frac{4 \times V^2}{320} \]  
\[ \text{Terms } J > L \]  
Stopping sight distance:  
\[ L = \frac{2h}{V^2} - \frac{906}{A} \]  
Overtaking sight distance:  
\[ L = \frac{2h}{V^2} - \frac{906}{A} \]  
ii. The flexibility of the road  
\[ L = 0.6V \]  
\[ \text{C. Road Pavement Thickness Planning} \]  
\[ \text{1. Design Life} \]  
Table 8 new pavement design life  
| Type of Pavement | Pavement Elements | Design Life (years) |
|------------------|-------------------|---------------------|
| Flexible Pavement | Asphalt layer and granular layer | 20 |
|                  | Road foundation   |                     |
|                  | All pavements for areas where a coating is not possible (overlay) | |
|                  | Cement treated base (CTB) | |
| Rigid Pavement | Base course, sub-base course, surface course, and road foundation | 40 |
| Road without Cover | All elements (include road foundation) | Minimum 10 |

\[ R = \left(1 + \frac{0.01i}{t}\right)^{0.45} \]  
\[ \text{Traffic growth over the design life is obtained by the cumulative} \]  
\[ \text{growth factor using the equation.} \]  
\[ \text{Information:} \]  
\[ R \]  
\[ \text{traffic growth multiplier} \]  
\[ i \]  
\[ \text{annual traffic growth rate} \]  
\[ \text{UR} \]  
\[ \text{plan life} \]  
(\text{years})  

\[ \text{b. Traffic on Design Lane} \]  
On two-way roads, the directional distribution factor (DD) value is taken as 0.50, while the value of the lane distribution factor (DL) is shown in Table 10 below.  

\[ \text{c. Load Equivalent Factor} \]  
Traffic loads must be converted to standard loads using the VDF values shown in Table 11 below.  

\[ \text{Table 9 traffic growth rate factor (i) %} \]  
| Jawa | Sumatra | Kalimantan | Indonesian Average |
|------|---------|------------|-------------------|
| Arterial and Urban | 4.8 | 4.83 | 5.14 | 4.75 |
| Collector and Rural | 3.5 | 3.5 | 3.5 | 3.5 |

\[ \text{Source: Direktorat Jenderal Bina Marga (2017)} \]  

\[ \text{Table 10 lane distribution factor (DL)} \]  
\[ \text{Source: Direktorat Jenderal Bina Marga (2017)} \]  

\[ \text{Table 11 VDF value by the type of vehicle} \]  
\[ \text{Source: Direktorat Jenderal Bina Marga (2017)} \]
3. Pavement Structure

The pavement structure design has been determined by various design charts, as shown in Table 12.

Table 12 type of pavement

| Pavement Structure                          | Design Chart | ESA (million) in 20 years (exponent 4 unless otherwise specified) | 6 | 0.1 | 4 | 10 | 30 | 200 |
|---------------------------------------------|--------------|------------------------------------------------------------------|---|-----|---|----|----|-----|
| Rigid pavement with heavy traffic (above ground with CBR ≥ 2.5%) | 4            | -                                                               | - | 2   | 2 | 2  |     |     |
| Rigid Pavement with low traffic (rural and urban area) | 4A           | -                                                               | 1.2| -   | - | -  | -   |     |
| Modified AC WC or modified SMA with CTB (ESA exponent 5) | 3            | -                                                               | - | 2   | 2 | 2  |     |     |
| AC with CTB (ESA exponent 5)                 | 3            | -                                                               | 1.2| 2   | 2 | 2  |     |     |
| AC thickness ≤ 100 mm with granular foundation layer (ESA exponent 5) | 3B           | -                                                               | - | 2   | 2 | 2  |     |     |
| AC or HRS than on granular foundation layer | 3A           | -                                                               | 1.2| -   | - | -  | -   |     |
| Basalt or Basalt with LPA class A or original rock | 5            | 3                                                               | 3  | -   | - | -  |     |     |
| Foundation layer Soil Cement                | 6            | 1                                                               | 1  | -   | - | -  |     |     |
| Pavement without cover (japet, gravel road) | 7            | 1                                                               | -  | -   | - | -  |     |     |

Source: Direktorat Jenderal Bina Marga (2017)

4. Pavement Foundation Plan

Flexible pavement with sub-standard foundation design required reinforcement with additional layers of asphalt repeatedly during its service life. The minimum thickness of the support layer to achieve a design CBR value of 6% is shown in Table 13 below.

Table 13 minimum road foundation design

| Subgrade CBR (%) | Subgrade Strength Class | Description of Foundation Structure | Flexible Pavement |
|------------------|-------------------------|-------------------------------------|-------------------|
|                  |                         |                                     | Traffic Load on The Design Lane with a Design Life of 40 Years (million ESA 5) |
| > 6              | SG6                     | Subgrade improvement can be in the form of cement stabilization or embankment material of choice | < 2 | 2 – 4 | > 4 |
| 5                | SG5                     |                                      | Minimum Thickness of Subgrade Improvement | 100 |
| 4                | SG4                     |                                      | No Improvement Needed | 100 |
| 3                | SG3                     |                                      | 100 | 150 | 200 |
| 2.5              | SG2.5                   |                                      | 150 | 200 | 200 |
|                  |                         | Expansive soil (expansion potential > 5%) | 175 | 250 | 350 |
| Pavement on clay | SG1                     | Support layer | 400 | 500 | 600 |
|                  |                         | Support layer and geogrid | 1000 | 1100 | 1200 |
|                  |                         |                                      | 650 | 750 | 850 |

Source: Direktorat Jenderal Bina Marga (2017)

D. Road Drainage Planning

1. Runoff Coefficient

\[ c = \left( C_1 \times A_1 \right) + \left( C_2 \times A_2 \right) + \left( C_3 \times A_3 \times f_k \right) / \frac{A_1 + A_2 + A_3}{f_k} \]  

Information:

\[ C_1, C_2, C_3 \] = flow coefficient according to conditions surface

\[ A_1, A_2, A_3 \] = the area of the drainage area calculated according to conditions surface

\[ f_k \] = runoff factor according to land use

2. Runoff Factor

Table 14 runoff coefficient and runoff factor

| No. | Ground Surface Conditions | Runoff Coefficient (C) | Runoff Factor (fk) |
|-----|---------------------------|------------------------|--------------------|
|     | MATERIAL                  |                        |                    |
| 1.   | Concrete Road & Asphalt Road | 0.70 – 0.95            | -                  |
| 2.   | Gravel Road & Dirt Road   | 0.40 – 0.70            | -                  |
| 3.   | Shoulder Road:            |                        |                    |
|      | Fine-Grained Soil         | 0.40 – 0.65            | -                  |
|      | Coarse-Grained Soil       | 0.10 – 0.20            | -                  |
|      | Hard Massive Rock         | 0.70 – 0.85            | -                  |
|      | Soft Massive Rock         | 0.60 – 0.75            | -                  |
| 4.   | LAND USE                  |                        |                    |
| 1.   | Urban Area                | 0.70 – 0.95            | 2.0                |
| 2.   | Suburbs                   | 0.60 – 0.70            | 1.5                |
| 3.   | Industrial Area           | 0.60 – 0.90            | 1.2                |
| 4.   | Dense Settlements         | 0.40 – 0.60            | 2.0                |
| 5.   | Non-Dense Settlements     | 0.40 – 0.60            | 1.5                |
| 6.   | Parks and Gardens         | 0.20 – 0.40            | 0.2                |
| 7.   | Rice Fields               | 0.45 – 0.60            | 0.5                |
| 8.   | Hills                     | 0.70 – 0.80            | 0.4                |
| 9.   | Mountains                 | 0.75 – 0.90            | 0.3                |

Source: Departemen Pekerjaan Umum (2006)

3. Concentration Time

\[ t_c = t_1 + t_2 \]  

\[ t_1 = \frac{2 \times 8.28 \times l_b \times n_e}{\sqrt{l_b}} \]  

\[ t_2 = \frac{L}{60 \times v} \]
Information:

\[ T_c = \text{concentration-time (minutes)} \]
\[ t_1 = \text{time to reach the start of the channel from point furthest (minutes)} \]
\[ t_2 = \text{flow time in the channel along with L from the end of the channel (minutes)} \]
\[ I_0 = \text{distance from the farthest point to the drainage facility (m)} \]
\[ L = \text{channel length (m)} \]
\[ n_d = \text{drag coefficient} \]
\[ I_s = \text{slope of longitudinal channel} \]
\[ V = \text{average water velocity in the drainage channel (m/second)} \]

Table 15 resistance coefficient value

| No. | Surface Conditions                          | \( n_d \) |
|-----|-------------------------------------------|----------|
| 1.  | Layer of Cement and Asphalt Concrete       | 0.013    |
| 2.  | Smooth and Impermeable Surface             | 0.020    |
| 3.  | Smooth and Sturdy Surface                  | 0.100    |
| 4.  | Thin and Bare Grassy Soil with a Slightly Rough Surface | 0.200 |
| 5.  | Grassylands and Grasses                    | 0.400    |
| 6.  | Bare Forest                                | 0.600    |
| 7.  | Dense Forest and Dense Bare Forest with Sparse to Dense Grass | 0.800 |

Source: Departemen Pekerjaan Umum (2006)

4. Hydrological Analysis

Maximum daily rainfall data in a year or minimum rainfall data is required in the last ten years, which is expressed in mm/day. The return period for the construction of drainage canals is set at five years. The following equation obtains rain intensity.

\[
X_T = \bar{X} + \frac{\varepsilon X_s}{X_s} (T_T - Y_n) \\
t = \frac{90\% \times X_o}{4} \quad \text{(27)} \\
\]

Information:

\( X_T \) = the amount of rainfall for the return period \( T \) years (mm/24 hours)
\( \bar{X} \) = arithmetic mean of cumulative rain
\( X_s \) = standard deviation
\( Y_T \) = variation which is a function of return period
\( Y_n \) = value that depends on \( n \)
\( S_n \) = standard deviation is a function of \( n \)
\( I \) = rainfall intensity (mm/hour)

Table 16 value of \( Y_T \)

| Return Period (years) | Reduced Variety |
|-----------------------|-----------------|
| 2                     | 0.3665          |
| 5                     | 1.4999          |
| 10                    | 2.2502          |
| 25                    | 3.1985          |
| 50                    | 3.9019          |
| 100                   | 4.6001          |

Source: Badan Standar Nasional (1994)

Table 17 value of \( Y_n \)

| No. | 0.9522 | 0.9596 | 0.9715 |
|-----|--------|--------|--------|
| 1   | 0.9725 | 0.9928 | 1.0106 |
| 5   | 0.1152 | 0.1272 | 0.1381 |
| 10  | 0.0782 | 0.0932 | 0.1050 |
| 25  | 0.0545 | 0.0648 | 0.0750 |
| 50  | 0.0364 | 0.0438 | 0.0504 |
| 100 | 0.0208 | 0.0241 | 0.0271 |

Source: Badan Standar Nasional (1994)

5. Water Flow Rate

\[ Q = \frac{1}{2} \times X \times A \quad \text{(29)} \]

Information:

\( Q \) = water flow rate (m³/second)
\( C \) = average flow coefficient
\( A \) = total service area (km²)

6. Pavement and Road Shoulder Cross Slope

The slope of the road shoulder is taken to be 2% greater than the slope of the road surface.

Table 19 pavement cross slope

| No. | Type of Road Pavement | Cross Slope, \( i_a \) (%) |
|-----|-----------------------|---------------------------|
| 1   | Asphalt, Concrete     | 2 – 3                      |
| 2   | Japit (compacted road) | 2 – 4                      |
| 3   | Gravel                | 3 – 6                      |
| 4   | Soil                  | 4 – 6                      |

Source: Departemen Pekerjaan Umum (2006)

7. Water Flow Design Speed

Table 20 water flow rate by material type

| No. | Type of Material | Allowable Water Flow Rate (m³/second) |
|-----|------------------|--------------------------------------|
| 1   | Fine Sand        | 0.45                                 |
| 2   | Sandy Loam       | 0.50                                 |
| 3   | Alluvial Silt    | 0.60                                 |
| 4   | Fine Gravel      | 0.75                                 |
| 5   | Firm Loam        | 0.75                                 |
| 6   | Solid Loam       | 1.10                                 |
| 7   | Coarse Gravel    | 1.20                                 |
| 8   | Boulders         | 1.50                                 |
| 9   | Masonry          | 1.50                                 |
| 10  | Concrete         | 1.50                                 |
| 11  | Reinforced Concrete | 1.50                          |

Source: Departemen Pekerjaan Umum (2006)
8. Channel Slope

Table 21 channel slope by material type

| No. | Type of Material | Channel Slope, i (\%) |
|-----|------------------|-----------------------|
| 1.  | Soil             | 0 – 5                 |
| 2.  | Gravel           | 5 – 7.5               |
| 3.  | Masonry          | 7.5                   |

Source: Departemen Pekerjaan Umum (2006)

9. Type and Material of Channel

Table 22 type and material of channel

| No. | Type of Channel | Materials |
|-----|-----------------|-----------|
| 1.  | Trapezoid       | a. Soil   |
|     |                 | b. River Rock Masonry |
| 2.  | Triangle        | a. Soil   |
|     |                 | b. River Rock Masonry |
| 3.  | Rectangular     | a. River Rock Masonry |
|     |                 | b. Reinforced Concrete |
| 4.  | Semi-Circle     | a. River Rock Masonry |
|     |                 | b. Reinforced Concrete |

Source: Departemen Pekerjaan Umum (2006)

10. Channel Cross Section

The following equation obtains the cross-sectional component of the trapezoidal channel.

\[ lebar\ atas = b + (2 \times z) \]  (30)

\[ luas = (b + z) \times h \]  (31)

\[ keliling = b + (2 \times h) + \sqrt{(1 + z^2)} \]  (32)

\[ jari - jari\ hidrolis = \frac{(b + z) \times h}{b + (2 \times h) + \sqrt{(1 + z^2)}} \]  (33)

\[ kecepatan = \frac{1}{\pi} \times R^{1/2} \times h^{1/2} \]  (34)

\[ debit = F \times V \]  (35)

Information:

- \( b \) = channel width (m)
- \( z \) = the ratio of the slope of the trough
- \( h \) = depth of waterlogged channel (m)
- \( n \) = manning roughness number
- \( R \) = hydraulic radius (m)
- \( i \) = channel slope
- \( F \) = area (m²)
- \( V \) = speed (m/second)

Table 23 slope

| No. | Water Flow Rate, \( Q \) (m³/second) | Slope (1 : m) |
|-----|-----------------------------------|--------------|
| 1.  | 0.00 – 0.75                       | 1 : 1        |
| 2.  | 0.75 – 15                         | 1 : 1.5      |
| 3.  | 15 – 80                           | 1 : 2        |

Source: Departemen Pekerjaan Umum (2006)

11. Guard Height

\[ W = \sqrt{\frac{0.5}{h}} \]  (36)

Information:

\( W \) = guard height (m)

12. Channel Longitudinal Slope

\[ i_c = \left( \frac{V}{n \sqrt{R}} \right)^{1/2} \]  (37)

Table 24 manning roughness number

| No. | Type of Channel | Very Good | Good | Moderate | Bad |
|-----|-----------------|-----------|------|----------|-----|
| 1.  | Artificial Channel | 0.017     | 0.023 | 0.025    |     |
| 2.  | Earth channel, regular straight | 0.023     | 0.028 | 0.030    | 0.040|
| 3.  | Channel on the rock wall, regular straight | 0.020     | 0.030 | 0.033    | 0.035|
| 4.  | Channel on the rock wall, not straight and irregular | 0.035     | 0.040 | 0.045    | 0.048|
| 5.  | The rock channel is blown up, there is vegetation | 0.025     | 0.030 | 0.035    | 0.040|
| 6.  | Bottom of the channel from the ground, rocky side of the channel | 0.028     | 0.030 | 0.033    | 0.035|
| 7.  | Curved channel with low flow velocity | 0.030     | 0.025 | 0.028    | 0.030|

Source: Departemen Pekerjaan Umum (2006)

13. Road Geometric Planning

The results of the road planning that have been carried out are obtained in the form of horizontal and vertical road alignment plans, road pavement thickness plans, and road design drainage dimensions.

The last stage in this research is to draw conclusions from the planning results and provide suggestions.

RESULTS AND DISCUSSIONS

The Inari – Bofuwer segment plans to be an arterial road with a 2-lane 2-way undivided road type (2/2 UD) with a lane width of 7.5 meters and a shoulder width of 1.5 meters.

A. Road Geometric Planning

The planned route path is shown in Figure 3 below.

Figure 3 Road route plan
(Source: Research Results)
The calculation results for the azimuth angle, bend angle, and distance are shown in Table 25.

Table 25 angle and distance value

| Point | STA | Azimuth Angle (°) | Bend Angle (°) | Distance (m) |
|-------|-----|------------------|---------------|-------------|
| P0    | 61 + 500 | 176.87           | -             | 419.00      |
| P1    | 61 + 919 | 102.97           | 73.90         | 481.81      |
| P2    | 62 + 400.82 | 126.62           | 23.65         | 196.72      |
| P3    | 62 + 597.54 | 150.62           | 24.00         | 94.91       |
| P4    | 62 + 722.45 | 139.04           | 11.58         | 471.16      |
| P5    | 63 + 193.61 | 88.76            | 50.27         | 246.21      |
| P6    | 63 + 439.82 | 150.33           | 61.56         | 198.84      |
| P7    | 63 + 668.66 | 92.78            | 57.55         | 789.38      |
| P8    | 64 + 458.04 | 56.35            | 36.42         | 142.15      |
| P9    | 64 + 680.18 | 142.95           | 86.59         | 547.39      |
| P10   | 65 + 227.57 | 171.16           | 28.20         | 198.29      |
| P11   | 65 + 425.87 | 128.13           | 43.02         | 99.10       |
| P12   | 65 + 554.96 | 156.67           | 28.53         | 633.42      |
| P13   | 66 + 188.39 | 197.68           | 41.01         | 146.07      |
| P14   | 66 + 334.45 | 169.89           | 27.79         | 343.06      |
| P15   | 66 + 677.51 | 104.02           | 65.87         | 786.65      |
| P16   | 67 + 464.16 | 38.95            | 65.06         | 289.74      |
| P17   | 67 + 783.90 | 105.69           | 66.73         | 291.03      |
| P18   | 68 + 074.94 | 138.28           | 32.58         | 312.58      |

Source: Research Results

1. Horizontal Alignment

Used vehicle design speed (Vr) 60 km/hour, $e_{max}$ 10%, and centrifugal force (f) 0.14, so that the calculation results of the minimum bending radius (R_{min}) with equation (6) are 119 meters.

Planning the horizontal curved shape is carried out at bend P1 with the calculation flow by Figure 2. The value of the bend radius (R) used is 200 meters, and the super-elevation value (e) obtained from AASHTO 2018 is 8%. The transitional arc length (L_{s}) obtained using equations (7), (8), and (9) are 50 meters, 5.34 meters, and 38.1 meters, respectively, so that the enormous value is 50 meters. The arc length (L_{c}) obtained using equation (11) is 207.96 meters, greater than 20 meters. Furthermore, the calculation of the tangent shift to the spiral (p) with equation (12) is obtained by 0.52 meters, which is greater than 0.25 meters.

Then the coefficient of friction (f) is calculated with equation (13) obtained at 0.062, which is greater than 0.03. The results of the calculations that have been carried out are obtained for the P1 bend using a spiral-circle-spiral horizontal curve.

The results of calculations for planning the horizontal curved shape at other bend points are shown in Table 26 below.

Table 26 horizontal curve

| Point | R (m) | e (%) | L_{s} (m) | L_{c} (m) | P (m) | f |
|-------|-------|-------|-----------|-----------|-------|---|
| P1    | 200   | 8     | 50        | 207.96    | 0.52  | 0.062 |
| P2    | 150   | 9.2   | 50        | 119.2     | -     | -   |
| P3    | 130   | 9.6   | 50        | 4.45      | -     | -   |
| P4    | 250   | 9.6   | 50        | 0.53      | -     | -   |
| P5    | 150   | 9.2   | 50        | 81.61     | 0.69  | 0.097 |
| P6    | 130   | 9.2   | 50        | 89.68     | 0.80  | 0.126 |
| P7    | 130   | 9.2   | 50        | 80.58     | 0.80  | 0.126 |
| P8    | 130   | 9.6   | 50        | 32.63     | 0.80  | 0.122 |
| P9    | 150   | 9.2   | 50        | 23.83     | 0.69  | 0.097 |
| P10   | 130   | 9.6   | 50        | 47.61     | 0.80  | 0.122 |
| P11   | 130   | 9.6   | 50        | 14.73     | -     | -   |
| P12   | 130   | 9.6   | 50        | 43.05     | 0.80  | 0.122 |
| P13   | 130   | 9.6   | 50        | 13.05     | -     | -   |
| P14   | 200   | 8     | 50        | 179.93    | 0.52  | 0.062 |
| P15   | 200   | 8     | 50        | 177.10    | 0.52  | 0.062 |
| P16   | 200   | 8     | 50        | 182.93    | 0.52  | 0.062 |
| P17   | 200   | 8     | 50        | 63.73     | 0.52  | 0.062 |

Source: Research Results

Based on the above calculation results, it is found that there are two types of horizontally curved shapes used, namely spiral-circle-spiral with a total of 13 bends and spiral-spiral with a total of 5 bends.

2. Vertical Alignment

The existing vertical alignment at the road planning location is shown in Figure 4 below.

Figure 4 Existing vertical alignment
(Source: Research Results)

Vertical alignment planning is carried out at the PPV1 bend by calculating the design slope using the following equation.

$$\eta_n = \frac{\Delta h}{\Delta L} \times 100\%$$  (38)

It was obtained for $g_1$ of -7.17% and $g_2$ of -0.89%, and then the algebraic difference was calculated using the following equation.

$$A = g_1 - g_2$$  (39)

The algebraic difference is -6.29% which is a concave vertical curve. Furthermore, to obtain the value of stopping sight distance and overtaking sight distance, equations (1) and (2) are used, respectively 92.63 meters and 347.85 meters. The vertical arch length (L) is obtained by using equations (14) to (20), which are respectively 251.4 meters, 58.02 meters, 135.15 meters, 792.18 meters, 121.77 meters, 542.96 meters, and 36 meters. The calculation of the length of the vertical curve used the
enormous value that meets, where the station's calculation will not overlap at the next vertical bend point. The PPV1 bend uses a vertical bend length value of 251.4 meters ~ 252 meters.

The vertical alignment of the plan at the road planning location is shown in Figure 5 below.

![Figure 5 Vertical alignment plan](Source: Research Results)

The calculation results for the design slope and algebraic differences at other vertical bend points are shown in Table 27 below.

### Table 27 Vertical arch type

| No. | Type | Elevation | Elevation (rm) | Distance (rm) | Grade (%) | Year | Rock Type |
|-----|------|-----------|---------------|--------------|-----------|------|-----------|
| 1   |      | 20.03     | 20.10         | 20.26         | 20.45     | 200  | Asus      |
| 2   |      | 20.26     | 20.32         | 20.48         | 20.65     | 200  | Asus      |
| 3   |      | 20.48     | 20.54         | 20.70         | 20.86     | 200  | Asus      |
| 4   |      | 20.70     | 20.76         | 20.92         | 21.08     | 200  | Asus      |
| 5   |      | 20.92     | 21.00         | 21.16         | 21.32     | 200  | Asus      |

Source: Research Results

Based on the calculation results above, there are 13 concave vertical curves and 13 convex vertical curves.

### B. Road Pavement Thickness Planning

The thickness of the pavement is planned with flexible pavement using a layer of asphalt for a design life (UR) of 20 years. The traffic growth rate factor (i) 4.75%, lane distribution factor (DL) 1, and direction distribution factor (DD) 0.50 are used. The traffic growth multiplier is obtained using equation (21) of 32.21.

Based on the LHR data from the survey, four types of vehicles pass through the road, with the LHR values obtained as shown in Table 28 below.

### Table 28 ESA4 and ESA5 value

| Type of Vehicle | LHR | ESA4 | ESA5 | Number of Days | OD | DE | R | ESA4 | ESA5 |
|-----------------|-----|------|------|----------------|----|----|---|------|------|
|                 |     |      |      |                |    |    |   |      |      |
|                 | 1.0 | 32.21| 32.21| 0.90           | 32.21| 32.21| 0.90 | 32.21| 32.21|
|                 | 2.0 | 32.21| 32.21| 0.80           | 32.21| 32.21| 0.80 | 32.21| 32.21|
|                 | 3.0 | 32.21| 32.21| 0.70           | 32.21| 32.21| 0.70 | 32.21| 32.21|
|                 | 4.0 | 32.21| 32.21| 0.60           | 32.21| 32.21| 0.60 | 32.21| 32.21|

Source: Research Results

As seen in Table 28, the values for VDF 4 and VDF 5 are obtained based on Table 11. The calculation of ESA 4 and ESA 5 uses equation (22), and if added up for each type of vehicle, it will produce CESA 4 and CESA 5.

Based on the calculation results above, the CESA 4 value is 169295.8. The type of pavement used based on Table 12 is Burda or Burtu with LPA Class A or original rock because the road planning location is a forest with soft soil. The thickness of the pavement layers obtained from Design Chart 5 in the 2017 Road Pavement Design Manual is 250 mm Class A Aggregate Foundation and 110 mm Class B Aggregate Foundation.

The road planning location has an average subgrade CBR value of 3.23%, so it is necessary to improve the subgrade in cement stabilization on the foundation by providing an additional layer of asphalt as reinforcement.

The thickness of the subgrade improvement layer based on Table 13 was used at 150 mm so that the CBR value increased to 6%.

### C. Road Drainage Planning

Road drainage planning is carried out in segment one, which is located in the STA. 61 + 500 – 61 + 700 with a channel length of 200 meters. The flow coefficient (C) value for each type of surface is obtained based on Table 14 of 0.95, 0.65, and 0.80 and for the runoff factor (fK) of 0.4. The average flow coefficient (C) is obtained using equation (23) of 0.347. The drag coefficient (nd) value for each type of surface is obtained based on Table 15 of 0.10, 0.20, and 0.30. The transverse slope (i), on each surface type is obtained based on Table 19 of 2% and 4%. Concentration time (Tc) was obtained using equations (24), (25), and (26) for right side road drainage of 5.02 minutes and 5.01 minutes for left side road drainage.

Rainfall intensity (I) is obtained by using equation (28) of 121.66 mm/hour. In segment one, the water flow rate is obtained using equation (29) of 0.247 m²/second. Drainage channels must have dimensions that can accommodate the flow of water. Therefore, the flow rate of the channel water must be greater than the design water flow rate, with the velocity in the channel not exceeding the permitted speed.

Road drainage is planned to use a trapezoidal shape with masonry material because, for stability, the slope of the wall can be adjusted, and for its manufacture, it does not require enormous costs [7], [8]. The permissible speed according to Table 20 is 1.50 m/s and the permissible channel slope according to Table 21 is 7.5%.
dimensions were obtained using equations (30) to (37), as shown in Table 29.

Table 29 road drainage dimensions

| Segment         | Water Flow Rate (m³/second) | Height (m) | Width (m) | Water Flow Rate Channel (m³/second) | Guard Height (m) |
|-----------------|-----------------------------|------------|-----------|-------------------------------------|-----------------|
| STA. 61+500 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 61+700          | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 61+900 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 62+150          | 0.309                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 62+150 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 62+350          | 0.309                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 62+350 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 62+600          | 0.370                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 62+900 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 63+100          | 0.494                       | 0.50       | 0.50      | 0.75                                | 0.50            |
| STA. 63+500 -   | 0.123                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 63+600          | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 63+800 -   | 0.123                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 64+250          | 0.432                       | 0.50       | 0.50      | 0.75                                | 0.50            |
| STA. 64+250 -   | 0.185                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 64+400          | 0.123                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 64+500 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 65+700          | 0.370                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 65+100 -   | 0.123                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 65+150          | 0.185                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 65+250 -   | 0.803                       | 0.60       | 0.60      | 1.08                                | 0.55            |
| 65+900          | 0.432                       | 0.50       | 0.50      | 0.75                                | 0.50            |
| STA. 66+230 -   | 0.494                       | 0.50       | 0.50      | 0.75                                | 0.50            |
| 66+650          | 0.370                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 66+950 -   | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 67+150          | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 67+350 -   | 0.309                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| 67+600          | 0.247                       | 0.40       | 0.40      | 0.48                                | 0.45            |
| STA. 67+800 -   | 0.494                       | 0.50       | 0.50      | 0.75                                | 0.50            |

1. Road planning in the Inari – Bofuwer segment is a type of arterial road with type 2/2 UD, which has the following dimensions:
   a. Road width = 7.5 meters
   b. Shoulder width = 1.5 meters
   c. Design speed = 60 km/hour
2. The horizontal alignment component of the road in the Inari – Bofuwer segment consists of two types of bends, namely the Spiral-Circle-Spiral with 13 bends and the Spiral-Spiral with 5 bends.
3. The vertical alignment component of the Inari – Bofuwer segment consists of 13 concave vertical curves and 13 convex vertical curves.
4. The pavement design for the Inari – Bofuwer segment uses the Burda or Burtu pavement types with LPA class A or original rock with the following thickness:
   a. Class A Aggregate Foundation Layer = 250 mm
   b. Class B Aggregate Foundation Layer = 110 mm
   c. Soil Stabilization Layer = 150 mm
5. Planning for road drainage in the Inari – Bofuwer segment has three types of dimensions as follows:
   a. Type I : 0.40 m x 0.40 m; guard height 0.45 m
   b. Type II : 0.50 m x 0.50 m; guard height 0.50 m
   c. Type III : 0.60 m x 0.60 m; guard height 0.55 m

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