19.3 BASIC PLAN

19.3.1 Design Policy

The following design policies are established:

Common

- Introduction of stage construction (see Sections 19.3.3, 19.3.4 and 19.3.5),
- Maximum utilization of existing road reserve,
- Provision of Non Motorized Transport(NMT) facilities,
- Provision of greenbelt with many plants and trees along sidewalk to create a pedestrian friendly road and enrich the environment,
- Provision of bus stop space for harmonized development with public transport,
- Provision of access to the road side residents, and
- Provision of mitigation measures against negative environment impact.

Furthermore, the following design policies are considered for each road:

C2

- Consideration for traffic access (accessibility) to the roadside area since most of roadside area are already built up,
- Provision of on-road parking areas in built-up business and commercial areas, and
- Minimum social impact and relocation of structures/houses along road.

C3

- Introduction of high standard design (high speed and access control) giving priority to mobility,
- Consideration of through traffic (heavy truck, high volume and long trip traffic), and
- Minimum social impact and relocation of structures/houses for built-up sections.

Lologo Radial Street

- Minimum social impact and relocation of structures/houses along road since Lologo area is already built-up with many structures/houses, and
- Consideration of accessibility for properties along the road.

Nyakuron Radial Street

- Consideration of better road alignment to promote the new development area (Nyakuron South) since there are only few affected structures/houses at present.
- Consideration of accessibility for properties along the road.

19.3.2 Route Location

The route locations of C2 and C3 were established in Chapter 18 (See Figure 18.4-1 Proposed Route Locations for Juba Urban Road Network).

This section discusses the study of route locations for the 2 Radial Streets: CSA (in Lologo) and CSB (in Nyakuron).

(1) Identification of Control Points

The control points were identified as presented in Table 19.3.2-1 and Figure 19.3.2-1 from satellite images and verified on site. These control points were considered in establishing the most appropriate route alignments for Lologo Radial Street and Nyakuron Radial Street.

Table 19.3.2-1 Route Location Control Points

Route	Control Points
Lologo Radial Street	1.C2 Intersection 2. Small river crossing 3. Prison Training Center 4. KhorRoml river crossing 5. New Water Treatment Plant
Nyakuron Radial Street	1. Military Area

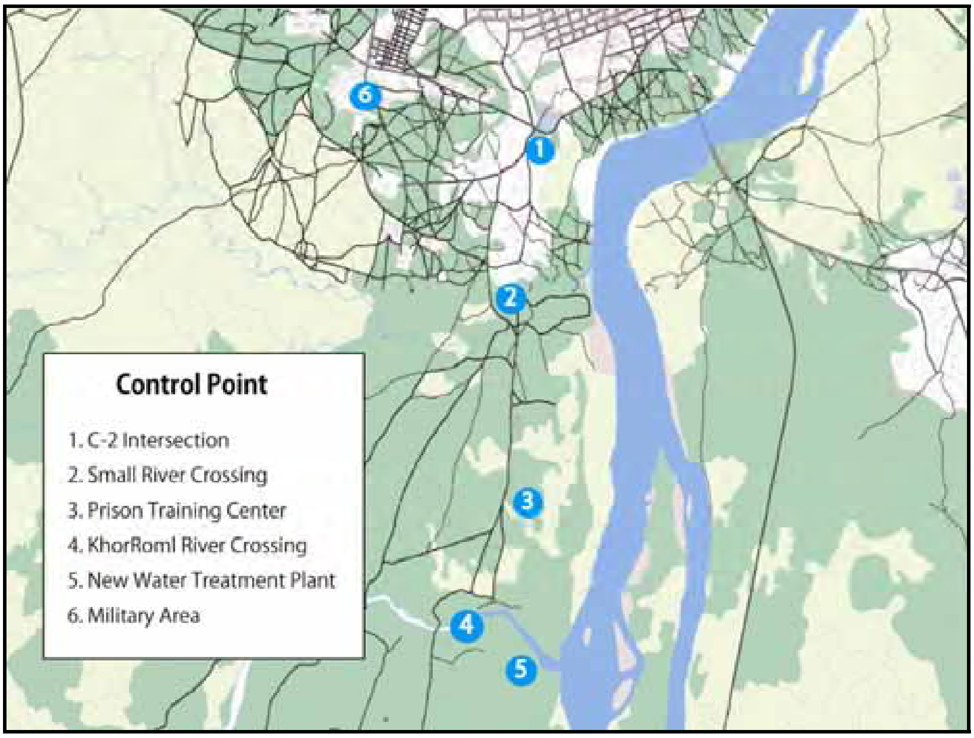


Figure 19.3.2-1 Route Location Control Points

(2) Alternative Route Location

Two alternative route alignments for each road were selected and compared for evaluation as shown in Figure 19.3.2-2.

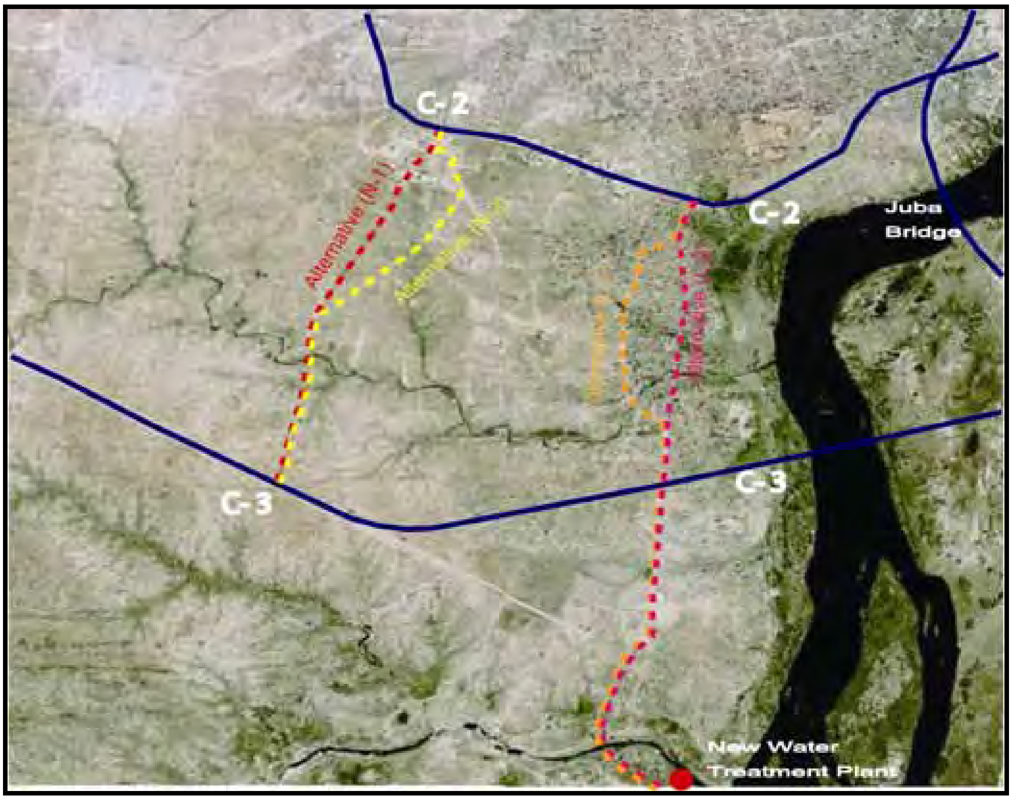
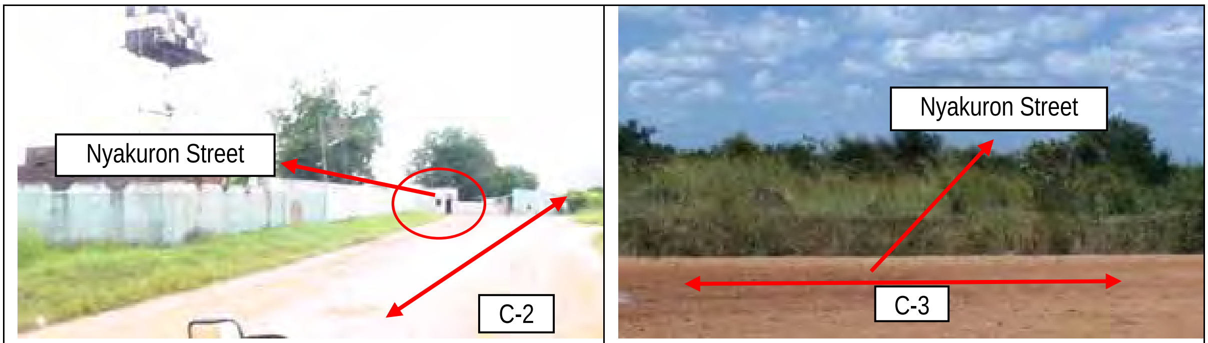


Figure 19.3.2-2 Alternative Alignments of Lologo and Nyakuron Radial Streets

The identified route locations are verified and checked on site to determine the existing conditions of the proposed alignments on the ground. Photographs shown in Figure 19.3.2-3 present the actual conditions on site.

 Intersection of C3 and Lologo Radial Street (entrance of Lologo Prison Training Center)	 Alternative (L-1): Existing Bridge
 Alternative (L-2)	 End point (intersecting with C2)

Figure 19.3.2-3 (a) Existing Conditions of CSA (Lologo Radial Street)



Start point (intersection with C2)
(Entrance of Military Area)

End point (intersection with C3)
(Nyakuron St. not existing)

Figure 19.3.2-3 (b) Existing Conditions of CSB (Nyakuron Radial Street)

(3) Evaluation of Alternative Route Location

Alternative route alignments were evaluated as shown in Table 19.3.2-2 for CSA in Lologo and Table 19.3.2-3 for CSB in Nyakuron.

Table 19.3.2-2 Alternative Routes of CSA (Lologo Radial Street)

Evaluation Item	Alternative (L-1)	Alternative (L-2)
Location	Along present route	Utilize some existing narrow local streets
Road Alignment/ Geometry	2 main curves (R=200m): acceptable (minimum design radius is 86m according to AASHTO)	Smoother than L-1(Straight alignment)
Road Length	3.6 km	3.3km (300m shorter than L-1)
Affected Structure	Less structures/houses affected than L-2	Affected structures/houses is 2 times of Alternative L-1. Some big trees will be cut for road const-ruction.
ROW	wider than L-2	30m of road in new alignment section. Other section will need to be widened.
Evaluation	○ ***(Recommended)*** (acceptable alignment, less ROW acquisition and less affected structures/ houses)	**X *(Not recommended)*** (better alignment, but big social and environmental impact - many ROW required and many affected structures/houses and trees)

Table 19.3.2-3 Alternative Routes of CSB (Nyakuron Radial Street)

Evaluation Item	Alternative (N-1)	Alternative (N-2)
Route	New Alignment	Utilize some existing narrow local streets
Road Alignment/ Geometry	Smooth (basically straight alignment)	Irregular road alignment
Road Length	2.2km	2.4km (200m longer than N-1)
Affected Structure	Affects temporary structures inside military base which will be relocated to another area	No affected structures/houses
ROW	Requires ROW acquisition	Requires ROW acquisition
Evaluation	○ ***(Recommended)*** (better and shorter alignment)	**X *(Not recommended)*** (longer road alignment, more expensive)

19.3.3 Future Traffic Demand

The future traffic demand for the Study Roads is estimated based on the road section layouts shown in Figure 19.3.3-1.

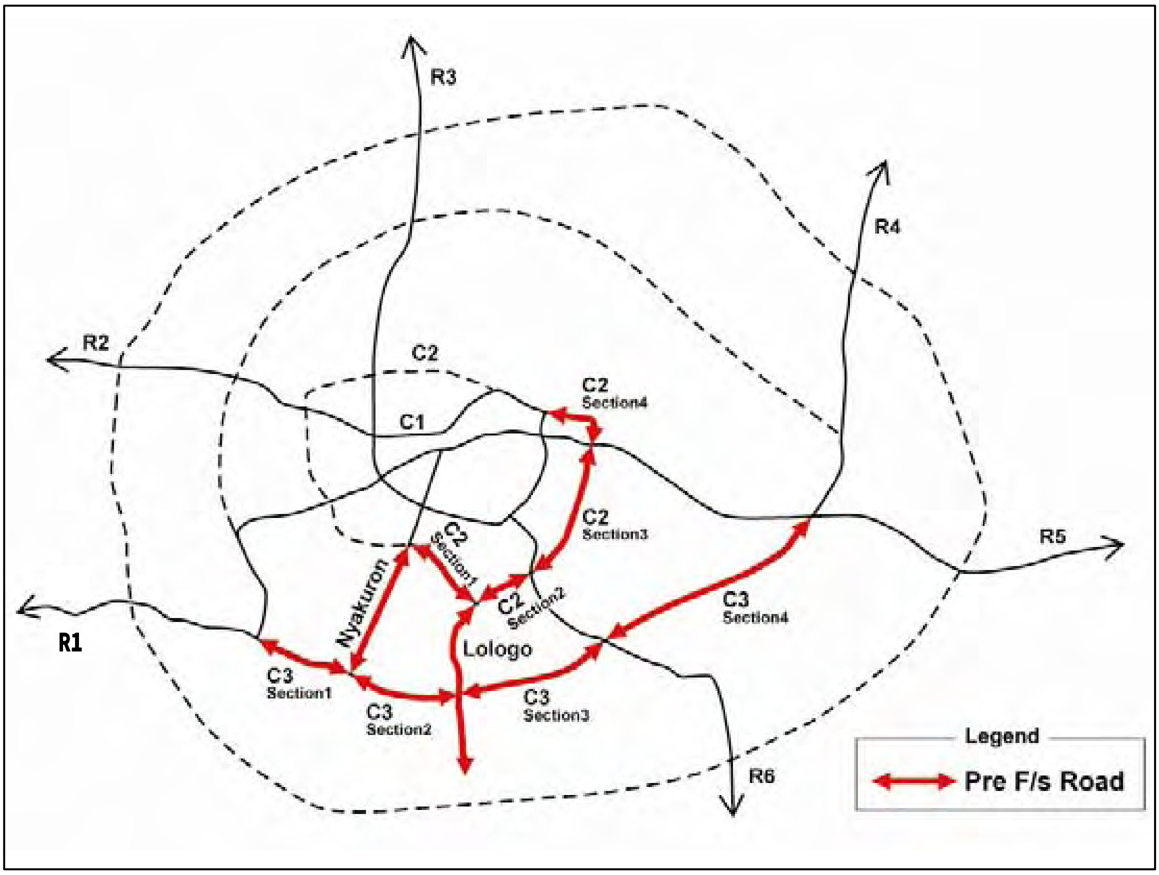


Figure 19.3.3-1 Segment of the Study Roads

The projected traffic volume by road section and the volume/capacity ratio in cases of 2 and 4 lanes are shown in Table 19.3.3-1 and graphically illustrated in Figure 19.3.3-2.

Table 19.3.3-1 Estimated Traffic Volume and Volume/Capacity Ratio

	Road		C2				C3				Lologo	Nyakuron
	Section		1	2	3*	4	1	2	3	4	-	-
Traffic Volume in 100PCU	2008		71	85	(34)	100	45	45	30	24	34	26
	2015		164	133	(99)	126	89	89	92	24	191	91
	2025		185	228	(212)	336	303	351	312	373	218	203
Volume/ Capacity Ratio (V/C)	2-lane	2008	0.36	0.43	(0.17)	0.50	0.22	0.22	0.15	0.12	0.17	0.13
		2015	0.82	0.67	(0.49)	0.63	0.45	0.45	0.46	0.12	0.95	0.45
		2025	0.93	**1.14**	**(1.06)**	**1.68**	**1.52**	**1.75**	**1.56**	**1.86**	**1.09**	**1.01**
	4-lane	2008	0.14	0.17	(0.07)	0.20	0.09	0.09	0.06	0.05	0.07	0.05
		2015	0.33	0.27	(0.20)	0.25	0.18	0.18	0.18	0.05	0.38	0.18
		2025	0.37	0.46	(0.42)	0.67	0.61	0.70	0.62	0.75	0.44	0.41

Note: * C2 Section 3 is discussed in Chapter 17.

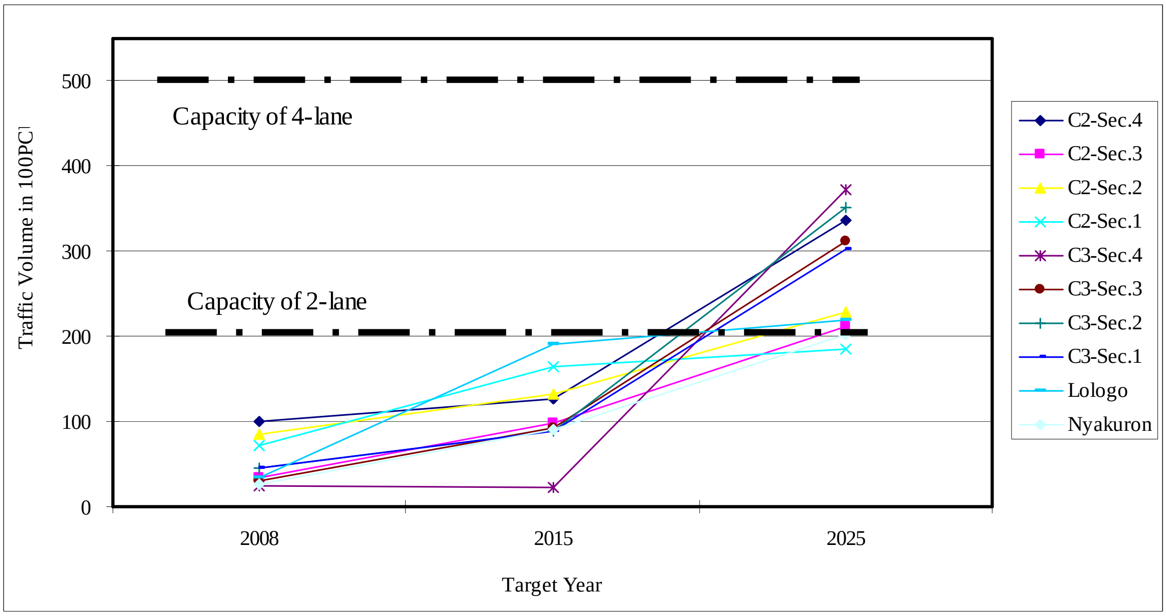


Figure 19.3.3-2 Estimated Traffic Volume and Traffic Capacity

In year 2015, the traffic volume of all road sections is less than 20,000pcu/day (2-lane capacity). However, in year 2025, section 4 of C3 attracts the highest traffic of about 37,300 pcu/day. As seen in Figure 19.3.3-2, most of the road sections will exceed the traffic volume of 20,000 pcu/day (2-lane capacity) in year 2020-2025, therefore it will be necessary to widen these roads to 4-lanes before 2025.

The traffic capacity of a 2-lane road will be exceeded in the year shown in Table 19.3.3-2.

Table 19.3.3-2 The Year When Traffic Demand Exceeds 2-Lane Road Capacity

Road	Section	Year when Traffic Demand exceeds 2-lane Road Capacity
C2	1	After 2025
	2	Y 2023
	3	Y 2024
	4	Y2019
C3	1	Y2021
	2	Y 2020
	3	Y 2020
	4	Y 2021
Lologo Radial Street		Y 2019
Nyakuron Radial Street		Y2025

19.3.4 Standard Cross-sections

The cross sections for the Study Roads are determined taking into account the traffic demand, functional classification, topography, land use along the roads and stage construction scheme (discussed in Section 19.3.5). Figure 19.3.4-1(a) shows the proposed standard cross section of the two-lane initial stage and the four-lane ultimate stage of Circumferential Street C2(outside the CCD*) and C3, while Figure 19.3.4-1(b) shows the standard cross section of Circumferential Street C2 inside the CCD* (the stage construction is not proposed). Standard cross section for initial stage and ultimate stage of Lologo and Nyakuron Radial Streets is shown in Figure 19.3.4-1(c).

* CCD: Central Commercial District

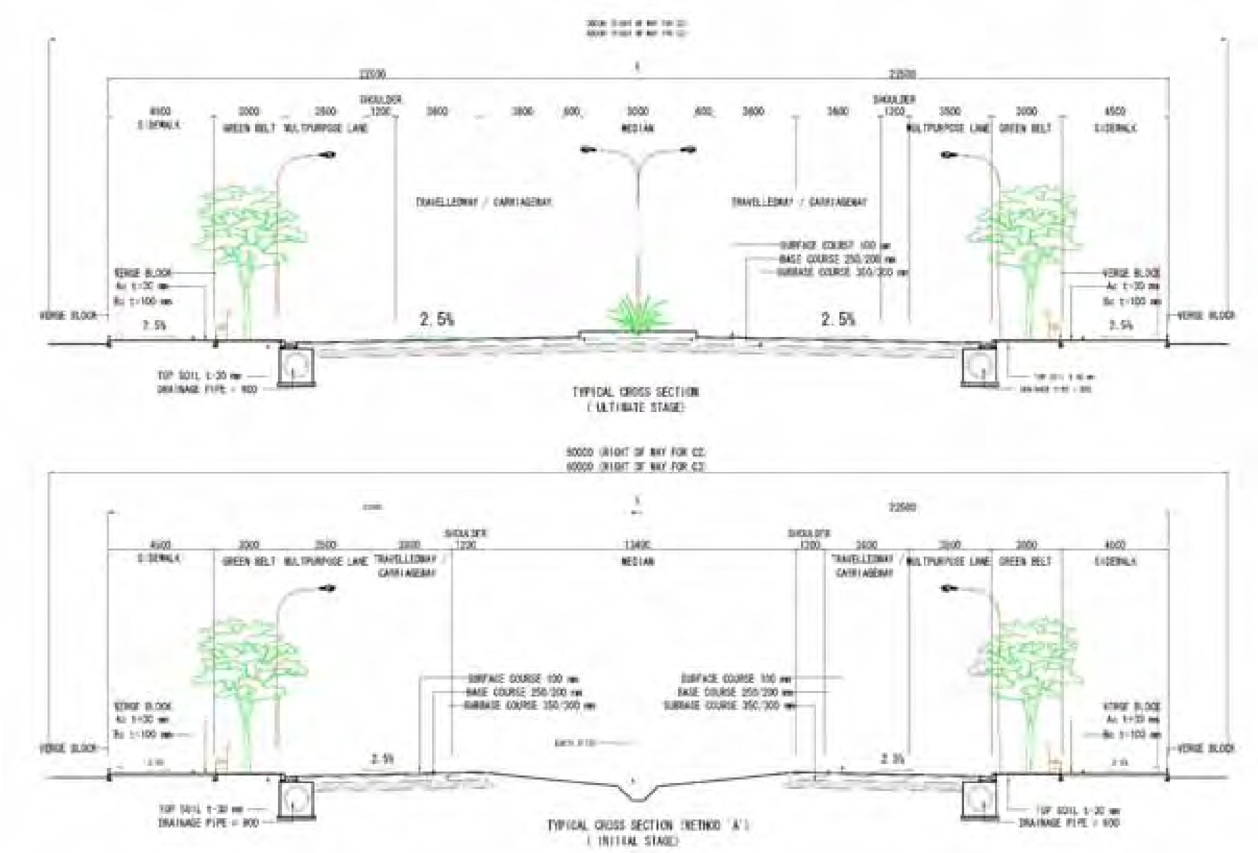


Figure 19.3.4-1(a) Typical Cross Section of Circumferential Streets (C2 outside CCD and C3)

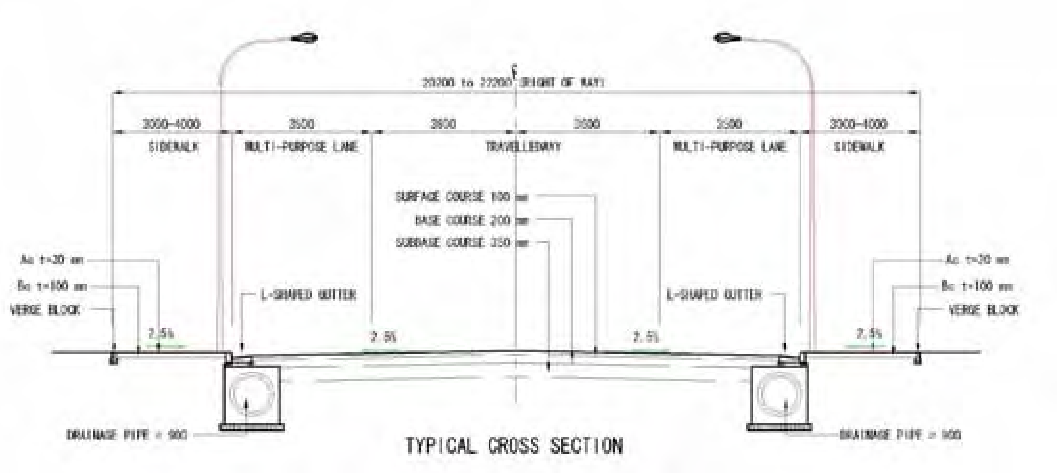


Figure 19.3.4-1(b) Typical Cross Section of Circumferential Street C2 (Inside CCD)

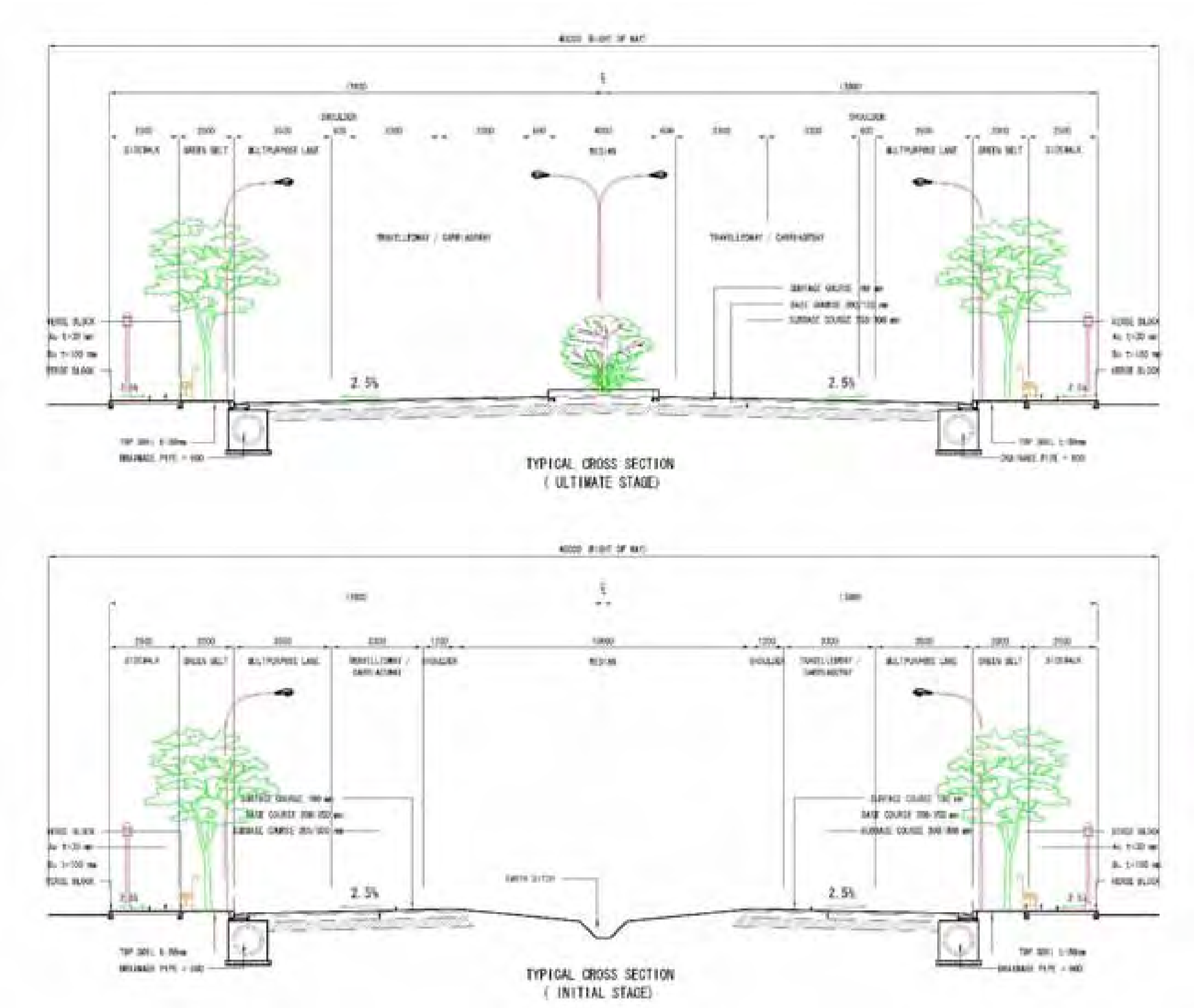


Figure 19.3.4-1(c) Typical Cross Section of Lologo and Nyakuron Radial Streets

(1) Number of Lanes

The Master Plan Study proposes 6 lanes and 4 lanes for Arterial Streets and 4 lanes and 2 lanes for Collector Streets. However, the results of the future traffic demand, as discussed in 19.3.3, show that for all the Study Roads, 2-lanes can accommodate the traffic demand until year 2015. Thereafter, the streets will require widening to 4-lanes. Therefore, all the Study Roads are proposed to have only two lanes in the initial stage.

(2) Travelled Way Lane

The Master Plan proposes a width of 3.6m for Arterial Streets and 3.3m for Collector Streets. This is the standard width recommended by AASHTO. As there are no other standards available in Juba at present, the lane width for the Study Roads shall be determined in conformity with the standard of AASHTO. As such, the lane width for Circumferential Streets, C2 and C3, shall be 3.6m wide whereas for Collector Streets, Lologo and Nyakuron Radial Streets, it shall be 3.3m.

(3) Multi-purpose Lane

The Study Roads are provided with a 3.5m wide multi-purpose lane on either side. The purpose of this lane is to provide exclusive space for bus bays, on-street parking, and for the use of bikes/bicycles and other slow vehicles.

(4) Median

Raised/mounted median is provided for the ultimate stage for all Study Roads, except Section 3 of C2 (inside the CCD). The width of the median shall be 5.0 meters for Arterial Streets, C2 and C3 and 4.0 meters for Collector Streets, CSA (Lologo Radial Street) and CSB (Nyakuron Radial Street).

However, instead of a raised median, an earth median with sodding is provided for the initial stage. The initial width of the median shall be 13.4 meters and 10.6 meters for Circumferential Streets and Collector Streets respectively. An earth ditch shall be provided in the middle of the median for the purpose of drainage of the median.

19.3.5 Stage Construction

(1) General

Stage construction is a scheme of initially constructing the minimum cross-section of a road that is required for the immediate traffic demand and in the future widening to the ultimate section in accordance with the increase in the traffic demand. The basic idea of stage construction is to minimize initial construction cost when the initial traffic demand is low but it is projected to increase in the future.

The results of future traffic demand projection discussed in 19.3.3 indicate that a 2-lane road satisfies the traffic demands of all Study Roads until year 2015. From this perspective, adoption of stage construction scheme is considered to be effective. Therefore initial stage construction of 2 lanes is proposed for all the Study Roads.

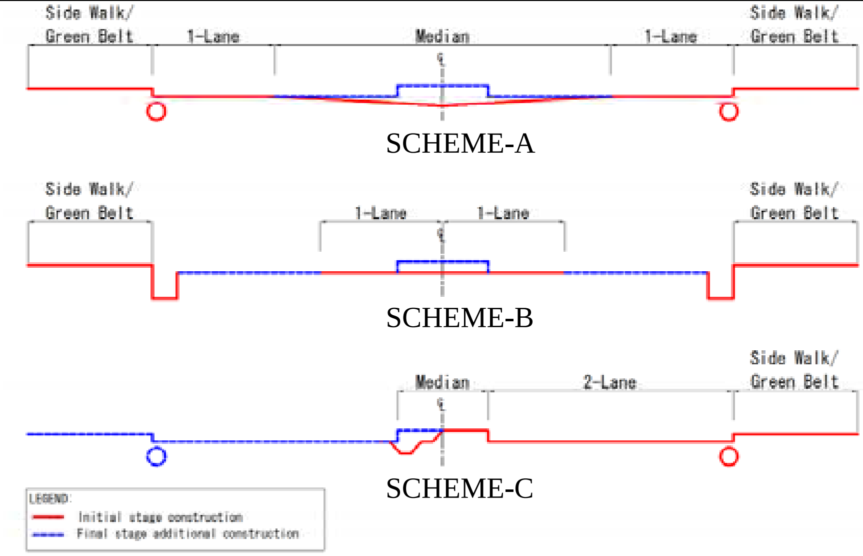
(2) Comparison of Stage Construction Scheme

In general, there are three schemes of stage construction:

- Scheme A: outer initial lane method,
- Scheme B: inner initial lane method, and
- Scheme C: one side (partial) initial lane method.

A simple comparison of these schemes is shown in Table 19.3.5-1.

Table 19.3.5-1 Comparison of Stage Construction Schemes

Illustration			
Schemes	A	B	C
Description	The outer lanes are initially constructed providing a wide median at the center for additional construction.	The inner lanes and median are initially constructed at the center of the road while the sidewalk and greenbelt are constructed at its final position.	One side of the ultimate stage cross section is initially constructed and adding the other side during ultimate stage construction.
Widening	Appropriate when widening is expected in near future.	Appropriate when widening is required only in far future.	Similar to Scheme 'B'.
Protection of ROW	Protection of ROW area is not required as encroachment is difficult.	Similar to Scheme 'A' .	The ROW needs protection as the open area could easily be encroached.
Bridges/Culverts	Initial stage construction scheme requires shifting of lanes to connect the bridge which is constructed on one side.	Initial stage construction scheme requires shifting of lanes to connect the bridge which is constructed on one side.	Initial stage construction scheme does not require shifting of lanes.
Road Drainage	Final scheme for road drainage can be done at initial stage – minor adjustment at ultimate stage.	Requires drainage system at initial stage, and its reconstruction at ultimate stage.	Final scheme for road drainage can be done on one side only.
Access to abutting properties	Provision of access from and to the abutting properties is easy.	Provision of access road from the sidewalk to the carriageway is required.	Provision of access from one side is required.
Construction Cost	Initial cost is almost equal to Scheme 'B' , and ultimate stage cost and construction work is minimum.	Initial cost is low but ultimate stage cost and construction work is highest.	Initial cost is minimum but ultimate stage cost and construction work is higher than other schemes.
Evaluation	**Recommended**	Not recommended	Not recommended

(3) Evaluation

The expected year for widening from 2 lanes to 4 lanes is after year 2015. This means that the period of operation with initial lanes, for all Study Roads, is about 10 to 13 years. The policy of stage construction should not only focus on minimizing the initial cost but also to keep the ultimate stage construction cost and construction work low. Scheme 'A' not only meets the basic policy mentioned above but the scheme is considered to be effective in enhancing development along the streets, as the streets are accessible from either side of the road. Furthermore, providing wide open space in the middle of the street during the initial stage makes it easy to widen during the construction of the ultimate stage as encroachment is considered difficult in such case.

Therefore, Scheme A; Outer initial lane method shall be adopted for all the Study Roads.

19.4 PRELIMINARY DESIGN

19.4.1 Alignment

(1) Design Speed and Geometric Standard

The design speed and geometric standards for the Circumferential Streets and Collector Streets are summarized in Table 19.4.1-1(a) and Table 19.4.1.-1(b). The following manuals/guidelines were referred in determining the standards.

- Geometric Design Manual, The Ministry of Transport and Roads, Government of Southern Sudan 2006
- A Policy on Geometric Design of Highways and Streets, the American Association of State Highway and Transport Officials (AASHTO)
- Road Structure Guidelines, Japan Association of Roads, February 2004

Table 19.4.1-1(a) Geometric Standards for Arterial Streets (C2, C3)

Item		Unit	Geometric Standards			
			Street C2		Street C3	
			Standard	Applied	Standard	Applied
Number of Lanes		No.	4 (Final)	2 (Initial)	4 (Final)	2 (Initial)
Design Speed		km/hr	50 – 100	50	50 – 100	60
Minimum Horizontal Radius		m	86	225	135	400
Minimum Horizontal Curve Length		m	80	94	100	116
Minimum Vertical Curve	Crest	m	800	2500	1400	2800
	Sag	m	700	3000	1000	3700
Minimum Vertical Length		m	50	100	40	50
Maximum Vertical Grade		%	8	4.2	7	3.5
Cross fall		%	1-3	2.5	1-3	2.5

Table 19.4.1-1(b) Geometric Standards for Collector Streets (Lologo/Nyakuron Radial Streets)

Item		Unit	Geometric Standard	
			Standard	Applied
Number of Lanes		No.	4 (Final)	2 (Initial)
Design Speed		km/hr	50	50
Minimum Horizontal Radius		m	86	200
Minimum Horizontal Curve Length		m	80	80
Minimum Vertical Curve	Crest	m	800	6100
	Sag	m	700	1900
Minimum Vertical Length		m	50	150
Maximum Vertical Grade		%	8	3.2
Cross fall		%	1-3	2.5

(2) Horizontal Alignment

The horizontal alignment is planned based on AASHTO standards and the topographic map prepared by using satellite images of Juba and its surrounding areas acquired in March of 2009.

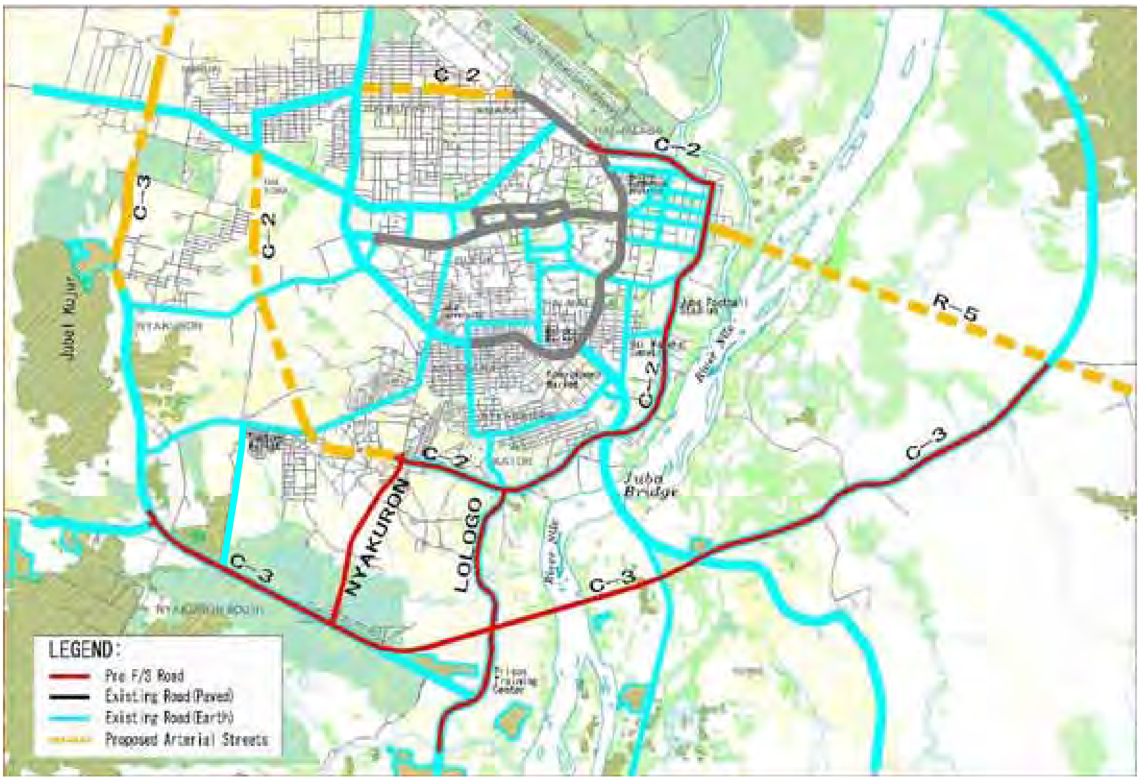


Figure 19.4.1-1 Pre-FS Streets Proposed Alignments

<u>Circumferential Streets</u>

The horizontal alignments basically follow the route determined in Chapter 18. The alignment of Circumferential Street C2 , starts from the intersection with Collector Street (Nyakuron) and proceeds east passing thru the Konyo-Konyo Market, and then towards the north passing near the Juba River Port, Hai Malakal Cemetry and the Juba Stadium. It then passes thru the Central Commercial District and ends at the intersection with the Circumferential Street C1. The total length of the alignment is about 7.9 km. The alignment is smooth for almost whole stretch with most of the curves having a radius greater than 500m. The minimum radius of curvature applied is 225m near the Juba Football Stadium. At station 6+400, the alignment takes a perpendicular bend. This point is recommended to be improved as an intersection during the construction of the adjoining street.

The horizontal alignment of Circumferential Street C3, similar to C2, starts from the intersection with Radial Street R1 on the eastern side of the Jebel Kujur Mountain and proceeds east utilizing the newly constructed 3km earth road at the Nyakuron South area. It then crosses the White Nile River, intersects with the Juba-Nimule Road (R6) and terminates at the intersection with the Juba-Lafon Road (R5) delineated by the Master Plan Study. The stretch of the alignment is about 12km and is smooth having curves of radius more than 400m.

Collector Streets

The horizontal alignments of two Collector Streets follow the route determined in Section 19.3.2 of this Chapter. The alignment of Lologo Radial Street starts from a tributary of the Nile River at Lologo south and proceeds north. The alignment takes a big S-shaped curve and intersects with C3 after passing near the Prison Training Center, and further proceeds north utilizing the existing road and ends at the intersection with C2. The alignment is about 3.6km long and is smooth through the entire stretch with the curve radius of 200 or more.

The alignment of Nyakuron Radial Street starts from the intersection with C3 and proceeds north utilizing the existing road and ends at the intersection with C2. The approximate length of the alignment is 2.2km and the minimum radius of curve applied is 200m.

(3) Vertical Alignment

The vertical alignment is determined taking into consideration the elevation of existing roads and cross roads, drainage condition and water levels at bridge and culverts sites. The alignment is planned based on the contour lines of the topographic map prepared by using satellite images of Juba and its surrounding areas acquired in December of 2006.

The terrain where the Study Roads are located is relatively flat. Although the standard value of maximum grade for design speeds 50-60km/h is 7 % to 8% for flat terrain, the maximum grade applied is 4.2 %. There are stretches in almost all Study Roads that have very flat topography where the grade is almost zero. The vertical alignment at these stretches is planned such that a minimum grade of 0.3% is maintained to facilitate road surface drainage.

A portion of C2 at the end point lies inside the Central Commercial District which is densely populated. The vertical alignment for this stretch is planned in such a way that the proposed finish level of the road has minimum effect on the roadside houses.

The horizontal alignment of C3 passes through a low land cultivated area after crossing the Nile River. An embankment structure is indispensable along this stretch and it is critical to keep the height of the embankment as low as possible so as to minimize the construction cost. The vertical alignment of this stretch is thus planned taking into consideration the elevation of the major existing roads.

19.4.2 Pavement Design

The pavement design calculation is presented in Appendix 13, which is summarized in this Section.

(1) Methodology

Pavement design is carried out based on "AASHTO Guide for Design of Pavement Structures 1993" (AASHTO Guide).

The AASHTO Guide gives the basic design equation for flexible pavement (asphalt pavement) as follows:

Basic Design Equation for Flexible Pavement

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\triangle PSI}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where

W_{18}	=	predicted number of 18-kip equivalent single axle load (ESAL) applications,
Z_R	=	standard normal deviate corresponding to level of reliability,
S_o	=	combined standard error of the traffic prediction and performance prediction,
$\triangle PSI$	=	difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t, and
M_R	=	resilient modulus of roadbed soil (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Where

a_i	=	i^{th} layer coefficient,
D_i	=	i^{th} layer thickness (inches), and
m_i	=	i^{th} layer drainage coefficient.

i=1 : Surface Course
i=2 : Base Course
i=3 : Subbase Course

(2) Design Inputs

The design inputs are shown in Table 19.4.2-1.

Table 19.4.2-1 Design Inputs

Item	Description	Design Condition	Design Input			
			C2	C3	Lologo Radial St.	Nyakuron Radial St.
Performance Period	The period of time that an initial pavement structure will last before it needs rehabilitation.	10 years	10 years (2016-2025)	10 years (2016-2025)	10 years (2021-2030)	10 years (2021-2030)
Traffic Load	The traffic load is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications (w_{18}) during the performance period.	w_{18} is calculated based on the future truck volume which is converted to 18-kip ESALs applying the axle load equivalency factors given in the AASHTO Guide.	w_{18} =13,171,000*	w_{18} =6,676,000**	w_{18} =6,349,000	w_{18} =5,407,000
Reliability	Means of incorporating some degree of certainty into the design process.	The level of reliability (R)=80 % Standard normal deviate corresponding to level of reliability (Z_R) = -0.841 Combined standard error of the traffic prediction and performance prediction (S_o) = 0.45	R=80% Z_R=-0.841 S_o=0.45	R=80% Z_R=-0.841 S_o=0.45	R=80% Z_R=-0.841 S_o=0.45	R=80% Z_R=-0.841 S_o=0.45
Performance Criteria	The Present Serviceability Index (PSI) is used to represent pavement performance. The total change in PSI (△ PSI) is defined as the difference between initial serviceability index (p_0: value immediately after construction) and terminal serviceability index (p_t: lowest index that will tolerate before rehabilitation, resurfacing or reconstruction)	p_0 = 4.2 pt = 2.5	p_0=4.2 pt=2.5 △PSI=1.7	p_0=4.2 pt=2.5 △PSI=1.7	p_0=4.2 pt=2.5 △PSI=1.7	p_0=4.2 pt=2.5 △PSI=1.7
Roadbed Soil Property	The resilient modulus (M_R) is used. The AASHTO Guide introduces the equation estimating M_R from CBR as M_R = 1,500 x CBR (CBR is regarded as 10 in case of CBR more than 10)	Other than Nyakuron Radial Road :CBR≥10 Nyakuron Radial Road: CBR=7	M_R=15,000psi (CBR≥10)	M_R=15,000psi (CBR≥10)	M_R=15,000psi (CBR≥10)	M_R=10,500psi (CBR=7)
Pavement Layer Material Properties	The pavement strength is expressed by the structural number (SN) which is calculated as : $SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$ where a_i=i^{th} layer coefficient D_i=i^{th} layer thickness (inches) m_i=i^{th} layer drainage coefficient	Asphalt concrete surface course: a_1=0.39 (E_{AC}=350,000 psi) Granular base course: a_2=0.135 (CBR=80) Granular subbase course: a_3=0.094 (CBR=20)	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094
Drainage Condition	The factor to modify the SN considering the effects of drainage.	m_2=m_3=1.0 (water removed within 1 week, and pavement structure is exposed to moisture levels approaching saturation during 5% of the year)	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0

* C2, Section 2 (High traffic volume section in C2, excluding the northern section within the Central Commercial District, which is discussed in Chapter 17.5.2.)
** C3, Section 2 (High traffic volume section in C3)

(3) Design

Required Structural Number

Table 19.4.2-2 shows the required structural number.

Table 19.4.2-2 Required Structural Number

		C-2	C-3	Lologo Radial Street	Nyakuron Radial Street
Inputs	W_{18}	13,171,000	6,676,000	6,349,000	5,407,000
	Z_R	-0.841	-0.841	-0.841	-0.841
	S_o	0.45	0.45	0.45	0.45
	△PSI	1.7	1.7	1.7	1.7
	M_R	15,000	15,000	15,000	10,500
Required SN		**3.776**	**3.381**	**3.353**	**3.738**

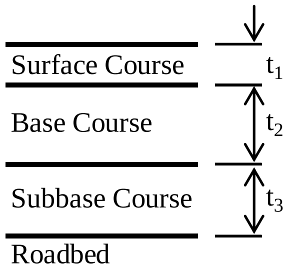
Selection of Layer Thicknesses

Table 19.4.2-3 shows the thicknesses selected.

Table 19.4.2-3 Layer Thicknesses Selected

		C-2	C-3	Lologo Radial Street	Naykuron Radial Street
Thickness	Surface Course (t_1)	10 cm	10 cm	10 cm	10 cm
	Base Course (t_2)	20 cm	15 cm	15 cm	20 cm
	Subbase Course (t_3)	35 cm	30 cm	30 cm	35 cm
	Total	65 cm	55 cm	55 cm	65 cm
Structural Number (SN)		3.893	3.442	3.442	3 893

Required Structural Number	3.776	3.381	3.353	3.738



The structural number (SN) is superior to the required.

19.4.3 Drainage Design

Provision of the drainage system is one of the most important factors to keep the streets in a safe condition for traffic and to extend the life of road structures, especially for the pavement. The drainage system consists of road surface drainage and road side drainage.

(1) Road Surface Drainage

To facilitate road surface drainage, L-shaped gutter with collector pipe are provided at both sides of the roads. From the existing condition of Juba, small diameter pipes are likely to be filled-up soon by soil and garbage causing maintenance problems. Therefore, the collector pipe of 900mm in diameter is planned to be provided for all Study Roads.

The initial section of the streets is constructed at the outer side, leaving a wide space in the middle. Water falling in this area should also be collected and discharged properly. For this purpose, an earth ditch (1000/500 x 500) is planned at the middle of the street. The water collected by the earth ditch will be discharged to the collector pipes of the lateral drainage by means of a catch basin and pipe culverts. Catch basins are planned to be provided at every 100m interval. Pipe culvert of diameter 900mm protected completely (360 degrees) by concrete is provided for connecting the catch basin with the lateral drainage.

The road drainages mentioned above needs to be properly connected to the designated outlets such as canal, ponds/lakes, river etc. so that water collected shall be effectively discharged. The details of these drainage structures are shown in the Preliminary Design Drawings in 19.4.8.

(2) Road Side Drainage

The road section which is basically an embankment in structure, as the proposed heights are higher than the existing ground level, is likely to block the natural flow of water. In order to protect the road structure from potential damage caused by floods during rainfall, earth ditch, as illustrated in Figure 19.4.3-1, should be provided at embankment sections where water collected at the toe of the embankment could endanger the structure of the road. As mentioned above, the ditch should be connected properly to the outlets.

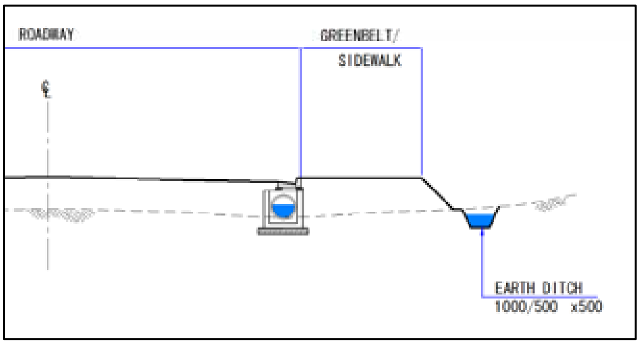


Figure 19.4.3-1 Road Side Drainage

Furthermore, for cross drainage, concrete pipe culverts of 1200 mm in diameter should be provided at an approximate interval of 250 meters along these stretches in order to allow free flow of water to the existing outlet.

19.4.4 Intersection Design

Traffic volume in and within Juba urban area is increasing rapidly with the increase of return of the IDPs and migrants from remote areas. As such, lack of proper traffic control systems at intersections have resulted in turning these points to bottlenecks of road network causing severe traffic congestion and increase of potential hazards against the pedestrians.

Under such circumstances, it is very important that the intersections are properly controlled so as to secure the traffic safety and efficient vehicle and pedestrian operation. This Study shall thus identify the critical intersections along the Study Roads, determine the type of intersection and conduct a preliminary design on the improvement of the intersections selected.

(1) Identification of Intersections

The Study Roads cross existing and newly proposed streets at many locations. Among them, the following points as shown in Figure 19.4.4-1 are identified as intersections to be taken for the preliminary design.

- The places where Circumferential Streets C2 or C3 join or cross Arterial Streets (Circumferential or Radial Streets)
- The places where Lologo and Nyakuron Radial Streets cross C2 and C3.

Other intersections are classified as minor intersections proposed to be treated as non signalized intersections controlled by provision of stop lines and road signs.

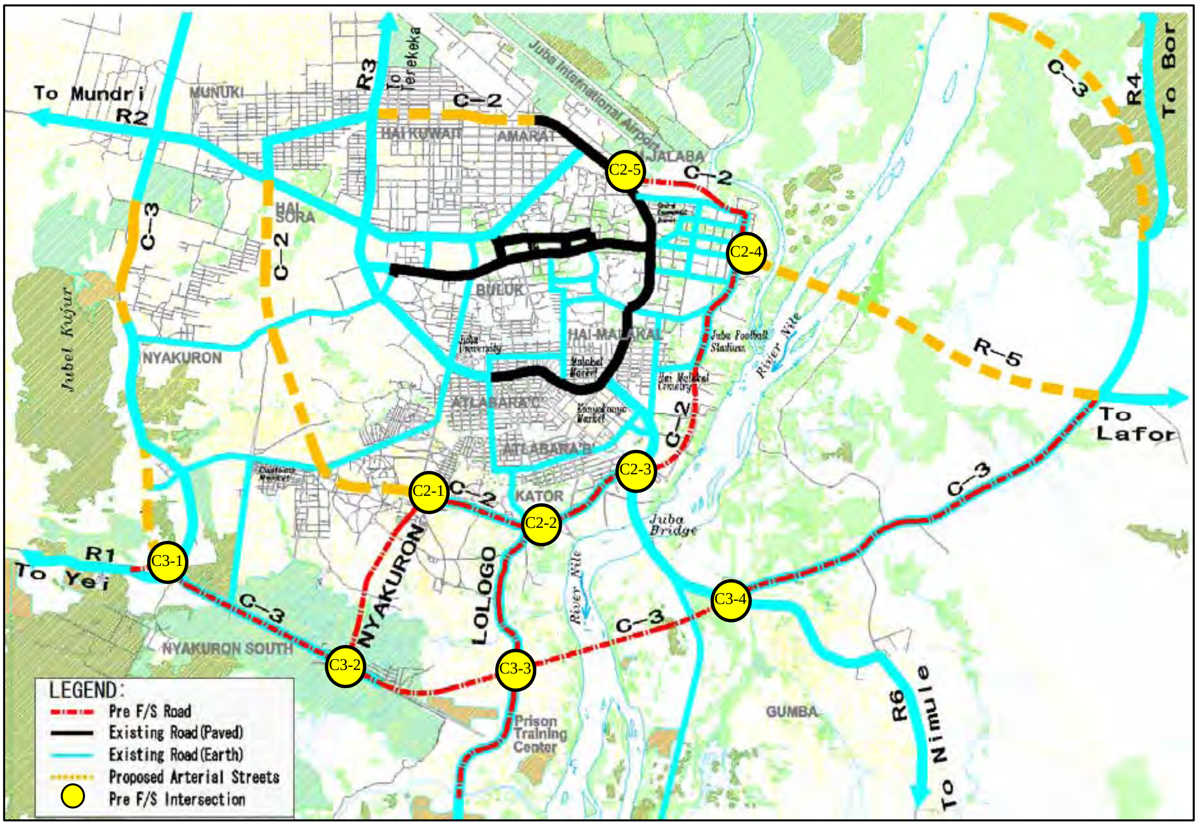


Figure 19.4.4-1 Location of Major Intersections to be Studied

(2) Applicable Type of Intersection

The types of intersections applicable for the identified 9 intersections are as follows;

- Non-signalized intersection (stop sign)
- Signalized Intersection
- Roundabout
- Signalized roundabout

(3) Conditions for Evaluation of Applicable Intersection Type

The conditions for evaluating the type of intersection applicable for the above 9 intersections are as follows;

- The estimated daily traffic volume of year 2015/2025 shall be applied assuming the peak hour factor of 0.10 (based on the traffic result).
- Non-signalized intersection shall be applied where the total traffic volume entering the intersection is less than 1,000 vehicle per hour.
- Traffic capacity at the signalized intersection (approach lane and exit lane) is assumed 1,500 PCU (passenger car unit) per hour per lane. Traffic capacity at signalized intersection shall be determined by the number of approach lanes, while traffic volume to be considered shall be determined by taking the higher values of the volumes of the approach lanes on opposite side (i.e. sum of the higher values of either north or south bound and east or west bound lanes).
- Traffic capacity of roundabout shall be determined by the number of circulatory lanes. The capacity of the circulatory lane is assumed 2,000PCU per lane. Traffic volume passing through the intersection shall be determined by the sum of traffic entering into the roundabout from all approaching legs.
- Roundabouts shall be planned in accordance with the planning guide as shown in Table 19.4.4-1 provided that the necessary road reserve is available or easily acquired.

Table 19.4.4-1 Uses of Roundabouts According to Road Class

	Arterial	Sub-Arterial	Collector
Arterial	B	B	C
Sub-Arterial		B	B
Collector			A
Notation:	A: appropriate B: acceptable C: not appropriate		

Source: Guide to Traffic Engineering Practice, Roundabout, AUSTROADS,1993

The relation between the size of roundabout and its traffic capacity is shown in Table 19.4.4-2.

Table 19.4.4-2 Traffic Capacity of Roundabout by its Size

Roundabout Inscribed Diameter (m)	Traffic Capacity (vehicle/hour)
25 to 30	Less than 1,500
30 to 40	Less than 2,000
45 to 55	Less than 4,000

Note: Edited from Guide to Traffic Engineering Practice, Roundabout, AUSTROADS, 1993

- Signalized intersection shall be applied under the following circumstances.
  - At intersections where the traffic volume exceeds the traffic capacity of roundabout or the road reserve necessary for roundabout is difficult to be acquired.
  - At intersections where securing enough weaving length is considered difficult. This is usually noticed at intersections where the cross roads are skewed or located in a small radius curve.
  - When the intersection is located in the sag or crest of the profile or when the vertical grade exceeds 2.5%.
- Signalized roundabout shall be excluded from the scope of the preliminary design as it is usually applied in case of a very high traffic volume, that is not applicable to the subject intersections.

(4) Estimated Traffic Volume

The estimated traffic volume for each direction of the objective intersections for the year 2015 and 2025 are shown in Table 19.4.4-3.

Table 19.4.4-3 Future Traffic Volume

Inter-section No.	Intersecting Roads	Functional Road Classification	No. of Legs	Traffic Volume									
				Year 2015					Year 2025				
				North	South	East	West	Section Total	North	South	East	West	Section Total
C2-1	C2/ CSB	Arterial/ Collector	3	-	455	1,125	740	2,320	1,120	1,015	1,205	855	4,195
C2-2	C2/ CSA	Arterial/ Collector	3	-	455	710	820	1,985	-	1,050	1,320	925	3,295
C2-3	C2/ R6(Lafon)	Arterial/ Arterial	4	720	1,055	480	640	2,895	900	1,185	695	1,110	3,890
C2-4	C2/ R5(Nimule)	Arterial/ Arterial	3	630	1,185	-	745	2,560	1,680	1,730	2,445	470	6,325
C2-5	C2/ C1	Arterial/ Arterial	3	1,065	560	560	-	2,185	1,780	830	1,475	-	4,085
C3-1	C3/ R1(Yei)	Arterial/ Arterial	3	760	-	745	615	2,120	2,105	-	1,515	915	4,535
C3-2	C3/ CSB	Arterial/ Collector	3	445	-	480	745	1,670	665	600	1,755	1,515	4,535
C3-3	C3/ CSA	Arterial/ Collector	4	230	445	460	450	1,585	980	940	1,560	1,755	5,235
C3-4	C3/ R6(Lafon)	Arterial/ Arterial	4	745	740	120	335	1,940	990	945	1,720	1,580	5,235

Note: Traffic volume is estimated assuming a peak hour traffic ratio of 10%.

(5) Traffic Capacity Analysis

A simplified traffic capacity analysis for roundabout and signalized intersection for the year 2015 and 2025 is carried out. The results are shown in Table 19.4.4-4.

Table 19.4.4-4 Simplified Analysis of Traffic Capacity at Intersections

Inter-section No.	Intersecting Roads	Functional Road Classification	No. of Legs	YEAR 2015							YEAR 2025						
				Roundabout		Signalized Intersection					Roundabout		Signalized Intersection				
				No of Cir. Lanes	VCR	No. of Approach Lanes				VCR	No of Cir. Lanes	VCR	No. of Approach Lanes				VCR
C2-1	C2/ CSB	Arterial/ Collector	3	2	0.58	3	3	2	2	0.35	2	1.05	4	4	3	3	0.37
C2-2	C2/ CSA	Arterial/ Collector	3	2	0.50	2	2	2	2	0.43	2	0.82	3	3	3	3	0.53
C2-3	C2/ R6(Lafon)	Arterial/ Arterial	4	2	0.72	3	3	2	2	0.38	2	0.97	4	4	3	3	0.38
C2-4	C2/ R5(Nimule)	Arterial/ Arterial	3	2	0.64	2	2	2	2	0.64	2	1.58	2	2	2	2	1.39
C2-5	C2/ C1	Arterial/ Arterial	3	2	0.55	2	2	2	2	0.54	2	1.02	3	3	3	3	0.72
C3-1	C3/ R1(Yei)	Arterial/ Arterial	3	2	0.53	2	2	2	2	0.50	2	1.13	3	3	3	3	0.80
C3-2	C3/ CSB	Arterial/ Collector	3	2	0.42	2	2	2	2	0.40	2	1.13	3	3	3	3	0.54
C3-3	C3/ CSA	Arterial/ Collector	4	2	0.40	3	3	3	3	0.20	2	1.31	4	4	4	4	0.46
C3-4	C3/ R6(Lafon)	Arterial/ Arterial	4	2	0.49	3	3	3	3	0.24	2	1.31	4	4	4	4	0.45

Note: VCR: volume to capacity ratio

The above VCR analysis indicates that traffic capacity of roundabout as well as signalized intersection for year 2015 is less than 1.

However, VCR analysis results for the year 2025 indicates that seven out of nine locations have VCR exceeding 1.0 for roundabouts. The VCR of the other two locations is almost equal to 1, indicating the traffic volume, if increasing slightly, will exceed the capacity of the roundabout.

On the other hand, traffic volume of signalized intersection is less than traffic capacity for all locations in year 2015. Even in the year 2025, all locations have VCR of less than 1, except the intersection C2-4.

(6) Determination of Intersection Type

The future traffic volume in Table 19.4.4-3 shows that non-signalized intersection is not applicable at any location as the total traffic volume exceeds 1,000 vehicle per hour even in the year 2015. As such, either roundabout or signalized intersection is considered to be applicable for the locations considered.

The traffic capacity analysis indicates that the roundabout is applicable for all locations until year 2015. However, from the conditions of availability of road reserves, vertical grade at the intersection and crossing angles, application of roundabout is considered to be inappropriate, as shown in Table 19.4.4-5. Furthermore, the traffic capacity for the year 2025 shows that all intersections require a signalized intersection.
Therefore, from reasons mentioned above, signalized intersection is recommended for all intersections identified in this Study.

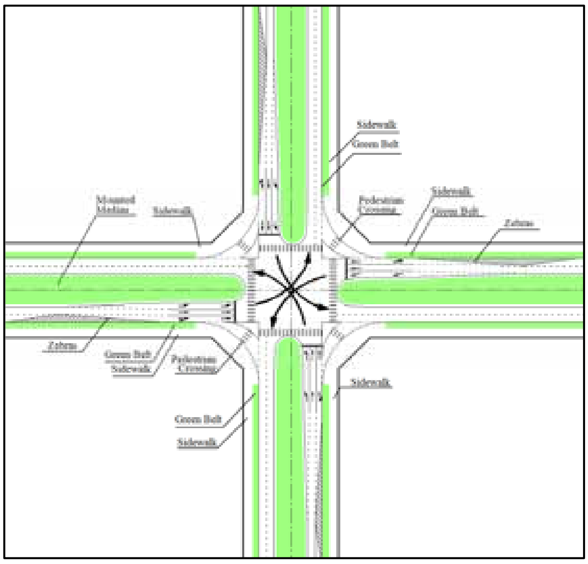
Table 19.4.4-5 Determination of Intersection Type

Inter-section No.	No. of Legs	VCR Analysis (2015 YEAR)			VCR Analysis (2025 YEAR)			Road Reserve Availability	Vertical Grade	Recommended Type
		Roundabout	Signalized Intersection	Applicable Type	Roundabout	Signalized Intersection	Applicable Type			
C2-1	3	0.58	0.35	RB or I/S	1.05	0.37	I/S	Yes	0.4	Signalized Intersection
C2-2	3	0.50	0.43	RB or I/S	0.82	0.53	RB or I/S	Yes	4.2 ✕	
C2-3	4	0.72	0.38	RB or I/S	0.97	0.38	RB or I/S	Difficult ✕	0.7	
C2-4	3	0.64	0.64	RB or I/S	1.58	1.39	I/S	Difficult ✕	2.3	
C2-5	3	0.55	0.54	RB or I/S	1.02	0.72	I/S	Difficult ✕	0.3	
C3-1	3	0.53	0.50	RB or I/S	1.13	0.80	I/S	Yes	1.4	
C3-2	3	0.42	0.40	RB or I/S	1.13	0.54	I/S	Yes	0.4	
C3-3	4	0.40	0.20	RB or I/S	1.31	0.46	I/S	Yes	2.0	
C3-4	4	0.49	0.24	RB or I/S	1.31	0.45	I/S	Yes	0.5	

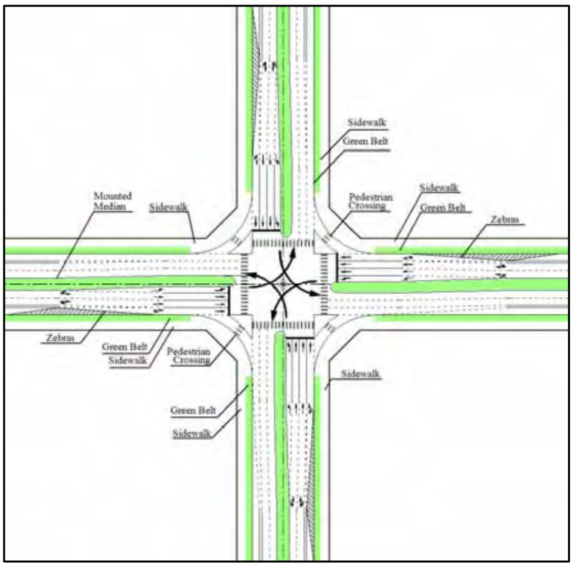
Note: RB: Roundabout, I/S: Signalized Intersection
✕ shows that the roundabout type is not applicable.

(7) Typical Plan of Proposed Intersection

The typical plan of recommended signalized intersection at initial and ultimate stages are illustrated in Figure 19.4.4-2.



a) Initial Stage



b) Ultimate Stage

Figure 19.4.4-2 Typical Plan of Proposed Signalized Intersection

19.4.5 Structure Design

The major road structures required along the Study Roads (C2, C3, CSA and CSB) are bridges and culverts, necessary to provide the openings for streams and rivers. Table 19.4.5-1 summarizes these structural requirements while Figure19.4.5-1 shows the locations and basic scale of these structures.

Table 19.4.5-1 Structures Along the Study Roads

Study Road	No. of Bridge Locations	No. of Culvert Locations
C2	2	7
C3	6	6
CSA in Lologo	2	3
CSB in Nyakuron	1	4

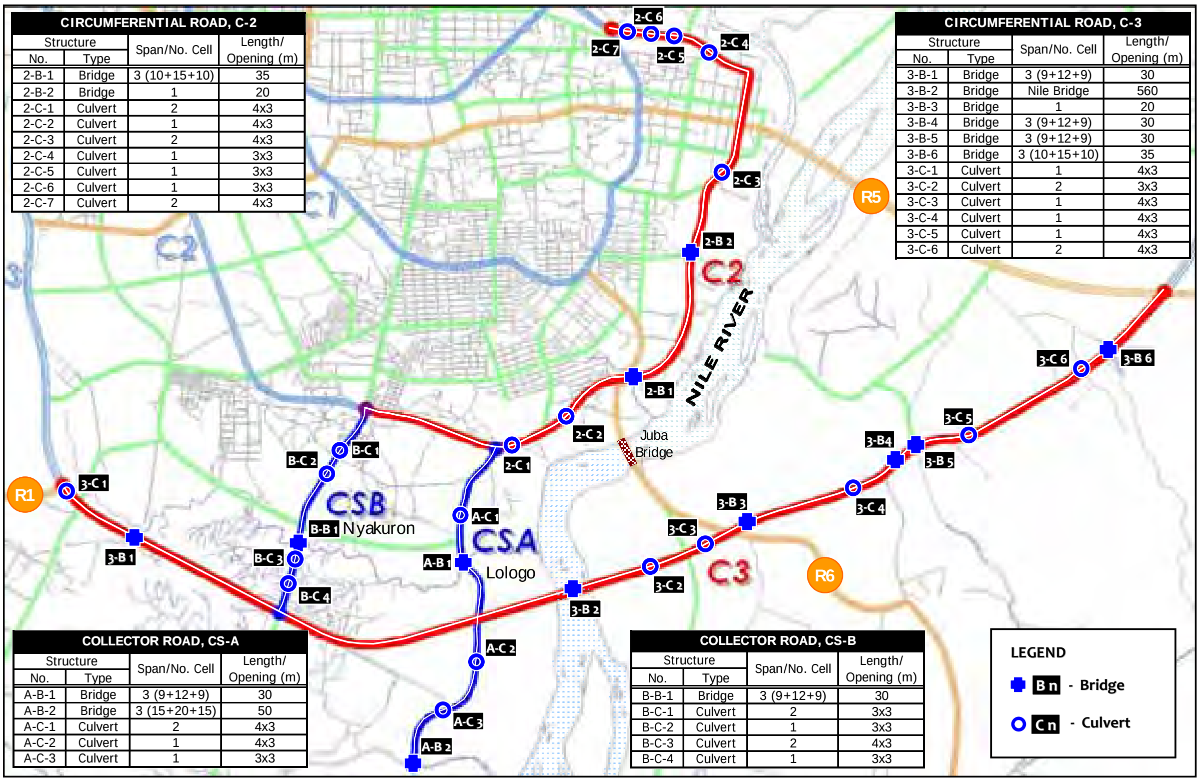


Figure 19.4.5-1 Locations and Basic Scales of Structures along the Study Roads

(1) Bridge and Culvert Planning and Design Policy

The following planning and design policies apply to the bridges and culverts along the Study Roads:

- <u>Provision of Sufficient Stream/River Opening</u>

  Where the proposed road alignment encounters obstacles such as streams and rivers, culvert or bridge structures are provided as cross-drainage facilities to allow uninterrupted traffic flow and discharge of water. Culverts and bridge openings shall be sufficient to allow discharge of the design flood water with sufficient freeboard. In any case, culverts and bridges shall not constrict the existing width of the streams or rivers.

- Consistency with Road Cross-Section
  The bridge deck sections and the bridge alignment/geometry shall be consistent with the road section where the structure is provided. The curb-to-curb width of the road, carriageway/traveledway including shoulders, shall be maintained in the bridge when the bridge length is not more than 60m. However, multi-purpose lanes provided in the approach roads shall not necessarily be carried over to the bridge section.

- Provision of Sidewalks
  Space for non-motorized vehicles such as sidewalks provided in the road section shall also be provided in the bridge deck section to separate pedestrians and non-motorized transport modes from motorized traffic.

- Consistency with Local Design Standards and Guidelines
  Culverts and bridge structures shall be designed based on the current design guidelines and specifications in the Southern Sudan and shall consider the present load demands.

- Choice of Bridge Type and Materials
  The choice of bridge type, materials and details shall be based on the locally available materials, equipment and technology with minimal maintenance requirements.

- Stage Construction
  Since the present traffic demand does not require the construction of the full road width and number of lanes necessary for the Arterial and Collector Streets under consideration, the design of bridge shall consider the stage construction proposed for the road sections, (except near intersections where bridges have to be constructed for the full road section – C2-B1 and C3-B3). In the case of stage construction, the bridge geometry and sections shall follow a staging sequence that will allow ease of expanding/widening the bridge to the final stage.

  On the other hand, culverts shall be constructed for the full road width section at the initial stage.

- Minimal Impacts
  Culverts and bridges shall be designed so as to give the minimal social and environmental impacts.

(2) Design Specification and Standards

The basic design requirements for culverts and bridges will be based on the recommendations of the following standards and specifications:

- Geometric Design Manual, Ministry of Transport and Roads, GOSS, 2006.
- Bridge Design Manual, Ministry of Transport and Roads, GOSS, 2006.
- Drainage Design Manual, Ministry of Transport and Roads, GOSS, 2006

However, when the above guidelines do not cover other aspects of design or when a safer and more efficient requirement is needed, the design of culverts and bridges shall refer to other standards, including:

- AASHTO LRFD Bridge Design Specifications, 4th Ed., 2007
- AASHTO Standard Specifications for Highway Bridges, 17th Ed., 2002
- Specifications for Highway Bridges, Japan Road Association, 2002
- Specification for River Facilities, Japan River Association, 1998.

(3) Bridge Deck Geometry and Cross-Section in Consideration of Stage Construction

In the bridge and culvert sections, especially the carriageway/traveledway and shoulders, the horizontal alignment and vertical profile follow, in principle, the geometry of the road section where the bridge is located (as discussed in Section 19.4.1). However, the cross-section geometry of bridges is decided based on the stage construction sequence of the road section. The cross-section elements for bridges and culverts are indicated in Table 19.4.5-2. As seen in the Table, some elements of the road sections including greenbelt, multi-purpose lane and median are not carried over to the bridge.

Table 19.4.5-2 Cross-Section Elements for Bridge and Culvert

Item / Road Class	Arterial Streets (C2 & C3)		Collector Streets (CSA & CSB)	
	Road Section	Bridge Section	Road Section	Bridge Section
Function	Interstate trunk road; primary distributor; district distributor		Access roads connecting local roads and local distributor	
Design Speed (km/hr)	60, 50		60, 50, 40	
Lane Width (m)	3.6	3.6	3.3	3.3
Median (m)*	5.0	-	4.0	-
Multi-purpose Lane (m)	3.5	-	3.5	-
Shoulder	1.2	1.2	0.6	0.6
Greenbelt	3.0	-	2.0	-
Sidewalk	4.5	2.5	2.5	2.5

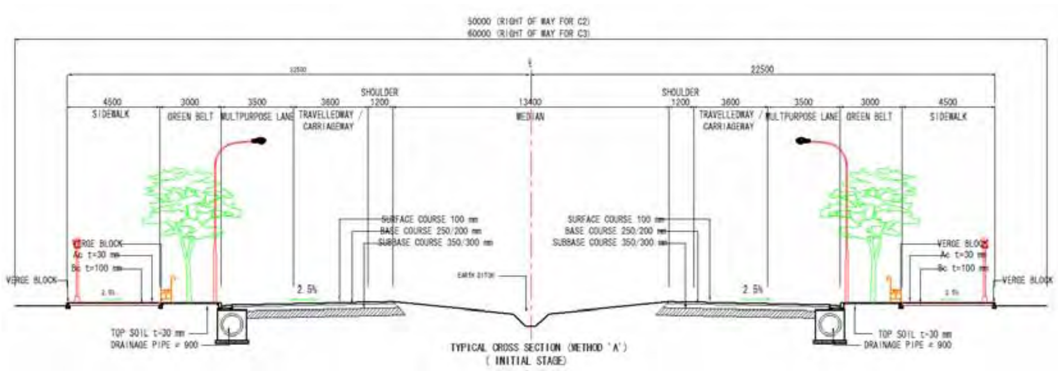
Note: *Median is not necessary on bridge section since two separate 2-lane bridges will be constructed in stages.

Since the traffic demand projection indicates that at the initial stage of road development, only two lanes are necessary until year 2015. In this regard, the road construction is proposed to be done in two stages to minimize initial investment costs for the road infrastructure and widened before the year 2025. Following this concept, the bridges are proposed to be constructed similarly in two stages as follows:

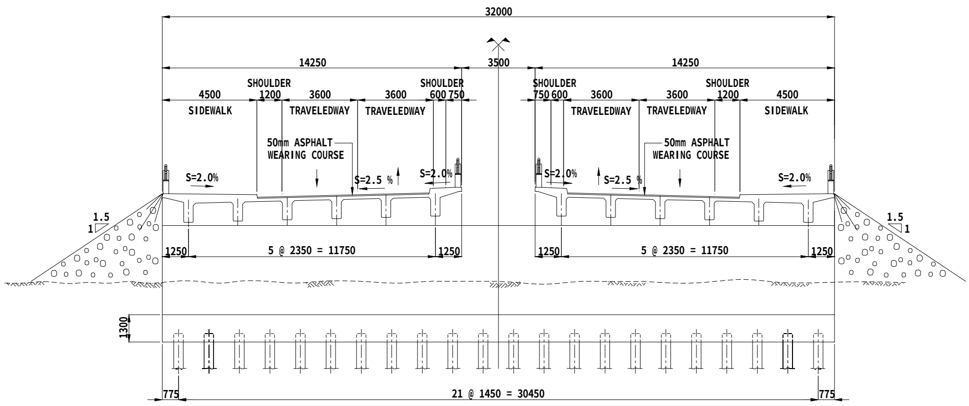
- Stage 1 – Initial stage construction involves construction of a two-lane bridge in one side of the road alignment. This option is considered more efficient and economical compared to constructing the initial bridge at the middle of the road alignment – since in this case the final stage will require widening on both sides of the bridge. On the other hand, when the bridge for the initial stage is constructed on one side, the four-lane final stage can be achieved by constructing another two-lane bridge on the other side.

- Stage 2 – Final or ultimate stage construction involves constructing the remaining two-lane bridge on the opposite side.

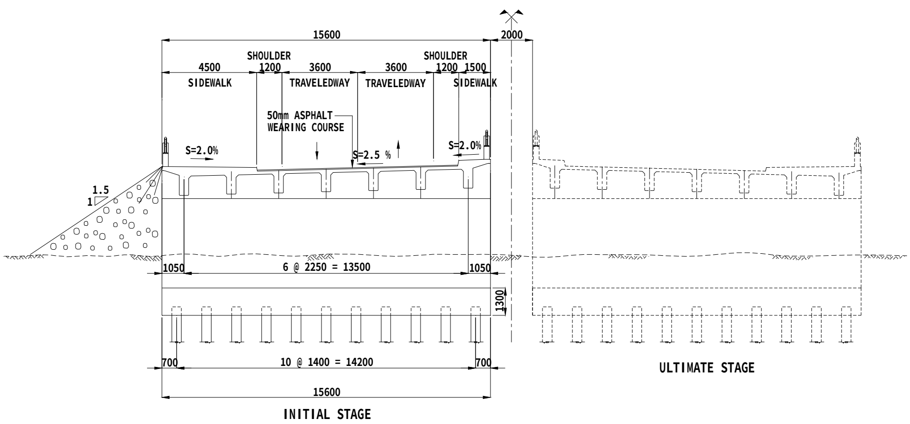
Figure 19.4.5-2 shows the proposed bridge and culvert cross-sections for the initial stage and full bridge construction and the culvert cross-section for the Circumferential Streets C2 and C3 while Figure 19.4.5-3 illustrates the bridge and culvert cross-sections for Collector Streets CSA and CSB.



(a) Typical Initial Stage Cross-Section for Circumferential Street

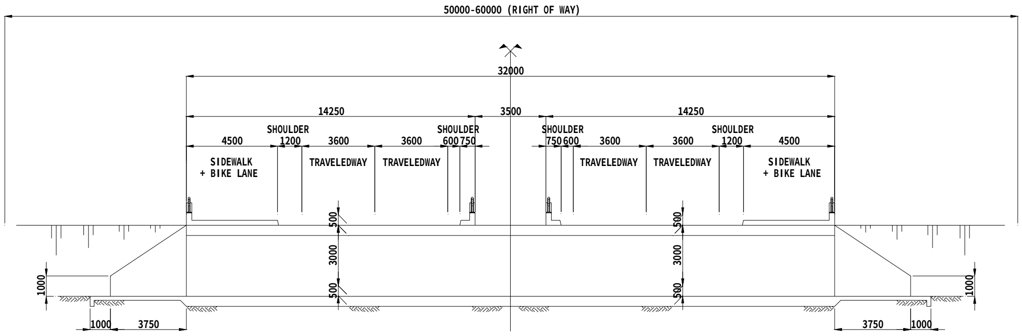


(b) Typical Full Bridge Section of C2-B1 and C3-B3



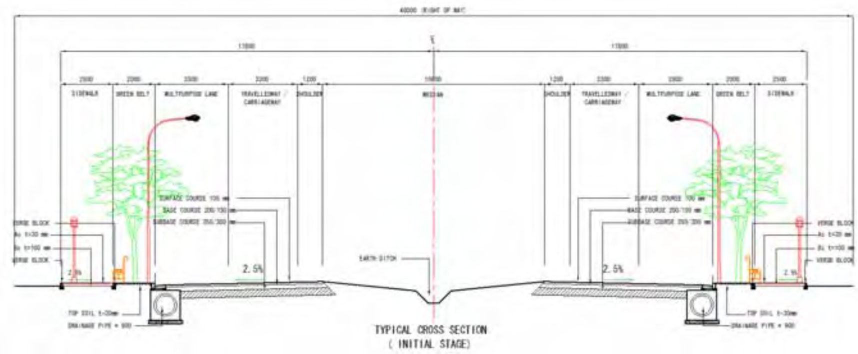
(c) Typical Initial Stage Bridge Section on Circumferential Streets (except C2-B1 & C3-B3)

Figure 19.4.5-2 (1) Typical Cross-Sections of Bridges on Circumferential Streets

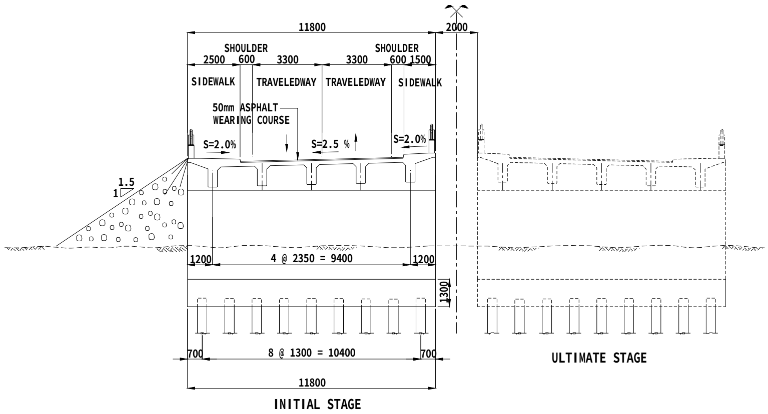


(d) Typical Culvert Section on Circumferential Streets C2 & C3

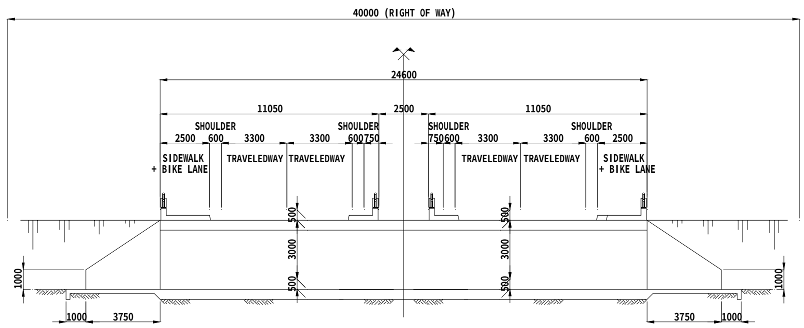
Figure 19.4.5-2 (2) Typical Cross-Sections of Culverts on Circumferential Streets



(a) Typical Initial Stage Cross-Section for Collector Street



(b) Typical Initial Stage Bridge Section on Collector Streets CSA & CSB



(c) Typical Culvert Section on Collector Streets CSA & CSB

Figure 19.4.5-3 Typical Cross-Sections of Bridge/Culverts on Collector Streets

(4) Existing Conditions

The existing conditions of bridge and culvert sites along the Study Roads are shown in Figure 19.4.5-4.

Figure 19.4.5-4 Existing Conditions of Study Roads at Bridge/Culvert Sites

As presented earlier in Table 19.4.5-1 and Figure 19.4.5-1, there are 31 streams, rivers and depression crossings along the Study Roads. These locations are identified from the satellite images and confirmed at sites. Three bridge and culvert structures are found at present on the existing C2 road alignment, three in C3 and one in CSA. Basically, the bridges along C2 and CSA are concrete deck bridges on Steel H-beam girders while the two bridges in C3 are steel bailey bridges. The existing Juba Bridge crossing the Nile River is a steel truss of Mabey and Johnson bridge type.

(5) Preliminary Design

1) Design Loads

The design loads follow the requirements of the MTR "Bridge Design Manual" including dead loads, vehicular live load (HL93), wind load, stream pressures, temperature changes and seismic provisions. Other load requirements can be referred to AASHTO Bridge Design Specifications.

Section 2.2.4 of this Report presents a very limited record of seismic activity in Juba area with the highest earthquake excitation recorded in May 24, 1990 with a magnitude of 7.1 (refer to Table 2.2.4-1). Since there have been records of previous seismic activities around Juba, bridges and structures shall be designed considering seismic excitations.

2) Design Flood and Freeboard Height

The design flood frequency shall be 1 in 50 years with a minimum vertical clearance (freeboard height) at design flood level (DFL) indicated in Table 19.4.5-3 below:

Table 19.4.5-3 Vertical Clearance According to Flood Discharge

Discharge, Q (m^3/sec)	Vertical Clearance (m)
0 – 3	0.30
3 – 30	0.60
30 – 300	0.90
> 300	1.20

3) Bridge Lengths and Culvert Openings

The bridge lengths and culvert openings are basically decided by:

- the existing topography and bank to bank width of the streams and rivers; the proposed opening lengths shall not constrict the existing opening, and
- the extent of the design flood.

Figure 19.4.5-1 summarizes the proposed bridge lengths and culvert openings for the different road projects.

4) Superstructure and Substructure

Since the proposed bridges have short spans, reinforced concrete deck on reinforced concrete girders is proposed as the superstructure type. This is basically the simplest form (considering the present available technology), most economical for spans of 20 m or less and will require less maintenance compared to steel structures.

Similarly the proposed substructures are of reinforced concrete. Since no geotechnical investigation is carried-out in this Study, pile foundation is assumed for the purpose of cost estimate. An appropriate foundation type shall be selected during the detailed design.

The concrete strength is assumed as shown in Table 19.4.5-4.

Table 19.4.5-4 Assumed Concrete Strength

Structural Element/Member		Concrete Grade*	Strength, f'c (MPa)**
Superstructure	Deck Slab	C30	24
	Barriers, Railing and Curbs	C30	24
Substructure	Abutment, Wing Wall and Pier	C30	24
	Leveling Concrete	C20	16
Foundation	Pile Cap	C30	24
	Spread Footing	C30	24
Pile	RC Cast-in-Place	C30	24
Retaining Wall	RC Retaining Wall	C30	24
Box Culvert	Top and Bottom Slab, Walls, Wing Walls, Aprons	C30	24
Revetment/Slope Protection	Plain Concrete	C20	16

*Source: MTR Bridge Design Manual, 2006

**28^{th} Day, 150mm cylinders

Reinforcing bars and/or deformed steel bars for concrete shall conform to the requirements of AASHTO M 31 (ASTM A615). Deformed and plain billet steel bars for concrete reinforcement shall be Grade 40 (fy = 276MPa) or Grade 60 (fy = 415MPa) or ASTM A 706.

5) Summary of Preliminary Design of Structure

The basic dimensions of the proposed structures along the Study Roads: C2, C3, CSA (Lologo) and CSB (Nyakuron) are presented in Tables 19.4.5-5 to 19.4.5-8 and shown in Figures 19.4.5-5 to 19.4.5-7.

Table 19.4.5-5 Schedule of Structures Along C2

Structure		Width (m)	Span	Total Length (m)
No.	Type			
2-B-1	3-Span RC bridge on pile foundation	28.5	10m + 15m + 10m	35
2-B-2	1-Span RC bridge on pile foundation	15.6	20m	20
2-C-1	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	32
2-C-2	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	32
2-C-3	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	32
2-C-4	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	32
2-C-5	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	32
2-C-6	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	32
2-C-7	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	32

Table 19.4.5-6 Schedule of Structures Along C3

Structure		Width (m)	Span	Total Length (m)
No.	Type			
3-B-1	3-Span RC bridge on pile foundation	15.6	10m + 15m + 10m	35
3-B-2	Nile River bridge	560	See Section 19.4.6	560
3-B-3	1-Span RC bridge on pile foundation	28.5	20	20
3-B-4	3-Span RC bridge on pile foundation	15.6	9m + 12m + 9m	30
3-B-5	3-Span RC bridge on pile foundation	15.6	9m + 12m + 9m	30
3-B-6	3-Span RC bridge on pile foundation	15.6	10m + 15m + 10m	35
3-C-1	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	32
3-C-2	2-Cell RC culvert (2-3x3)	7.2	Opening – 2@3m	32
3-C-3	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	32
3-C-4	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	32
3-C-5	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	32
3-C-6	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	32

Table 19.4.5-7 Schedule of Structures Along CSA

Structure		Width (m)	Span	Total Length (m)
No.	Type			
A-B-1	3-Span RC bridge on pile foundation	11.8	9m + 12m + 9m	30
A-B-2	3-Span RC bridge on pile foundation	11.8	15m + 20m + 15m	50
A-C-1	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	24.6
A-C-2	1-Cell RC culvert (1-4x3)	4.8	Opening – 1@4m	24.6
A-C-3	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	24.6

Table 19.4.5-8 Schedule of Structures Along CSB

Structure		Width (m)	Span	Total Length (m)
No.	Type			
B-B-1	3-Span RC bridge on pile foundation	11.8	9m + 12m + 9m	30
A-C-1	2-Cell RC culvert (2-3x3)	7.2	Opening – 2@3m	24.6
A-C-2	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	24.6
A-C-3	2-Cell RC culvert (2-4x3)	9.2	Opening – 2@4m	24.6
A-C-4	1-Cell RC culvert (1-3x3)	3.8	Opening – 1@3m	24.6

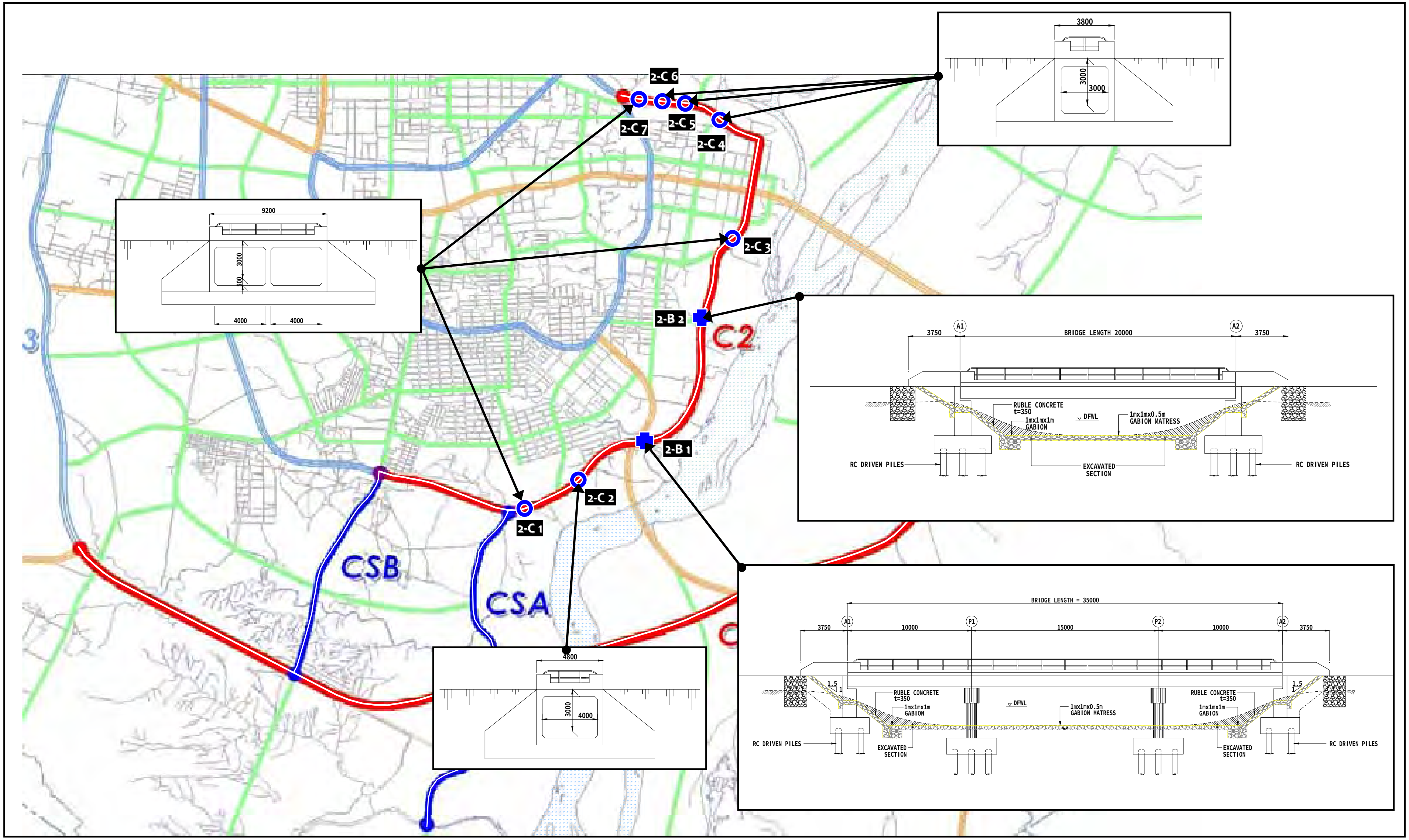


Figure 19.4.5-5 Proposed Structures Along C2

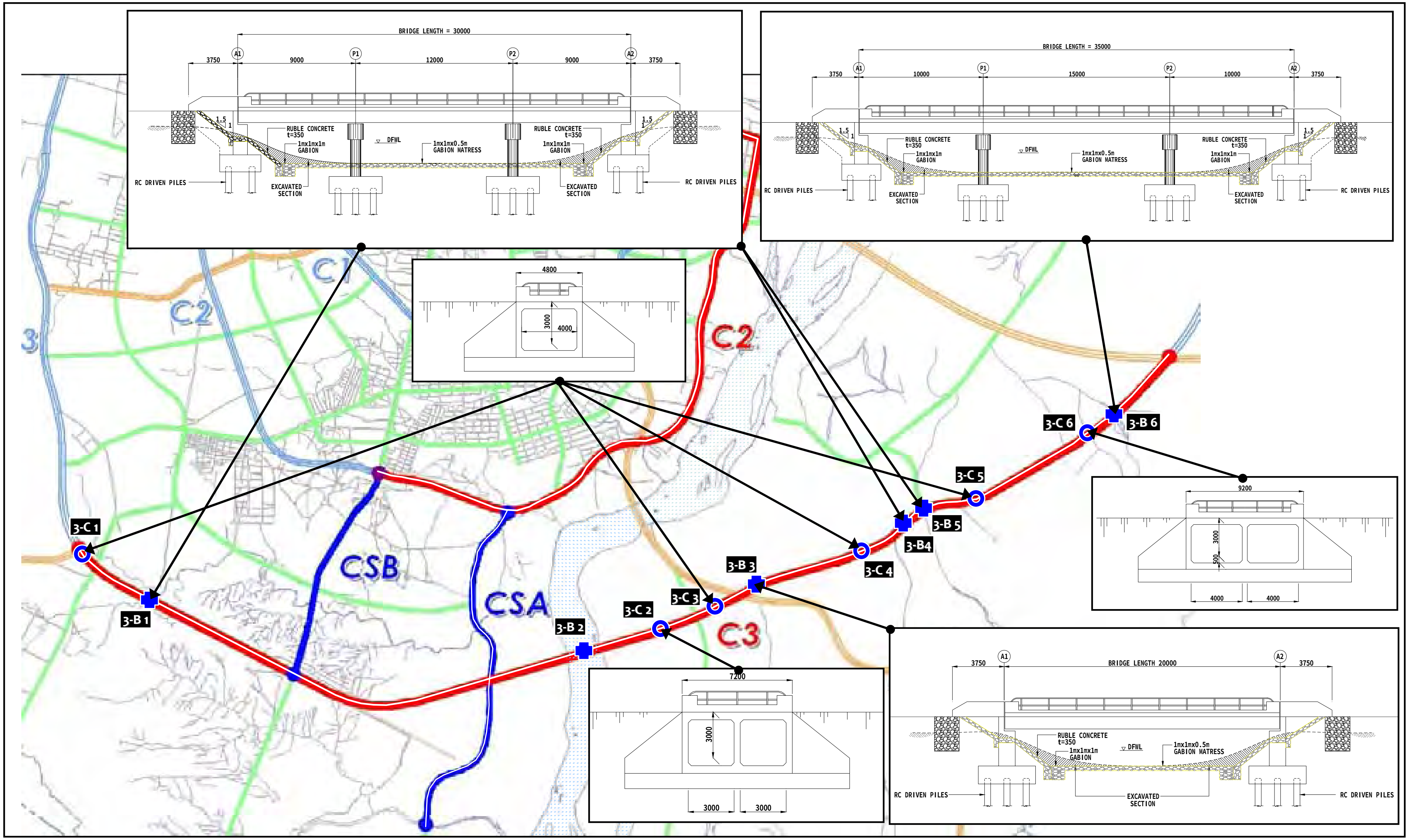


Figure 19.4.5-6 Proposed Structures Along C3

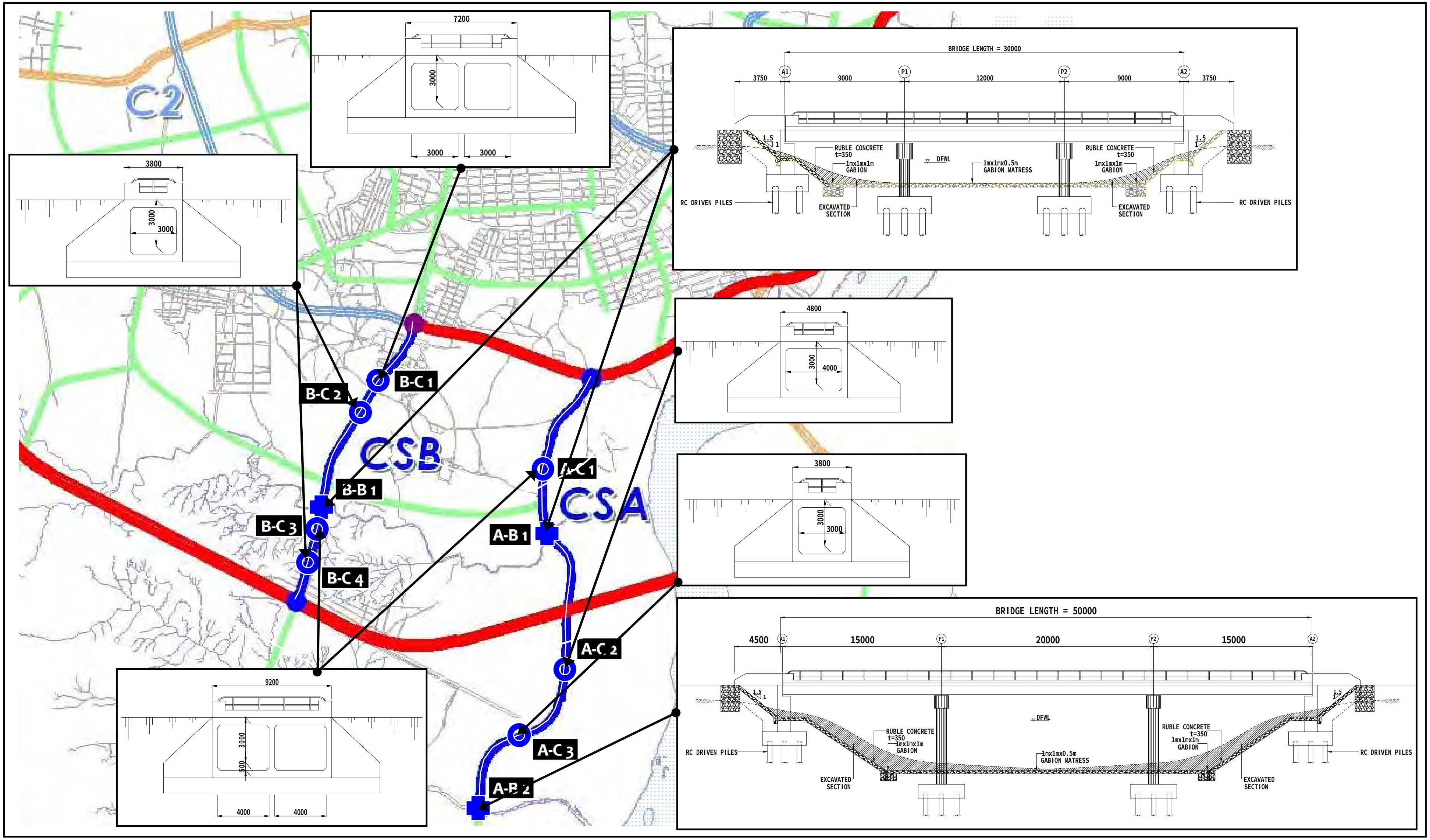


Figure 19.4.5-7 Proposed Structures Along CSA (in Lologo) and CSB (in Nyakuron)