Chapter 8 Preliminary Design of Flood Control Structures

8.1 Dam

The selection of dam sites in the Nadi River basin is described in detail in the section 6.3.1. Hereafter the preliminary design of the dam at NAD-3 dam site is described. The dam is adopted in the Master Plan and located in the main stream of Nadi River.

The preliminary design of dam is carried out based in [Revised Edition, Ministry of Construction, Technical Criteria for River Works, Editorial Supervisor: River Bureau, Ministry of Construction, Editor: Japan River Association] (hereinafter called “Technical Criteria”.

8.1.1 Type of Dam

The type of dam is to be Dry Type Flood Control Dam.

The purpose of this type of dam is flood control only. The dam has outlet without gate at the present riverbed level, through which the runoff and sediment sluice to the downstream river in normal period. However, in flood time the flood discharge over capacity of the outlet will be reserved temporally in the reservoir, after that according to receding of flood the reserved water will be released through the outlet, then water level of reservoir will go down to riverbed level, thus the flood control will be made.

Although in the detail study, sediment volume in the reservoir should be estimated by riverbed fluctuation analysis, the sediment accumulated in the reservoir will be decreased remarkably from the normal type of dam since the sediment is discharged thorough the outlet.

This type of dam is constructed for flood control purpose recently in Japan, the Masuda Dame in Shimane Prefecture was completed and operated as well as around 10 dams are under construction or under planning.

The type of dam is appropriate to be the concrete gravity type. In case of fill type dam, the reverbed outlet is to be installed inside the long diversion tunnel so that the possibility of sedimentation and clogging in the tunnel may be high and the maintenance is difficult since structural stability and erosion of tunnel and so on are concerned. All of this type of dam completed or under construction in Japan is concrete gravity type.

Therefore the type of dam is to be dry type flood control concrete gravity dam.

8.1.2 Typical Section of Non-overflow Section

The width of top of dam is to be 5m considering the width of approach road (2 lanes + allowance) and entrance availability of crane and heavy equipment for maintenance of dam body, spillway and reverbed outlet, bridge at top of dam and so on. The upstream slope of dam is to be 1:0.1 which is rather gentle compared with general dam since the dam is empty in normal time so that the stability of dam against full scale upstream-ward earthquake force is required. The downstream slope of dam is to be 1:0.75 which is rather steep compared with general dam since the stability condition is better than general dam which reserves water behind dam in normal time. Such slopes are able to secure stability of the dam considering the height of dam (39m) and strength of foundation rock which is likely to be more than rock class CM (refer to 6.3.1), and the many actual examples in Japan

The penetration length to the natural ground at both banks is assumed to be 10m due to lack of geological information.

The top elevation of dam is to be the Design High Water Level (DHL) + Wind Wave Height (h_w) based on 「Technical Criteria, Practical Guide for Designing (I) 2.1 Basic Section of Dam, Table 2-1」. As described in the section 8.1.3(1) below, since DHL is 68.5m and SWL (Surcharge Water Level) is 64.5m which is lower by 4m than DHL, so that the top elevation is determined by Wind Wave Height in the DHL.

$h_w = 0.00077V \cdot F^{0.5} = 0.00077 x 30 x 2{,}800^{0.5} = 1.2$ m

where;

h_w : Wind Wave Height(m) ,V: Average wind velocity during 10 minutes (assumed to be 30m/sec)、F: Maximum fetch(2.8km)

Therefore the top elevation of dam EL_t = DHL + h_w =68.5 +1.2 = 69.7 --→ 70.0 m.

The foundation is to be based on the rock by excavating 5m from present riverbed (EL.36.0) since the foundation rock seems to be hard and sound with rock classification of C_M〜C_H so that the excavation depth from the present riverbed is estimated relatively shallow.

Therefore the height of dam(H) = EL_t – Riverbed elevation +5.0 (Excavation depth of foundation) = 70.0-36.0＋5.0 ＝39.0m

The typical section of dam and typical section along dam axis are shown in the Figure 8-1 (a).

8.1.3 Typical Section of Overflow Section

(1) Emergency Spillway

The design discharge is to be 1,200m^3/sec based on 「Technical Criteria, Practical Guide for Planning, Chapter 12, 3.2 Design flood Discharge of Dam」, which is the design flood at the dam site and maximum flood discharge in the past and almost equal to the discharge with occurrence probability of once in 50 years.

The capacity of the emergency spillway is calculated as shown below:

$$Q = CBH^{3/2}$$

Where;

C : Discharge coefficient(2.0) , H : Free overflow water depth（assumed to be4.0m）B : Width of overflow (assumed to be75.0m)

$$Q = 2.0x\ 75.0x\ 4.0^{3/2} = 1{,}200 m^3/sec$$

The layout of span of spillway is to be 13m x 5 spans and 10m x 1 span (=75m) considering normal width of 15m of dam concrete block to prevent cracks due to thermal stress in placing dam concrete and 2m of pier width for the bridges at top of dam. And the type of spillway is to be free over flow type which is almost maintenance free..

The surcharge water level (SWL) which is the maximum reservoir water level is 64.5m as shown in flood control calculation in the section 6.3.1 (3) so that in case that the crest of overflow section is equal to SWL, DHL is to be 68.5m (64.5 + 4.0).

(2) Normal Discharge Facility

As to the ordinary discharge facility, the riverbed outlets without gate are to be installed since the type of dam is the dry type of dam. The outlet is 2.0m in width and 2.5m in height, and the number of outlet is to be two (2) to reduce the risk of clogging. By these outlets the design flood (design discharge) of 1,200m^3/sec is regulated by 940 m^3/sec in the reservoir and release the maximum discharge of 260 m^3/sec to the river.

(3) Energy Dissipater

The design discharge (Q_d) of the energy dissipater is to be 2/3 of the design flood discharge referring to 「Technical Criteria, Practical Guide for Designing (I) Chapter 2, 7.1.3 Design of Spillway」 ”

Q_d is to be 800 m^3/sec(＝1,200 x 2/3), although the maximum discharge after regulation of design flood discharge is 260 m^3/sec.

The dissipation is to be done by the hydraulic jump on the horizontal apron and the elevation of apron is to be EL 36.0 considering thickness of apron slab 1.5m and the width of apron is to be 30m considering the width of downstream river and topography.

The equations of energy dissipation are as shown below:

$V_1 = C(2gH)^{0.5}$、$h_1 = Q_d/(V_1 \cdot B)$、$F_1 = V_1/(g \cdot h_1)^{0.5}$、

$h_2/h_1 = 1/2 \{(1 + 8F_1^2)^{0.5} - 1\}$

$L = 4.5\ h_2$

Where;

V_1: Velocity at the beginning point of apron (m/sec), C: Velocity coefficient (assumed to be 0.9), g: Gravitational acceleration (9.8m/sec^2), H: Total difference of height (68.5－36.0＝32.5m), h_1: Water depth at beginning point of apron (m), Q_d: Design discharge (800 m^3/sec), B: Width of apron (30m), F_1: Fluid number beginning point of apron, h_2: conjugate water depth of hydraulic jump (m), L:Length of hydraulic jump (m)

H= 68.5 (DHL)-36.0 =32.5m、V_1＝0.90(2x9.8x32.5)$^{0.5}$=22.7 m/sec、

h_1＝800/22.7x30.0=1.17m、F_1＝22.7/(9.8x1.17)$^{0.5}$ =6.79

h_2/1.17=1/2 {(1 +8x 6.70^2)$^{0.5}$ – 1} =8.99

h_2 = 8.99 x 1.17=10.5m

L =4.5x10.5 =47.3m-→ Length of apron is to be 50.0m

(4) Height of Sub Dam

Assuming that the depth of free overflow water is 5.6m the overflow discharge of sub dam is as shown below:

$Q=CBh^{3/2}$ =2.0x30.0x5.6$^{3/2}$=795-→ 800 m^3/sec (Design discharge of energy dissipater)

The height of sub dam is to be W= h_2 – h =10.5-5.6=4.9 →5.0 m

3 – slits with width of 0.5m are facilitated to the sub dam to drain water and sediment in normal time

(5) Height of Side Wall of Dissipater

The height is to be not to allow the design flood discharge (1,200 m^3/sec) overflowing.

Assuming that overflow water depth of sub dam (h_0) is 7.5m, the overflow discharge of sub dam is as shown below:

$$Q= CB\ h_0^{3/2} = 2.0x30.0x7.5^{3/2}=1,232 >1,200\ m^3/sec$$

The required height of side wall $H_0＝5.0＋7.5＝12.5m$

(6) Drift Wood Prevention Dam

In front of the riverbed outlets the drift wood prevention dam with 3-slits with width of 1.0m is to be installed

The typical section of overflow section and of the energy dissipater are as shown in the Figure-8.1 (b) and (c) respectively.

8.1.4 Plan of Dam

The upstream view and plan of dam are drawn based on the above results as shown in the Figure-8.1 (d) and (e) respectively.

8.1.5 Concrete Volume related to Dam

(1) Dam Body

The volume of dam body is calculated according to the following formulas which are shown in the section 6.3.1 (3).

Elevation of top of dam: SWL (EL64.5) + 4.0m (Over flow depth of spillway) + 1.5m (Height allowance of dam) = EL 70.0

Elevation of lowest foundation: Present riverbed elevation (EL 36.0) – Excavation depth (assumed 5.0m) = EL 31.0

Height of dam: H = 70.0 – 31.0 = 39.0 m

Excavation width of riverbed: B = 45.0m (from upstream view of dam)

Length of top of dam: L=170.0m (from upstream view of dam)

$A_1 = mH^2/2$, $A_2 = n\ (H\text{-}5.0/m)^2/2$, $A_3 = 5.0x5.0/m/2$, $A_4 =2\ A_3 = 5.0^2/m$

$V_1 = A_1B+ A_3B+(A_1+A_3)(L\text{-}B\text{-}20.0)/2+A_3(L\text{-}B\text{-}20.0) = (A_1+ A_3)\ B + (A_1+3A_3)\ (L\text{-}B\text{-}20.0)/2$,

$V_2 =A_2\ B+A_2\ (L\text{-}B\text{-}20.0)/2 = A_2\ (B+L\text{-}20)/2$,

$V_3 = A_4 20.0$

$V = V_1+V_2+V_3$

In NAD-3 dam, referring to the Figure-8.1, the following figures are given;

H: 39.0m, B:45.0m, L:170.0m, m:0.75, n:0.10

$A_1 = mH^2/2= 0.75x39.0^2/2=570.4m2$

$A_2 = n\ (H\text{-}5.0/m)^2/2 = 0.10(39.0\text{-}5.0/0.75)^2/2 = 52.3m2$

$A_3 = 5.0x5.0/m/2 = 5.0x5.0/0.75/2 = 16.7m2$

$A_4 = 2\ A_3 = 5.0^2/m = 33.3m2$

$V_1 = A_1B + A_3B + (A_1 + A_3)(L\text{-}B\text{-}20.0)/2 + A_3(L\text{-}B\text{-}20.0) = (A_1 + A_3)\ B + A_1 + 3A_3)(L\text{-}B\text{-}20.0)/2$

= (570.4+16.7)x45.0+(570.4+3x16.7)(170.0-45.0-20.0)/2=58,996m3

$V_2 = A_2\ B + A_2(L\text{-}B\text{-}20.0)/2 = A_{2(}B + L\text{-}20)/2 = 52.3(45.0+170.0\text{-}20.0)/2 = 5{,}099m3$

$V_3 = A_4 20.0 = 33.3x20.0 = 666m3$

$V = V_1 + V_2 + V_3 = 58{,}996 + 5{,}099 + 666 = 64{,}800m3$

(2) Footing of Dam

The downstream footing of dam formulates the base of guide wall of emergency spillway so that the volume is rather larger than the normal condition. The volume is assumed as 20% of dam body.

64,800x20%= 13,000 m3

(3) Drift Wood Prevention Dam

Area of cross section (2.0+2.0+8.5x0.3)/2 x8.5=26.2m2

Volume 26.2x70.0(Length of dam)＝1,900m3

(4) Dissipater

Sub dam

(2.0+2.0+5.0)/2 x 30 = 135 m3

Guide wall

(1.0+1.0+14.0x0.2)/2 x14 x2 x 65(length)=4,400 m3

Apron base slab

1.5x30x55=2,500 m3

Dissipater total

135＋4,400＋2,500＝7,100m3

Total concrete volume related dam

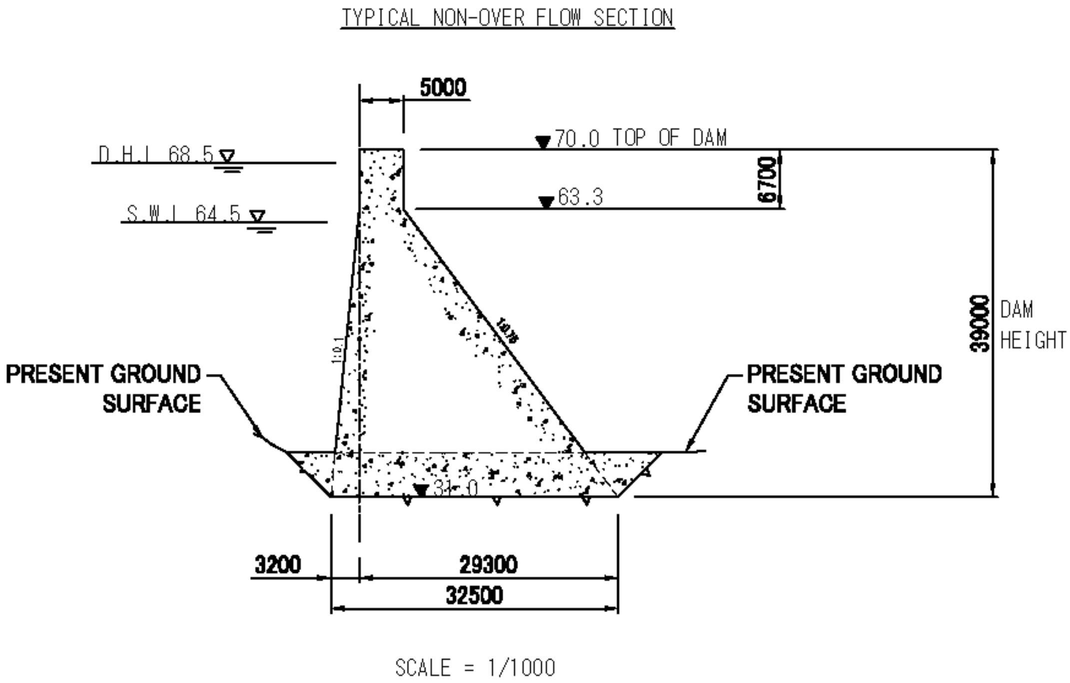
64,800 + 13,000+1,900+7,100=86,800m3

8.1.6 Outline of Reservoir and Dam

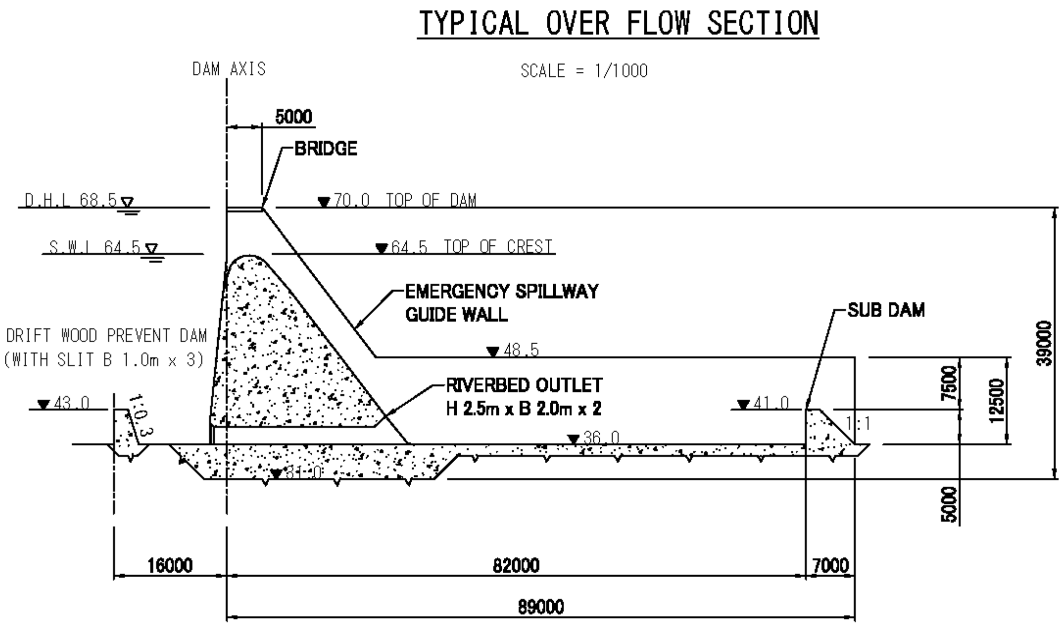
The outline of reservoir and dam at NAD-3 dam site is as shown in the Table 8-1.

Table 8-1 Outline of Reservoir and Dam

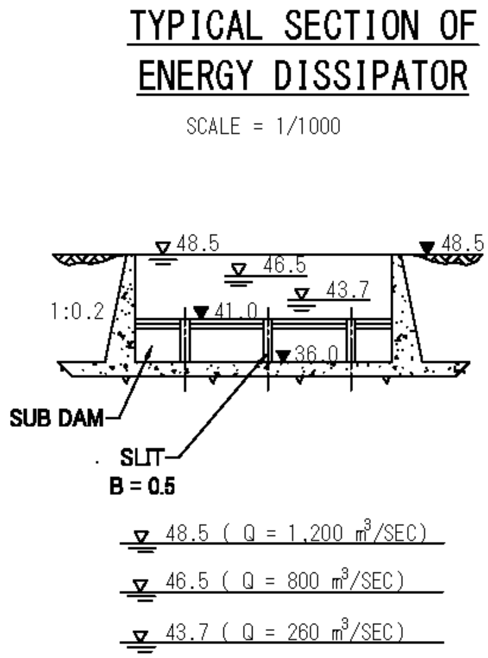
Description			Outline	Remarks
Reservoir		Catchment Area	110km2	
		Reservoir Area	1.66km2	at S.W.L.
		Reservoir Capacity	28,600,000m3	with 20% of allowance
		Design High Water Level	D.H.L.68.5m	
		Surcharge Water Level	S.W.L.64.5m	
		Design Flood Discharge	1,200m3/sec	Flood in March 2013(Maximum in the past, approx.1/50)
Dam	Dam	Type	Dry Type Concrete Gravity	
		Top of Dam	EL70.0m	
		Lowest Foundation Level	EL31.0m	present riverbed - 5.0m
		Height of Dam	39.0m	
		Crest Length	170.0m	
		Volume of Dam	87,000m3	
		Upstream Slope	1:0.1	
		Downstream Slope	1:0.75	
	Outlet	Emergency Spillway	Free Overflow, B13mx5spans+B10mx1span	overflow water depth 4.0m
		Flood Control Outlet	Riverbed Outlet without Gate, B2.0mxH2.5mx2lanes	
		Objective Flood Discharge	1,200m3/sec	
		Regulated Discharge	940m3/sec	
		Maximum Discharge after Regulation	260m3/sec	
		Design discharge of Dissipater	800m3/sec	2/3 of design flood discharge
		Type of Dissipater	Hydraulic Jump on Horizontal Apron	
		Length of Apron	50.0m	
		Width of Apron	30.0m	
		Height of Sub Dam	5.0m	overflow water depth 5.6m
		Height of Side Wall	12.5m	overflow water depth 7.5m



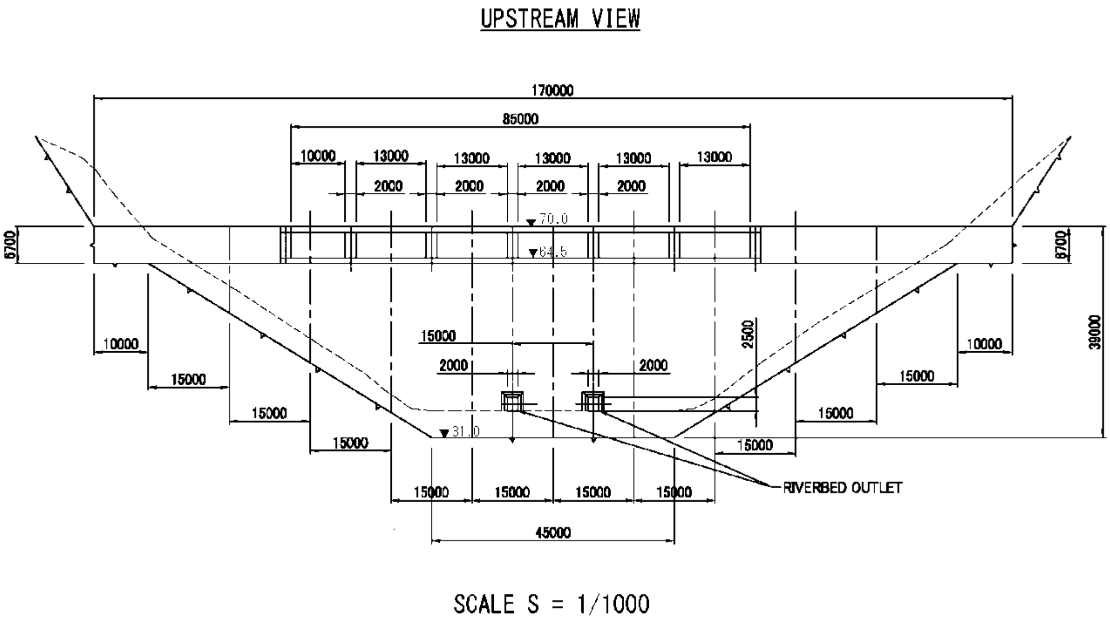
(a) Typical Section of Non-overflow Section



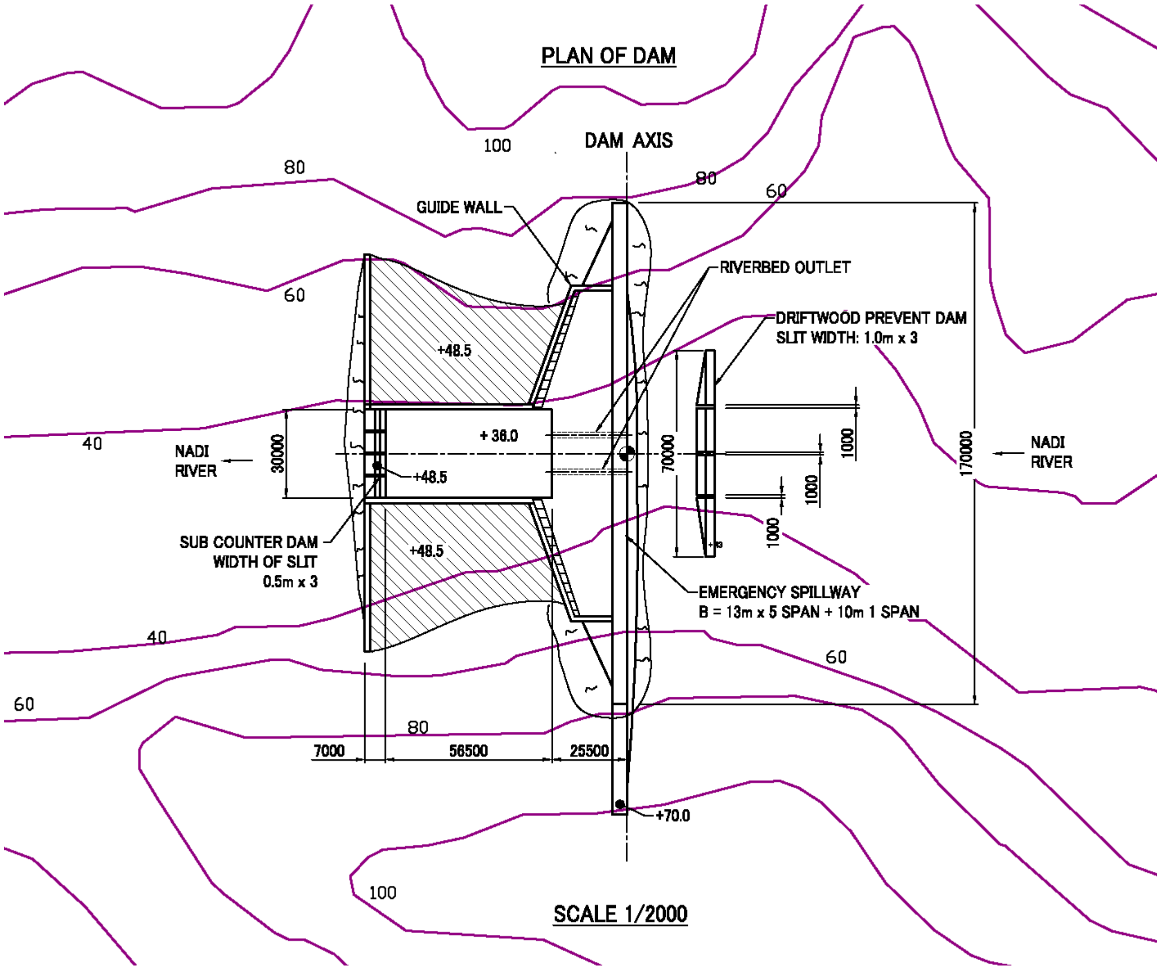
(b) Typical Section of Overflow Section



(c) Typical Section of Energy Dissipater



(d) Upstream View of Dam



(e) Plan of Dam

Figure 8-1 Preliminary Design of Dam

8.2 Plan and Preliminary Design for River Improvement

8.2.1 Discharge Capacity of Current River Channels

In order to plan and design the river improvement, discharge capacities of current river channels in Nadi, Nawaka, Malakua and Namosi Rivers were calculated and examined as shown in Figure 8-2 to Figure8-4.

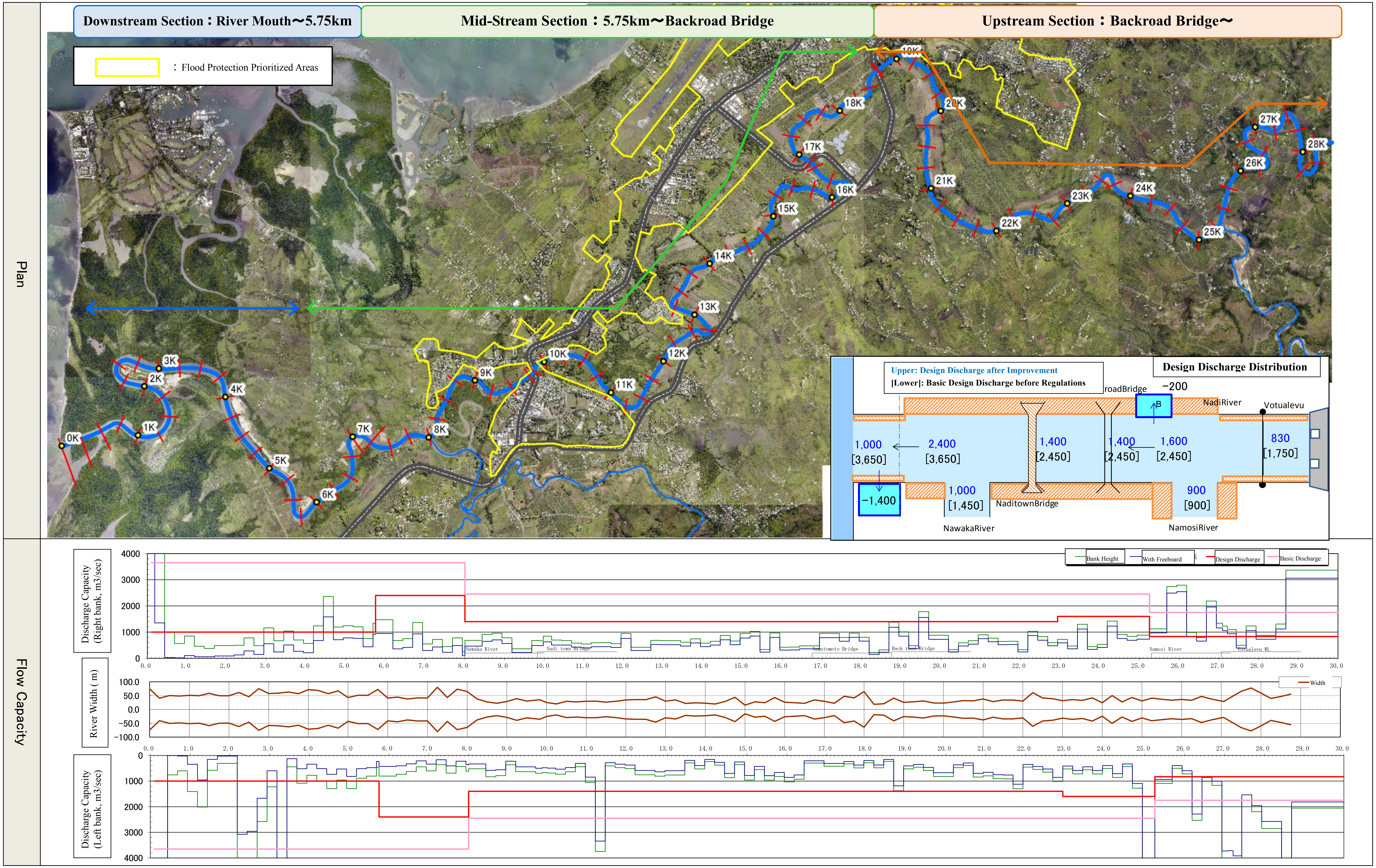


Figure 8-2 Plan and Discharge Capacity of Current River Channel (Nadi River)

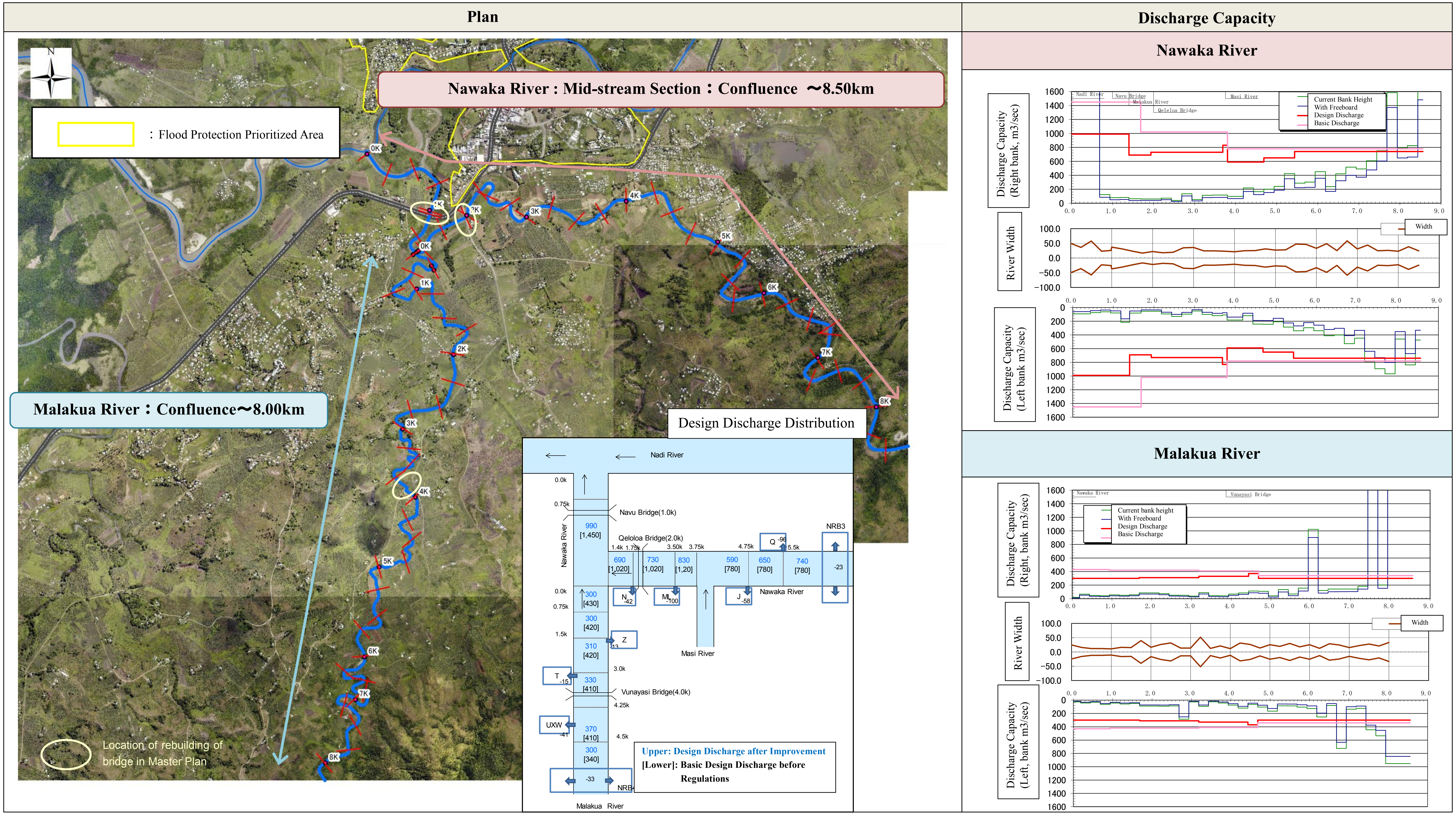


Figure8-3 Plan and Discharge Capacity of Current River Channel (Nawaka and Malakua River)

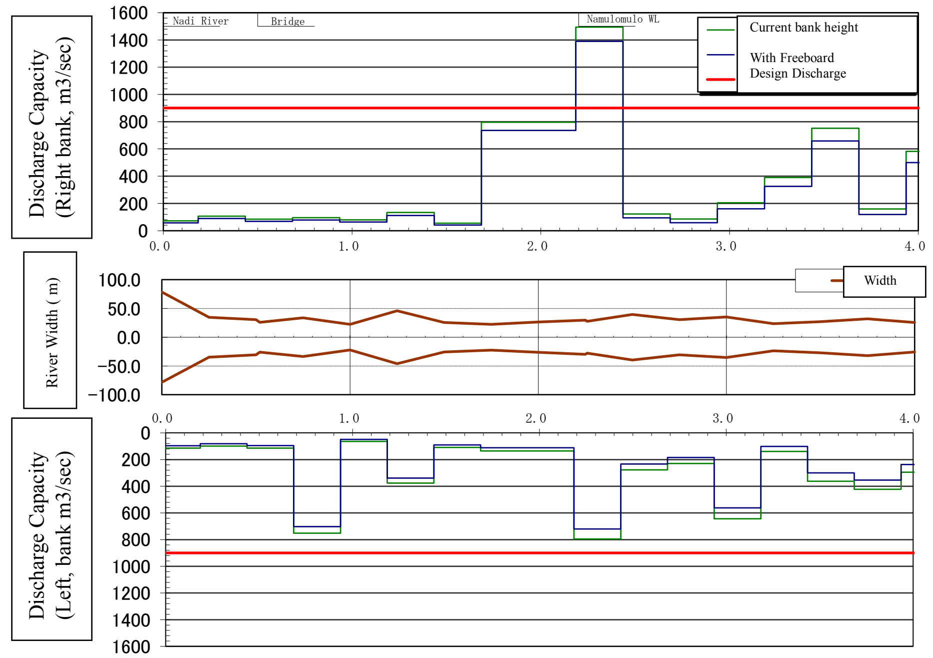
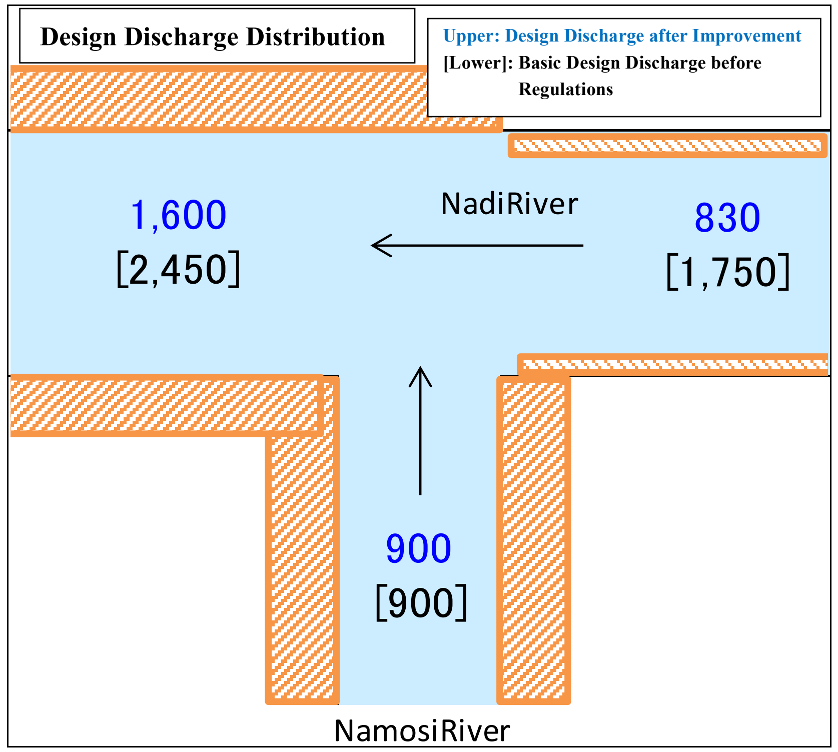
Plan	Discharge Capacity
	**Namosi River**  

Figure8-4 Plan and Discharge Capacity of Current River Channel (Namosi River)

8.2.2 Alignment Plan

River alignment was planned and designed by taking into account hydraulic characteristics and land use along the river. Basic concept for alignment plan of the Nadi River and its tributaries is summarized as follows:

1) River alignment:
   River alignment shall be planned and designed based on current alignment
2) Smoothing of river alignment by raised height of water level due to bend:
   Water level showing above HWL due to bend shall be considered for design of alignment with taking into account the hinterland conditions.
3) Widening of river bank (both side banks):

From the point of view of fairness, both banks are basically to be widened, and the widening riverbank is determined in consideration of the linear river channel improvement, housing relocation associated with river improvement (although housing relocation should be avoided as much as possible), the impact on land use.

(1) Smoothing of River Alignment

Smoothing of river alignment was planned and designed by taking into account raised height of water level due to bend.

Specifications of bend and smoothing sections for each river are shown in Table 8-2 to Table8-5, Figure 8-5 and Figure8-12, respectively. Water level calculation by non-uniform flow method including bend influence was carried out and the results are shown in Figure8-21 to Figure8-24.

Raised height of water level due to bend was examined by following method based on “the Technical Standard for River Works in Japan” formulated by the MLIT, Japan. Examination results are shown in Table 8-2～Table8-5. Bend radius that does not exceed HWL was secured by calculate back method in required sections for smoothing.

Calculation for Raised height of water level due to bend ($\triangle h_b$)

In the case of the subcritical flow at a single bend in river with simple cross section, difference in water level occurs between inner and outer banks, and its height ($\triangle h$) can be approximated by following formula:

$$\triangle h = bV2 \ / g \cdot r_c$$

$$\triangle h_b = \triangle h/2$$

In the above formula,

b: River width, V: Mean velocity, g: Acceleration of gravity, r_c: Bend radius at the center of river

In ordinary non-uniform flow calculation, water level along the central portion of bend should be considered to be calculated. It may be considered that water level decreases by $\triangle h/2$ at the inner bank at bend and rises by $\triangle h/2$ above the mean level at the outer bank

Raised height of water level based on the above formula means tentative raised height so that this calculation results cannot apply for boundary condition to calculate water level in upstream section.
For the calculation of non-uniform flow in upstream, mean velocity (V) is calculated by non-uniform flow calculation results consisting of influences of trees, confluence of tributaries and piers of bridge.

Source: Technical Standard for River Works in Japan (Volume for River Survey) (MLIT, Japan)

Table 8-2 Bend Specifications and Smoothing Sections (Nadi River)

Nadi River													
Bend Specifications													
No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing	No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing
Nad.1	0.75	2.00	300	Right side			Nad.22	17.5	17.75	140	Left side		
Nad.2	2.25	2.75	130	Left side			Nad.23	17.75	18.00	140	Right side		
Nad.3	3.50	4.00	280	Left side			Nad.24	18.25	18.50	90	Right side		
Nad.4	5.00	5.50	360	Left side			Nad.25	18.50	18.75	170	Left side		
Nad.5	5.75	5.75	80	Left side			Nad.26	19.00	19.25	90	Left side		
Nad.6	6.25	6.75	340	Left side			Nad.27	19.75	20.00	80	Left side		
Nad.7	7.00	7.00	120	Left side			Nad.28	20.00	20.25	150	Right side		
Nad.8	7.25	7.50	330	Right side			Nad.29	21.75	22.00	150	Right side		
Nad.9	8.00	8.00	120	Right side			Nad.30	22.25	22.50	340	Left side		
Nad.10	8.75	9.00	110	Left side			Nad.31	22.75	22.75	50	Right side		
Nad.11	9.25	9.25	150	Right side			Nad.32	23.50	23.75	80	Left side		
Nad.12	10.25	10.75	380	Left side			Nad.33	24.25	24.75	460	Left side		
Nad.13	11.25	11.50	150	Right side			Nad.34	25.00	25.00	50	Right side		
Nad.14	12.50	12.50	50	Left side			Nad.35	25.75	26.25	270	Left side		
Nad.15	12.75	12.75	55	Right side			Nad.36	26.25	26.50	90	Right side		
Nad.16	13.25	13.25	30	Left side	●	No changes because of high hinterland	Nad.37	26.75	27.00	140	Left side		
Nad.17	14.75	15.00	250	Right side			Nad.38	27.25	27.25	70	Right side		
Nad.18	15.25	15.50	50	Left side	●	Smoothing more than BR with 70m	Nad.39	27.50	27.50	60	Left side		
Nad.19	16.00	16.00	100	Right side			Nad.40	28.25	28.50	100	Right side		
Nad.20	16.25	16.25	40	Right side	●	No changes because of high hinterland	Nad.41	28.75	28.75	60	Left side		
Nad.21	17.00	17.25	240	Left side									

Table 8-3 Bend Specifications and Smoothing Sections (Nawaka River)

Nawaka River						
Bend Specifications						
No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing
Naw.1	0.25	0.25	200	Right side		
Naw.2	0.50	0.50	100	Left side	●	Smoothing more than BR with 130m
Naw.3	0.75	0.75	80	Left side		
Naw.4	1.25	1.50	50	Right side		
Naw.5	2.00	2.00	30	Right side	●	Smoothing more than BR with 60m
Naw.6	2.25	2.50	40	Left side	●	Smoothing more than BR with 60m
Naw.7	2.50	2.50	50	Right side	●	Smoothing more than BR with 60m
Naw.8	2.75	2.75	30	Left side	●	Smoothing more than BR with 80m
Naw.9	3.00	3.00	40	Right side	●	Smoothing more than BR with 70m
Naw.10	3.25	3.25	200	Left side		
Naw.11	3.50	3.50	80	Right side		
Naw.12	4.25	4.25	80	Left side		
Naw.13	5.25	5.25	50	Left side		
Naw.14	5.50	5.75	80	Right side		
Naw.15	6.00	6.25	150	Left side		
Naw.16	6.75	6.75	40	Left side	●	Smoothing more than BR with 60m
Naw.17	7.25	7.25	70	Right side		
Naw.18	7.50	7.75	130	Left side		
Naw.19	8.00	8.00	220	Left side		
Naw.20	8.25	8.50	80	Right side		

Table8-4 Bend Specifications and Smoothing Sections (Malakua River)

Malakua River													
Bend Specifications													
No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing	No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing
Mal.1	0.25	0.25	40	Left side			Mal.22	4.00	4.00	110	Left side		
Mal.2	0.50	0.50	40	Right side			Mal.23	4.25	4.25	30	Left side		
Mal.3	0.75	0.75	40	Right side			Mal.24	4.25	4.25	20	Right side		
Mal.4	1.00	1.00	20	Right side	●	Smoothing more than BR with 50m	Mal.25	4.50	4.50	30	Left side		
Mal.5	1.00	1.25	20	Left side	●	Smoothing more than BR with 50m	Mal.26	4.75	4.75	50	Left side		
Mal.6	1.25	1.25	90	Right side			Mal.27	5.00	5.00	20	Right side		
Mal.7	1.50	1.50	80	Left side			Mal.28	5.50	5.50	40	Left side		
Mal.8	1.50	1.50	20	Right side	●	Smoothing more than BR with 30m	Mal.29	5.75	5.75	40	Right side		
Mal.9	1.75	1.75	50	Left side			Mal.30	6.00	6.00	100	Left side		
Mal.10	2.00	2.00	120	Right side			Mal.31	6.25	6.25	35	Right side		
Mal.11	2.25	2.25	150	Left side			Mal.32	6.50	6.50	30	Left side		
Mal.12	2.50	2.50	110	Left side			Mal.33	6.50	6.75	30	Right side		
Mal.13	2.75	3.00	40	Right side			Mal.34	6.75	6.75	30	Left side		
Mal.14	3.00	3.00	20	Left side	●	Smoothing more than BR with 30m	Mal.35	6.75	7.00	40	Left side		
Mal.15	3.25	3.25	30	Right side	●	Smoothing more than BR with 40m	Mal.36	7.00	7.00	100	Right side		
Mal.16	3.25	3.25	20	Left side	●	Smoothing more than BR with 40m	Mal.37	7.25	7.25	20	Right side		
Mal.17	3.25	3.25	30	Right side	●	Smoothing more than BR with 40m	Mal.38	7.50	7.50	60	Left side		
Mal.18	3.25	3.50	20	Left side	●	Smoothing more than BR with 40m	Mal.39	7.50	7.50	60	Right side		
Mal.19	3.25	3.50	15	Right side	●	Smoothing more than BR with 40m	Mal.40	7.75	7.75	30	Left side		
Mal.20	3.50	3.50	20	Left side	●	Smoothing more than BR with 30m	Mal.41	8.00	8.00	50	Right side		
Mal.21	3.75	3.75	40	Right side									

Table8-5 Bend Specifications and Smoothing Sections (Namosi River)

Namosi River						
Bend Specifications						
No.	Start Distance (km)	End Distance (km)	Bend Radius (m)	Bend Direction	Exceeding HWL	Bend Radius (BR) after Smoothing
Nam.1	0.25	0.50	100	Left side		
Nam.2	0.52	0.52	60	Left side		
Nam.3	0.75	0.75	30	Right side	●	No changes because of high hinterland
Nam.4	1.50	1.50	50	Right side		
Nam.5	1.75	2.00	110	Left side		
Nam.6	2.25	2.25	80	Right side		
Nam.7	2.75	2.75	140	Right side		
Nam.8	2.75	3.00	40	Right side		
Nam.9	3.25	3.50	80	Left side		
Nam.10	3.50	3.75	80	Right side		
Nam.11	3.75	4.00	30	Left side		

Figure8-5 Location of Bend Sections for Smoothing(Nadi River, Overall Plan)

Figure8-6 Location of Bend Sections for Smoothing (Nadi River, Section from Nad.1- Nad.11)

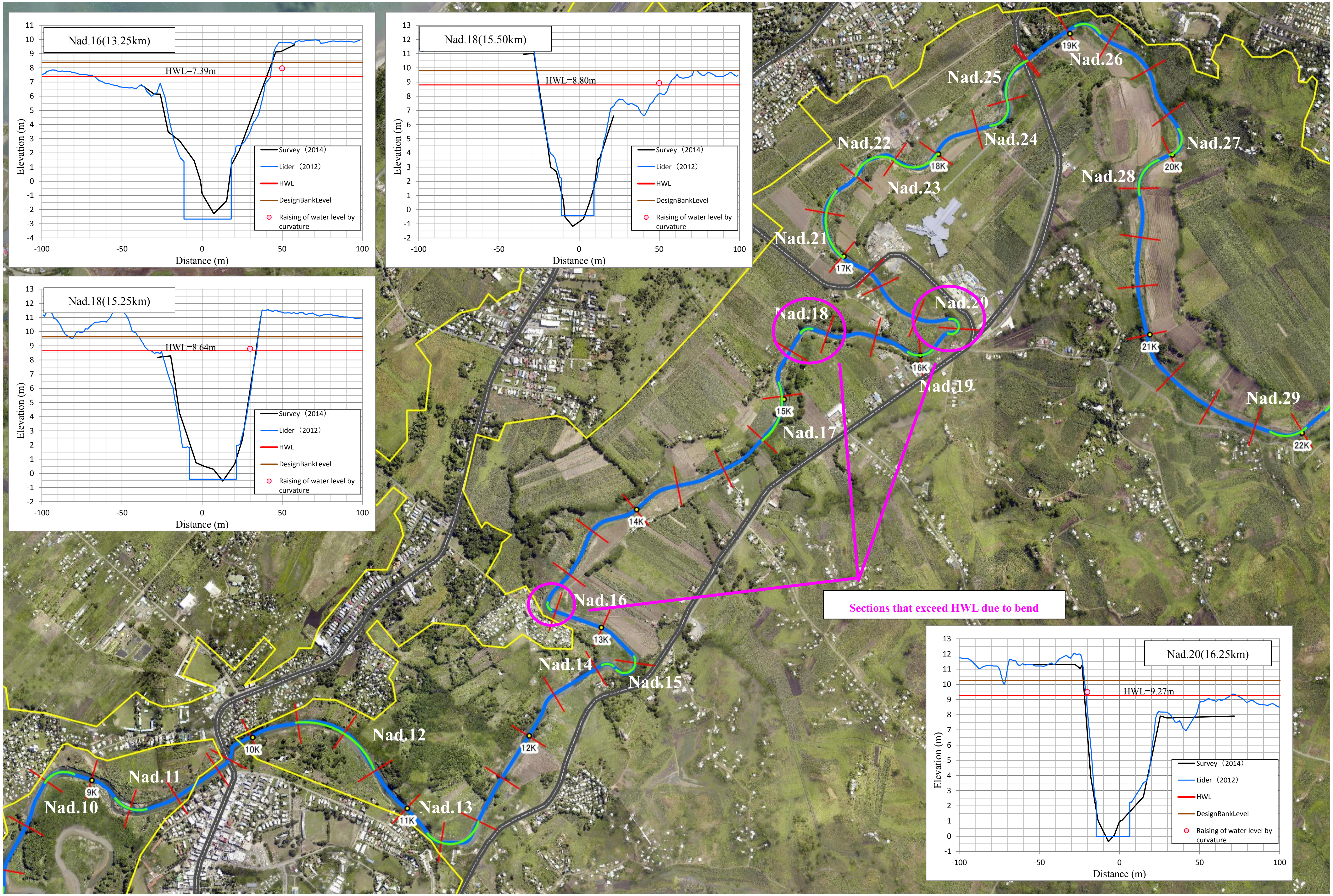


Figure8-7 Location of Bend Sections for Smoothing (Nadi River, Section from Nad.12- Nad.27)

Figure8-8 Location of Bend Section for Smoothing(Nadi River, Section from Nad.28- Nad.41)

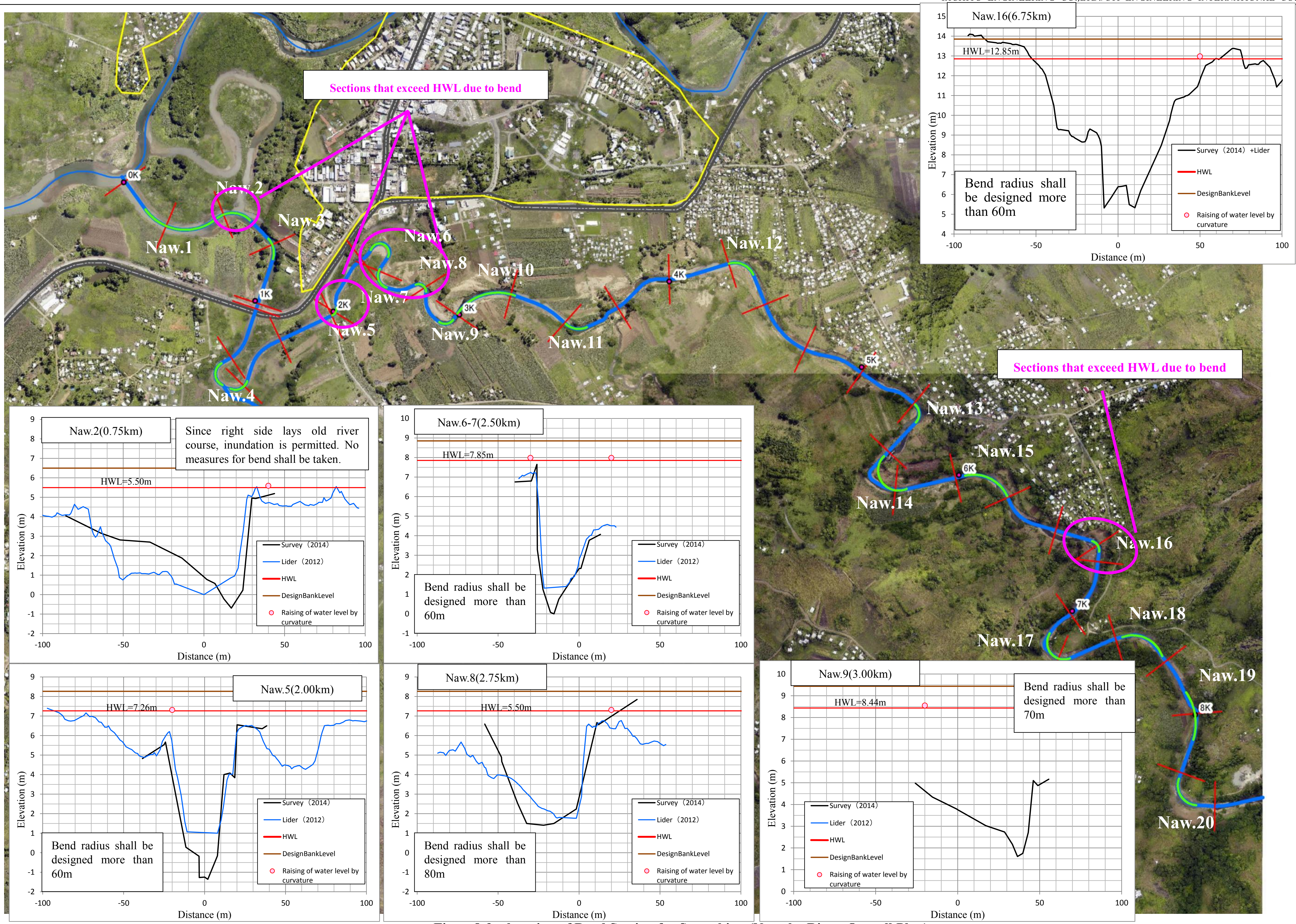


Figure8-9 location of Bend Section for Smoothing (Nawaka River, Overall Plan)

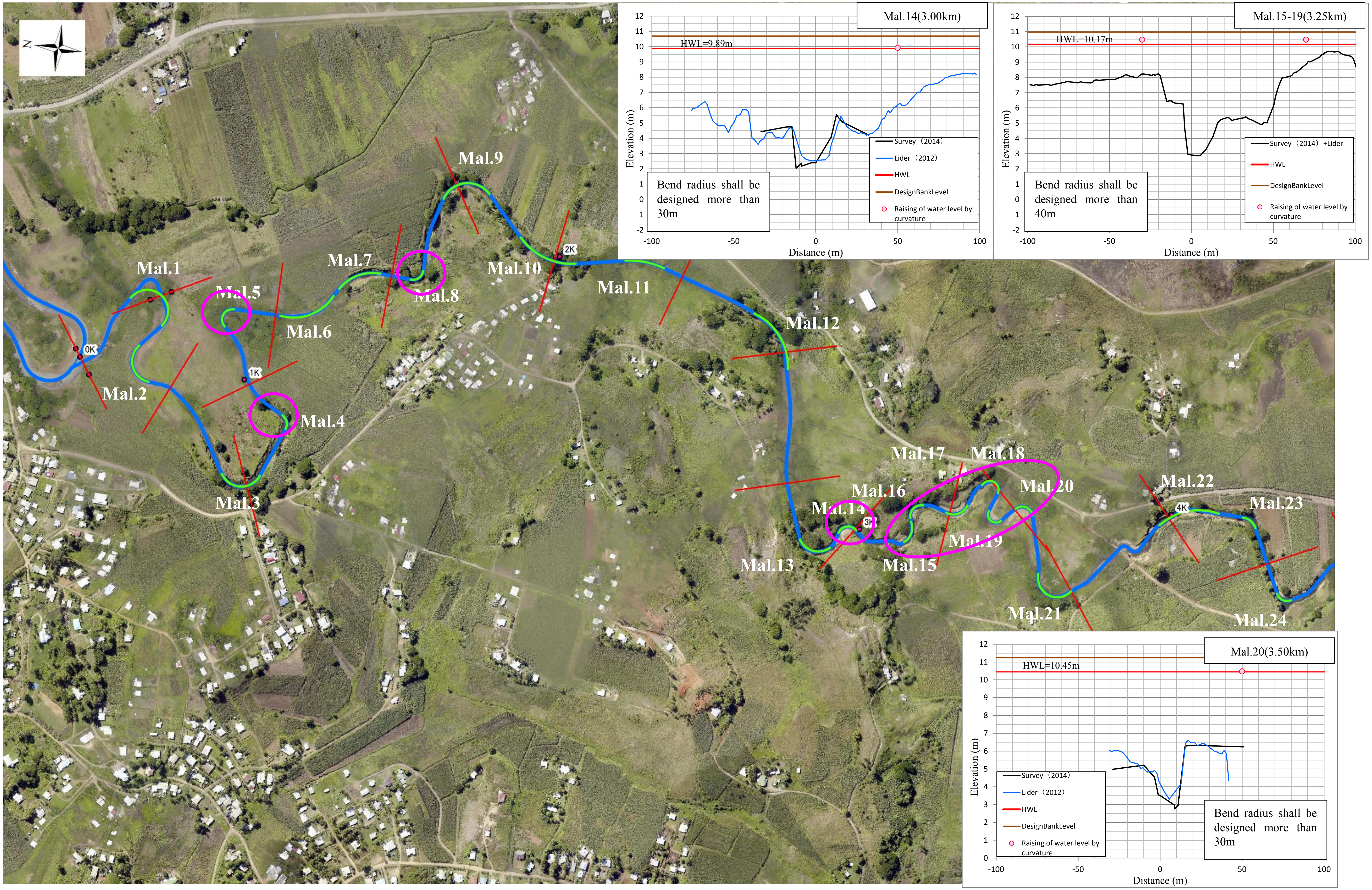


Figure8-10 Location of Bend Section for Smoothing (Nawaka River, Section from Mal.1- Mal.23)

Figure8-11 Location of Bend Section for Smoothing (Nawaka River, Section from Mal.24- Mal.41)

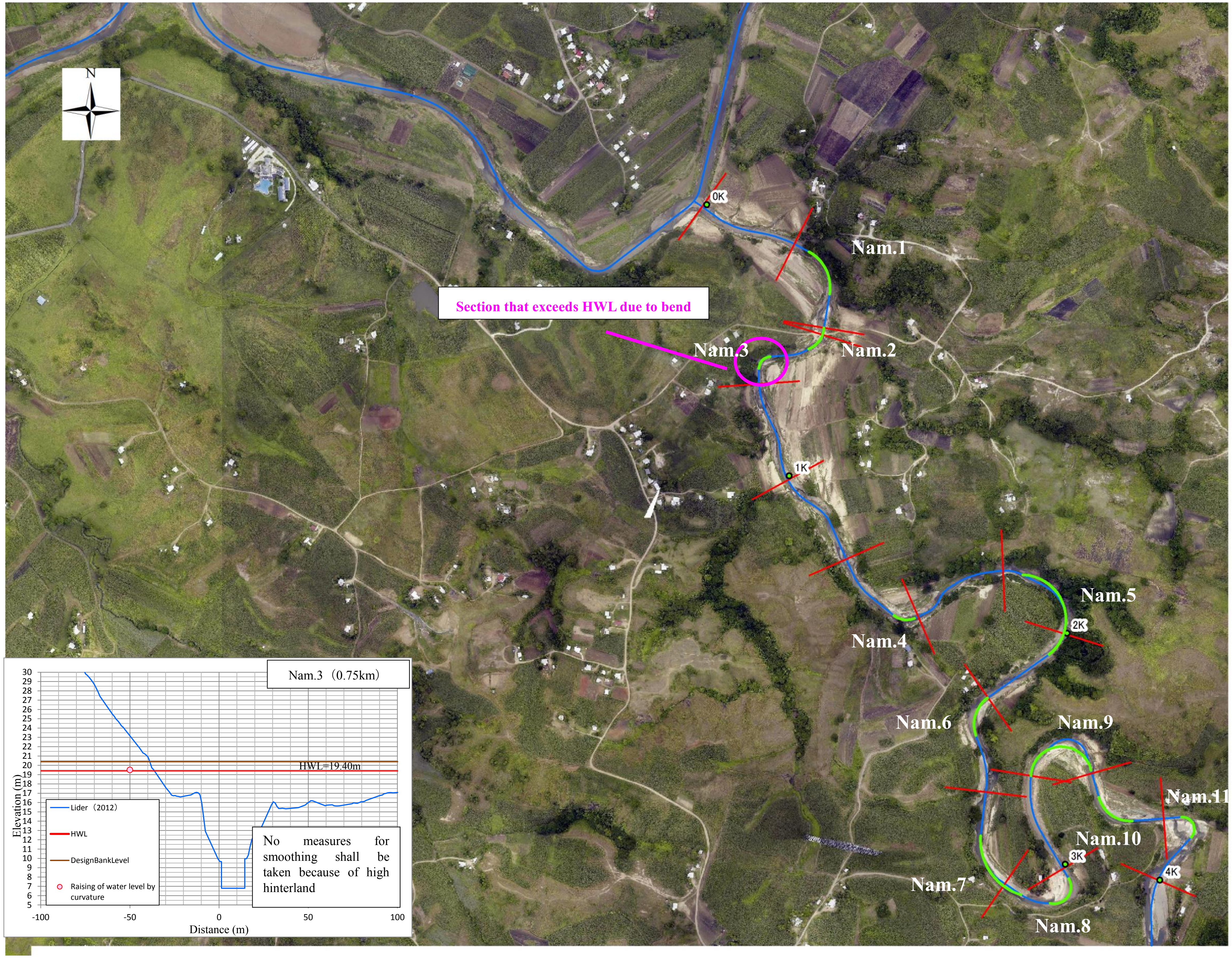


Figure8-12 Location of Bend Section for Smoothing (Namosi River)

(2) Preliminary Design for Plan of Nadi River

Preliminary designs for plan of Nadi River are shown in Figure8-13 to Figure8-15.

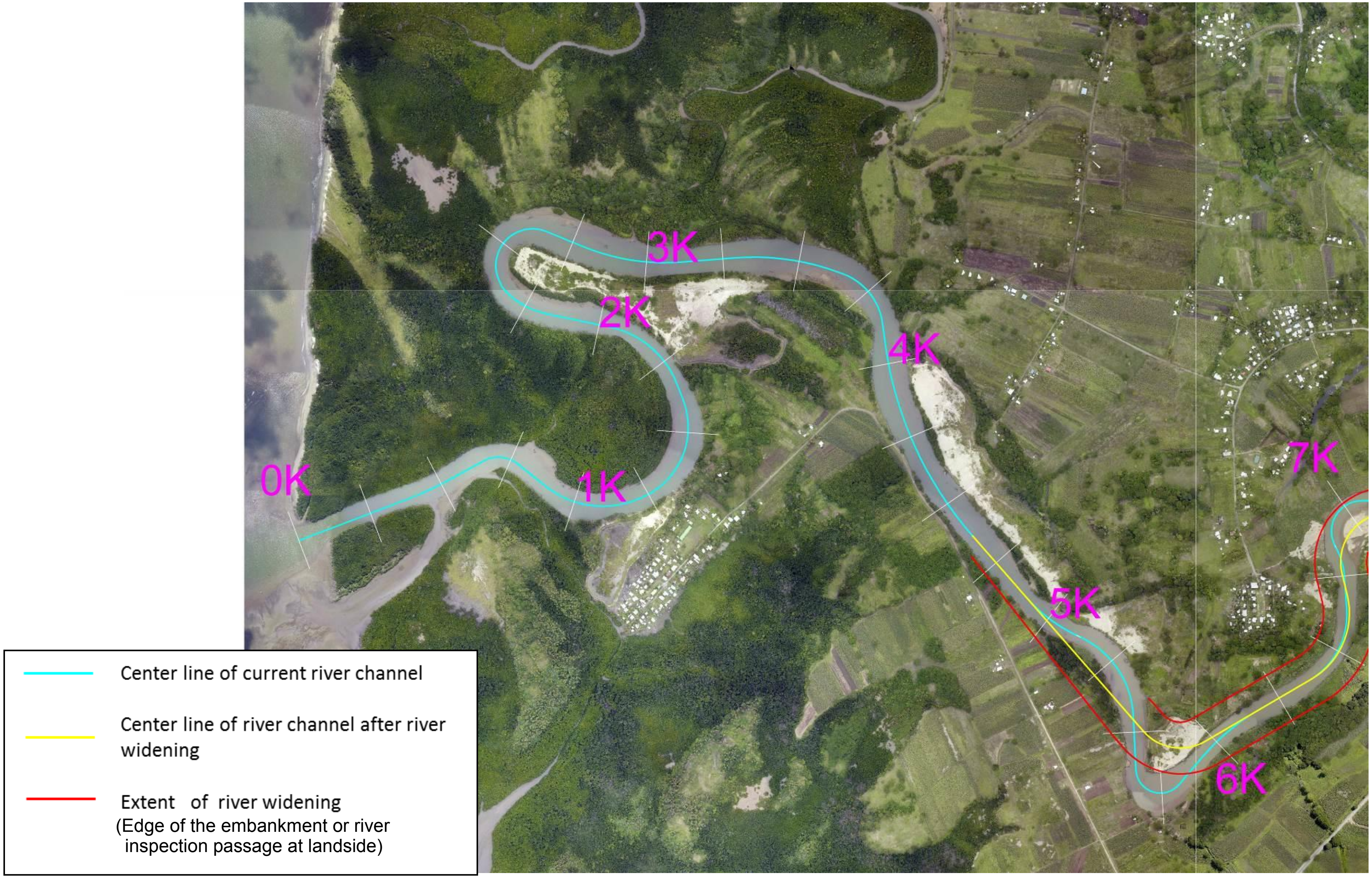


Figure8-13 Preliminary Design for Plan of Nadi River (1)

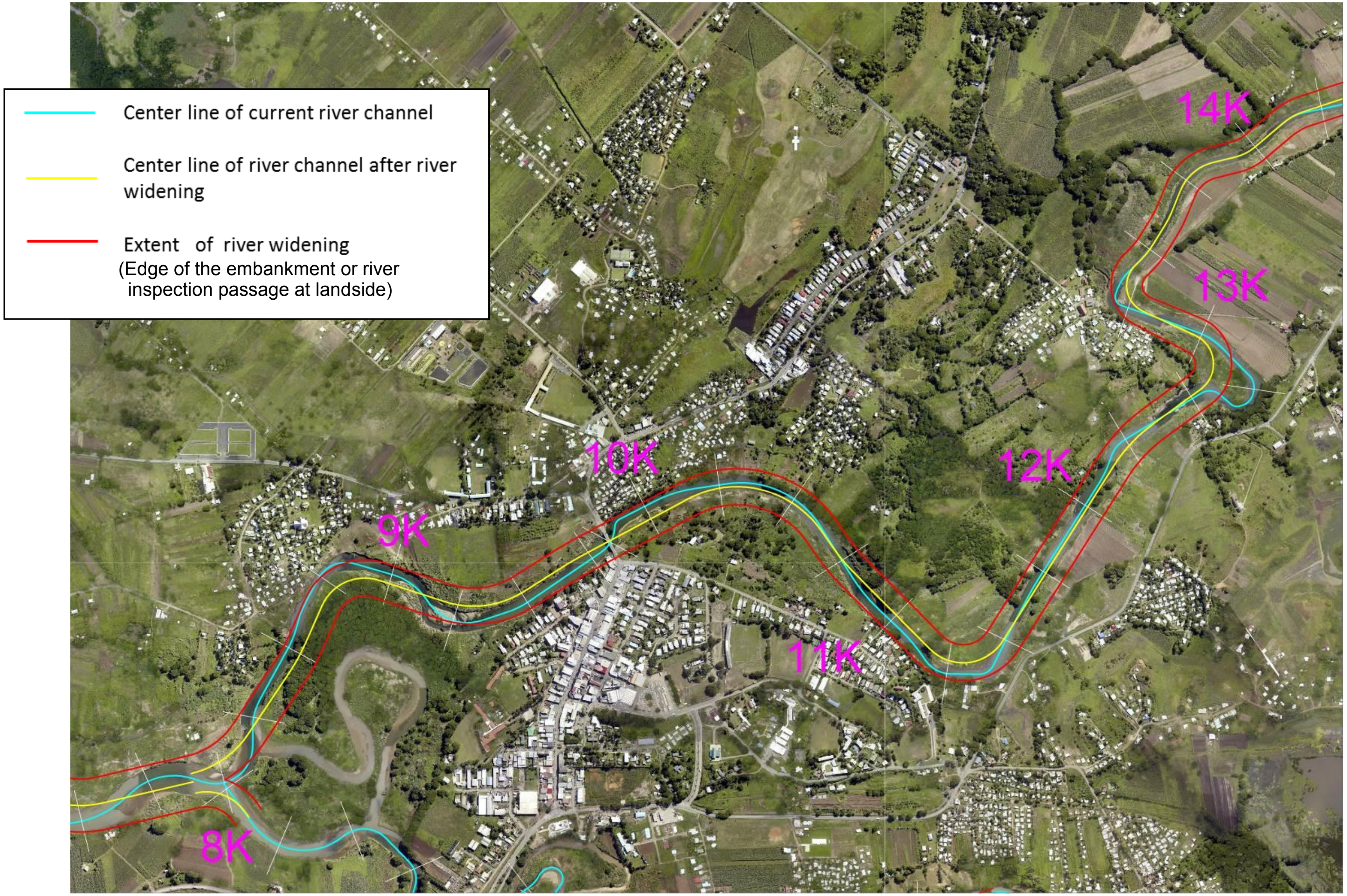


Figure8-14 Preliminary Design for Plan of Nadi River (2)

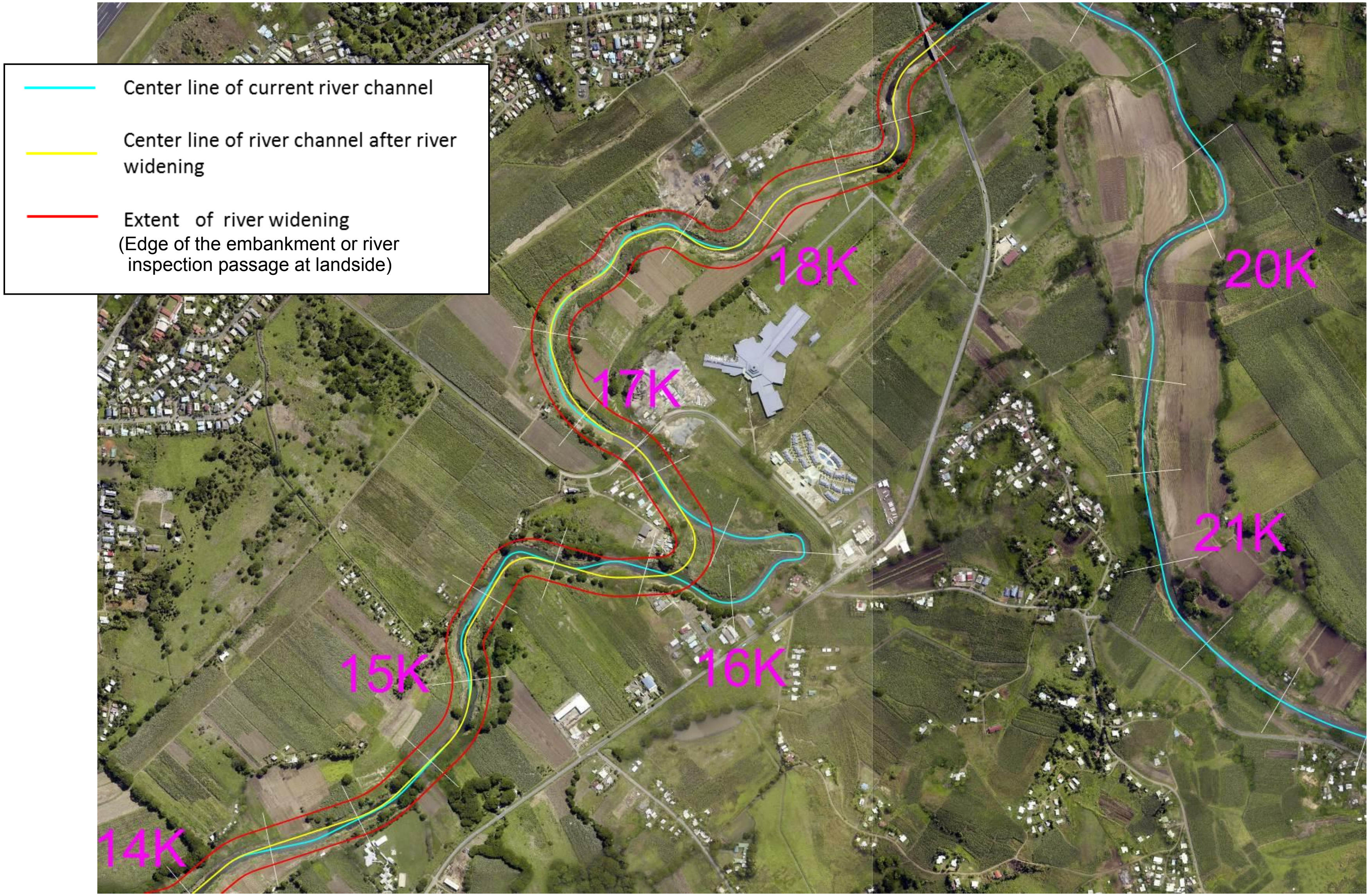


Figure8-15 Preliminary Design for Plan of Nadi River (3)

8.2.3 Longitudinal Plan

The design high water level and the design riverbed are determined based on the basic way of thinking for the longitudinal plan shown below.

(1) Design High Water

The Nadi River

The design high water level in a section from the lower reaches to the middle reaches is roughly set up to the inland ground level, and it is set up based on the overflow depth of the retarding basin and the non-uniform flow calculation result at the time of design flow discharge for a section in the upper reaches.

○Reference Point

Nadi River (refer to Figure8-22)

Reference Point 1: Old Queens Road Bridge

Reference Point 2: Backroad Bridge

Reference Point 3: The overflow section of the retarding basin

The High Water Level which is set based on the above is shown in Figure8-22.

The High Water Level is set for Master Plan Level, however, after priority project before the completion of Master Plan, flood water level will exceed the High Water Level (but under designed dike crown elevation) by target design scales level flood (2012 flood).

The Nawaka River

The High Water Level is set up on the assumption that the high water level at the confluence of the Nawaka River and the Nadi River is the end of downstream of the Nadi River (see Figure8-16) and in consideration for the overflow depth at the retarding basin. The High Water Level which is set based on the above is shown in Figure8-23.

The Malakua River

The High Water Level is set up on the assumption that the high water level at the confluence of the Malakua River and the Nawaka River is the end of downstream of the Nadi River (see Figure8-17) and in consideration for the overflow depth at the retarding basin. The High Water Level which is set based on the above is shown in Figure8-24.

The Namosi River

The High Water Level in the section from 0 km to 0.75 km is set up as the high water level at the confluence (25.3 km from the estuary) of the Namosi River and the Nadi River, the high water level is set up to envelope the non-uniform flow calculation water level in the upstream section from 0.75 km. The High Water Level which is set up based on the above is shown in Figure8-27.

(2) Design Embankment Height (free-board)

In accordance with “Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 20”, the design embankment height is provided with a freeboard for a given flow rate.

Regarding surrounding dike, after completion of priority project, water level will exceed the High Water

Level (but under designed dike crown elevation) by target design scales level flood (2012 flood). The comparison of water level and HWL is as follows; (Figure 8-27, 8-28)

<Surrounding Dike at Nadi River at left side>

HWL at Master Plan + Free board > Water Lever after priority project > HWL at Master Plan

<Surrounding Dike at Nawaka River at right side>

Water Lever after priority project > HWL at Master Plan + Free board

Therefore, surrounding dike elevation is set as follows:

<Surrounding Dike at Nadi River at left side>

Elevation of Surrounding dike : HWL at Master Plan + Free board

<Surrounding Dike at Nawaka River at right side>

Elevation of Surrounding dike : Water Lever after priority project

* Regarding Surrounding Dike at Nawaka River at right side, it is required to construct higher dike than Master Plan Level in order to protect important protected area.

* After priority project, flood water level will exceed designed HWL, which is same situation in middle stream of Nadi River.

(3) Design Riverbed Height

<u>The Nadi River</u>

The design riverbed height in the section from 0.0 km to 11.0 km is set up nearly 1.0 m* lower than the present riverbed height, and it is set up nearly the present riverbed height for other sections. (* In the Nadi River, commercial facilities and houses close to the river at and near Nadi Bridge, and a vertical cross-sectional plan has been determined from the viewpoint of reducing the social impact (house relocation) as much as possible, in consideration of river channel situation at Nadi Bridge (HWL, river channel width). Consequently, the design riverbed height has been set up nearly 1.0 m lower than the present riverbed height with the cross-section that can safely flow down the design flood discharge.

<u>The Nawaka River</u>

The design riverbed height is set up nearly the present riverbed height.

<u>The Malakua River</u>

The design riverbed height is set up nearly the present riverbed height.

<u>Namosi River</u>

The design riverbed height is set up nearly the present riverbed height.

(4) Design Riverbed Slope

The design riverbed slope is set up nearly the present riverbed slope on due consideration of ensuring stability of the riverbed.

(5) Water Level Rise

The water level rise due to bridge pier, or due to the meeting section are considered but the water level rising amount due to curvature is corresponded by the correction of cross-shape or planar normal line if necessary, after checking the terrain situation behind the ground.

The Nawaka River

The truck train bridge located at 1.0 km is planned a bridge designed to be underwater during a flood and taking into consideration of water level rise because that the railroad cannot be raised due to the train service.

1) According to interviews with administrators, from the view point of safety operation and on performance of the train, longitudinal slope of the railroad is to be level basically and it is unacceptable to change the current railroad height. (see 8.5.2(2)2)

2) According to interviews with local consultants who have a lot of experience for submersible bridges, they have designed submersible bridges to secure the safety of the structure for the water level above the planned railroad height so far. Therefore, the detailed design of this submerged bridge will be necessary to confirm the safety of the structure on the same design concept.

■The way of thinking for the initial water level in the Nawaka River (see Figure8-16)

The regulated peak of hydrograph of both the Nadi River and the Nawaka River, indicate the crushed shape. There is a little bit of time lag between the occurrence time of peak flow for both the Nawaka River and the Nadi River, but, the flow rate of the Nadi River at the time of peak flow of the Nawaka River is nearly equal to the peak flow of the Nadi River. Therefore, the initial water level in the Nawaka River is set up the high water level of the Nadi River.

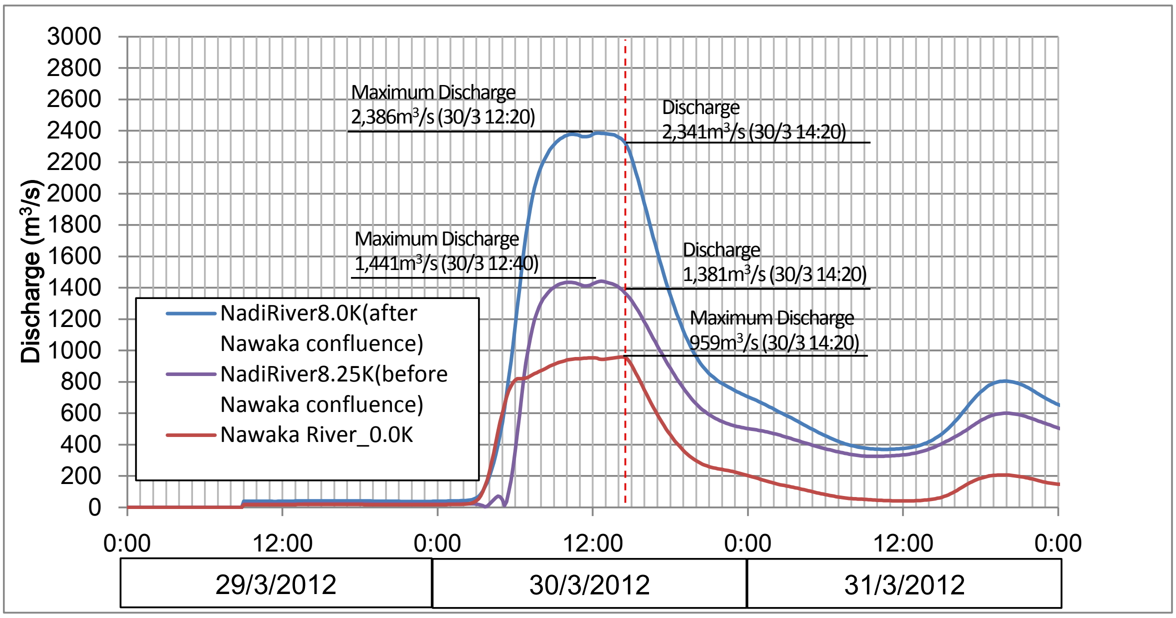


Figure8-16 Hydrograph at the confluence of the Nadi River and the Nawaka River

■The way of thinking for the initial water level in the Malakua River (see Figure8-17)

The regulated peak of hydrograph of both the Nawaka River and the Malakua River, indicate the crushed shape. There is a little bit of time lag between the occurrence time of peak flow for both the Malakua River and the Nawaka River, but, the flow rate of the Nawaka River at the time of peak flow of the Malakua River is nearly equal to the peak flow of the Nawaka River. Therefore, the initial water level in the Malakua River is set up the high water level of the Nawaka River.

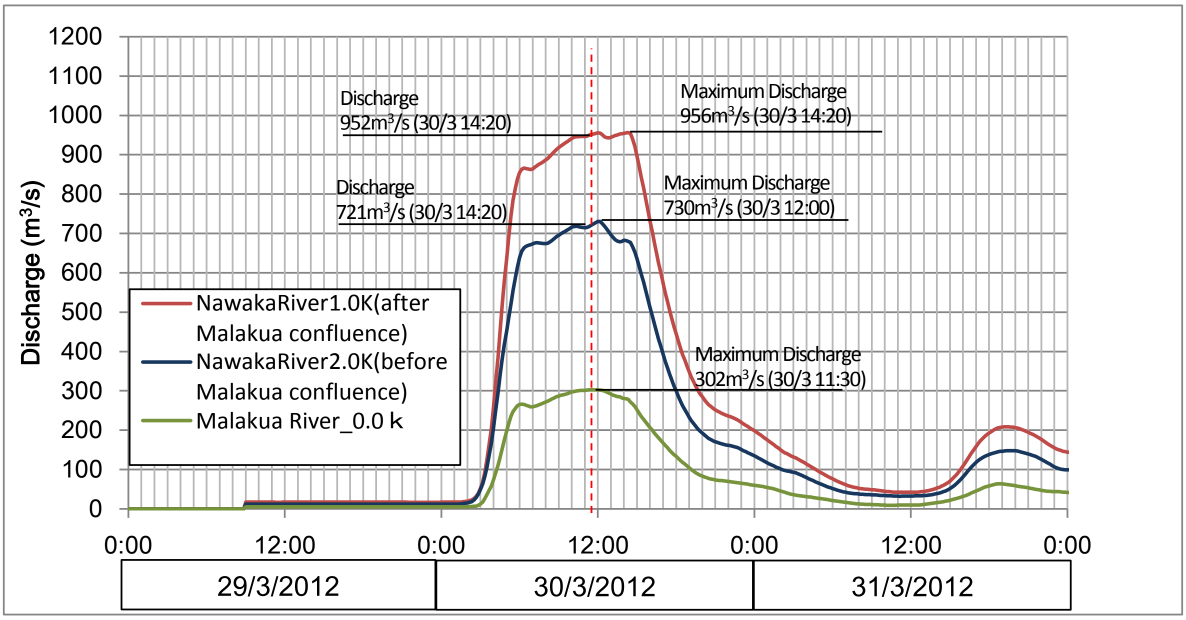


Figure8-17 Hydrograph at the confluence of the Nawaka River and the Malakua River

■The way of thinking for the initial water level in the Namosi River (see Figure8-19)

Though, the Nadi River indicates the hydrograph regulated by the dam, there is no regulating facility in the Namosi River. As there is a time lag between the time of peak flow at the confluence of both the Nadi River and the Namosi River, the high water level at the confluence will be determined by the water level in the following 2 cases (refer to Figure8-20).

・Case1: The tributary peak discharge flow and the water level in the main river at the occurrence time of the peak flow in the tributary are utilized as the flow rate and the initial water level respectively.

・Case2: The water level at the occurrence time of the peak discharge flow in the main river and the discharge flow of the tributary at that time are utilized as the initial water level and the flow rate respectively.

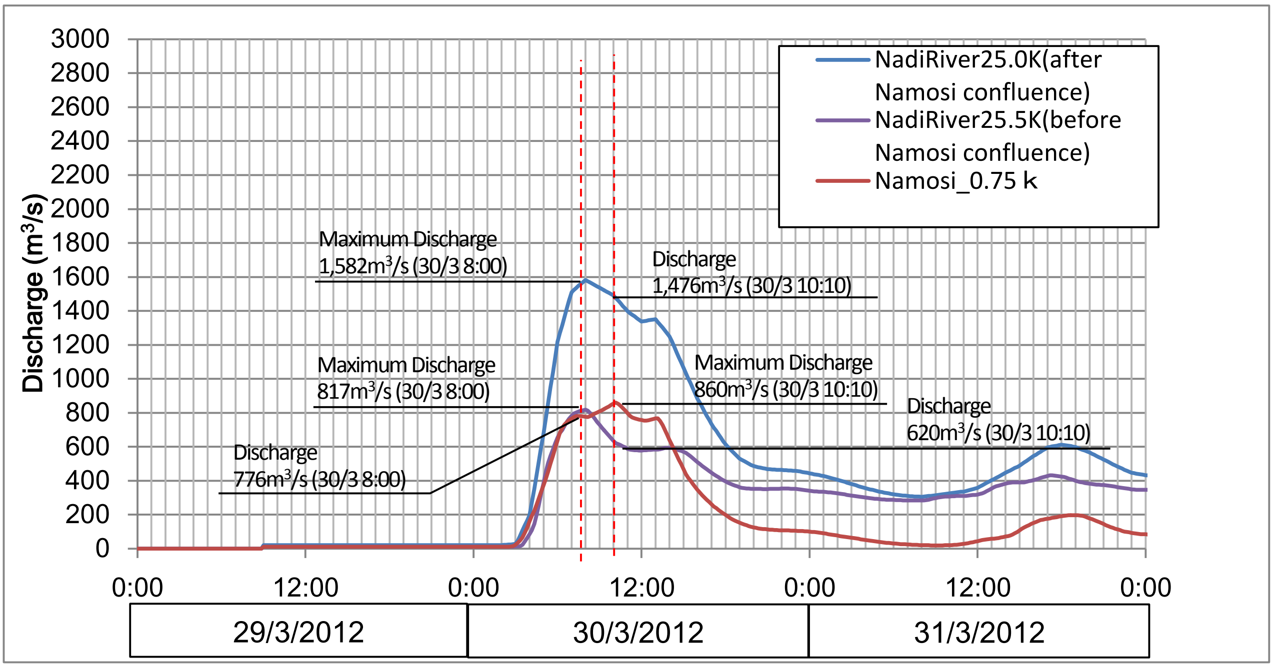


Figure8-18 Hydrograph at the confluence of the Nadi River and the Namosi River

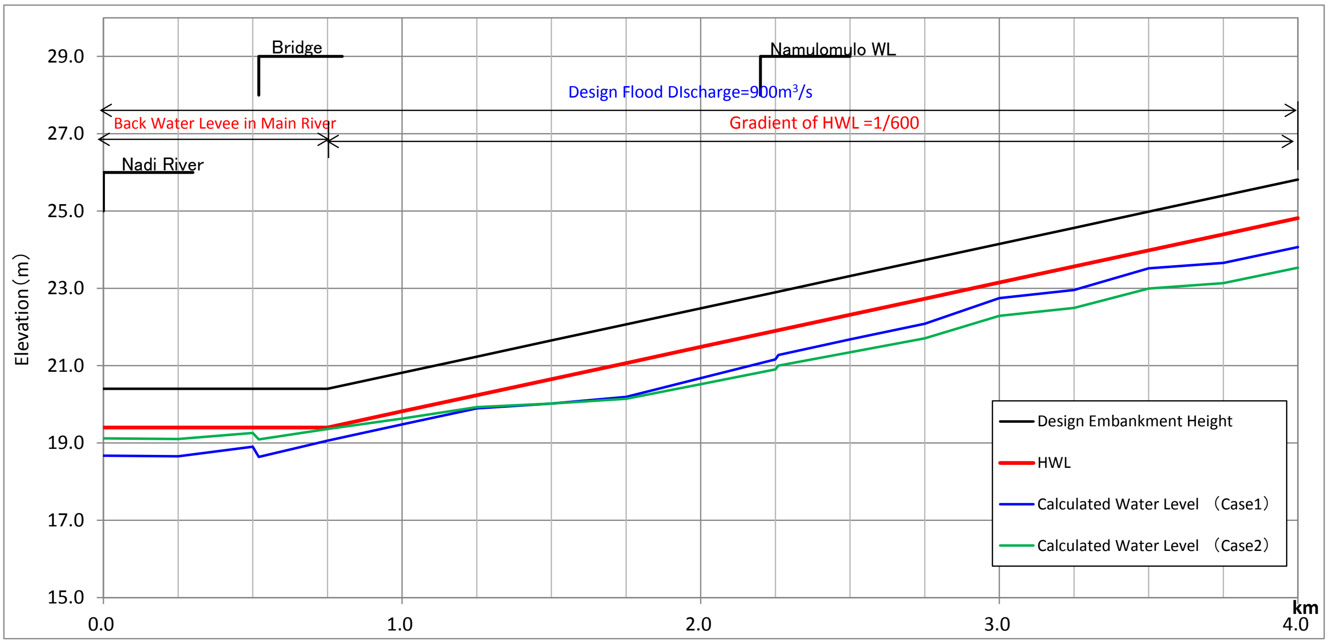


Figure8-19 Calculated Water Level in the Namosi River (Case1, Case2)

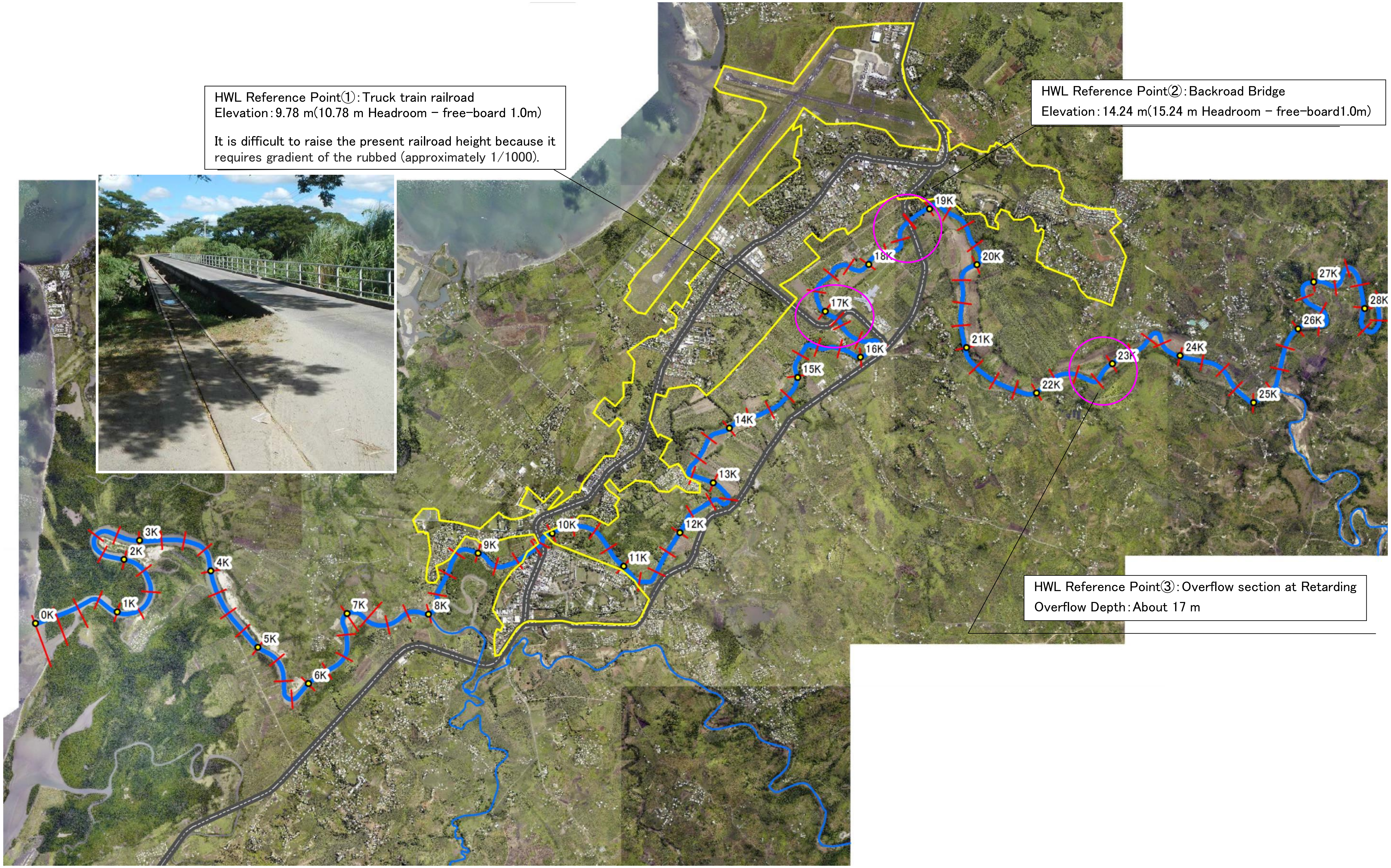


Figure8-20 Reference Point in determining the H.W.L

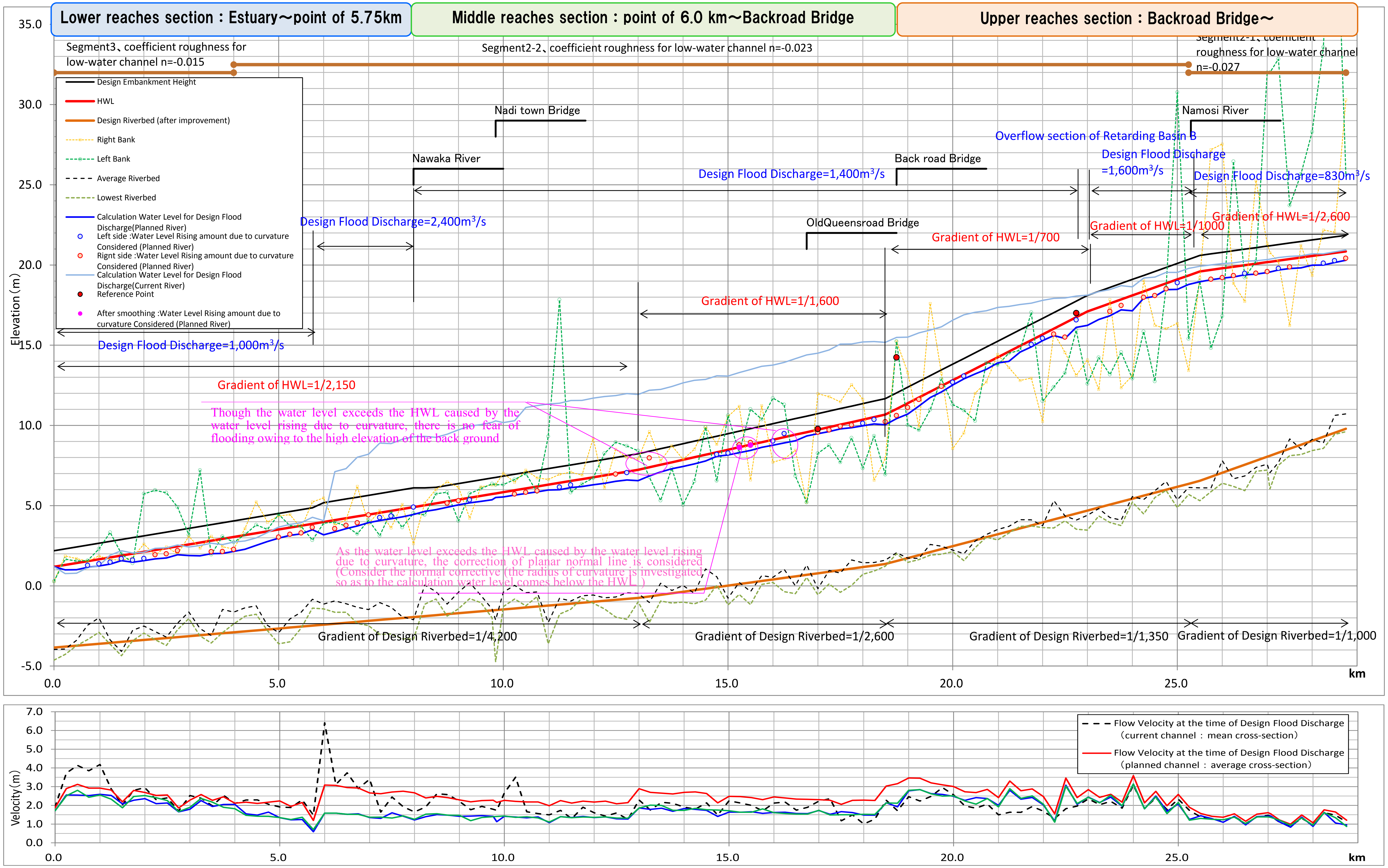


Figure8-21 Longitudinal feature (The Nadi River)

Table8-6 Longitudinal feature(The Nadi River)

Current feature

milepost	Structure	Interval	Left Bank	Right Bank	Lowest Riverbed	Average Riverbed	Headroom for bridge girder − free-board	Calculation water level of Design Flood	Water level rising amount due to	Water level after curvature	HWL − non-uniform flow calculation	Flow velocity
0.000		0.000	0.280	0.270	−4.630	−3.963		1.19	0.00		0.00	1.91
0.250		0.250	1.660	1.860	−4.270	−3.935		0.77	0.00		0.54	3.72
0.500		0.250	1.550	1.700	−3.730	−3.395		0.79	0.00		0.63	4.13
0.750		0.250	1.580	1.540	−3.350	−2.444		1.13	0.12	1.25	0.29	3.85
1.000		0.250	2.300	1.860	−2.900	−1.994		1.24	0.12	1.37	0.29	4.18
1.250		0.250	3.330	1.650	−3.642	−3.374		1.91	0.12	2.04	−0.27	2.87
1.500		0.250	2.000	1.593	−4.356	−4.088		2.19	0.12	2.31	−0.42	2.03
1.750		0.250	1.410	1.760	−3.420	−2.770		2.05	0.12	2.18	−0.17	2.80
2.000		0.250	5.736	2.605	−2.950	−2.503		2.10	0.12	2.22	−0.10	2.94
2.250		0.250	5.960	1.920	−3.354	−2.844		2.34	0.25	2.59	−0.36	2.30
2.500		0.250	5.800	2.430	−3.710	−3.200		2.37	0.25	2.62	−0.27	2.40
2.750		0.250	4.910	1.990	−2.730	−2.321		2.55	0.25	2.80	−0.33	1.70
3.000		0.250	3.170	3.083	−2.040	−1.631		2.42	0.00		0.16	2.52
3.250		0.250	7.200	2.350	−3.126	−2.665		2.52	0.00		0.18	2.38
3.500		0.250	1.950	3.097	−3.560	−3.099		2.65	0.12	2.77	0.04	1.97
3.750		0.250	3.080	2.440	−2.910	−1.471		2.57	0.12	2.69	0.24	2.54
4.000		0.250	2.714	2.286	−2.370	−1.636		2.73	0.12	2.85	0.20	2.10
4.250		0.250	3.200	3.570	−1.900	−1.374		2.80	0.00		0.36	2.28
4.500		0.250	3.800	5.230	−1.770	−1.244		2.99	0.00		0.30	2.29
4.750		0.250	3.520	3.970	−2.800	−2.460		3.32	0.00		0.08	2.06
5.000		0.250	4.460	4.360	−3.610	−2.923		3.66	0.06	3.72	−0.21	1.92
5.250		0.250	3.750	4.440	−3.490	−2.061		3.83	0.06	3.89	−0.26	1.88
5.500		0.250	3.714	3.587	−2.640	−1.645		3.93	0.06	3.99	−0.25	2.29
5.750		0.250	2.850	5.230	−1.390	−0.836		4.28	0.15	4.42	−0.56	1.48
6.000		0.250	3.910	5.480	−1.440	−1.141		4.06	0.00		−0.08	6.41
6.250		0.250	3.970	3.780	−1.645	−0.936		7.12	0.20	7.31	−3.22	3.12
6.500		0.250	3.720	4.115	−1.650	−1.116		7.31	0.20	7.51	−3.30	3.74
6.750		0.250	3.240	6.200	−2.340	−1.339		8.02	0.20	8.21	−3.89	2.89
7.000		0.250	4.090	3.867	−2.480	−1.479		8.20	0.47	8.68	−4.23	3.39
7.250		0.250	3.130	4.700	−3.027	−1.045		8.90	0.18	9.08	−4.51	1.64
7.500		0.250	4.620	3.610	−3.000	−1.332		8.87	0.18	9.05	−4.37	2.44
7.750		0.250	3.640	5.080	−3.300	−1.919		9.14	0.00		−4.34	1.92
8.000	NavuBridge（支川）	0.250	4.525	2.624	−3.320	−2.117		9.29	0.45	9.75	−4.84	1.64
8.250		0.250	4.424	5.156	−1.150	0.049		9.32	0.00		−4.29	1.92
8.500		0.250	5.740	6.013	−0.820	−0.356		9.26	0.00		−4.12	2.62
8.750		0.250	5.836	6.480	−1.890	−1.138		9.45	0.26	9.71	−4.45	2.57
9.000		0.250	4.050	6.150	−1.430	−0.393		9.73	0.26	9.98	−4.61	2.21
9.250		0.250	5.750	4.220	−0.800	0.202		9.96	0.18	10.14	−4.65	1.76
9.500		0.250	6.060	6.170	−1.050	−0.600		10.05	0.00		−4.44	1.95
9.750		0.250	6.360	6.290	−2.000	−1.450		10.20	0.00		−4.47	1.79
9.830	NaditownBridge	0.080	6.300	6.300	−4.730	−2.131	5.300	10.29	0.00		−4.53	1.73
10.000		0.170	6.310	7.020	−1.300	−0.398		10.18	0.00		−4.34	2.66
10.250		0.250	6.630	6.460	−0.820	0.028		10.30	0.07	10.36	−4.41	3.51
10.500		0.250	6.990	7.210	−1.250	−0.431		11.12	0.07	11.19	−5.12	1.66
10.750		0.250	5.850	6.730	−0.670	−0.376		11.23	0.07	11.30	−5.11	1.56
11.000		0.250	9.310	6.630	−3.610	−2.289		11.33	0.00		−5.03	1.49
11.250		0.250	17.830	6.950	−1.760	−0.769		11.39	0.16	11.55	−5.13	1.73
11.500		0.250	5.820	7.090	−1.460	−0.950		11.56	0.16	11.72	−5.18	1.29
11.750		0.250	6.350	6.900	−0.770	−0.622		11.56	0.00		−4.90	1.90
12.000		0.250	6.720	9.190	−1.080	−0.574		11.70	0.00		−4.93	1.60
12.250		0.250	8.250	6.100	−1.440	−0.750		11.80	0.00		−4.92	1.43
12.500		0.250	8.950	8.510	−1.950	−0.700		11.86	0.44	12.30	−5.30	1.60
12.750		0.250	8.720	8.000	−2.090	−0.434		11.99	0.46	12.45	−5.33	1.25
13.000		0.250	8.420	7.900	−1.000	−0.463		11.92	0.00		−4.69	2.28
13.250		0.250	6.770	9.620	−2.290	−1.039		12.19	1.20	13.39	−6.00	1.75
13.500		0.250	5.320	7.780	−0.950	0.164		12.25	0.00		−4.70	2.16
13.750		0.250	7.330	8.740	−1.070	−0.291		12.43	0.00		−4.72	2.11
14.000		0.250	5.040	7.880	−1.010	0.022		12.65	0.00		−4.79	1.90
14.250		0.250	6.510	8.510	−1.120	−0.464		12.81	0.00		−4.80	1.80
14.500		0.250	9.880	9.920	−0.890	1.057		12.87	0.00		−4.70	2.13
14.750		0.250	6.550	8.820	0.050	0.567		13.09	0.11	13.20	−4.87	1.48
15.000		0.250	10.620	10.560	−1.190	−0.769		13.08	0.11	13.19	−4.70	2.24
15.250		0.250	8.290	11.190	−0.540	0.216		13.29	0.49	13.78	−5.14	2.13
15.500		0.250	11.010	6.600	−1.170	−0.354		13.49	0.49	13.98	−5.18	2.00
15.750		0.250	10.380	11.230	0.090	0.637		13.69	0.00		−4.74	1.70
16.000		0.250	11.700	7.710	0.210	0.532		13.76	0.25	14.01	−4.90	2.12
16.250		0.250	11.300	7.910	−0.360	1.033		13.92	0.58	14.50	−5.24	2.18
16.500		0.250	6.850	8.450	−0.490	0.008		14.16	0.00		−4.74	1.74
16.750		0.250	5.200	5.200	0.520	1.307		14.39	0.00		−4.81	1.89
17.000	OldQueensRoadBridg	0.250	8.260	11.980	−0.550	−0.182	9.780	14.50	0.09	14.59	−4.86	2.22
17.250		0.250	8.770	11.790	0.120	0.952		14.70	0.09	14.80	−4.91	2.36
17.500		0.250	7.700	11.470	−0.400	0.795		15.07	0.14	15.21	−5.17	1.18
17.750		0.250	9.220	12.540	0.030	1.613		15.08	0.15	15.23	−5.03	1.49
18.000		0.250	7.330	11.630	0.720	1.442		15.20	0.15	15.35	−4.99	1.01
18.250		0.250	9.340	6.590	0.920	1.459		15.23	0.30	15.52	−5.01	1.26
18.500		0.250	6.940	7.920	1.220	1.597		15.18	0.18	15.35	−4.68	2.27
18.750	BackroadBridge	0.250	15.240	15.240	2.000	2.061	14.240	15.49	0.18	15.66	−4.63	1.71
19.000		0.250	10.020	13.290	1.460	1.727		15.50	0.34	15.84	−4.45	2.46
19.250		0.250	9.710	9.900	1.640	1.713		15.77	0.34	16.11	−4.37	2.23
19.500		0.250	10.980	17.600	1.910	2.582		15.95	0.00		−3.85	2.48
19.750		0.250	12.890	13.240	1.970	2.471		16.15	0.32	16.46	−4.00	2.95
20.000		0.250	11.300	8.550	2.130	2.231		16.57	0.16	16.72	−3.91	2.56
20.250		0.250	10.940	9.530	1.570	2.008		16.89	0.16	17.05	−3.87	1.97
20.500		0.250	10.280	12.000	2.380	2.787		17.05	0.00		−3.52	1.85
20.750		0.250	13.910	12.710	3.030	3.198		17.15	0.00		−3.26	2.07
21.000		0.250	13.770	14.420	2.860	3.516		17.36	0.00		−3.11	1.49
21.250		0.250	14.500	13.610	3.290	3.708		17.42	0.00		−2.82	1.63
21.500		0.250	14.690	12.800	3.710	4.122		17.53	0.00		−2.58	1.63
21.750		0.250	17.040	12.950	3.730	4.116		17.62	0.15	17.77	−2.45	1.94
22.000		0.250	11.510	10.250	3.630	3.745		17.80	0.15	17.95	−2.27	1.69
22.250		0.250	12.390	15.760	3.610	5.316		17.92	0.08	18.00	−1.97	1.29
22.500		0.250	13.270	14.550	4.060	4.353		17.94	0.08	18.02	−1.63	1.82
22.750	遊水地B越流堤	0.250	15.930	13.120	3.530	4.097	17.000	18.06	0.45	18.51	−1.77	1.96
23.000		0.250	12.600	14.080	3.470	4.401		18.12	0.00		−1.02	2.35
23.250		0.250	14.230	12.240	4.360	4.812		18.34	0.00		−0.99	2.03
23.500		0.250	13.170	17.840	3.950	4.254		18.47	0.27	18.74	−1.14	2.21
23.750		0.250	14.560	12.350	3.760	4.100		18.71	0.27	18.98	−1.13	1.85
24.000		0.250	12.920	13.110	5.220	5.562		18.64	0.00		−0.54	3.08
24.250		0.250	15.850	19.040	4.480	5.384		19.19	0.05	19.24	−0.89	1.83
24.500		0.250	12.750	16.240	5.510	5.928		19.25	0.05	19.30	−0.70	2.40
24.750		0.250	18.600	16.030	5.950	6.508		19.54	0.05	19.59	−0.74	1.77
25.000		0.250	30.760	16.360	4.870	5.363		19.54	0.41	19.96	−0.86	2.34
25.250		0.250	15.400	13.420	5.700	6.132		19.786	0.00		−0.44	1.73
25.500		0.250	19.000	19.210	5.310	6.107		19.919	0.00		−0.32	1.38
25.750		0.250	14.823	27.190	5.870	6.105		20.009	0.03	20.04	−0.34	1.28
26.000		0.250	16.820	27.540	6.400	7.812		20.085	0.03	20.11	−0.32	1.19
26.250		0.250	26.450	18.850	6.203	6.673		20.133	0.08	20.21	−0.32	1.40
26.500		0.250	19.220	17.730	5.930	6.847		20.241	0.08	20.32	−0.34	1.03
26.750		0.250	20.230	25.280	7.140	7.381		20.265	0.06	20.32	−0.24	1.37
27.000		0.250	31.990	21.330	7.220	7.586		20.339	0.06	20.40	−0.22	1.47
27.060		0.060	32.000	20.770	6.050	7.059		20.366	0.00		−0.17	1.42
27.250		0.190	32.840	20.220	7.512	7.687		20.466	0.09	20.56	−0.29	1.11
27.500		0.250	23.710	16.230	8.120	9.156		20.54	0.10	20.64	−0.27	0.89
27.750		0.250	25.660	21.220	8.180	8.522		20.575	0.00		−0.11	1.30
28.000		0.250	28.300	19.350	8.430	9.132		20.699	0.00		−0.14	0.96
28.250		0.250	33.570	22.178	8.566	8.908		20.699	0.11	20.81	−0.15	1.61
28.500		0.250	46.710	22.050	9.440	10.625		20.826	0.11	20.94	−0.18	1.47
28.750		0.250	25.620	30.300	9.611	10.714		20.937	0.12	21.05	−0.20	1.11

Design feature

milepost	Allocation of Flow rate	Fee-board	HWL	Designed Embankment Height	Design Riverbed (after improvement)	Design water depth	Design river width	Gradient of HWL	Lowest Riverbed (after improvement)	Calculation Water Level for Design Flood Discharge	Water level rising amount due to curvature	Water level after consideration of curvature	HWL − non-uniform flow calculation	Flow velocity
0.000		1.0	1.19	2.19	−3.85	5.038	80			1.19	0.00		0.00	1.87
0.250		1.0	1.30	2.30	−3.79	5.095	80			0.99	0.00		0.31	2.89
0.500		1.0	1.42	2.42	−3.73	5.152	80			1.00	0.00		0.42	3.12
0.750		1.0	1.54	2.54	−3.67	5.208	80			1.16	0.12	1.28	0.26	2.92
1.000		1.0	1.65	2.65	−3.61	5.265	80			1.24	0.12	1.37	0.29	2.92
1.250		1.0	1.77	2.77	−3.55	5.322	80			1.35	0.12	1.48	0.29	2.81
1.500		1.0	1.89	2.89	−3.49	5.379	80			1.57	0.12	1.70	0.19	2.19
1.750		1.0	2.00	3.00	−3.43	5.435	80			1.47	0.12	1.60	0.40	2.79
2.000		1.0	2.12	3.12	−3.37	5.492	80			1.57	0.12	1.70	0.42	2.69
2.250		1.0	2.23	3.23	−3.31	5.549	80			1.68	0.25	1.94	0.30	2.53
2.500		1.0	2.35	3.35	−3.25	5.606	80			1.74	0.25	1.99	0.36	2.55
2.750	1000	1.0	2.47	3.47	−3.20	5.662	80			1.94	0.25	2.19	0.28	1.86
3.000		1.0	2.58	3.58	−3.14	5.719	80			1.89	0.00		0.69	2.28
3.250		1.0	2.70	3.70	−3.08	5.776	80			1.87	0.00		0.83	2.58
3.500		1.0	2.82	3.82	−3.02	5.833	80			2.01	0.12	2.13	0.69	2.27
3.750		1.0	2.93	3.93	−2.96	5.889	80			2.02	0.12	2.14	0.80	2.46
4.000		1.0	3.05	4.05	−2.90	5.946	80			2.15	0.12	2.27	0.78	2.12
4.250		1.0	3.16	4.16	−2.84	6.003	80			2.28	0.00		0.89	2.17
4.500		1.0	3.28	4.28	−2.78	6.060	80			2.53	0.00		0.76	2.10
4.750		1.0	3.40	4.40	−2.72	6.116	80			2.76	0.00		0.63	2.17
5.000		1.0	3.51	4.51	−2.66	6.173	80			2.97	0.06	3.03	0.48	2.23
5.250		1.0	3.63	4.63	−2.60	6.230	80			3.15	0.06	3.21	0.42	1.94
5.500		1.0	3.75	4.75	−2.54	6.287	80			3.24	0.06	3.30	0.45	2.15
5.750		1.0	3.86	4.86	−2.48	6.343	150			3.50	0.15	3.64	0.22	1.19
6.000		1.2	3.98	5.18	−2.42	6.400	150			3.18	0.00		0.80	3.08
6.250		1.2	4.09	5.29	−2.36	6.457	150			3.37	0.20	3.56	0.53	3.07
6.500		1.2	4.21	5.41	−2.30	6.514	150	1/2150	1/4200	3.57	0.20	3.77	0.45	2.95
6.750		1.2	4.33	5.53	−2.24	6.570	150			3.73	0.20	3.93	0.40	2.93
7.000	2400	1.2	4.44	5.64	−2.18	6.627	150			3.94	0.47	4.42	0.03	2.66
7.250		1.2	4.56	5.76	−2.12	6.684	150			4.07	0.18	4.25	0.31	2.62
7.500		1.2	4.68	5.88	−2.06	6.741	150			4.18	0.18	4.36	0.32	2.71
7.750		1.2	4.79	5.99	−2.00	6.797	150			4.30	0.00		0.49	2.76
8.000		1.2	4.91	6.11	−1.95	6.854	150			4.45	0.45	4.90	0.01	2.67
8.250		1.0	5.03	6.11	−1.89	6.911	100			4.64	0.00		0.38	2.39
8.500		1.0	5.14	6.14	−1.83	6.968	100			4.75	0.00		0.39	2.48
8.750		1.0	5.26	6.26	−1.77	7.024	100			4.90	0.26	5.15	0.10	2.41
9.000		1.0	5.37	6.37	−1.71	7.081	100			5.05	0.26	5.30	0.07	2.29
9.250		1.0	5.49	6.49	−1.65	7.138	100			5.17	0.18	5.35	0.14	2.19
9.500		1.0	5.61	6.61	−1.59	7.195	100			5.26	0.00		0.34	2.25
9.750		1.0	5.72	6.72	−1.53	7.251	100			5.36	0.00		0.36	2.27
9.830		1.0	5.76	6.76	−1.51	7.270	100			5.51	0.00		0.25	2.16
10.000		1.0	5.84	6.84	−1.47	7.308	100			5.54	0.00		0.30	2.26
10.250		1.0	5.96	6.96	−1.41	7.365	100			5.65	0.07	5.72	0.24	2.21
10.500		1.0	6.07	7.07	−1.35	7.422	100			5.76	0.07	5.83	0.25	2.18
10.750		1.0	6.19	7.19	−1.29	7.478	100			5.85	0.07	5.92	0.27	2.18
11.000		1.0	6.30	7.30	−1.23	7.535	100			5.97	0.00		0.33	1.98
11.250		1.0	6.42	7.42	−1.17	7.592	100			5.99	0.16	6.16	0.26	2.25
11.500		1.0	6.54	7.54	−1.11	7.649	100			6.12	0.16	6.28	0.25	2.12
11.750		1.0	6.65	7.65	−1.05	7.705	100			6.19	0.00		0.46	2.23
12.000		1.0	6.77	7.77	−0.99	7.762	100			6.30	0.00		0.47	2.18
12.250		1.0	6.89	7.89	−0.93	7.819	100			6.39	0.00		0.49	2.22
12.500		1.0	7.00	8.00	−0.87	7.876	100			6.52	0.44	6.96	0.04	2.08
12.750		1.0	7.12	8.12	−0.81	7.933	100			6.60	0.46	7.05	0.07	2.14
13.000		1.0	7.23	8.23	−0.75	7.989	80			6.56	0.00		0.68	2.89
13.250		1.0	7.39	8.39	−0.66	8.049	80			6.85	1.12	7.97	−0.58	2.69
13.500		1.0	7.55	8.55	−0.56	8.109	80			7.10	0.00		0.45	2.65
13.750		1.0	7.70	8.70	−0.47	8.170	80			7.30	0.00		0.40	2.61
14.000		1.0	7.86	8.86	−0.37	8.230	80			7.44	0.00		0.42	2.69
14.250		1.0	8.02	9.02	−0.27	8.290	80			7.60	0.00		0.42	2.72
14.500		1.0	8.17	9.17	−0.18	8.350	80			7.78	0.00		0.39	2.63
14.750		1.0	8.33	9.33	−0.08	8.410	80			8.08	0.11	8.18	0.14	2.13
15.000		1.0	8.48	9.48	0.01	8.470	80			8.16	0.11	8.27	0.22	2.48
15.250		1.0	8.64	9.64	0.11	8.530	80			8.30	0.49	8.79	−0.15	2.47
15.500	1400	1.0	8.80	9.80	0.21	8.590	80	1/1600	1/2600	8.45	0.49	8.93	−0.13	2.42
15.750		1.0	8.95	9.95	0.30	8.650	80			8.64	0.00		0.32	2.31
16.000		1.0	9.11	10.11	0.40	8.710	80			8.77	0.25	9.02	0.09	2.45
16.250		1.0	9.27	10.27	0.50	8.771	80			8.91	0.58	9.49	−0.23	2.39
16.500		1.0	9.42	10.42	0.59	8.831	80			9.04	0.00		0.38	2.33
16.750		1.0	9.58	10.58	0.69	8.891	80			9.34	0.00		0.24	2.32
17.000		1.0	9.73	10.73	0.78	8.951	80			9.48	0.09	9.58	0.16	2.31
17.250		1.0	9.89	10.89	0.88	9.011	80			9.62	0.09	9.71	0.18	2.27
17.500		1.0	10.05	11.05	0.98	9.071	80			9.79	0.15	9.94	0.11	2.05
17.750		1.0	10.20	11.20	1.07	9.131	80			9.86	0.16	10.02	0.18	2.27
18.000		1.0	10.36	11.36	1.17	9.191	80			9.97	0.16	10.13	0.23	2.28
18.250		1.0	10.52	11.52	1.26	9.251	80			10.09	0.28	10.37	0.15	2.26
18.500		1.0	10.67	11.67	1.36	9.311	70			10.04	0.19	10.23	0.44	3.03
18.750		1.0	11.03	12.03	1.55	9.483	70			10.43	0.19	10.61	0.42	3.16
19.000		1.0	11.39	12.39	1.73	9.655	70			10.71	0.40	11.11	0.27	3.46
19.250		1.0	11.74	12.74	1.92	9.827	70			11.21	0.40	11.61	0.13	3.45
19.500		1.0	12.10	13.10	2.10	9.999	70			11.74	0.00		0.36	3.20
19.750		1.0	12.46	13.46	2.29	10.171	70			12.09	0.35	12.43	0.02	3.10
20.000		1.0	12.81	13.81	2.47	10.343	70			12.52	0.17	12.69	0.12	3.00
20.250		1.0	13.17	14.17	2.66	10.515	70			12.90	0.17	13.07	0.10	2.72
20.500		1.0	13.53	14.53	2.84	10.687	70	1/700		13.21	0.00		0.32	2.68
20.750		1.0	13.89	14.89	3.03	10.859	70			13.50	0.00		0.39	2.85
21.000		1.0	14.24	15.24	3.21	11.031	65			13.89	0.00		0.35	2.41
21.250		1.0	14.60	15.60	3.40	11.203	65			13.99	0.00		0.61	3.30
21.500		1.0	14.96	15.96	3.58	11.375	65			14.57	0.00		0.39	2.78
21.750		1.0	15.31	16.31	3.77	11.547	65		1/1350	14.89	0.15	15.05	0.27	2.88
22.000		1.0	15.67	16.67	3.95	11.719	65			15.28	0.15	15.44	0.24	2.47
22.250		1.0	16.03	17.03	4.14	11.891	65			15.61	0.08	15.69	0.34	1.55
22.500		1.0	16.39	17.39	4.32	12.063	65			15.42	0.08	15.50	0.89	3.46
22.750		1.0	16.74	17.74	4.51	12.235	65			16.11	0.46	16.57	0.17	2.41
23.000		1.0	17.10	18.10	4.69	12.407				16.24	0.00		0.86	2.84
23.250		1.0	17.35	18.35	4.88	12.471				16.61	0.00		0.74	2.43
23.500		1.0	17.60	18.60	5.06	12.536				16.84	0.27	17.11	0.49	2.59
23.750		1.0	17.85	18.85	5.25	12.601				17.21	0.27	17.48	0.38	2.17
24.000		1.0	18.10	19.10	5.43	12.666				17.15	0.00		0.95	3.58
24.250	1600	1.0	18.35	19.35	5.62	12.731		1/1000		17.93	0.05	17.98	0.37	2.13
24.500		1.0	18.60	19.60	5.81	12.796				18.05	0.05	18.09	0.51	2.75
24.750		1.0	18.85	19.85	5.99	12.860				18.46	0.05	18.51	0.34	1.98
25.000		1.0	19.10	20.10	6.18	12.925				18.48	0.42	18.90	0.20	2.58
25.250		1.0	19.35	20.35	6.36	12.990				18.789	0.00		0.56	1.90
25.500		1.0	19.60	20.60	6.55	13.055				18.953	0.00		0.65	1.56
25.750		1.0	19.70	20.70	6.80	12.901				19.08	0.03	19.11	0.59	1.41
26.000		1.0	19.79	20.79	7.05	12.747				19.176	0.03	19.21	0.59	1.37
26.250		1.0	19.89	20.89	7.30	12.593				19.254	0.08	19.34	0.55	1.55
26.500		1.0	19.99	20.99	7.55	12.439				19.392	0.08	19.47	0.51	1.15
26.750		1.0	20.08	21.08	7.80	12.286				19.429	0.06	19.49	0.59	1.53
27.000		1.0	20.18	21.18	8.05	12.132				19.529	0.06	19.59	0.59	1.61
27.060	830	1.0	20.20	21.20	8.11	12.095		1/2600	1/1000	19.565	0.00		0.64	1.55
27.250		1.0	20.27	21.27	8.30	11.978				19.685	0.10	19.78	0.49	1.22
27.500		1.0	20.37	21.37	8.55	11.824				19.776	0.10	19.87	0.50	0.99
27.750		1.0	20.47	21.47	8.80	11.670				19.82	0.00		0.65	1.48
28.000		1.0	20.56	21.56	9.05	11.516				19.987	0.00		0.58	1.06
28.250		1.0	20.66	21.66	9.30	11.362				19.997	0.11	20.11	0.55	1.76
28.500		1.0	20.75	21.75	9.55	11.209				20.154	0.11	20.26	0.49	1.64
28.750		1.0	20.85	21.85	9.80	11.055				20.298	0.12	20.42	0.44	1.20

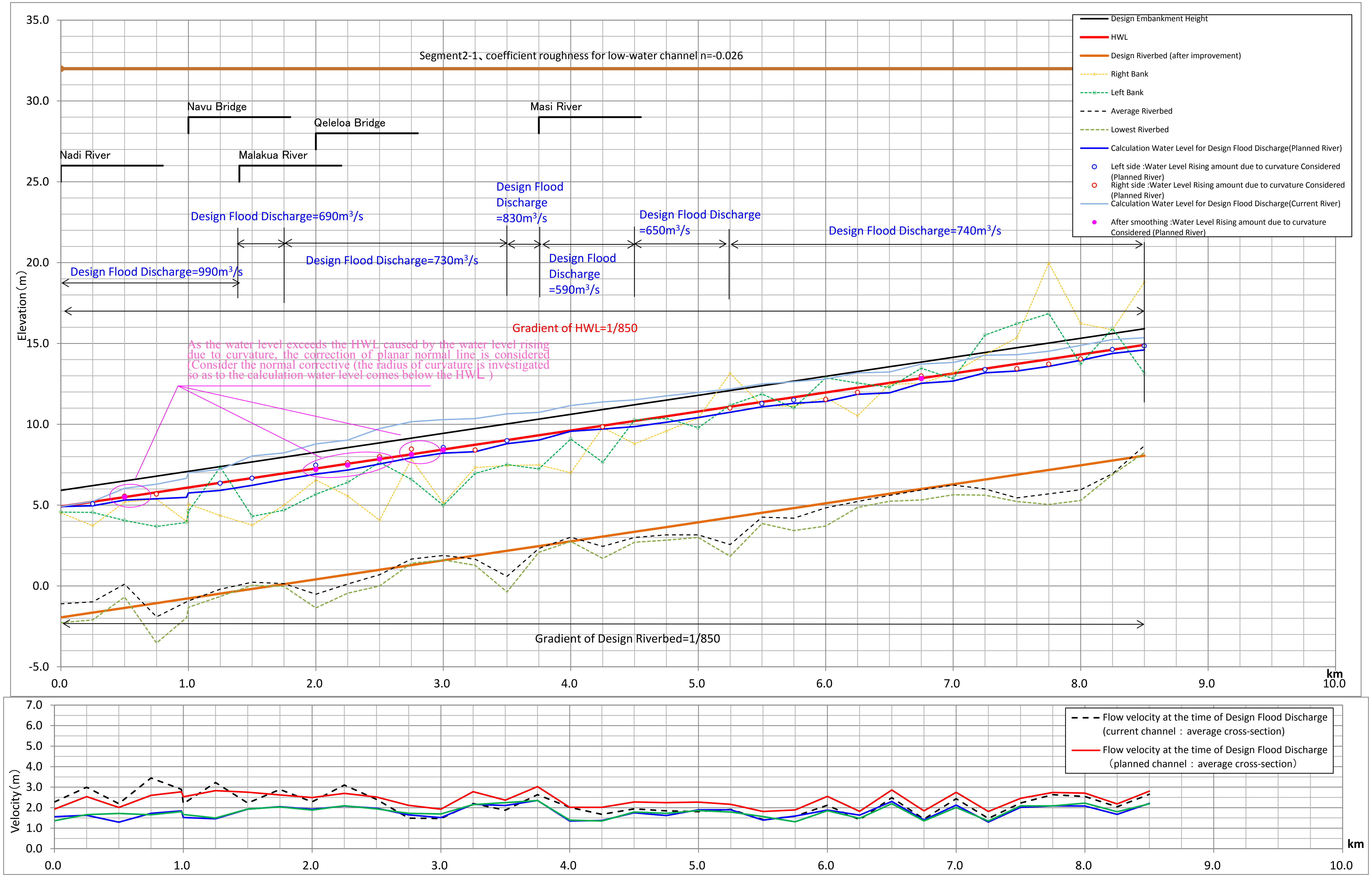


Figure8-22 Longitudinal feature (The Nawaka River)

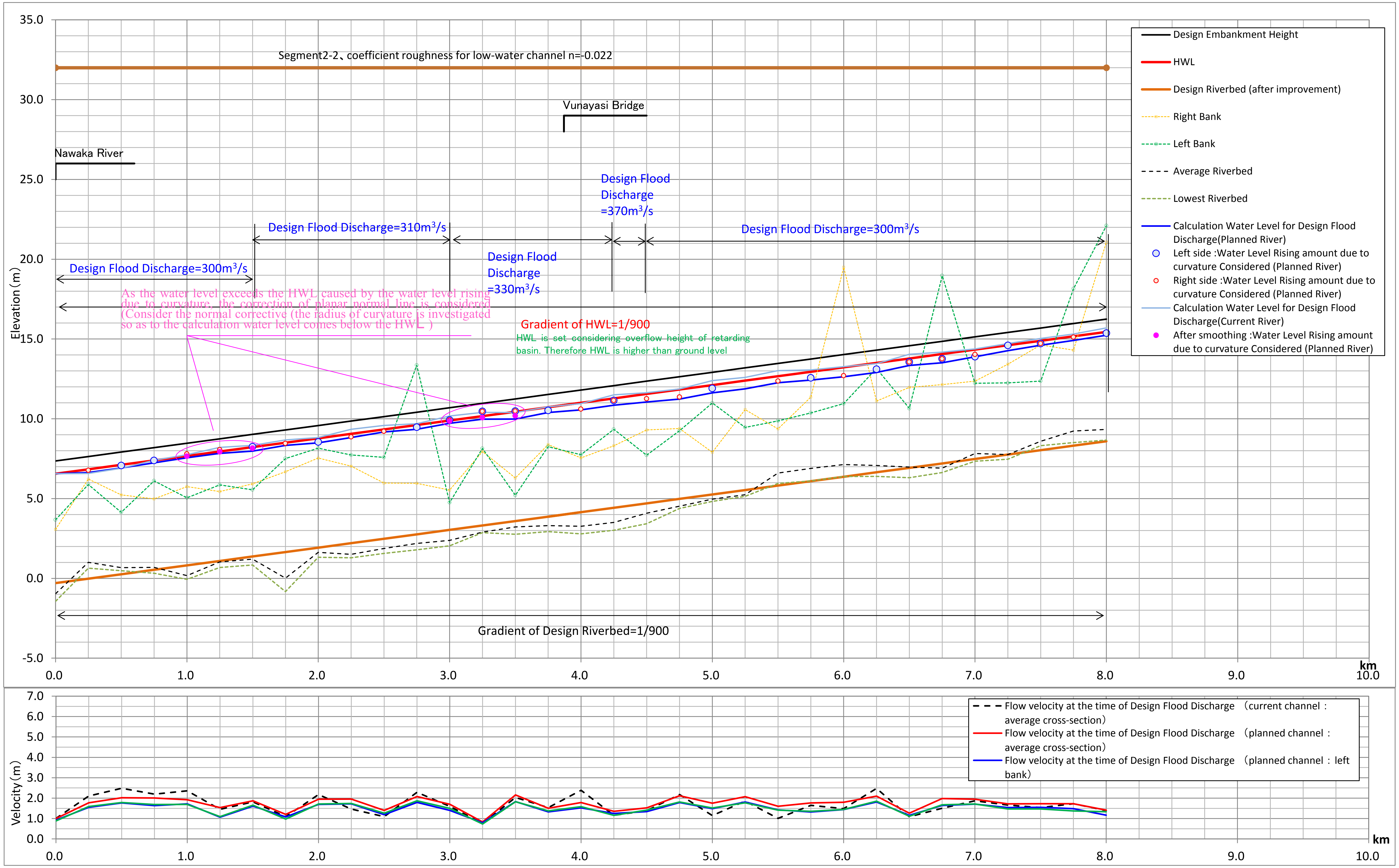


Figure8-23 Longitudinal feature (The Malakua River)

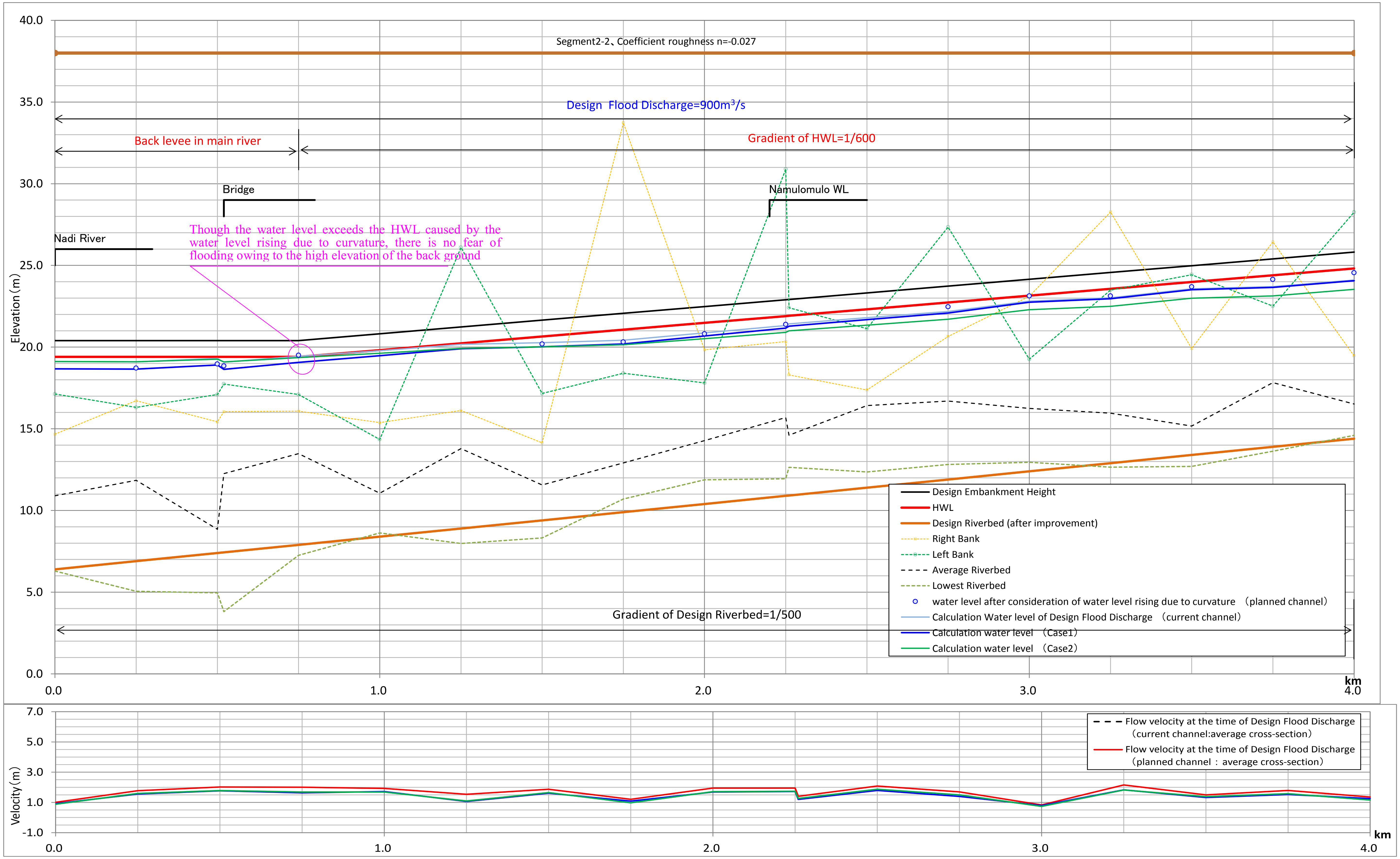


Figure8-24 Longitudinal feature (The Namosi River)

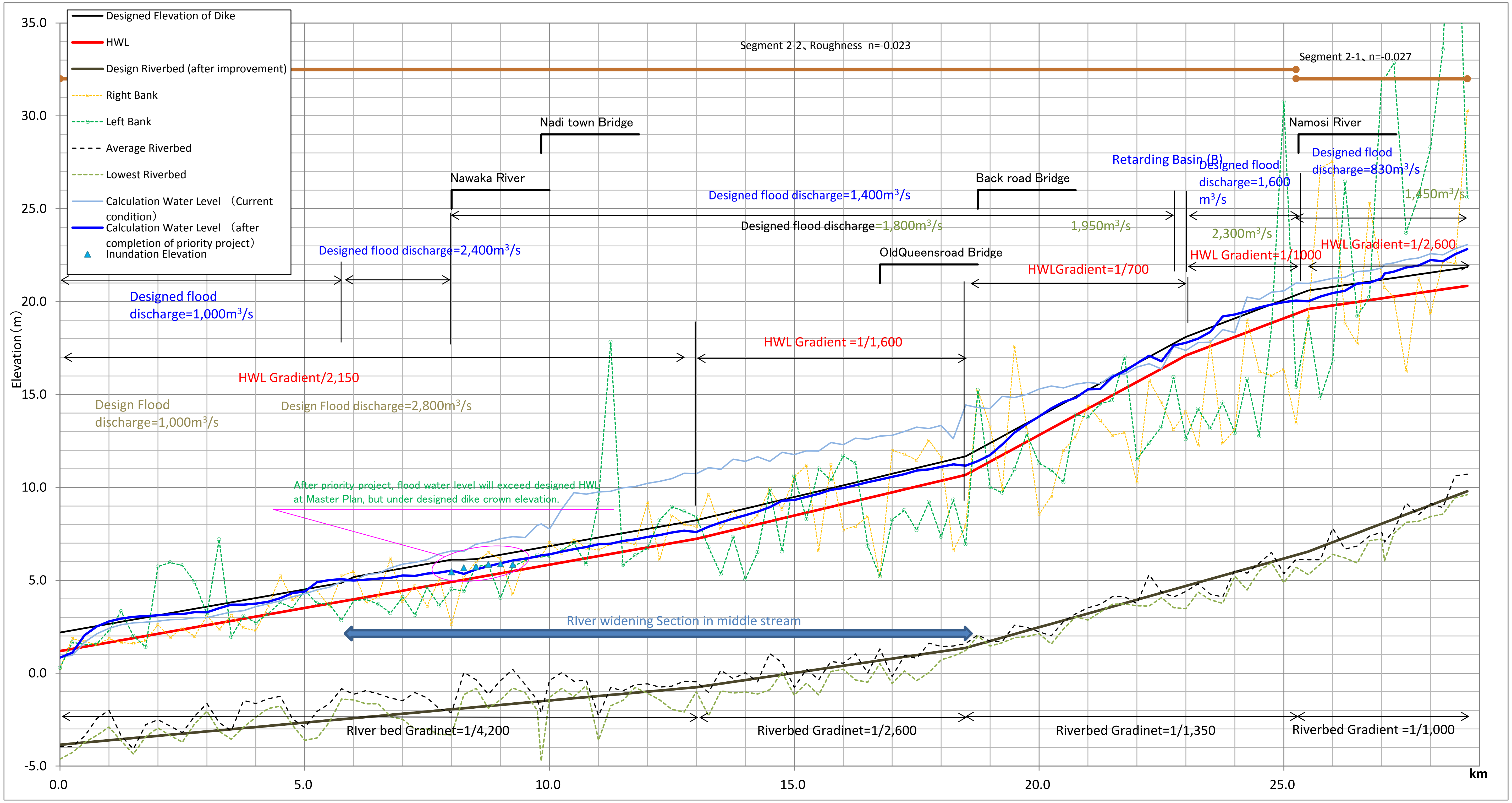


Figure8-25 River Water Level and Inundation Elevation near surrounding dike at Priority Project (Nadi River at left side section)

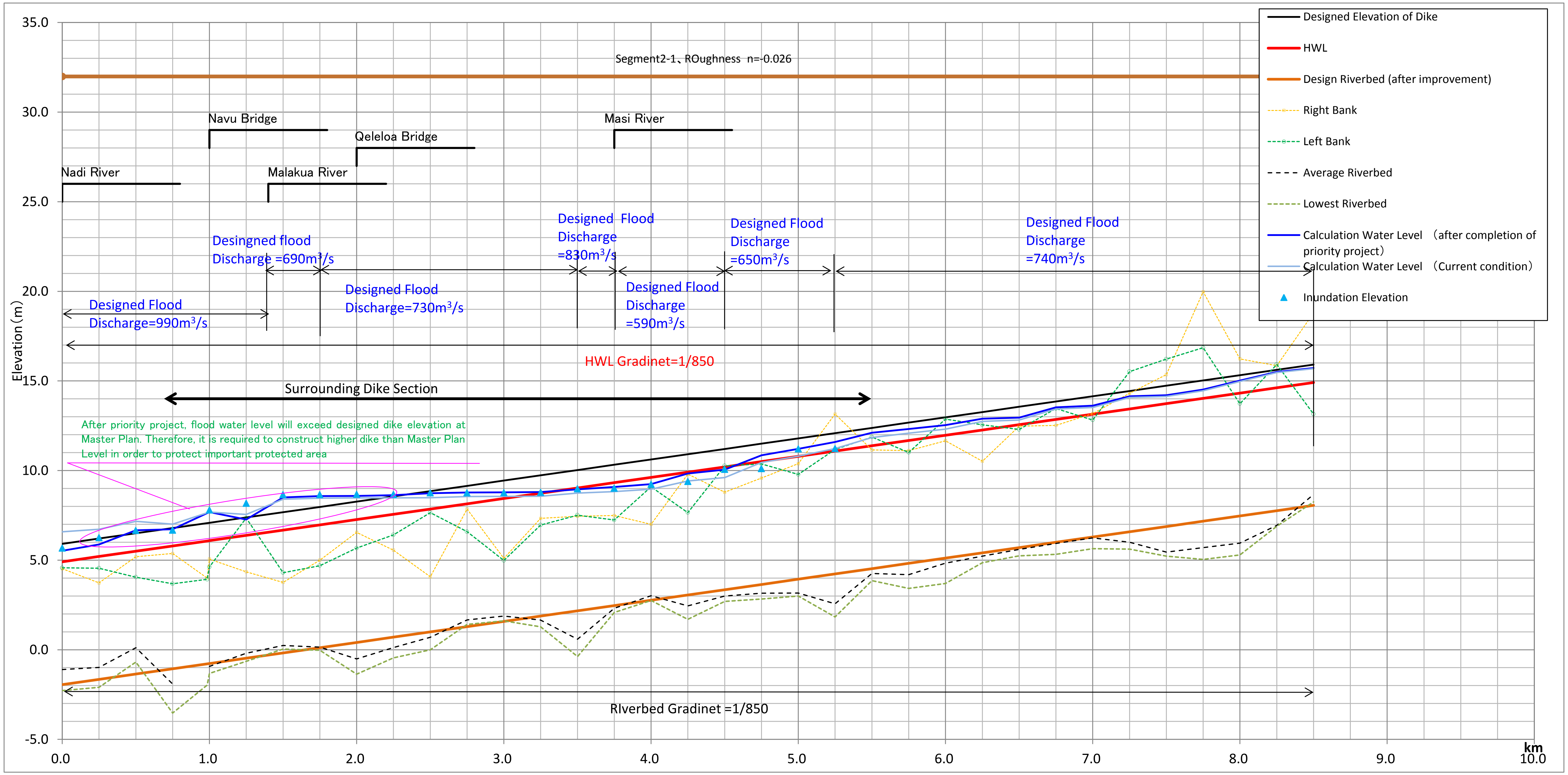


Figure8-26 River Water Level and Inundation Elevation near surrounding dike at Priority Project (Nawaka River at right side section)

8.2.4 Cross-sectional Plan

It is necessary to set up the required cross-section taking land use of riverside area or the natural environment into consideration with ensuring the cross-sectional area of a channel where flows safely down the design flood discharge within the design high water level. The concept of the cross-sectional plan is shown below. As stated above, standard cross-sectional features and standard cross-sections are shown in Table 8-8 and Fig.8-29 to Fig.8-33.

① Riverbank to be widened (left and right bank)
From the point of view of fairness, both banks are basically to be widened, and the widening riverbank is determined in consideration of the linear river channel improvement, housing relocation associated with river improvement (although housing relocation should be avoided as much as possible), the impact on land use.

② Slope Gradient
The slope gradient of riverside is basically set as 20 % because of the current slope gradient being about 20%, and from the viewpoint of avoiding housing relocation and land acquisition as much as possible, and the stability of the slope shall be fully checked*. The slope gradient of land side is basically set as 30 % in consideration for the stability of bank against the percolation and so on. (*The stability of the bank slope shall be checked in the Feasibility Study.)

③ Revetment
There are no river bank erosion and luxuriant growth of vegetation in the current river channel (see Fig.8-28), and the flow velocity at river banks is 2 m to 3 m (refer to Fig.8-23 – Fig.8-26). Therefore, revetment works are basically not installed for the river bank on the basis that it is possible to protect the river bank with vegetation.

④ Design Roughness Coefficient
Design Roughness Coefficient (Tabele 5.3-15) for both the riverbed section and the river bank follow the current value of the river. (see Table 8-7)

⑤ Area where houses adjoin
For the part of the area where houses adjoin, the outer levee widening is adopted for the embankment and housing relocation is avoided as much as possible.

⑥ Bank Width
In accordance with “Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 21”, the embankment section is provided with a bank width for a given flow rate.

⑦ Inspection Passage
In accordance with “Cabinet Order concerning Structural Standards for River Management Facilities, etc. Chapter III Article 27”, the embankment is provided a inspection passage.

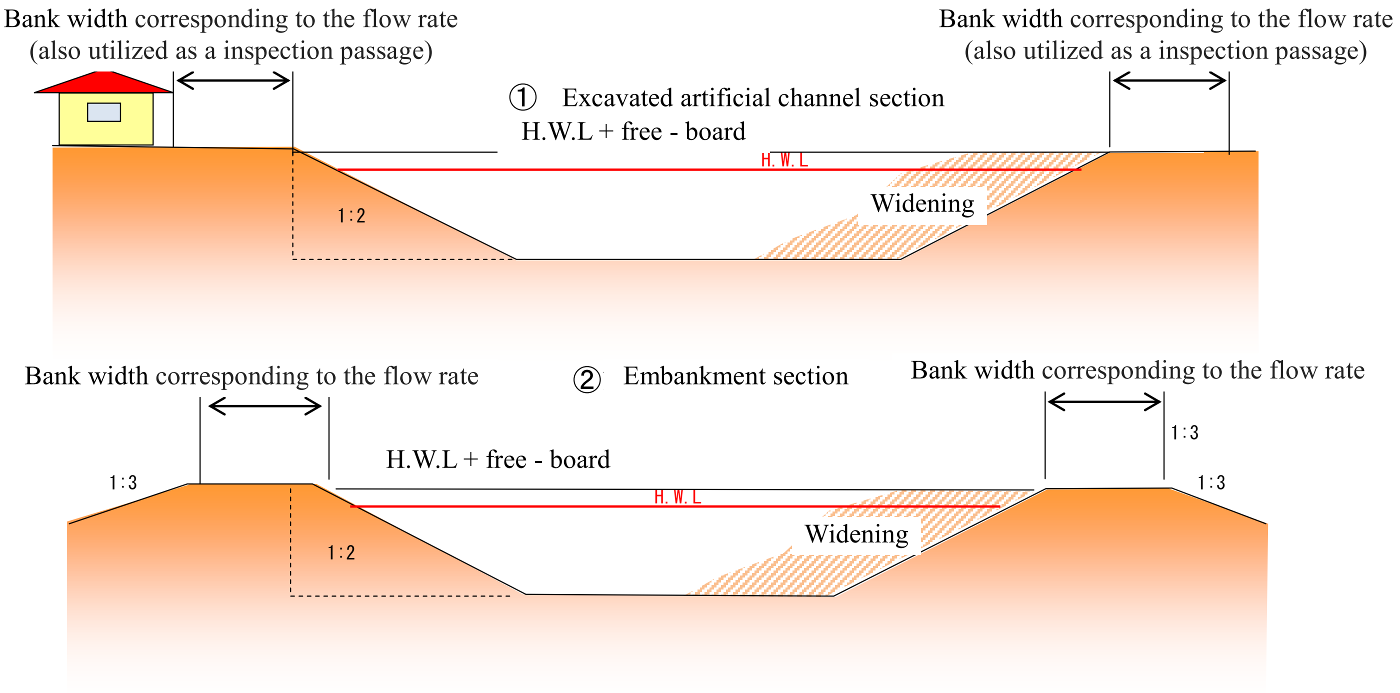


Figure8-27 Examples of cross-sectional shape

Figure8-28 Current situation of river bank(Downstream from Backroad Bridge)

Table 8-7 Design Roughness Coefficients

Section (Segmentation)	Roughness coefficient [Low-water channel]	Roughness coefficient [High-water channel]
Nadi River, River channel section 1 (0.00km – 4.00km, Segment 3)	0.015	– (Thick growth of only mangrove [dead water zone]))
Nadi River, River channel section 2 (4.00km – 25.25km, Segment 2-2)	0.023	0.060
Nadi River, River channel section 3 (25.25km –, Segment 2-1)	0.027	0.060
Malakua River (0.0km – 7.0km, Segment 2-2)	0.022	0.060
Nawaka River (0.0km – 10.0km, Segment 2-1)	0.026	0.060
Namosi River (0.0km – 5.0km, Segment 2-1)	0.027	0.060

Table8-8 Standard Cross-section Features

Section		Width of river bed (m)	Width for each water depth	Slope gradient of river side	Slope gradient of land side
Nadi River					
Section1	0.00～5.50km	56.80m	80m(water depth 5.80m)	20%	30%
Section2	5.75～8.00km	125.60m	150m(water depth 6.10m)	20%	30%
Section3	8.25～12.75km	71.20m	100m(water depth 7.20m)	20%	30%
Section4	13.00～18.25km	50.60m	85m(water depth 8.60m)	20%	30%
Section5	18.50～20.75km	26.00m	70m(water depth 11.00m)	20%	30%
Section6	21.00～22.75km	21.00m	65m(water depth11.00m)	20%	30%
Section7	23.00～28.75km	About the current state	About the current state	About the current state	About the current state
Nawaka River					
Section1	0.00～1.40km	42.60m	70m(water depth 6.86m)	20%	30%
Section2	1.50～8.50km	27.60m	55m(water depth 6.86m)	20%	30%
Malakua River					
Section1	0.00～8.00km	9.60m	37m(water depth 6.86m)	20%	30%
Namosi River					
Section1	0.00～0.75km	10.0m	50m(water depth 10.0m)	20%	30%
Section2※	0.75km～4.00km	10.0m	50m(water depth 10.0m)	20%	30%

* Eembankment is basically not installed in the Namos River Secition 2 because of the terrain behind the ground being in high elevation as a result of the field survey.

Typical Cross Section (1)

1:400

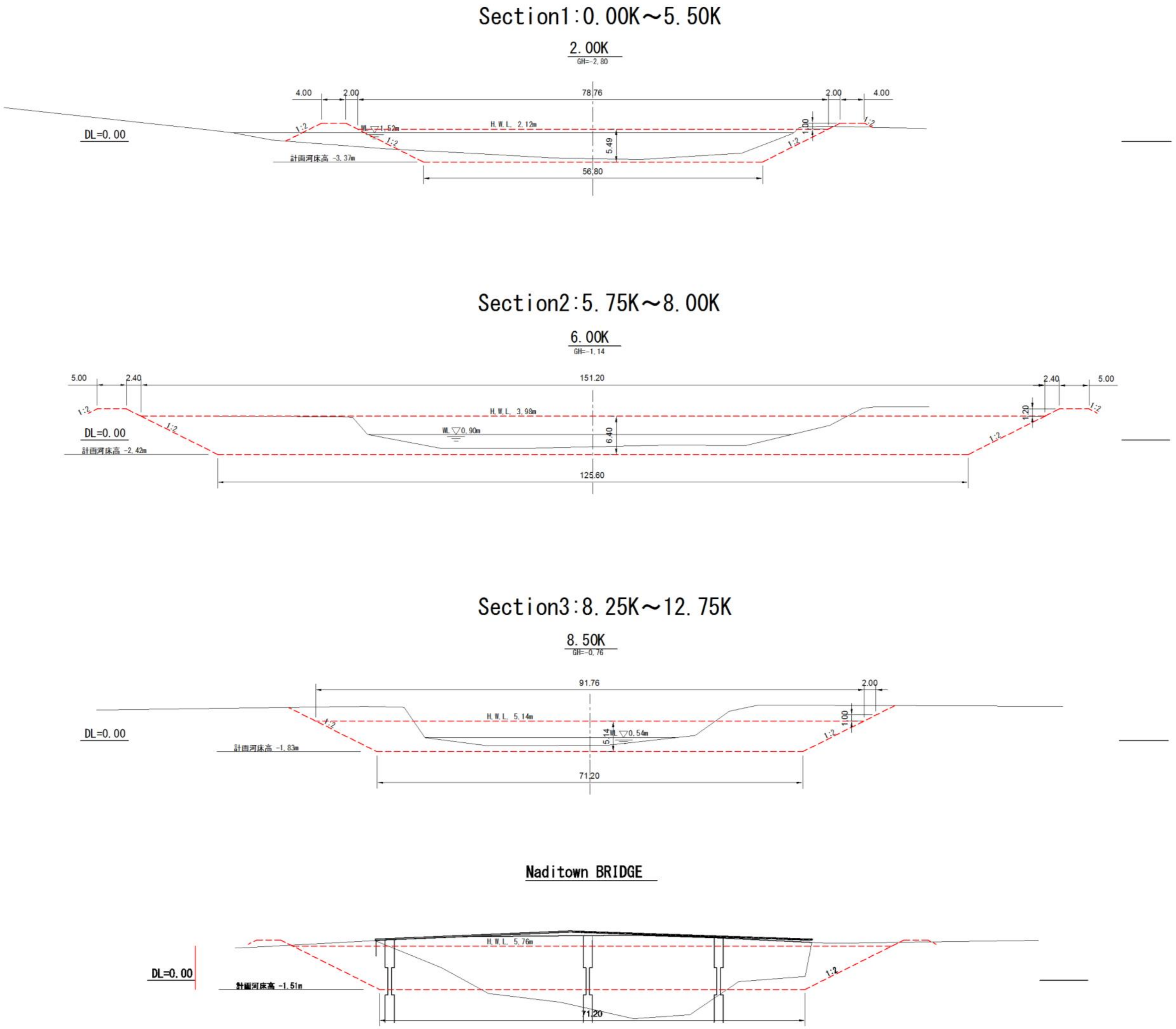


Figure8-29 Standard Cross-section of the Nadi River (1)

Typical Cross Section (2)

1:400

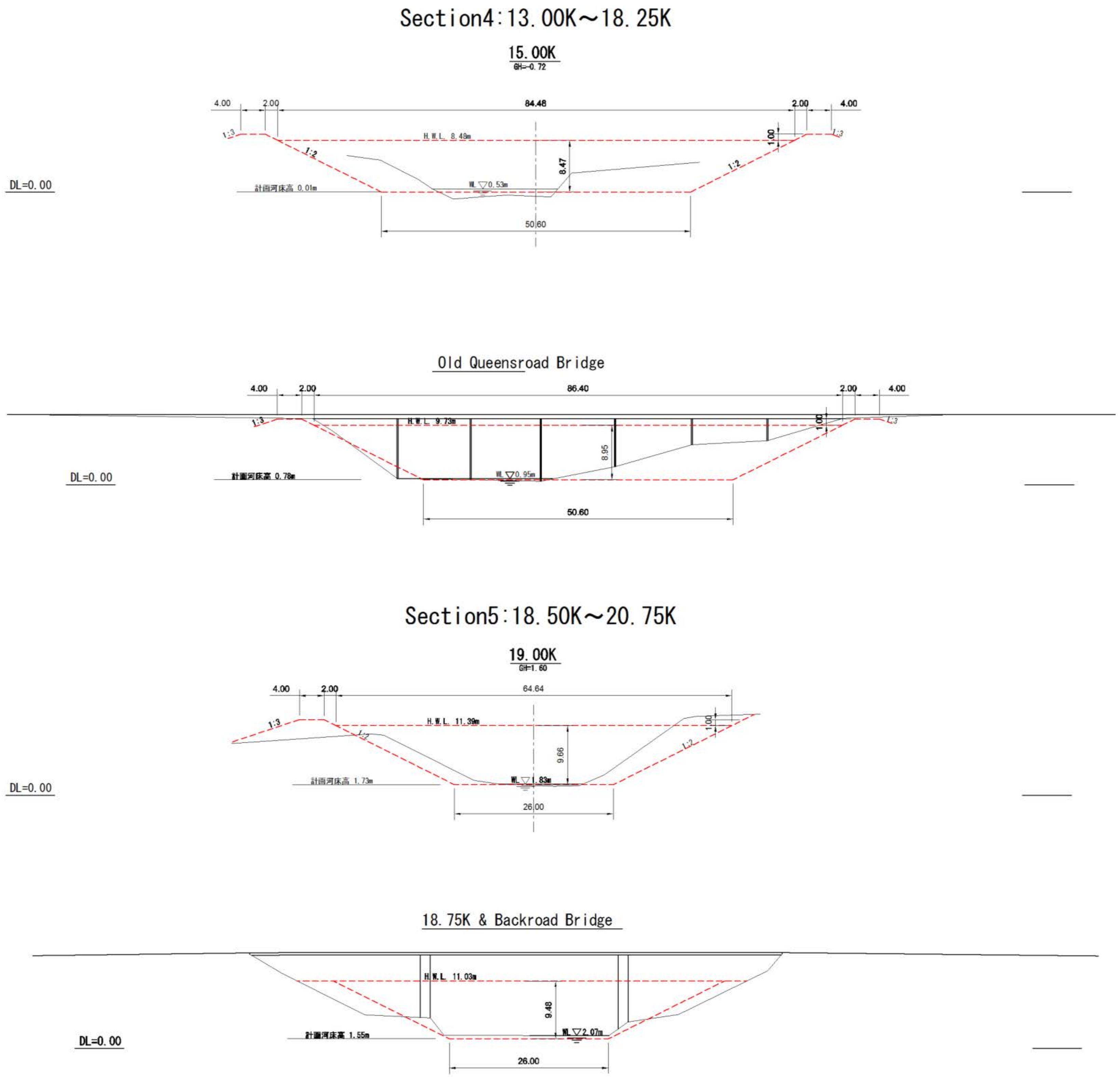


Figure8-30 Standard Cross-section of the Nadi River (2)

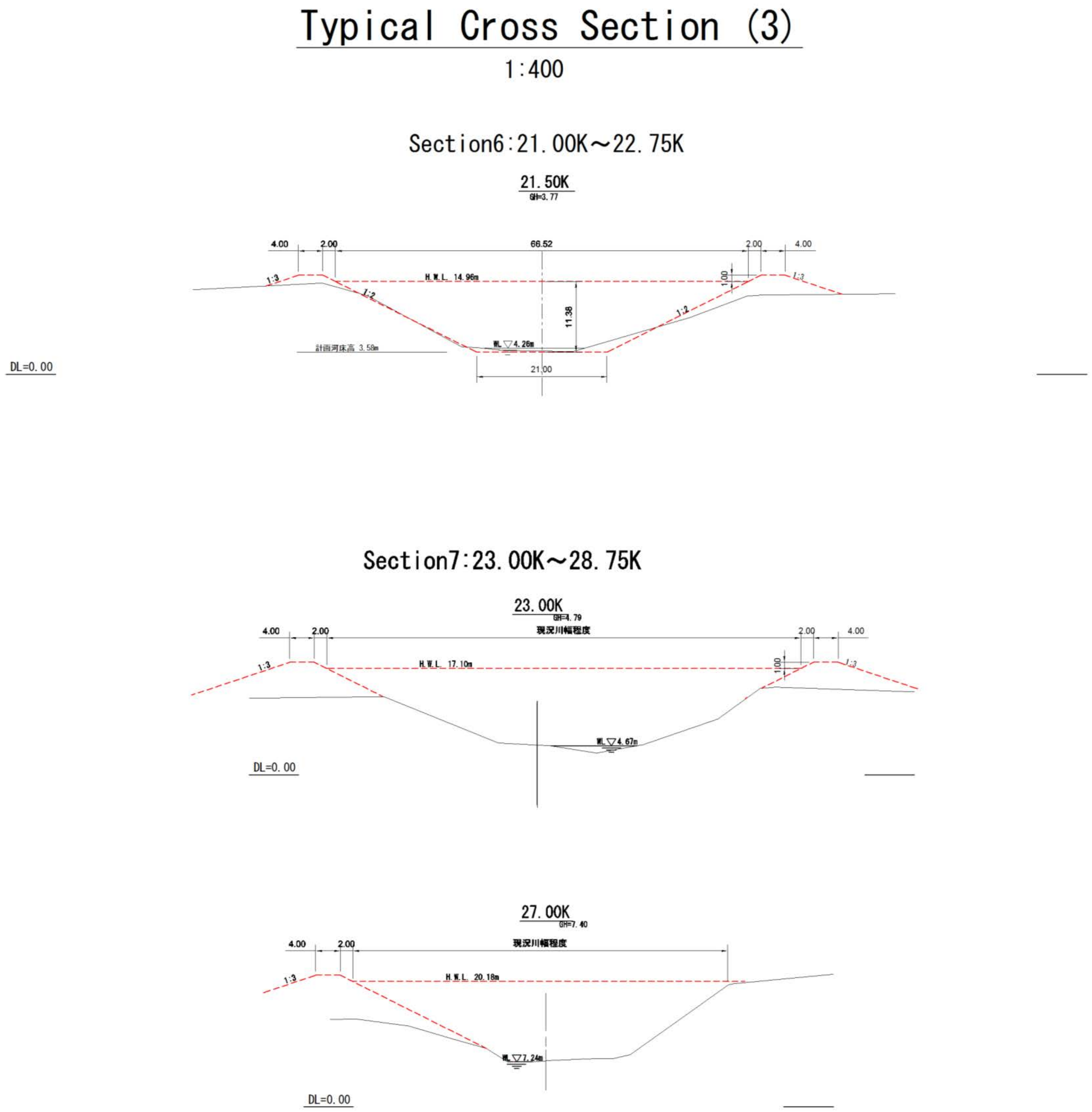


Figure8-31 Standard Cross-section of the Nadi River(3)

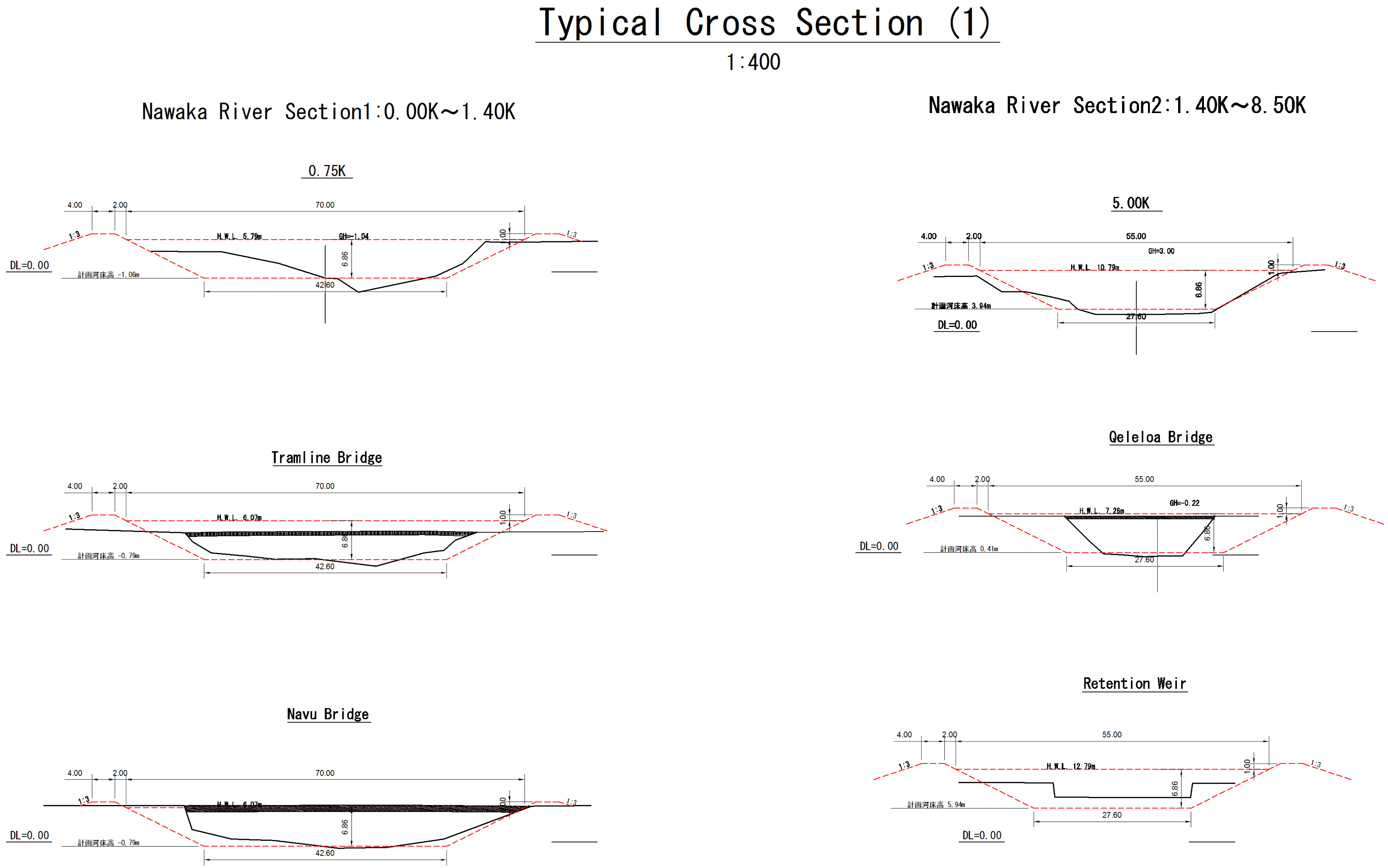


Figure8-32 Standard Cross-section of the Nawaka River

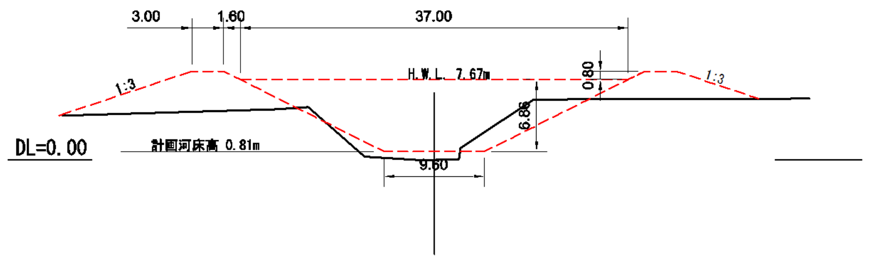
Typical Cross Section (1)

1:400

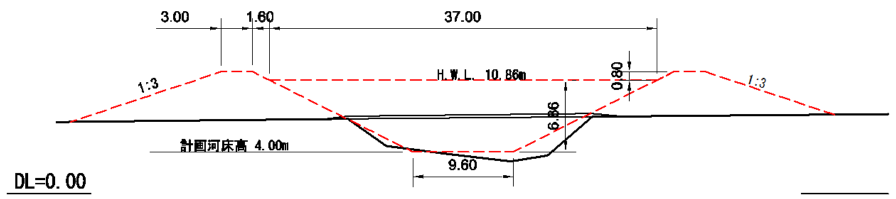
Malakua River Section1:0.00K～8.00K

1.00K

GH=0.01



Timber/ Rail Bridge



7.00K

GH=8.71

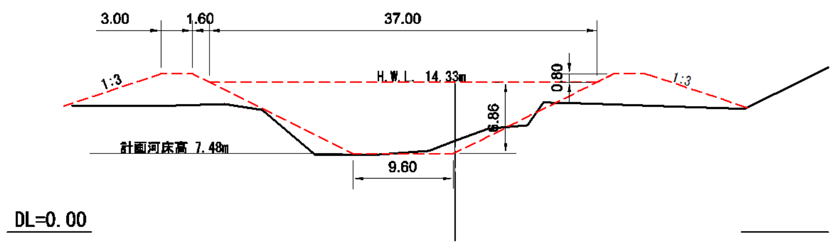
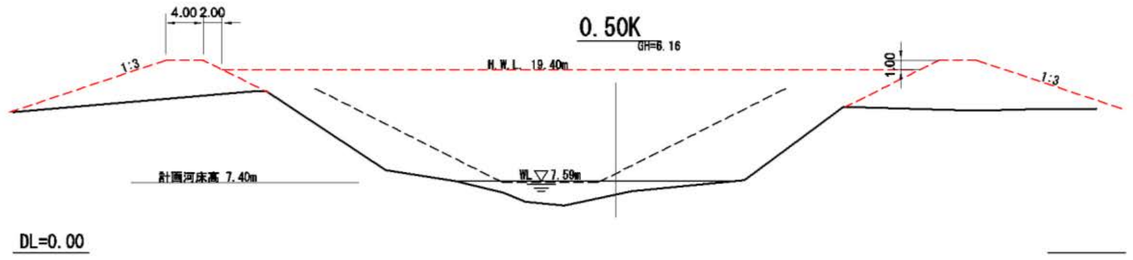


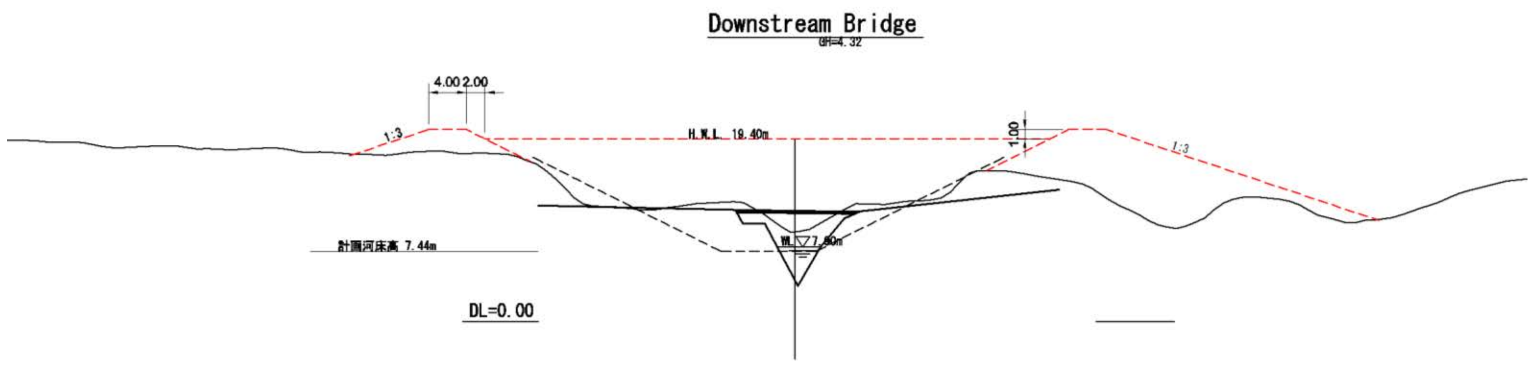
Figure8-33 Standard Cross-section of the Malakua River

Typical Cross Section (1)

1:400

Section1:0.00K～0.75K





Section2:1.00K～4.00K

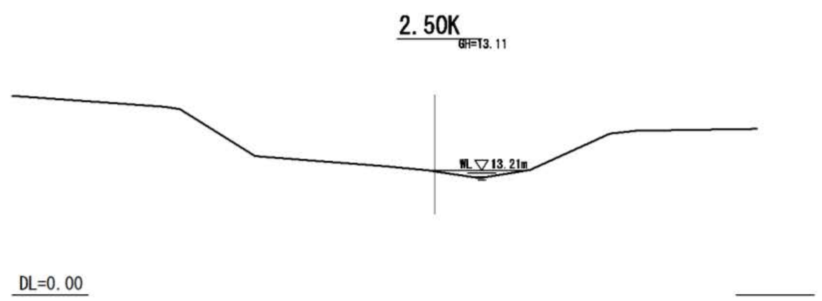


Figure8-34 Standard Cross-section of the Namosi River