Ministry of Agriculture
National Drainage & Irrigation Authority
Agricultural Sector Development Unit

Provision of Design and Supervision Services for the Construction of Sluice at Herstelling, E.B.D, Region No. 4

Consultancy Services for Engineering Designs and Supervision of Works: Rehabilitation of Drainage and Irrigation System (Earthworks, Structures and Access Dams) – Mocha

Module A – Design Reports Summary and Bidding Document

Sluice Hydraulic Design Report

Pump and Pump Station Hydraulic Design Report

Pump Station Structural & Geotechnical Design Report

Bidding Document

SRKN'gineering

107 Lamaha Street
North Cummingsburg
Georgetown
Guyana

5/18/2017

<table>
<tr><td colspan="3">SRKN'gineering
107 Lamaha Street
North Cummingsburg
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Guyana</td><td colspan="2">Project Reference:
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Consultancy Services for Engineering Designs and Supervision of Works: Rehabilitation of Drainage and Irrigation System (Earthworks, Structure and Access Dams) – Mocha</td></tr>
<tr><td>Document:</td><td>Module A (Mod.A)</td><td>DM Subject:</td><td colspan="2">Design Reports Summary & Bidding Document</td></tr>
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National Drainage and Irrigation Authority (NDIA),
Agriculture Sector Development Unit (ASDU).</td></tr>
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1.0 Introduction

1.1 Background

The Government of Guyana (GOG), represented by the Ministry of Agriculture (MOA), National Drainage and Irrigation Authority (NDIA) in association with the Agriculture Sector Development Unit (ASDU) herein referred to as the “Client”. The Client has engaged the Design and Supervision Services of SRKN’gineering and Associates of 107 Lamaha Street, North Cummingsburg, Georgetown, Guyana, herein referred to as the “Consultant”.

The Design and Supervision Services rendered by the Consultant are aimed towards the effectuation of the following projects:

i. Provision of Design and Supervision of Services for the Construction of Sluice at Herstelling, E.B.D, Region No. 4, and
ii. Consultancy Services for Engineering Designs and Supervision of Works: Rehabilitation of Drainage and Irrigation System (Earthworks, Structures and Access Dams) – Mocha

The aforementioned projects shall be executed with financing made available by the Client and the CARICOM Development Fund (CDF). The Client through representation by ASDU and NDIA will administer the execution of the said projects in accordance with the requirements specified in the Contract Document more so the Terms of Reference.

1.2 Projects and related Components

Common to the projects identified above is a Design Component which is followed by a Supervision Component. The Supervision Component is geared towards the execution or implementation of the outcome presented in the Design Component. Both projects fall under the purview of the Ministry of Agriculture, however, they shall be managed under separate departments within the said Ministry.

The “Provision of Design and Supervision of Services for the Construction of Sluice at Herstelling, E.B.D, Region No. 4”, is being managed by the National Drainage and Irrigation Authority. The design aspect of this project is related to the design of several hydraulic structures, inclusive but not limited to conveyance channels, sluice(s), culvert(s) and bridge(s), ultimately functioning together to accomplish the effective drainage of the catchment area(s) identified.

On the other hand, the “Consultancy Services for Engineering Designs and Supervision of Works: Rehabilitation of Drainage and Irrigation System (Earthworks, Structures and Access Dams) – Mocha”, shall be managed by the Agriculture Sector Development Unit. The designs associated with this project evolve around the development of a Main System, related Tertiary Units and the necessary infrastructure to support the cultivation of 2.68 square kilometres of farm lands in Barnwell North. The Client has provided a list of potential crops of economic value for cultivation to be considered during the designs.

The contents of this report and those to follow are specific to the Design Component associated with the execution of the abovementioned projects. The designs required under the two projects are lumped together as a result of the relationship and interdependences of the proposed solutions required to achieve the desired objectives.

1.3 Problem Statements

The statements of problem tabulated below are based on the Clients hypothesis and understanding of the issues related to the projects being analysed, as were expressed in the Terms of Reference. These will serve as the basis of the solutions formalized in addition to any other specific problems identified during the analysis.

PROJECT	Rehabilitation of D&I System – Mocha	Construction of Sluice at Herstelling
CLIENT	**ASDU, Ministry of Agriculture**	**NDIA, Ministry of Agriculture**
1	Back lands of Mocha are uncultivated, under cultivated and underdeveloped as a result of constraints associated with access	Need for sufficient drainage to new housing projects and existing residential areas of Herstelling
2	Dysfunctional Drainage and Irrigation (D&I) System	Insufficient Drainage of Mocha farming area

Table 1 – Problem Statements

1.4 Project Deliverables

The Consultant is obligated to furnish the reports so detailed in Table 2 as is specified in the Terms of Reference for the Design phase of the projects. Each of these reports shall comprise three separate components, namely:

i. R1 – Hydrologic Design Report
ii. R2 – Main System Design Report
iii. R3 – Hydraulic Design Report

PROJECT	Rehabilitation of D&I System – Mocha				Construction of Sluice at Herstelling			
CLIENT	**ASDU, Ministry of Agriculture**				**NDIA, Ministry of Agriculture**			
	Reports Herein	**R1**	**R2**	**R3**	**Reports Herein**	**R1**	**R2**	**R3**
1	Inception Report				Design Report			
2	Draft Design Report	*		*	Draft Final Report	*	*	*
3	Final Design Report				Final Report			

Table 2 – Design Deliverables

Each report (R1, R2 and R3) will include three different but connected Design Modules to be reviewed collectively. These modules will be presented as follows:

i. Design Module 1 (DM1) – Presents the Basis of the Design utilized
ii. Design Module 2 (DM2) – Presents the respective Designs
iii. Design Module 3 (DM3) – Presents all the relevant Appendices

The amalgamation of the different reports stated above will address the Scope of Works of each project provided in the section that follows.

1.5 Project Scope Deliverables

The scope of works identified is tabulated below in Table 3 and Table 4 for the ASDU and NDIA Projects respectively. The Terms of Reference stipulates the scope under which the Consultant must perform his designs. General and detailed outlines of the scope of works as stated by the Client, in the Terms of Reference are presented below. In addition, the tables also indicate the item(s) as specified in the scope of works that are encompassed/addressed by this report.

It should be noted that the tables presented below only highlight the scope of works required under the design component of the projects. Furthermore, a synopsis of the scope of works highlighted in the terms of reference is tabulated below.

PROJECT	Rehabilitation of D&I System – Mocha	
CLIENT	**ASDU, Ministry of Agriculture**	
Outline of Scope of Works		**Herein**
1	Review of existing D&I Systems and make recommendations	*
2	Recommend sections of the Project Area for crop cultivation based on the expected crops to be cultivated	
3	Recommend suitable drainage coefficient based on the crops to be cultivated and the effects of climate change on rainfall	*
4	Examine any available hydro meteorological data for the area. Discuss likely effects of intake and discharging for the project area's drainage and irrigation waters with the NDIA	
5	Examine the need to supplement gravity drainage with pumped drainage and if it is necessary, execute all structural and electrical/mechanical designs	
6	Examine the feasibility of supplementing irrigation supply	
7	Advise on a possible D&I layout with structures of the 900 acres	
Detailed Design Scope		
1	Engineering Surveys	
2	Geotechnical Investigations	
3	Drainage Designs	
4	Structural Design	
5	Road Design	
6	Environmental Management and Monitoring Plan	
7	Location Plan	
8	Structural Drawings	
9	Site Plans	
10	Quantities and Cost Estimates	

Table 3 – ASDU Scope of Design Services

PROJECT	Construction of Sluice at Herstelling, E.B.D, Region 4	
CLIENT	**NDIA, Ministry of Agriculture**	
Outline of Scope of Works		**Herein**
1	Design of Hydraulic Structures based on the prevailing Hydrology	*
2	Conduct geotechnical investigation towards the design of the Herstelling Sluice	*
3	Assess the conditions of the existing sluice and inlet channel for expansion	*
4	Consider both mechanical (pumping) and gravity drainage for the overall drainage requirements of the area	*
5	Siting of New Sluice along river defence and design of connection of new sluice to existing sluice and river defence	*
6	Financial Module detailing cost of channel rehabilitation, and associated hydraulic and engineering structures for the sluice	
Detailed Design Scope		
1	Production of Engineering and Topographic Plans for proposed construction	*
2	Geotechnical Investigations necessary to design structure	*
3	Hydraulic Design of Sluice	*
4	Structural Design of Sluice	*
5	Detail Working Drawings	*
6	Prepare Tender Documents	*
7	Prepare Engineer's Estimate	*

Table 4 – NDIA Scope of Design Services

1.6 Module Outline

Module A summaries the Designs completed for the Sluice and Pump Station at Herstelling. Three design reports are attached, namely the;

- Sluice Hydraulic Design Report
- Pump and Pump Station Hydraulic Design Report
- Pump Station Structural and Geotechnical Design Report

In addition, the Bidding Document prepared for the Sluice and Pump Station is incorporated into Module A. The main features of this Bidding Document are as follows:

- Invitation for Bids
- Instruction to Bidders
- Bid Data Sheet
- Evaluation and Qualification Criteria
- Drawings

- Preambles
- Method of Measurement
- Bill of Quantities
- General Conditions of Contract
- Specific Conditions of Contract
- Specifications

The Bidding Document excludes the finical details of the other design solutions proposed for this project.

Finally, this Module concludes with the Engineering Drawings for the combination structure of the Outfall Sluice and Pump Station. It includes the Site Layout, Structural Drawings with details for the substructure and superstructure.

Herstelling Sluice and Pump Station

2017

Sluice Design Report

SRKN'gineering & Associates

5/12/2017

1.0 Introduction

The Herstelling Sluice Design Report provides the Hydraulic Assessment of the exiting single door sluice. The assessment is based on the drainage load computed for the respective sluice drainage area. The existing sluice discharge potential is calculated on the basis of the available tide free period during a twenty four hour tidal cycle. Specifically, the Demerara River is the downstream boundary condition of this analysis.

In essence the drainage load computed for the catchment area should be evacuated through the outfall sluice in its entirety within a day. However, the existing single door sluice was found to be inadequate to accomplish such a task. Therefore, an additional sluice was designed to supplement the discharge capacity at the Herstelling Outfall.

The sluice is designed with a 4m wide gate and a 0.3m high sill, at an invert of 12.8mGD. It is envisioned that the sill shall facilitate the flows through the sluice to contract to its critical point thus requiring the least amount of energy. It should be noted that the sluice from the structural standpoint is designed as a combination unit with a pump station to provide mechanical discharge during tide lock periods. The pump station design report trails this design report.

2.0 Herstelling Sluice Design

The Outfall Sluice located at Herstelling serves the areas of Herstelling, Mocha, Arcadia, Barnwell, and South of Providence and Tyd-En-Vylt. The Main Drainage Systems utilized to convey the drainage load from the catchments identified are Main Drain 1 (MD1), Main Drain 2 (MD2) and Main Drain 5-North (MD5-N). The Secondary Drainage System used is Secondary Drain 1-North (SD1-N). Refer to Figure 1.

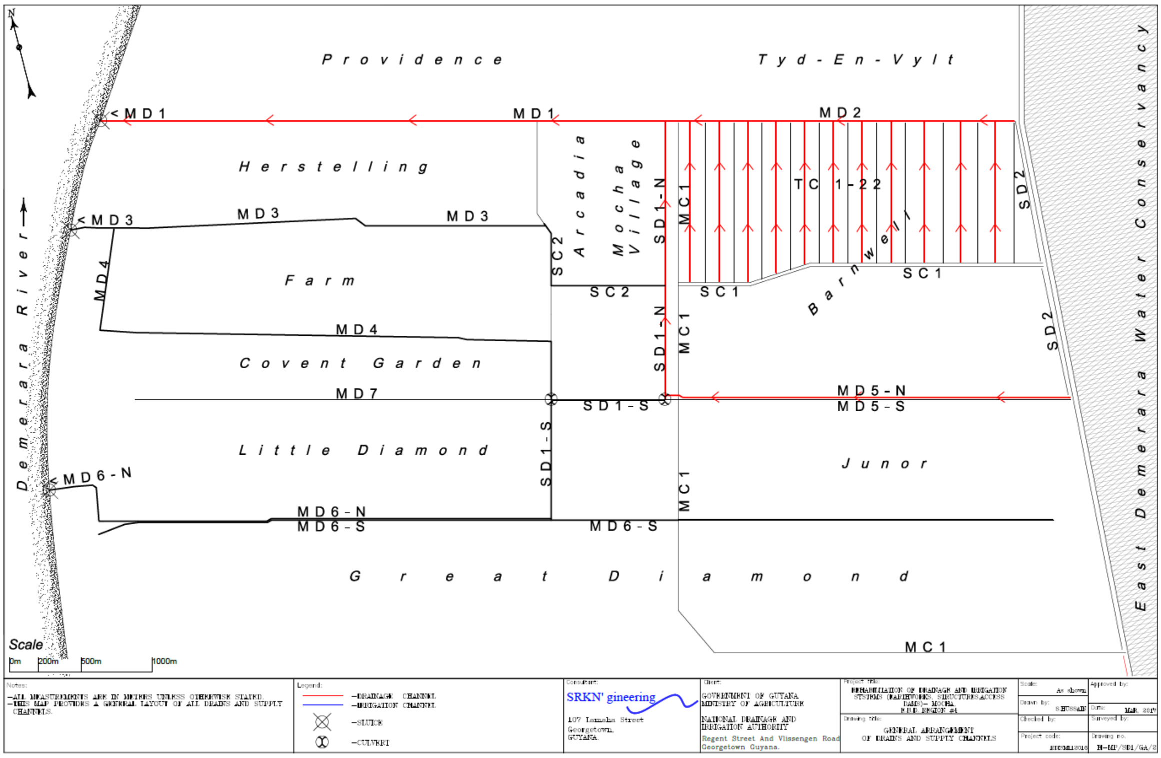

Figure 1 – Block A Design Boundary Highlighted

2.1 Sluice Drainage Load and Area

The catchment areas under the scope of this project were quantified and are presented below in Table 1. However, the drainage load of the Herstelling Outfall Sluice emanates from the catchment areas tabulated in Table 2.

Watershed		
No.	Locations	Area (m^2)
1	Providence South	3,283,451
2	Tyd-En-Vlyt South	1,905,742
3	Herstelling	2,526,217
4	Mocha/Arcadia North	1,025,430
5	Barnwell North	2,638,204
6	Farm	2,584,478
7	Barnwell South	2,385,185
8	Covent Garden	1,378,379
9	Junor North	1,606,899
10	Mocha/Arcadia South	704,654

Table 1 – Catchment Areas

Table 2 summarizes the drainage load for the Herstelling Sluice. This load is computed on the basis of a 20 years return period. The drainage load is computed based on the required drainage modulus of the catchment area. The Hydrological Design Report presents in detail the analysis done to derive the design drainage modulus.

From the computations performed, the Herstelling Outfall Sluice must have a discharge potential of 23 cubic meters per second (refer to Table 2). The existing outfall sluice is a 3.9m wide single door at an average invert of 13.1mGD. The capacity of which was assessed during the tide free periods to determine its adequacy.

Runoff using Drainage Modulus			
Drainage Modulus		144	mm/d
Return Period, T_R		20	
Total Discharge at Outlet		23	m^3/s
Watershed No.	Area m^2	Flow, Q m^3/s	
1	3,283,451	5.5	
2	1,905,742	3.2	
3	2,526,217	4.2	
4	1,025,430	1.7	
5	2,638,204	4.4	
7	2,385,185	4.0	

Table 2 – Design Flows

2.2 Discharge Capacity

Traditionally outfall structures are designed based on the drainage modulus required. The drainage modulus gives an indication to the total depth of water that must be discharged within a twenty four period. In accordance with the design level adopted for this project, the design drainage modulus was computed to be 5.7 inches of water to be discharged within a day.

The existing single door outfall sluice at Herstelling was assessed to determine its capacity to dispose the required drainage volume. Tidal data from the Demerara River was utilized for the analysis.

For the design drainage modulus, the existing sluice is inadequate to convey the drainage load from the catchment areas identified. The hydraulic analyses indicated a total gate width of 8m being required for the design parameters utilized. Please refer to Appendix for design computations.

Drainage Modulus

Return Period	Drainage Modulus	
Tr, yrs	m (mm/d)	m(in/d)
5	101.9	4.0
10	122.8	4.8
15	134.9	5.3
20	143.6	5.7
30	155.9	6.1
50	171.7	6.8

Table 3 – Drainage Modulus

2.3 Sluice Hydraulic Design

From the hydraulic analysis presented in the Appendix, a total gate width of 8m is required at the Herstelling Outfall Sluice. Therefore, a 4m wide gate is proposed to augment the existing discharge potential at the Herstelling Outfall.

The sluice is designed to convey 50% of the total drainage load within a day. The sluice design invert is set at 12.8mGD and it is outfitted with a 0.3m high sill. The sill height was set on the premise of the critical sill height required. In theory the critical sill height will cause the design flows to contract over the sill and move through a critical flow regime. Figure 2 presents the hydraulic profile expected through the structure.

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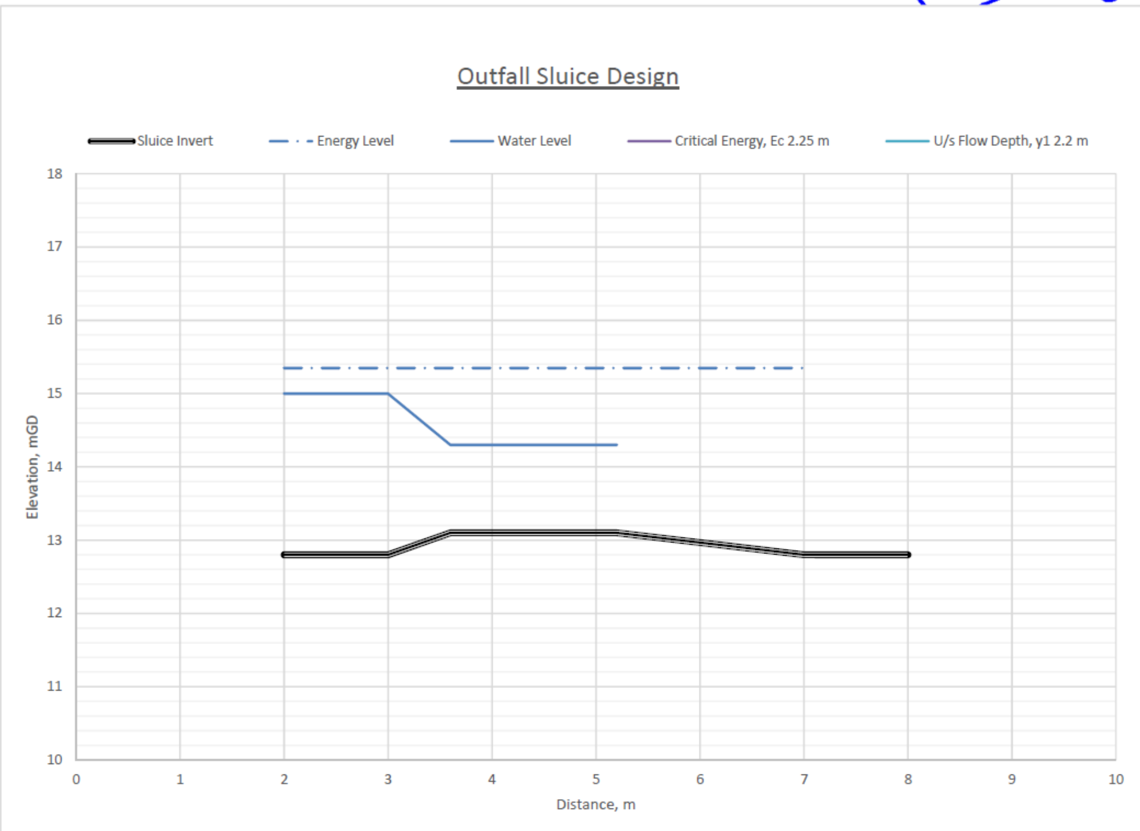

Figure 2 – Sluice Design

3.0 Appendix

DESIGN OF TIDAL OUTFALL SLUICE

Project:	CSH/RDISM_112016		
Sluice Location:	Herstelling	**Date:**	16-May-2017
Chainage (Km+m):	0+000	**Sheet:**	1 of 3
Designed by:	**G.W.**		

Assumptions and Parameters

		Units	
1	Catchment Area, A	Km^2	13.760
2	Length of Drain	m	6,400
3	Avg. Top Width	m	22
4	DrainSurface Area, A_w	m^2	**140,800**
5	Design Return Period, T_R	years	20
6	Drainage Coefficient, D_C	mm/day	143.6
7	Design Flow (Inflow, *I*), Q = AD_C	m^3/s	23.00
8	Max. Allowable Storage Level (MASL)	mGD	16.10
9	Design Drainage Level, DDL	mGD	15.10
10	Tide Locked Period, T_{S1}	hrs	8.25
11	Tide Locked Period, T_{S2}	hrs	8.75
12	Drainage Period, T_{D1}	hrs	4.13
13	Drainage Period, T_{D2}	hrs	4.00
14	Permitted Rise in Drain, $\Delta d = Q.T_S/A_w$	m	**5.15**
15	Total Volume to be stored in Drain, V_C	m^3	**724,500**
16	Sill Elevation	mGD	13.1
17	Sill Height, Δz	m	-
18	Design Sluice Width	m	**7.9**

Total Discharge Volume for Tidal Cycle

Volume, V (m^3)

$$V = C.T.A.D_C$$

Where,

C, Discharge Coefficient	0.7
T, Length of Tidal Period (Hrs)	24.83
A, Catchment Area (m^2)	**13,760,000**
D_C, Drainage Coefficient (mm/day)	**143.6**

So,

V (m^3)	**1,431,181**

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DESIGN OF TIDAL OUTFALL SLUICE

Project:	CSH/RDISM_112016		
Sluice Location:	Herstelling	**Date:**	16-May-2017
Chainage (Km+m):	0+000	**Sheet:**	2 of 3
Designed by:	G.W.		

Discharge During Drainage Period (T_{D1})

Time Step (1/2hr)	Water Level in Drain, h_u	Water Level in River, h_d	$2/3h_u$	*Type of Discharge	μ or C_d	Δt (sec)	Drained Vol (m^3/m)
1	2.98	2.78	1.98	Sub.C	1.2	1400	9,234
2	2.88	2.68	1.92	Sub.C	1.2	1800	11,444
3	2.78	2.50	1.85	Sub.C	1.2	1800	12,541
4	2.68	2.38	1.78	Sub.C	1.2	1800	12,444
5	2.55	2.28	1.70	Sub.C	1.2	1800	11,413
6	2.45	2.15	1.63	Sub.C	1.2	1800	11,265
7	2.34	2.05	1.56	Sub.C	1.2	1800	10,561
8	2.23	1.95	1.48	Sub.C	1.2	1800	9,782
9	2.15	1.93	1.43	Sub.C	1.2	900	4,367
						Sum	**93,051**

Discharge During Drainage Period (T_{D2})

Time Step (1/2hr)	Water Level in Drain, hu	Water Level in River, h_d	$2/3h_u$	*Type of Discharge	μ or C_d	Δt (sec)	Drained Vol (m^3/m)
1	2.95	2.75	1.97	Sub.C	1.2	1800	11,765
2	2.83	2.63	1.88	Sub.C	1.2	1800	11,230
3	2.73	2.45	1.82	Sub.C	1.2	1800	12,290
4	2.63	2.33	1.75	Sub.C	1.2	1800	12,182
5	2.50	2.25	1.67	Sub.C	1.2	1800	10,762
6	2.40	2.15	1.60	Sub.C	1.2	1800	10,284
7	2.30	2.03	1.53	Sub.C	1.2	1800	10,158
8	2.18	1.96	1.45	Sub.C	1.2	1800	8,694
						Sum	**87,365**

Total Capacity (m^3/m)	**180,416**

Notes:

Sluice Designed to discharge 70% of the drainage load per day.

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DESIGN OF TIDAL OUTFALL SLUICE

Project:	CSH/RDISM_112016		
Sluice Location:	Herstelling	**Date:**	16-May-2017
Chainage (Km+m):	0+000	**Sheet:**	3 of 3
Designed by:	**G.W.**		

Design Parameters

Discharge, Q	23.00	m^3/s
U/s Flow Depth, y_1	2.2	m
Sluice Invert	12.8	mGD
Total Design Sluice Width	8.0	m
Number of Gates	2.0	
Width of Single Gate	4.0	m
Unit Discharge, q	5.75	$m^3/m.s$

Critical Depth, y_c	1.5	m
Critical Energy, E_c	2.25	m

Assuming Flow on Sill is Critical

$E_1 = E_2 = E_3$

U/s Velocity, v_1	2.61	m/s
Velocity on Sill, v_2	3.83	m/s

Using Momentum and Continuity Equation

Critical Sill Height, ΔZ_c	0.30	m
Design Sill Height, ΔZ	0.3	m
Energy Level, EL	2.55	m

Assuming,

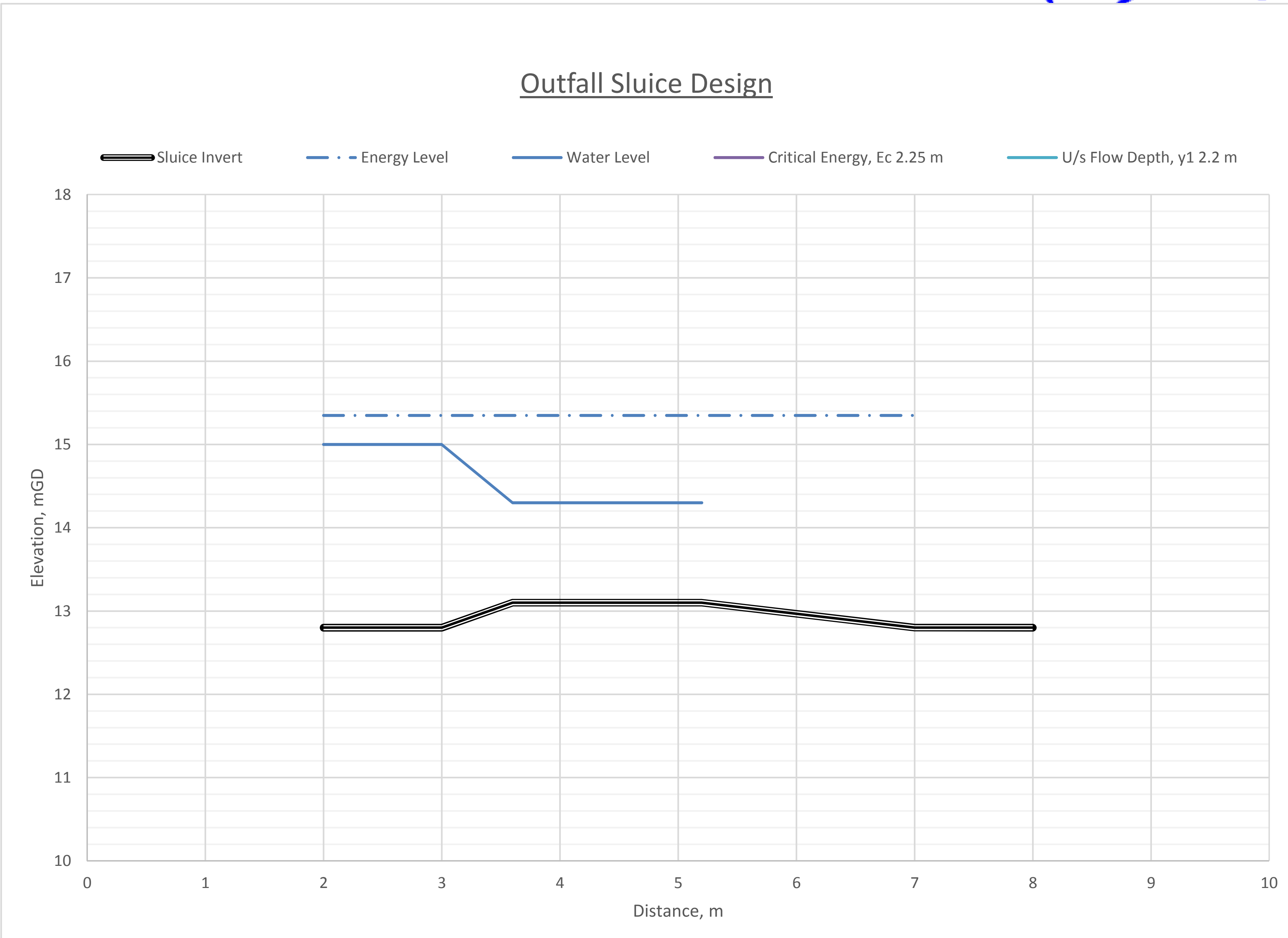
$H/L = h_u/L = y_1/L =$ 0.55 $0.1 < H/L < 0.6$

So,

Length of Weir, L	4.0	m
U/s Sill Slope, m_{us}	2	
D/s Sill Slope, m_{ds}	6	

Sluice Design Parameters

U/s Throat Length	1	m
D/s Throat Length	1	m
Wing Wall Length	3	m
Wing Wall Angle, 1:n	1	


Outfall Sluice Design
Sluice Invert
Energy Level
Water Level
Critical Energy, Ec 2.25 m
U/s Flow Depth, y1 2.2 m
Elevation, mGD
18
17
16
15
14
13
12
11
10
0
1
2
3
4
5
6
7
8
9
10
Distance, m

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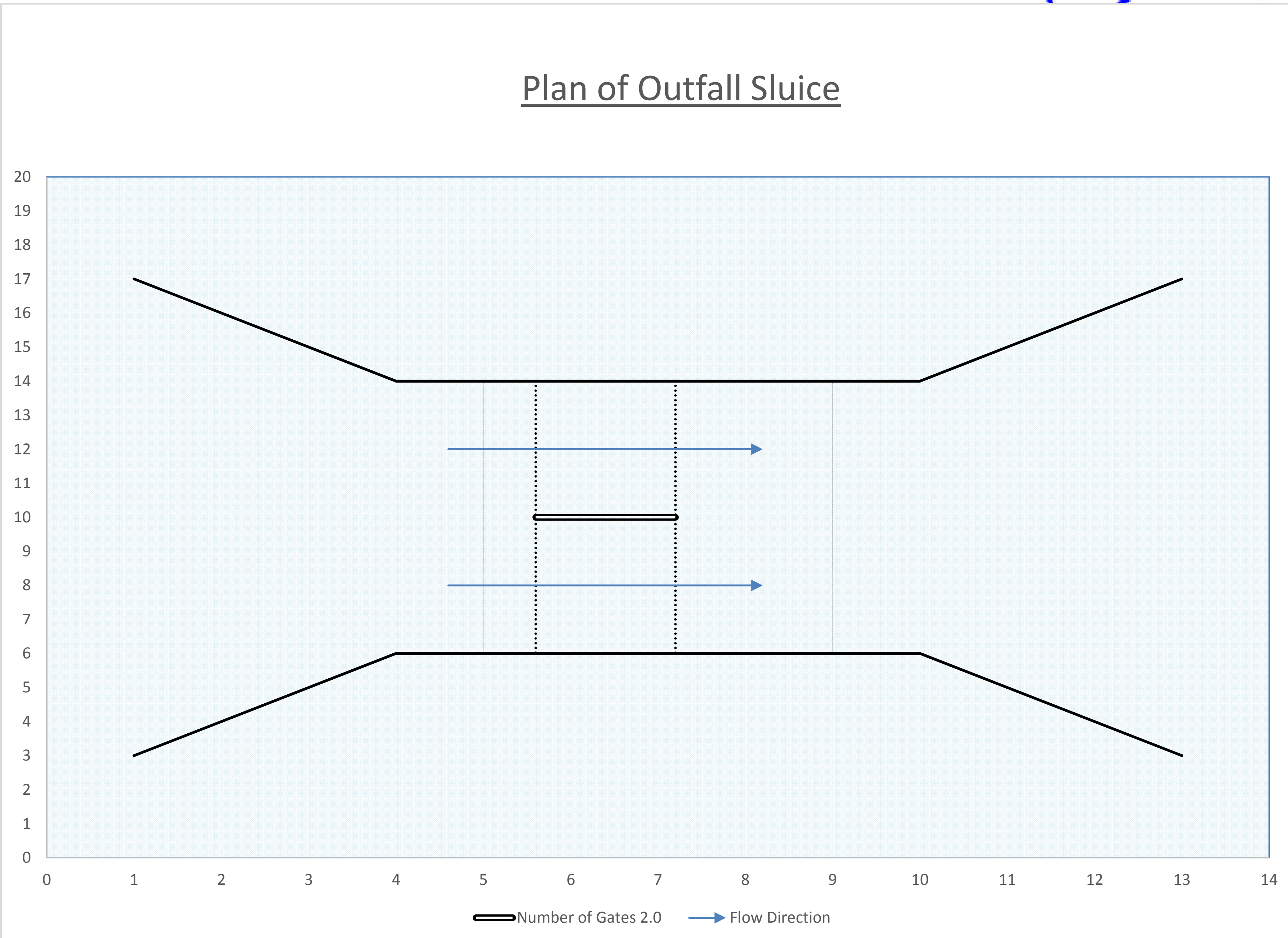


Herstelling Sluice and Pump Station

2017

Pump Design Report

Gregory Williams
SRKN'gineering & Associates
5/12/2017

Table of Content

1.0 Introduction

The Pump Station Design Report provides the details of the Hydraulic Analysis completed for the Herstelling Pump Station. The Hydraulic Analysis encompassed the sizing of the pump and pump station based on the discharge requirements quantified. The pump capacity was determined based on the drainage load of Canal No.3 (Main Drains 1 and 2).

The pump design caters for an axial flow pump with a vertical suction. The required total dynamic head to facilitate the pump's performance at its best efficient point was computed as the sum of the static head plus the losses due to friction and bends. The total dynamic head plus five percent allowance was computed to be 5.5m.

The design approach adopted for the pump station was the empirical methods developed by Posser and MDOT for the pump sump detailing. The design that produced the largest pump sump was utilized for the Herstelling Pump Station. As such a sump invert of 11.3mGD with a width of at least 4.3m was established. The minimum required distance from the back wall of the sump to the track rack was computed to be 8.1m. To preserve the pump's performance and the integrity of the impeller blades an overflow weir of 1m high is recommended to avoid the migration of silts into the pump sump.

2.0 Herstelling Pump and Pump Station Design

2.1 Pump Description

The Pump Station proposed at Herstelling, East Bank Demerara is designed to discharge 100 cubic feet per second. The use of steel pipes on the suction and delivery sides of the pump at 1.2192m (48inches) and 1.3m in diameter respectively will produce turbulent flows at an average velocity of 2.42 m/s on the suction side and 2.13 m/s on the delivery side of the pump. Refer to Table 1 for design details.

Project:	CSH/RDISH_112016			
Location:	Herstelling Outfall - Canal No. 3			
Date:	22-May-2017			
Pump Discharge	2.83	m^3/s		
No. Pumps	1			
Total Discharge	2.83	m^3/s		
Assumed Pipe Diameter				
Suction Side	1.2192	m		
Delivery Side	1.3	m		
Assuming Pipe is following full				
Cross Sectional Area, A				
Area, A = $\pi d^2/4$				
Suction Side	1.167	m^2		
Delivery Side	1.327	m^2		
Average Velocity, V				
Suction Side	2.42	m/s		
Delivery Side	2.13	m/s		
Velocity Head				
Suction Side	0.30	m		
Delivery Side	0.23	m		
Reynolds Number		Flow		
Suction Side	1,547,130	Turbulent		
Delivery Side	1,875,565	Turbulent		

Table 1 - Pump Capacity and Hydraulic Parameters

The flow regime of this axial flow pump significantly influences the losses due to friction within the system. The pump is designed with a vertical intake on the suction side and then transitions horizontally on the delivery side.

The inlet to the pump sump smoothly transitions from Canal No. 3 drain invert to eliminate any contractions in the flow patterns which may produce an increase in the flow velocity.

2.2 Pump Hydraulic Criteria

The hydraulic properties of the proposed axial flow pump was determined based on the discharge requirement, total dynamic head, suction and delivery sides elevation and the average flow regime expected. The total dynamic head was determined as the sum of the static head and the total of all losses anticipated.

Referring to Figure 1, the static head was computed to be 4.2m at an elevation of approximately 19.2mGD. The static head was determined based on the minimum anticipated pumping level of the pump to the level of the pump delivery side. The sum of the total losses due to friction, bends, entry and exit were approximately 1m. As such the total dynamic head computed was 5.2m which corresponds to an elevation of 20.2mGD. However, for the purpose of this design the total dynamic head shall be considered as 5.5m which provides an additional 5% allowance as a buffer (safety factor).

The friction losses were computed using Darcy-Welsbach equation and the equivalent pipe roughness factor was selected from the table provided in the Appendix. The friction factor was iteratively determined to compute the losses due to friction.

The computations and analysis of the hydraulic requirements for the pump can be found in the Appendix attached.

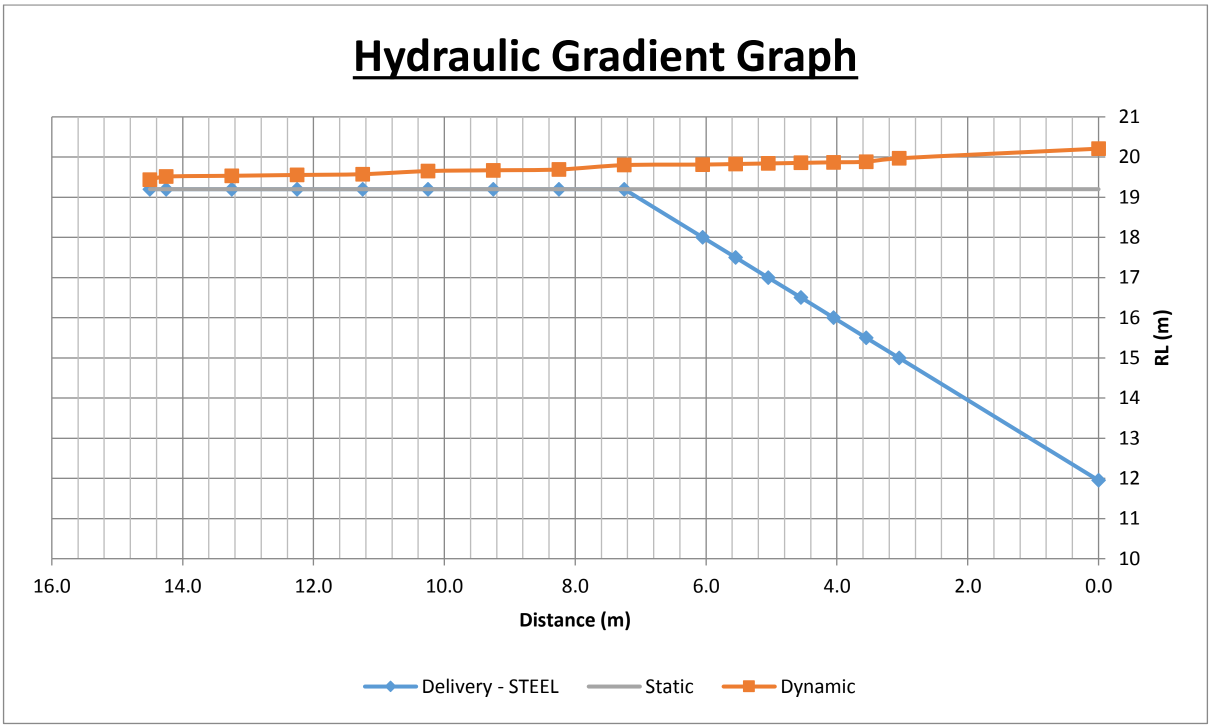


Figure 1 – Pump Hydraulic Gradient

2.3 Pump Station Design

Two empirical methods are available for the design of pump stations. The first method considered is based on the design principles established by Prosser which depends greatly on the Bell-mouth diameter on the suction side of the pump. The dimensions and general arrangement of the pump sump are based on suggested ratios of the Bell-mouth diameter as indicated in the ILRI publication 16 (Third Edition).

Table 2 identifies the minimum dimensions required for the pump sump. A range of Bell-mouth diameters were considered for this analysis to facilitate souring from any supplier. The design invert is reduced from the minimum pumping level or cut off point (elevation) for the pump. Consequently the lowest design invert of the sump under this method was computed to be at an elevation of 12mGD.

Pump Station Type			**Pump Capacity**			**Average WL**			
Single			2.83	m^3/s		15	mGD		
Intake Type			44,856	GPM					
Vertical									
Using Method in Drainage Principles & Application, Simple Pump Sumps (after Prosser 1977)									
Bell-Mouth Diameter				**Pump Station Specs**					
	1	2	3	4	5	6	7	8	
Range	m	S (m)	C (m)	B (m)	A (m)	W (m)	Y (m)	**Design Invert**	
Lower	0.8	1.2	0.4	0.6	4	2.4	2.4	13.4	mGD
Upper	1.5	2.25	0.75	1.125	7.5	4.5	4.5	12	mGD

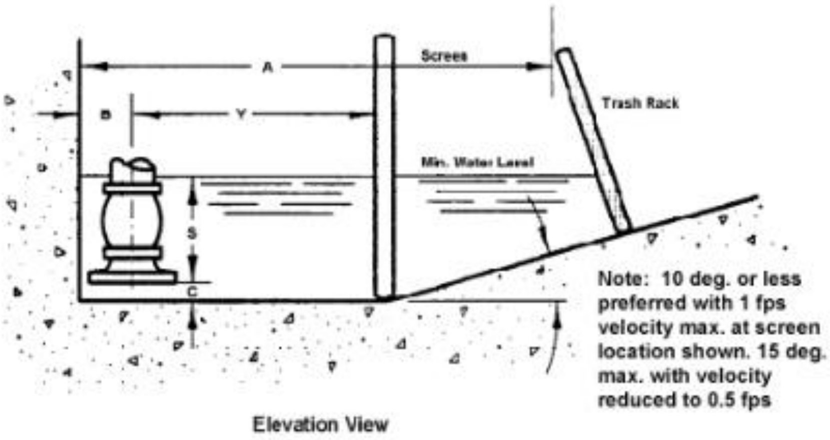
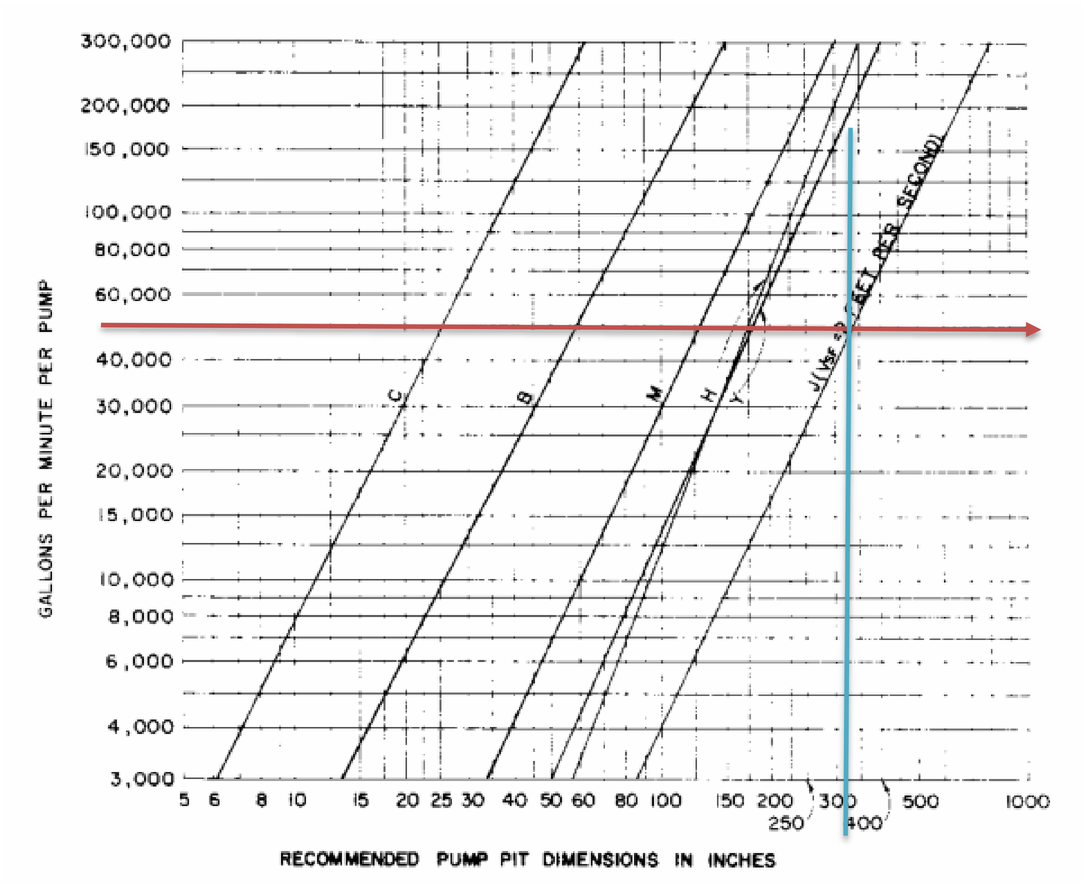


Table 2 – Method 1 using Simple Pump Sumps design approach

The second method utilized the design Nomograph prepared by MDOT, Pump Station Hydraulic Design. This method is based on the discharge capacity of the pump in units of gallons per minutes. The corresponding sump dimensions are read from the graph in units of inches. Table 3 presents the design summary. Reducing from the minimum water level or pump cut-off elevation, the sump invert was computed to be at an elevation 11.3mGD.

Of the two methods considered, the one offering the largest pump sump dimensions was selected. Such a move is anticipated to curtail the occurrence of cavitation and increase the longevity of the pump's operation. The outputs of the second design method using the Design Nomograph was adopted for the design of the Herstelling Pump Station. A width of 4.3m, a length of 8.1m with the bottom of the suction side of the pump being 0.65m from the sump invert were the minimum requirements for the sump design.

Using Design Nomograph from MDOT Drainage Manual



The above graph is reproduced from Hydraulic Institute Standards.

A = Minimum distance from trash rack to backwall (length of pump pit).
B = Maximum distance from centerline of pump to backwall.
C = Average dimension from underside of bell to bottom of pit.
S = Minimum dimension from minimum water level to underside of bell.
W = Minimum center-to-center spacing of pumps.
Y = Minimum distance to pump centerline from downstream end of any obstruction in sump (obstruction must be streamlined).

Figure 10-B-1 Recommended Pump Pit Dimensions

From Chart					
	B =	60	inches	1.52	m
	C =	25	inches	0.64	m
	Y =	180	inches	4.57	m
	A (J) =	320	inches	8.13	m
	S (M) =	120	inches	3.05	m
	W (H) =	170	inches	4.32	m
	Design				
	Invert			11.3	mGD

Table 3 – Method 2 using MDOT Design Nomograph

3.0 Appendix

Calculation Interval				Pipe Material									
Delivery Side	1	m		Galvanised Iron/Steel									
Features	Distance (m)		Station	Elev (RL m)	Static (m)	Cumulative (m)	Losses (m)			Hydraulic Gradient		Reduce Level (m)	
							Friction	Minor	Cumulative	Dynamic	Static	Dynamic	Static
1	2	3	4	5	6	7	8	9	10	11 (7 + 10)	12	13 (11+5)	14
EXIT PIPE	*14.5*		P	19.20	0.00	0.00	0.005	0.232	0.24	0.24	4.20	19.44	19.20
Bend	14.25	Delivery - STEEL	O	19.20	0.00	0.00	0.020	0.058	0.31	0.31	4.20	19.51	19.20
	13.25		N	19.20	0.00	0.00	0.020		0.33	0.33	4.20	19.53	19.20
	12.25		M	19.20	0.00	0.00	0.020		0.35	0.35	4.20	19.55	19.20
	11.25		L	19.20	0.00	0.00	0.020		0.37	0.37	4.20	19.57	19.20
Bend	10.25		K	19.20	0.00	0.00	0.020	0.058	0.45	0.45	4.20	19.65	19.20
	9.25		J	19.20	0.00	0.00	0.020		0.47	0.47	4.20	19.67	19.20
	8.25		I	19.20	0.00	0.00	0.020		0.49	0.49	4.20	19.69	19.20
Bend	7.25		H	19.20	0.00	0.00	0.034	0.075	0.60	0.60	4.20	19.80	19.20
	6.05	Suction - STEEL	G	18.00	1.20	1.20	0.014		0.61	1.81	4.20	19.81	19.20
	5.55		F	17.50	0.50	1.70	0.014		0.63	2.33	4.20	19.83	19.20
	5.05		E	17.00	0.50	2.20	0.014		0.64	2.84	4.20	19.84	19.20
	4.55		D	16.50	0.50	2.70	0.014		0.65	3.35	4.20	19.85	19.20
	4.05		C	16.00	0.50	3.20	0.014		0.67	3.87	4.20	19.87	19.20
	3.55		B	15.50	0.50	3.70	0.014		0.68	4.38	4.20	19.88	19.20
Mini. WL	3.05		A	15.00	0.50	4.20	0.086		0.77	4.97	4.20	19.97	19.20
PIPE ENTRY	0			11.95				0.240	1.01	5.21	4.20	20.21	19.20

Table 4 – Pump Hydraulic Computations

<u>Notes</u>				
Friction Calculated using Darcy-Weisbach Equation				
Using,				
	$h_f = (f.L.v^2)/(d_i.2g)$			
Pipe Diameter				
Suction Side	1.2192	m		
Delivery Side	1.3	m		
Reynolds Number				
Suction Side	1,547,130			
Delivery Side	1,875,565			
Friction Factor, f				
f assumed				
Suction Side	0.1145			
Delivery Side	0.1102			
Equivalent Pipe Roughness, *K (Table 6.3)*				
Suction Side	0.15			
Delivery Side	0.15			
	$1/f^{0.5}$	$-2 \log [k/3.7d_i + 2.51/R_e.f^{0.5}]$		
Suction Side	2.955	2.956	0.0333	4.79451E-06
Delivery Side	3.012	3.012	0.0312	4.03135E-06
Average Velocity				
Suction Side	2.42	m/s		
Delivery Side	2.13	m/s		

Table 5 – Friction Loss Analysisq

Classification of pipes	Values of k [mm]		
	Good	Normal	Poor
Smooth pipes			
Extruded non-ferrous pipes, e.g. aluminium, brass, copper, lead, and non-metal pipes of Alkathene, glass, Perspex, plastics, fibre glass.	–	0,003-0,015	–
Fibre cement	–	0,015	–
Metal			
Spun iron, bitumen coated	–	0,03	–
Malleable iron	0,03	0,06	0,15
Coated steel	0,03	0,06	0,15
Galvanised iron/steel	0,06	0,15	0,30
Coated cast iron	0,06	0,15	0,30
Concrete			
Monolithic construction in oiled steel moulds, with smooth surface and precast smooth walled pipe without shoulders or hollows at joints.	0,06	0,15	–
Precast, smooth wall pipes in lengths exceeding 1,8 m, with spigot and socket or "ogee" joints, smoothed internally.	–	0,15	0,30

Table 6 – Equivalent Pipe Roughness

2017

Herstelling Sluice and Pump Station

Structural and Geotechnical Design Report

Gregory Williams
SRKN'gineering & Associates
5/12/2017

Table of Contents

Introduction

This report details the Structural and Geotechnical Designs carried out in relation to the combined Sluice and Pump Station to be located at Herstelling, East Bank Demerara.

The structure is to be supported on piles and consists of a single door sluice alongside a sump which is to be spanned by a slab upon which the pump house will be constructed. The overall arrangement is similar to a two door sluice with the sump and pumping system forming one half while the single door sluice forms the other.

The Geotechnical Design consisted of determination of pile capacity, earth pressure on wingwalls and abutment walls, and sliding and overturning stability of the final revetments to link the new structure with the existing sluice.

The Structural Design consisted of design of all concrete members, including the base slab, wingwalls, abutment walls, bridge slabs, and gantry members.

Existing Geotechnical Information

The existing information was obtained from a borehole done on the site on 2nd April, 2017 by Colin Mattis & Associates. See Appendix 3 for full report.

<u>Herstelling Borehole Log</u>

Depth (m)	Elevation (mGD)	N	Description	Shear Vane (initial) (kPa)	Shear vane (remoulded) (kPa)
0.00	18.07		Medium to soft brown silty clay		
1.00	17.07			36.50	16.62
1.68	16.39				
2.00	16.07		Very soft grey silty clay with lens of silt	19.88	12.50
3.00	15.07			22.42	8.24
3.20	14.87				
4.00	14.07			23.23	8.24
5.00	13.07			19.01	7.47
6.00	12.07			17.39	6.66
6.86	11.21				
7.62	10.45	1			
9.15	8.92	1			
10.67	7.40		Soft grey silty clay with pockets of sand		
11.43	6.64	3			
12.20	5.87	3	Soft bluish grey silty clay		
13.72	4.35	3			
15.24	2.83	17			
16.77	1.30		Stiff to very stiff bluish grey silty clay		
18.29	-0.22	22			
19.82	-1.75	25			
21.34	-3.27	32			

Design Parameters

Design Codes and Standards

For the structural design of reinforced concrete members: **BS8110**

Maximum Elevation of structure

A design elevation of 18.2mGD was used for this structure. This was found to be the highest point of the existing earthen river defence in this area and sufficiently above the Highest Astronomic Tide for the Demerara River (17.26mGD) to be acceptable. It is also similar to the elevation of the existing sluice that is found adjacent to this structure which was found to be approximately 18mGD.

Elevation of inlet and outlet wingwalls

Considering the survey data available for the existing sluice the inlet wingwalls were set at 16mGD and those of the outlet were set at 17mGD.

Invert of Sluice

The required sluice invert was determined during the Hydraulic Analysis to be 12.8mGD.

Width of Sluice Opening

The required sluice opening width was determined during the Hydraulic Analysis to be 4.2m.

Invert of Sump

The required sump invert was determined during the Hydraulic Analysis to be 11.3mGD. This value corresponds to a 100cft/s pump discharge with the water level in the canal being at or higher than the Design Drainage Level (15.1mGD).

Width of Sump Opening

The required sump opening width was determined during the Hydraulic Analysis to be 3.5m. However, this value was increased to 4.5m to allow for adequate space to fit the pump house on top of the sump.

Inlet and Outlet Wingwall Angles

The angles of the wingwalls to the abutment wall was set at 115°. This is the same as for the existing sluice and was viewed as adequate for the new structure.

Length of Inlet

The length of the inlet was determined based on the requirements for the sump. The Hydraulic design of the sump requires minimum length at the Sump invert elevation followed by a slope of angle 10° up to the elevation of the channel bed. These lengths combined gave the total length of the inlet for the structure.

Length of Outlet

The length of the outlet slab was governed by the need to provide a discharge box for the outlet pipe of the pump station. In order not to impede flow from the sluice and for ease of construction the entire outlet slab was set at an elevation of 12.8mGD. By allowing a 45° angle for the discharge pipe from the top of the structure down to this elevation the length of the outlet slab was determined. It should be noted that it is likely that the discharge pipe will end significantly before the elevation of the outlet slab but the discharge stream should still impact within the area of the discharge box.

Design Material Properties

Steel Reinforcement

All steel reinforcement was designed to consist of High Tension Steel of strength 460N/mm^2.

Concrete

All concrete for this structure was designed to have a minimum compressive strength of 30MPa at 28 days.

Timber

All timber members were designed to be constructed of Greenheart unless otherwise stated.

Cover to Reinforcement

The cover to reinforcement for all members except the base slab was designed to be 50mm.

The cover to reinforcement for the base slab was designed to be 75mm.

Design Summary

Piles

Considering the elevation of the top of the pile to be approximately 12.5mGD.

The assumed soil strength parameters with depth are shown below:

Elevation (mGD)	Thickness of layer (m)	Assumed Cohesion (kPa)
12.5	5.5	15
7	4	25
3	4	100

Consider Piles spaced at 2m x 2m grid.

Consider a pile supporting a section of the abutment wall of the sump.

Height of abutment wall (m) = 6.4

Thickness of abutment wall (m) = 0.6

Allow for a F.S. of 1.5.

Design Output

Use 350mm butt diameter timber piles of minimum length 15m on a 2m x 2m grid.

See Appendix 1 for Design Calculations.

Structural Members

Base Slab

The base slab will be designed as a flat slab. Piles are assumed to support it on a 2m x 2m grid.

The critical section will be under the 600mm thick abutment wall.

Design Output

Used 500mm thick slab with T20mm diameter bars both ways on both top and bottom faces.

See Appendix 1 for Design Calculations.

Sump Wall

Wall is to be tied into the base slab at its bottom as well as the pump house floor slab at its top.

Maximum Height of wall (m) = 6.9

Maximum moment will occur on the base of the wall.

Allowing for a cohesion of 10kPa in the fill material to allow for an adequate F.S. on this material strength. Allow for a 10kPa surcharge to account for vehicular traffic adjacent to the wall.

Design Output

Use a 600mm thick wall with T20mm diameter main bars at 150mm spacing on the tension face and T16mm diameter bars at 150mm spacing on the inner face. Distribution steel to be T12mm diameter bars at 150mm both faces.

See Appendix 1 for Design Calculations.

Sluice Wall

Wall is to be tied into the base slab at its bottom. Wall is to be tied into the bridge slab at its top as well as supported by tie beams and tie beam columns.

Maximum Height of wall (m) = 5.4

Maximum moment will occur on the base of the wall.

Allowing for a cohesion of 10kPa in the fill material to allow for an adequate F.S. on this material strength.

Allow for a 10kPa surcharge to account for vehicular traffic adjacent to the wall.

Design Output

Use a 400mm thick wall with T20mm diameter main bars at 150mm spacing on the tension face and T16mm diameter bars at 150mm spacing on the inner face. Distribution steel to be T12mm diameter bars at 150mm both faces.

See Appendix 1 for Design Calculations.

<u>Sluice Wall Bracing Column</u>

These columns are to be used to support the tie beams to be used in the sluice wall. As a simplification of the design forces and moments are taken directly from the previously done Sluice Wall design.

Design Output

Use a 600mm x 600mm column with four (4) T20mm diameter bars in the tension and compression face. Links are to be 12mm diameter at a spacing of 150mm.

See Appendix 1 for Design Calculations.

<u>Sump Wingwall</u>

This refers to the cantilever wingwall for the inlet of the structure adjacent to the sump. The crest elevation of this wall is set at 16mGD with the minimum base elevation being approximately 11.3mGD.

Height of wall (m) = 4.7

Maximum moment will occur on the base of the wall.

Allowing for a cohesion of 10kPa in the fill material to allow for an adequate F.S. on this material strength.

Allow for a 10kPa surcharge to account for vehicular traffic adjacent to the wall.

Design Output

Use a 600mm thick wall with T20mm diameter bars at 150mm centers in the tension face and T16mm diameter bars at 150mm centres in the inner face. Distribution steel is to be T12mm diameter bars at 150mm centres in both faces.

See Appendix 1 for Design Calculations.

<u>Sluice Wingwall</u>

This refers to the cantilever wingwall for the inlet of the structure adjacent to the sluice. The crest elevation of this wall is set at 16mGD with the minimum base elevation being approximately 12.8mGD.

Height of wall (m) = 4.2

Maximum moment will occur on the base of the wall.

Allowing for a cohesion of 10kPa in the fill material to allow for an adequate F.S. on this material strength.

Allow for a 10kPa surcharge to account for vehicular traffic adjacent to the wall.

Design Output

Use a 400mm thick wall with T20mm diameter bars at 150mm centers in the tension face and T16mm diameter bars at 150mm centres in the inner face. Distribution steel is to be T12mm diameter bars at 150mm centres in both faces.

See Appendix 1 for Design Calculations.

Sump Covering Slab

This refers to the slab forming the ground floor of the pumphouse. Its primary loading will be the pump engine and the discharge piping.

The discharge pipe opening is supported by two (2) beams in order to support the pipe with the associated drawdown force, allow for greater stiffness at this point, and to allow for vibration and associated impact loading.

The slab was designed to allow for the passage of an excavator over it as the final weight of the pump engine is not known. It is expected that this design loading is adequate for its purpose.

Design Output

Use a 350mmm thick slab with 20mm diameter bars in both the top and bottom faces at 150mm spacing.

Distribution steel to be 12mm diameter bars at 150mm spacing in both faces.

See Appendix 1 for Design Calculations.

Discharge Pipe Column

This refers to the column supporting the discharge pipe. Its primary loading will be the weight of the discharge pipe and the force exerted by the water being discharged. The force exerted by the water was taken as that produced by a 45° angle of the discharge pipe.

Design Output

Use a 350mm x 350mm column with 8 T20mm diameter bars for main reinforcement and 12mm diameter links at 150mm centres.

See Appendix 1 for Design Calculations.

Gantry and Door

The gantry system inclusive of gantry columns, gantry beam and pulley arrangement as well as the timber door was based on that used for the Sluices at Bagotville and La Grange. Rechecking of these members was done to ensure their suitability for this project.

Revetment Works

This refers to the permanent revetment works to be done in order to protect the material located between the new structure and existing sluice. It is essential to prevent erosion in this region since it is adjacent to the path of discharge from the existing sluice and therefore is susceptible to turbulence. Additionally, new fill will have to be placed in this area which will be more highly erodible.

The top elevation of this wall will be equal to that of the outlet retaining wall (17mGD).

The ground level on the downstream side of the wall is taken to be equal to the invert of the outlet slab (12.8mGD).

Height of soil to be retained = 4.2m

Design Output

Utilized 12m long steel sheet piles for the main wall along with 3 sets of 12m long steel sheet piles driven parallel to the wingwall of the new structure to form an anchorage system.

These anchoring sheet piles are to be welded together from their tops to the bottom of the excavation in this area (approximately 13mGD).

Additionally, rock armour is to be provided for the area downstream of the revetment wall to prevent erosion, which will lead to the height of soil retained increasing, which in turn can lead to movement of the revetment.

See Appendix 2 for Design Calculations.

Appendix I

Pile Capacity

REFERENCES	CALCULATIONS			OUTPUT	
	Location: **Herstelling Sluice**				
	Pile Capacity timber Piles				
	Dimensions of pile (mm)	Butt Diameter	350		
	Length of pile (m)		15		
	Unit weight of concrete (KN/m^3)		24		
	The total load due to the bridge loadings will be considered as evenly distributed among the supporting piles.				
	Weight due to base slab (KN) =		48		
	Weight due to beams (KN) =		0		
	Weight due to pile cap (kN) =		5.184		
	Weight due to water loading (KN) =		131.81		
	Weight due to wingwall (kN) =		198.72		
	Ultimate Load, w				
	w = Gk + Qk			**Ultimate Load, w**	
	w (KN)	383.71		**w (KN)**	**383.71**
	Number of piles		1		
	Axial load per pile (KN) =		w		
				Axial load per	
	Axial load per pile (KN) =		383.71	**pile (KN)**	**383.71**
	Loading due to self weight of pile (KN)		11.224406		
				Required Pile	
	Required pile capacity (KN) =		394.93	**Capacity (KN)**	**394.93**
	Cohesion soils				
	Pile dimensions	Butt Diameter	350 mm		
	Depth of pile penetration (m)		14		
	Average perimeter of pile r, (m)		0.942		
	Tip Area A, (m2)		0.0490625		
	Pile Capacity (KN) =	$c_1rh + 7.4c_2A$			
	Cohesion at pile base (kN/m2) =	150			
	Pile End Capacity (kN) =	7.4cA			
	Pile End Capacity (kN) =	54.459375			
	Cohesion along length of pile				
	Depth / Length / Cohesion				
	0-6m / 5.5 / 15				
	6-10m / 4 / 25				
	10-15m / 4 / 100				
	Pile Skin friction capacity (kN)	548.715			
	Factor of safety (F.S.) =	1.53			

Base Slab

REFERENCES	CALCULATIONS			OUTPUT	
	LOCATION: Herstelling Sluice				
	FLAT SLAB: Edge Panel				
	SLAB:				
BS 8110	Condition of Exposure		Very Severe		
Table 3.3	Cover, C (mm)		75		
	Grade of Concrete, f_{cu} (N/mm^2)		30		
BS 8110	Using High YieldSteel				
Table 3.1	Strength of Steel, f_y (N/mm^2)		460		
	DEPTH OF BEAM				
	Member will be designed as a flat slab.				
		Width	Length		
	Span (m x m)	1	2		
	Assumed bar diameter (mm)		20		
				Depth of Slab,	
	Assumed slab thickness(mm)		500	**h (mm)**	**500.00**
	Effective depth to reinforcement, d (mm)				
	d (mm) = Thickness - Cover - 1/2Bar Size				
				Assumed effective depth	
	d (mm) = 415			**d (mm)**	**415.00**
	LOADINGS				
	Unit Weight of Concrete (KN/m^3)		24		
	Considering an edge panel of dimensions:				
	Area of floor supported (length x wi	2	1		
	Live Loads				
BS 6399:	Assume Slab will be subjected to traffic traffic.				
Part 1	Live Load (UDL), (kN/m^2)		68		
	Live Load (Central Point Load), (kN)		0		
	Additional Live Load (kN)		0		
	Dead Loads				
	Thickness of slab supported by beam (mm)		0		
	Self Weight of beam (kN)		24		
	Other dead loads supported by beam, UDL (kN/m		198.72		
	Other dead loads supported by beam (Central Pc		0		
	Additional Dead Load (kN)		0		
	Considering slab simply supported				
	Total moments for panel				
	Moments				
	Moment from live load (UDL), kNm		33.83		
	Moment from Live Load (Central Point), kNm		0		
	Additional Live moment (kNm)		0		
	Moment from slab, kNm		0		
	Moment due to self weight, kNm		6		
	Moment from other dead UDL, kNm		49.68		
	Moment from dead load (central point), kNm		0		
	Additional Dead moment (kNm)				

	Design Dead Load, G_k	
	G_k (KN) 421.44	
	Imposed Load (KN)	
	Q_k (KN) 135.34	
	Ultimate Load, *w*	
	$w = 1.4G_k + 1.6Q_k$	**Ultimate Load, w**
	w (KN) 806.55	***w* (KN) 806.55**
	Design Bending Moment, M	**Design Bending Moment**
	M (KNm) 62.53 69.552	**M (KNm) 62.53**
	UDL Wall	
	<u>Column Strip.</u>	
BS8110:	Negative bending moment for the column strip = 75%M + wall moment	
Table 3.18	Width of column strip (m) 0.5	
		Design Negative
	Considering a section 1m wide	**Bending Moment**
	M_{max} (KNm)= 232.91 **(per m width)**	**M_{max} (KNm) 232.91**
BS 8110	Ultimate Design Moment, M_u	**Ultimate Design**
Cl 3.4.4	$M_u = 0.156 f_{cu} bd^2$	**Moment, M_u**
	M_u (KNm) 806.01	**M_u (KNm) 806.01**
	Since $M < M_u$ no compression reinforcement in needed	
	<u>MAIN STEEL</u>	
	Main bars (tension steel) diameter (mm) 20	
BS 8110	$K = \frac{M}{f_{cu}bd^2}$	
Cl 3.4.4		
	K = $\frac{232.91}{5166.75}$	
		Coefficient
	K = 0.05	**k 0.05**
	Since K < k' = 0.156 no compression reinforcement needed	
BS 8110	Lever Arm (z)	
Cl 3.4.4	$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$	
	z (mm) 393.05	**Lever Arm**
	Check z < 0.95d z< 394.25	**z (mm) 393.05**
	Therefore Area of Tension Steel Required (per m width)	
	$A_s = M/0.95f_y z$	**Area of Tension Bars,**
	A_s (mm^2/m) 1355.96	**A_s (mm^2/m) 1355.96**

	Middle Strip.	
BS8110: Table 3.18	Negative bending moment for the middle strip = 25%M Width of middle strip (m) 0.5	
	For a 1m wide section: M_{max} (KNm)= 31.27	**Maximum Positive Bending Moment** **M_{max} (KNm) 31.27**
BS 8110 Cl 3.4.4	Ultimate Design Moment, M_u $M_u = 0.156 f_{cu} bd^2$ M_u (KNm) 806.01	**Ultimate Design Moment, M_u** **M_u (KNm) 806.01**
	Since M < M_u no compression reinforcement in needed	
	MAIN STEEL Main bars (tension steel) diameter (mm) 20	
BS 8110 Cl 3.4.4	$K = \frac{M}{f_{cu}bd^2}$ K = $\frac{31.27}{5166.75}$ K = 0.0061	**Coefficient** **k 0.0061**
	Since K < k' = 0.156 no compression reinforcement needed	
BS 8110 Cl 3.4.4	Lever Arm (z) $z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$ z (mm) 412.19 Check z < 0.95d z< 394.25	**Lever Arm** **z (mm) 394.25**
	Therefore Area of Tension Steel Required (per m width) $A_s = M/0.95 f_y z$ A_s (mm^2/m) 181.48	**Area of Tension Bars,** **A_s (mm^2/m) 181.48**
	Negative Bending Reinforcement.	
BS8110: Cl 3.7.3.1	67% of reinforcement required for the column strip must be placed in a width equal to half of the column strip Width of section (m) = 0.25 Area of reinforcement required (mm^2) = 454.25 Required reinforcement per metre (mm^2/m) = 1816.99	**Area of Tension Bars,** **A_{sreq} (mm^2/m) 1816.99**
	Provide: No. 6.666667 T 20 mm ϕ bars Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2094.395	**Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2094.40**
	Positive Bending Reinforcement: ***Use:*** No 6.666667 T 20 mm ϕ bars Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2094.40	**Area of Steel provided** **A_{sprov} (mm^2/m) 2094.40**

	Shear.	
	Maximum Design Shear Capacity v_{max} (N/mm^2)	
	$$v_{max} = \frac{V}{u_o d}$$	
	V (KN) = 806.55 < 0.8*sqrt(30	**Maximum Design Shear Capacity**
	v_{max} (N/mm^2) = 1.54 < 4.38178	**v_{max} (N/mm^2)** **1.54**
	Design Shear Stress v = V/ud	
BS8110: Cls. 3.7.7.6	Checking design shear stress at a distance 1.5d from the loaded area: v = 0.39	**Applied Shear Stress** **v (kN/m^2)** **0.39**
BS8110: Table 3.8	Design concrete shear stress	
	vc = $0.79\{100A_s/(b_v d)\}^{1/3}\ (400/d)^{1/4}/\gamma_m$	
	vc = 0.50	
	Modification Factor = 1.17	
	vc = 0.58	**Shear Capacity** **vc (kN/m^2)** **0.58**
	No shear reinforcement is required.	

Sump Wall

REFERENCES	CALCULATIONS			OUTPUT
	Location: **Herstelling Sluice**			
	Member: Wingwall			
BS 8110	Condition of Exposure		Very Severe	
Table 3.3	Cover, C (mm)		50	
	Grade of Concrete, f_{cu} (N/mm^2)		30	
BS 8110	Using High Yield Steel			
Table 3.1	Strength of Steel, f_y (N/mm^2)		460	
	Assumed thickness of Wall (mm)		600	
	Height of wall (m)		6.9	
	LOADINGS			
	Bending Moment.			
	Considering the water table level with the ground surface.			
	Depth of soil to be retained, D (m)		6.9	
Foundation Analysis and Design by J.E. Bowles.	Soil properties will be assumed as follows:			
	Cohesion (KN/m^2)	10		
Table 2.6	Saturated Unit Weight (KN/m^3)	16		
Table 11.3	K_a (Rakine)	1		
Table 11.4	K_p (Rakine)	1		
	Assumed Surcharge, S (KN/m^2)	10		
	Considering a 1m wide section of wall.			
	Depth of Tension Crack (m)	1.25		
	Force due to surcharge (kN), P_1		69.00	
	Force due to earth pressure (kN), P_2		255.38	
	Force due to hydrostatic pressure (kN), P_3		7.66	

Dead Load, G_k (Surcharge)

G_k (KN) 69.00

Earth and Water Load, E_k

E_k (KN) 263.042

Ultimate Load, *w*

w = $1.4G_k + 1.2E_k$

w (KN) 412.25

Ultimate Load, w

***w* (KN) 412.25**

Maximum bending moment occurs at the base of the wall.

Moment at base of wall (KNm) = $(P_1L/4) + 2(P_2+P_3)L/20)$

Moment at base of wall (KNm) = 314.64

Factored Moment due to lateral loads M_1

M_1 (KNm) = 389.47

M_1 (KNm) **389.47139**

Assumed bar diameter (mm) 20

Assumed slab thickness(mm) 600

Depth of Slab,

h (mm) 600

Effective depth to reinforcement, d (mm)

d (mm) = Thickness - Cover - 1/2Bar Size

d (mm) = 540

Assumed effective depth

d (mm) 540

Design Moment, M_1

M (KNm) 389.47

Design Moment, M

M (KNm) 389.47

BS 8110
Cl 3.4.4

Ultimate Design Moment, M_u

$M_u = 0.156\, f_{cu}\, bd^2$

M_u (KNm) 1364.688

Ultimate Design Moment, M_u

M_u (KNm) 1364.69

Since M < M_u no compression reinforcement in needed

<u>MAIN STEEL</u>

Main bars (tension steel) diameter (mm) 20

BS 8110
Cl 3.4.4

$$K = \frac{M}{f_{cu}bd^2}$$

$$K = \frac{389.47}{8748}$$

K 0.0445

Coefficient

k 0.0445

Since K < k' = 0.156 no compression reinforcement needed

BS 8110 Cl 3.4.4	Lever Arm (z) $z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$ z (mm) 511.82 Check z < 0.95d z = 511.8163	**Lever Arm** **z (mm) 511.82**
	Therefore Area of Tension Steel Required $A_s = M/0.95 f_y z$ A_s (mm^2/m) 1741.33	**Area of Tension Bars,** **A_s (mm^2/m) 1741**
	Using T20 Bar at 150mm center to center spacing Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2093.333	**Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2093.3333**
BS 8110 Table 3.25	***Secondary Steel*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 780	**Secondary Steel Area,** **A_{smin} (mm^2/m) 780**
	Using T12 Bar at 150mm center to center spacing Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 753.6	**Area of Tension Bar provided** **A_{sprov} (mm^2/m) 753.6**
BS 8110 Table 3.10	<u>**Deflection.**</u> ***Modification Factor,*** Design Service Stress, f_s $f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}}$ f_s (N/mm^2) 255.10	**Design Service Stress,** **f_s (N/mm^2) 255.10**
	Modification Factor, $\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$ M.F. 1.377	**Modification Factor** **M.F. 1.377**
BS8110: Table 3.9	Allowable Span/Depth Ratio 27.54 Actual Span/Depth Ratio 12.78	**Allowable Span/Depth 27.54** **Actual Span/Depth 12.78**

	Shear.	
	Maximum Shear force (kN) = $P_1 / 2 + wL/3$	
	Applied shear force V (KN) = 218.55	**Applied Shear Force V (KN) 218.55**
	Applied Shear Stress v (N/mm^2) = 0.40	**Applied Shear Stress v (N/mm2 0.40**
BS8110: Table 3.8	Design Concrete Shear Strength	
	v_c (N/mm^2) = $0.79\{100A_s/(b_v d)\}^{1/3}\ (400/d)^{1/4}/\gamma_m$	
	v_c (N/mm^2) = 0.43	
	Modification Factor = 1.06	
	v_c = 0.45	**Design Shear Strength v_c (N/mm^2) = 0.45**
	No Shear Reinforcement Required	

Sluice Wall

REFERENCES	CALCULATIONS		OUTPUT
	Location: **Herstelling Sluice**		
	Member: **Wingwall**		
BS 8110	Condition of Exposure	Very Severe	
Table 3.3	Cover, C (mm)	50	
	Grade of Concrete, f_{cu} (N/mm^2)	30	
BS 8110	Using High Yield Steel		
Table 3.1	Strength of Steel, f_y (N/mm^2)	460	
	Assumed thickness of Wall (mm)	400	
	Height of wall (m)	5.4	
	LOADINGS		
	Bending Moment.		
	Considering the water table level with the ground surface.		
	Depth of soil to be retained, D (m)	5.4	
Foundation Analysis and	Soil properties will be assumed as follows:		
Design by J.E. Bowles.	Cohesion (KN/m^2)	10	
Table 2.6	Saturated Unit Weight (KN/m^3)	16	
Table 11.3	K_a (Rakine)	1	
Table 11.4	K_p (Rakine)	1	
	Assumed Surcharge, S (KN/m^2)	10	
	Considering a 1m wide section of wall.		
	Depth of Tension Crack (m)	1.25	
	Force due to surcharge (kN), P_1	54.00	
	Force due to earth pressure (kN), P_2	137.78	
	Force due to hydrostatic pressure (kN), P_3	7.66	
	Dead Load, G_k (Surcharge)		
	G_k (KN)	54.00	
	Earth and Water Load, E_k		
	E_k (KN)	145.442	

	Ultimate Load, *w*	
	$w = 1.4G_k + 1.2E_k$	**Ultimate Load, w**
	w (KN) 250.13	***w* (KN) 250.13**
	Maximum bending moment occurs at the base of the wall.	
	Moment at base of wall (KNm) = $(P_1L/4) + 2(P_2+P_3)L/20)$	
	Moment at base of wall (KNm) = 142.79	
	Factored Moment due to lateral loads M_1	
	M_1 (KNm) = 199.91	M_1 (KNm) **199.90505**
	Assumed bar diameter (mm) 20	
	Assumed slab thickness(mm) 400	**Depth of Slab, h (mm) 400**
	Effective depth to reinforcement, d (mm)	
	d (mm) = Thickness - Cover - 1/2Bar Size	
	d (mm) = 340	**Assumed effective depth d (mm) 340**
	Design Moment, M_1	**Design Moment, M**
	M (KNm) 199.91	**M (KNm) 199.91**
BS 8110	Ultimate Design Moment, M_u	
Cl 3.4.4	$M_u = 0.156 f_{cu} bd^2$	**Ultimate Design**
	M_u (KNm) 541.008	**Moment, M_u**
		M_u (KNm) 541.01
	Since $M < M_u$ no compression reinforcement in needed	
	MAIN STEEL	
	Main bars (tension steel) diameter (mm) 20	
BS 8110 Cl 3.4.4	$K = \frac{M}{f_{cu}bd^2}$	
	K $\frac{199.91}{3468}$	
	K 0.0576	**Coefficient k 0.0576**
	Since K < k' = 0.156 no compression reinforcement needed	

BS 8110 Cl 3.4.4	Lever Arm (z) $$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$$ z (mm) 316.62 Check z < 0.95d z = 316.6155 Therefore Area of Tension Steel Required $$A_s = M/0.95 f_y z$$ A_s (mm^2/m) 1444.81 ***Using T20 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2093.333	**Lever Arm** **z (mm) 316.62** **Area of Tension Bars,** **A_s (mm^2/m) 1445** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2093.3333**
BS 8110 Table 3.25 BS 8110 Table 3.10 BS8110: Table 3.9	***Secondary Steel*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 520 ***Using T12 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 753.6 **Deflection.** ***Modification Factor,*** Design Service Stress, f_s $$f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}}$$ f_s (N/mm^2) 211.66 Modification Factor, $$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$$ M.F. 1.391 Allowable Span/Depth Ratio 27.82 Actual Span/Depth Ratio 15.88	**Secondary Steel Area,** **A_{smin} (mm^2/m) 520** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 753.6** **Design Service Stress,** **f_s (N/mm^2) 211.66** **Modification Factor** **M.F. 1.391** **Allowable Span/Depth 27.82** **Actual Span/Depth 15.88**

	Shear.	
	Maximum Shear force (kN) = P_1 / 2 + wL/3	
	Applied shear force V (KN) = 148.02	**Applied Shear Force V (KN) 148.02**
	Applied Shear Stress v (N/mm^2) = 0.44	**Applied Shear Stress v (N/mm2 0.44**
BS8110: Table 3.8	Design Concrete Shear Strength	
	v_c (N/mm^2) = $0.79\{100A_s/(b_v d)\}^{1/3}\ (400/d)^{1/4}/\gamma_m$	
	v_c (N/mm^2) = 0.56	
	Modification Factor = 1.06	
	v_c = 0.60	**Design Shear Strength v_c (N/mm^2) = 0.60**
	No Shear Reinforcement Required	

Sluice Wall Bracing Column

REFERENCES	CALCULATIONS			OUTPUT
	LOCATION: **Herstelling Sluice**			
	BEAM: **Wingwall Column**			
BS 8110	Condition of Exposure		Severe	
Table 3.3	Cover, C (mm)		50	
	Grade of Concrete, f_{cu} (N/mm^2)		30	
BS 8110	Using High Yield Steel			
Table 3.1	Strength of Steel, f_y (N/mm^2)		460	
	Assume Beam dimensions (mm)	600	600	
	Effective Span (mm)		5400	
	DEPTH OF BEAM			
	Assumed bar diameter (mm)		20	
	Assumed link diameter (mm)		12	
	Effective depth			
	d (mm) = h - Cover - link diameter - 1/2 bar size			**Assumed effective depth**
	d (mm) = 528			**d (mm) 528**
	LOADINGS			
	Unit Weight of Concrete (KN/m^3)		24	
	Area of floor supported (length x wic	5.4	1.3	
	Live Loads			
	Live Load (UDL), (kN/m2)		0	
	Live Load (Central Point Load), (kN)		0	
	Additional Live Load (kN)		203.125	
	Dead Loads			
	Thickness of slab supported by beam (mm)		0	
	Self Weight of beam (kN)			
	Other dead loads supported by beam, UDL (kN/m		0	
	Other dead loads supported by beam (Central Pc		0	
	Additional Dead Load (kN)		0	
	Considering beam with Fixed Supports			
	Moments			
	Moment from live load (UDL), kNm		0	
	Moment from Live Load (Central Point), kNm		0	
	Additional Live moment (kNm)		161.6875	

	Moment from slab, kNm 0	
	Moment due to self weight, kNm 0	
	Moment from other dead UDL, kNm 0	
	Moment from dead load (central point), kNm 0	
	Additional Dead moment (kNm) 0	
	Design Dead Load, G_k	
	G_k (KN) 0.00	
	Imposed Load (KN)	
	Q_k (KN) 203.13	
	Ultimate Load, *w*	
	w = $1.4G_k + 1.6Q_k$	**Ultimate Load, w**
	w (KN) 325.00	***w* (KN) 325.00**
	Design Moment, M	**Design Moment,**
	M (KNm) 258.70	**M (KNm) 258.70**
BS 8110	Ultimate Design Moment, M_u	
Cl 3.4.4	$M_u = 0.156 f_{cu} bd^2$	**Ultimate Design**
	M_u (KNm) 782.83	**Moment, M_u**
		M_u (KNm) 782.83
	Since M < M_u no compression reinforcement in needed	
	<u>**MAIN STEEL**</u>	
	Main bars (tension steel) diameter (mm) 20	
BS 8110		
Cl 3.4.4	$K = \frac{M}{f_{cu}bd^2}$	
	K $\frac{258.70}{5018.112}$	
		Coefficient
	K 0.0516	**k 0.0516**
	Since K < k' = 0.156 no compression reinforcement needed	
BS 8110	Lever Arm (z)	
Cl 3.4.4	$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$	
	z (mm) 495.79	**Lever Arm**
	Check z < 0.95d z = 495.7906	**z (mm) 495.79**
	Therefore Area of Tension Steel Required	
	$A_s = M/0.95 f_y z$	**Area of Tension Bars,**
	A_s (mm^2/m) 1194.03	**A_{sreq} (mm^2/m) 1194.03**
	Provide: No. 4 T 20 mm ϕ bars	
	Area of Steel provided, A_{sprov}	**Area of Tension Bar provided**
	A_{sprov} (mm^2/m) 1256.637	**A_{sprov} (mm^2/m) 1256.64**

BS 8110 Table 3.10	**Deflection Modification Factor** Design Service Stress, f_s $$f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}}$$ f_s (N/mm^2) 291.39	**Design Service Stress,** **f_s (N/mm^2) 291.39**
	Modification Factor, $$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$$ M.F. 1.396	**Modification Factor** **M.F. 1.396**
BS 8110 Table 3.9	**Deflection** Allowable Span/effective depth ratio 20 (Simply sup 26 (Continuou	**Allowable Span/Depth** **Ratio 20.00**
	Actual Span/effective depth ratio 7.33	**Actual Span/Depth** **Ratio 7.33**
BS 8110 Table 3.25	***Check.*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 468	**Secondary Steel Area,** **A_{smin} (mm^2/m) 468**

	SHEAR REINFORCEMENT		
BS8110: Table 3.5	V = 0.6F	**Maximum Shearing Force V (KN)**	**195.00**
	V (KN) = 195.00		
BS8110: Cl 3.4.5.2	v (N/mm^2) = V / bd	**Maximum Shear Stress v (N/mm^2)**	**0.62**
	v (N/mm^2) = 0.62		
	Check: 0.62 ≤ (0.8√fcu) = 4.38		
	Design concrete shear stress		
BS8110: Table 3.8	v_c = $0.79\{100A_s/(b_vd)\}^{1/3}\ (400/d)^{1/4}/\gamma_m$		
	v_c = 0.43		
	Modification Factor = 1.06	**Design Concrete Shear Stress v_c (N/mm2)**	**0.46**
	v_c = 0.46		
BS81110: Table 3.7	Condition 1 v < 0.5vc FALSE		
	Condition 2 0.5vc<v<(vc+0.4) TRUE		
	Condition 3 (vc+0.4)<v<0.8√fcu FALSE		
	Condition 2 is satisfied		
BS8110: Table 3.7	Conditon 1 & 2		
	Assumed diameter of links (mm) = 12		
	Asv (mm2)= 113.10		
	Asv > 0.4bsv / 0.95*fy		
	sv (mm)≤ 205.9314		
	Link Spacing 150 < 0.75d = 396		

Sump Wingwall

REFERENCES	CALCULATIONS		OUTPUT
	Location: **Herstelling Sluice**		
	Member: Wingwall		
BS 8110	Condition of Exposure	Very Severe	
Table 3.3	Cover, C (mm)	50	
	Grade of Concrete, f_{cu} (N/mm^2)	30	
BS 8110	Using High Yield Steel		
Table 3.1	Strength of Steel, f_y (N/mm^2)	460	
	Assumed thickness of Wall (mm)	600	
	Height of wall (m)	5	
	LOADINGS		
	Bending Moment.		
	Considering the water table level with the ground surface.		
	Depth of soil to be retained, D (m)	5	
Foundation Analysis and Design by J.E. Bowles.	Soil properties will be assumed as follows:		
	Cohesion (KN/m^2)	10	
Table 2.6	Saturated Unit Weight (KN/m^3)	16	
Table 11.3	K_a (Rakine)	1	
Table 11.4	K_p (Rakine)	1	
	Assumed Surcharge, S (KN/m^2)	10	
	Considering a 1m wide section of wall.		
	Depth of Tension Crack (m)	1.25	
	Force due to surcharge (kN), P_1	50.00	
	Force due to earth pressure (kN), P_2	112.50	
	Force due to hydrostatic pressure (kN), P_3	7.66	
	Dead Load, G_k (Surcharge)		
	G_k (KN)	50.00	
	Earth and Water Load, E_k		
	E_k (KN)	120.162	

	Ultimate Load, *w*	
	$w = 1.4G_k + 1.2E_k$	**Ultimate Load, w**
	w (KN) 214.19	***w* (KN) 214.19**
	Maximum bending moment occurs at the base of the wall.	
	Moment at base of wall (KNm) = $(P_1L/2) + (P_2+P_3)L/3)$	
	Moment at base of wall (KNm) = 303.10	
	Factored Moment due to lateral loads M_1	
	M_1 (KNm) = 388.72	M_1 (KNm) **388.72031**
	Assumed bar diameter (mm) 20	
	Assumed slab thickness(mm) 600	**Depth of Slab, h (mm) 600**
	Effective depth to reinforcement, d (mm)	
	d (mm) = Thickness - Cover - 1/2Bar Size	
	d (mm) = 540	**Assumed effective depth d (mm) 540**
	Design Moment, M_1	**Design Moment, M**
	M (KNm) 388.72	**M (KNm) 388.72**
BS 8110	Ultimate Design Moment, M_u	
Cl 3.4.4	$M_u = 0.156 f_{cu} bd^2$	**Ultimate Design Moment, M_u**
	M_u (KNm) 1364.688	**M_u (KNm) 1364.69**
	Since M < M_u no compression reinforcement in needed	
	MAIN STEEL	
	Main bars (tension steel) diameter (mm) 20	
BS 8110 Cl 3.4.4	$K = \frac{M}{f_{cu}bd^2}$	
	K $\frac{388.72}{8748}$	
	K 0.0444	**Coefficient k 0.0444**
	Since K < k' = 0.156 no compression reinforcement needed	

BS 8110 Cl 3.4.4	Lever Arm (z) $$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$$ z (mm) 511.87 Check z < 0.95d z = 511.8738 Therefore Area of Tension Steel Required $$A_s = M/0.95 f_y z$$ A_s (mm^2/m) 1737.77 ***Using T20 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2093.333	**Lever Arm** **z (mm) 511.87** **Area of Tension Bars,** **A_s (mm^2/m) 1738** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2093.3333**
BS 8110 Table 3.25 BS 8110 Table 3.10 BS8110: Table 3.9	***Secondary Steel*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 780 ***Using T12 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 753.6 **Deflection.** ***Modification Factor,*** Design Service Stress, f_s $$f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}}$$ f_s (N/mm^2) 254.58 Modification Factor, $$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$$ M.F. 1.380 Allowable Span/Depth Ratio 9.66 Actual Span/Depth Ratio 9.26	**Secondary Steel Area,** **A_{smin} (mm^2/m) 780** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 753.6** **Design Service Stress,** **f_s (N/mm^2) 254.58** **Modification Factor** **M.F. 1.380** **Allowable Span/Depth 9.66** **Actual Span/Depth 9.26**

	Shear.	
	Applied shear force V (KN) = 214.19	**Applied Shear Force V (KN) 214.19**
	Applied Shear Stress v (N/mm^2) = 0.40	**Applied Shear Stress v (N/mm2 0.40**
BS8110: Table 3.8	Design Concrete Shear Strength	
	v_c (N/mm^2) = $0.79\{100A_s/(b_v d)\}^{1/3}\ (400/d)^{1/4}/\gamma_m$	
	v_c (N/mm^2) = 0.43	
	Modification Factor = 1.06	
	v_c = 0.45	**Design Shear Strength v_c (N/mm^2) = 0.45**
	No Shear Reinforcement Required	

Sluice Wingwall

REFERENCES	CALCULATIONS			OUTPUT
	Location:	**Herstelling Sluice**		
	Member:	**Wingwall**		
BS 8110	Condition of Exposure		Very Severe	
Table 3.3	Cover, C (mm)		50	
	Grade of Concrete, f_{cu} (N/mm^2)		30	
BS 8110	Using High Yield Steel			
Table 3.1	Strength of Steel, f_y (N/mm^2)		460	
	Assumed thickness of Wall (mm)		400	
	Height of wall (m)		4.2	
	LOADINGS			
	Bending Moment.			
	Considering the water table level with the ground surface.			
	Depth of soil to be retained, D (m)		4.2	
Foundation Analysis and Design by J.E. Bowles.	Soil properties will be assumed as follows:			
	Cohesion (KN/m^2)	10		
Table 2.6	Saturated Unit Weight (KN/m³)	16		
Table 11.3	K_a (Rakine)	1		
Table 11.4	K_p (Rakine)	1		
	Assumed Surcharge, S (KN/m^2)	10		
	Considering a 1m wide section of wall.			
	Depth of Tension Crack (m)	1.25		
	Force due to surcharge (kN), P_1		42.00	
	Force due to earth pressure (kN), P_2		69.62	
	Force due to hydrostatic pressure (kN), P_3		7.66	
	Dead Load, G_k (Surcharge)			
	G_k (KN)	42.00		
	Earth and Water Load, E_k			
	E_k (KN)	77.282		
	Ultimate Load, *w*			
	$w = 1.4G_k + 1.2E_k$			**Ultimate Load, w**
	w (KN)	151.54		***w* (KN) 151.54**

	Maximum bending moment occurs at the base of the wall.	
	Moment at base of wall (KNm) = $(P_1L/2) + (P_2+P_3)L/3)$	
	Moment at base of wall (KNm) = 188.01	
	Factored Moment due to lateral loads M_1 M_1 (KNm) = 243.25	M_1 (KNm) **243.24666**
	Assumed bar diameter (mm) 20	
	Assumed slab thickness(mm) 400	**Depth of Slab, h (mm) 400**
	Effective depth to reinforcement, d (mm) d (mm) = Thickness - Cover - 1/2Bar Size	
	d (mm) = 340	**Assumed effective depth d (mm) 340**
	Design Moment, M_1 M (KNm) 243.25	**Design Moment, M** **M (KNm) 243.25**
BS 8110 Cl 3.4.4	Ultimate Design Moment, M_u $M_u = 0.156 f_{cu} bd^2$ M_u (KNm) 541.008	**Ultimate Design Moment, M_u** **M_u (KNm) 541.01**
	Since $M < M_u$ no compression reinforcement in needed	
	<u>MAIN STEEL</u> Main bars (tension steel) diameter (mm) 20	
BS 8110 Cl 3.4.4	$K = \frac{M}{f_{cu}bd^2}$	
	K $\frac{243.25}{3468}$	
	K 0.0701	**Coefficient k 0.0701**
	Since K < k' = 0.156 no compression reinforcement needed	

BS 8110 Cl 3.4.4	Lever Arm (z) $$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$$ z (mm) 311.03 Check z < 0.95d z = 311.035 Therefore Area of Tension Steel Required $$A_s = M/0.95f_y z$$ A_s (mm^2/m) 1789.60 ***Using T20 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2093.333	**Lever Arm** **z (mm) 311.03** **Area of Tension Bars,** **A_s (mm^2/m) 1790** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2093.3333**
BS 8110 Table 3.25 BS 8110 Table 3.10 BS8110: Table 3.9	***Secondary Steel*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 520 ***Using T12 Bar at 150mm center to center spacing*** Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 753.6 **Deflection.** ***Modification Factor,*** Design Service Stress, f_s $$f_s = \frac{2f_y A_{s\ req}}{3A_{s\ prov}}$$ f_s (N/mm^2) 262.17 Modification Factor, $$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$$ M.F. 1.146 Allowable Span/Depth Ratio 8.02 Actual Span/Depth Ratio 12.35	**Secondary Steel Area,** **A_{smin} (mm^2/m) 520** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 753.6** **Design Service Stress,** **f_s (N/mm^2) 262.17** **Modification Factor** **M.F. 1.146** **Allowable Span/Depth 8.02** **Actual Span/Depth 12.35**

	Shear.	
	Applied shear force V (KN) = 151.54	**Applied Shear Force V (KN) 151.54**
	Applied Shear Stress v (N/mm^2) = 0.45	**Applied Shear Stress v (N/mm2 0.45**
BS8110: Table 3.8	Design Concrete Shear Strength	
	v_c (N/mm^2) = $0.79\{100A_s/(b_v d)\}^{1/3}\,(400/d)^{1/4}/\gamma_m$	
	v_c (N/mm^2) = 0.56	
	Modification Factor = 1.06	
	v_c = 0.60	**Design Shear Strength v_c (N/mm^2) = 0.60**
	No Shear Reinforcement Required	

Sump Covering Slab

REFERENCES	CALCULATIONS			OUTPUT	
	LOCATION: **Herstelling Sluice**				
	BEAM: **Bridge Slab**				
BS 8110	Condition of Exposure		Severe		
Table 3.3	Cover, C (mm)		50		
	Grade of Concrete, f_{cu} (N/mm^2)		30		
BS 8110	Using High Yield Steel				
Table 3.1	Strength of Steel, f_y (N/mm^2)		460		
	Assume Beam dimensions (mm)	1000	350		
	Effective Span (mm)		5100		
	DEPTH OF BEAM				
	Assumed bar diameter (mm)		20		
	Assumed link diameter (mm)		0		
	Effective depth				
	d (mm) = h - Cover - link diameter - 1/2 bar size				
				Assumed effective depth	
	d (mm) = 290			**d (mm)**	**290**
	LOADINGS				
	Unit Weight of Concrete (KN/m^3)		24		
	Area of floor supported (length x wic	5.1	1		
	Live Loads				
	Live Load (UDL), (kN/m2)		29.04375		
	Live Load (Central Point Load), (kN)		0		
	Additional Live Load (kN)		0		
	Dead Loads				
	Thickness of slab supported by beam (mm)		0		
	Self Weight of beam (kN)		42.84		
	Other dead loads supported by beam, UDL (kN/m		0		
	Other dead loads supported by beam (Central Po		0		
	Additional Dead Load (kN)		0		
	Considering slab as simply supported				
	Moments				
	Moment from live load (UDL), kNm		94.43		
	Moment from Live Load (Central Point), kNm		0.00		
	Additional Live moment (kNm)		0.00		
	Moment from slab, kNm		0.00		
	Moment due to self weight, kNm		27.31		
	Moment from other dead UDL, kNm		0.00		
	Moment from dead load (central point), kNm		0.00		
	Additional Dead moment (kNm)		0.00		

Reference	Calculation	Output
	Design Dead Load, G_k G_k (KN) 42.84 Imposed Load (KN) Q_k (KN) 148.12 Ultimate Load, *w* $w = 1.4G_k + 1.6Q_k$ *w* (KN) 296.97 Design Moment, M M (KNm) 189.32	**Ultimate Load, w** ***w* (KN) 296.97** **Design Moment,** **M (KNm) 189.32**
BS 8110 Cl 3.4.4	Ultimate Design Moment, M_u $M_u = 0.156\ f_{cu}\ bd^2$ M_u (KNm) 393.59 ***Since M < M_u no compression reinforcement in needed***	**Ultimate Design** **Moment, M_u** **M_u (KNm) 393.59**
BS 8110 Cl 3.4.4	**MAIN STEEL** Main bars (tension steel) diameter (mm) 20 $K = \frac{M}{f_{cu}bd^2}$ K $\frac{189.32}{2523}$ K 0.0750 ***Since K < k' = 0.156 no compression reinforcement needed***	**Coefficient** **k 0.0750**
BS 8110 Cl 3.4.4	Lever Arm (z) $z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$ z (mm) 263.38 Check z < 0.95d z = 263.3771 Therefore Area of Tension Steel Required $A_s = M/0.95f_y z$ A_s (mm^2/m) 1644.89 ***Provide:*** No. 6.666667 T 20 mm ϕ bars Area of Steel provided, A_{sprov} A_{sprov} (mm^2/m) 2094.395	**Lever Arm** **z (mm) 263.38** **Area of Tension Bars,** **A_{sreq} (mm^2/m) 1644.89** **Area of Tension Bar provided** **A_{sprov} (mm^2/m) 2094.40**

Reference	Calculations	Output
BS 8110 Table 3.10	**Deflection Modification Factor** Design Service Stress, f_s $$f_s = \frac{2 f_y A_{s\ req}}{3 A_{s\ prov}}$$ f_s (N/mm^2) 240.85	**Design Service Stress, f_s (N/mm^2) 240.85**
	Modification Factor, $$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0$$ M.F. 1.175	**Modification Factor M.F. 1.175**
BS 8110 Table 3.9	**Deflection** Allowable Span/effective depth ratio 20 (Simply sup 26 (Continuou	**Allowable Span/Depth Ratio 20.00**
	Actual Span/effective depth ratio 14.97	**Actual Span/Depth Ratio 14.97**
BS 8110 Table 3.25	***Check.*** Based on minimum area of steel required, A_{smin} = 0.13% bh A_{smin} (mm^2/m) 455	**Secondary Steel Area, A_{smin} (mm^2/m) 455**
BS8110: Table 3.5	**SHEAR REINFORCEMENT** V = 0.5F V (KN) = 148.49	**Maximum Shearing Force V (KN) 148.49**
BS8110: Cl 3.4.5.2	v (N/mm^2) = V / bd v (N/mm^2) = 0.51 Check: 0.51 ≤ (0.8√fcu) = 4.38	**Maximum Shear Stress v (N/mm^2] 0.51**
BS8110: Table 3.8	Design concrete shear stress v_c = $0.79\{100A_s/(b_v d)\}^{1/3}(400/d)^{1/4}/\gamma_m$ v_c = 0.61 Modification Factor = 1.06 v_c = 0.65 No Shear reinforcement required.	**Design Concrete Shear Stress v_c (N/mm2) 0.65**

Discharge Pipe Column

Axial Loading due to weight of discharge pipe:

Considering a 10mm thick, 1.3m diameter pipe.

Weight per unit length (kN), (F.S. 1.5) = 5

Estimated length of discharge pipe (m) = 6

Axial Load on column (kN) = 30

Horizontal Load on column due to water loading.

Volume discharged (m^3/s) = 2.83

Mass discharged (kg/s) = 2830

Velocity of water existing pump (m/s) = 2.13

At the 45° bend the discharge stream changes from horizontal to -45° below horizontal. As such the horizontal velocity changes from 2.13m/s to 1.5m/s.

Horizontal force exerted by discharge stream = (2830kg/s)*(2.13 – 1.5)m/s

= 1783N = 1.8kN

Considering column to be 4.5m height.

Moment due to discharge (kNm) = 8.1

Allowing a F.S. of 1.5, Design moment = 12.15kNm

REFERENCES	CALCULATIONS				OUTPUT
	LOCATION				
	Column				
BS 8110	Condition of Exposure			Very Severe	
Table 3.3	Cover, C (mm)			50	
	Grade of Concrete, f_{cu} (N/mm^2)			30	
BS 8110	Using High Yield Steel				
Table 3.1	Strength of Steel, f_y (N/mm^2)			460	
	COLUMN				
	Height (m)	4.5			
		x axis		y axis	
	Assumed Dimensions (mm)	350		350	
		h'		b'	
		278		278	
BS8110:	Unit weight of concrete	24			
Table 19					
	Effective Height of Column =	1.2 x L			
	L_e (m) =	5.4			
BS8110:	Classification of Column:				
Cl 3.8.1.3	l_{ex} / h =	15.43		Unbraced< 10	
	Column is classified as slender.				
	Loading				
	Design Axial Load, N (kN)			50	
	Initial Design Moment, Mx (kNm)			12.15	
	Initial Design Moment, My (kNm)			12.15	
	Assumed Reinforcement				
	Provide No.	4	T	20 mm ϕ bars	
	Area of steel provided (mm^2)	1256.64			
	Assumed link diameter (mm)			12	

Bending due to deflection

For slender columns

Additional bending on the x axis

BS8110: Cl 3.8.3.1

au = $\beta_a Kh$

$$K = \frac{N_{uz} - N}{N_{uz} - N_{bal}} \leq 1$$

$$N_{uz} = 0.45 f_{cu} A_c + 0.95 f_y A_{sc}$$

N_{uz} = 2185.936 kN

N_{bal} = $0.25 f_{cu} bd$ = 918.75 kN

K = 1.69 ≤ 1

Use K = 1.00

$$\beta_a = \frac{1}{2000}\left(\frac{l_e}{b'}\right)^2$$

Where b' is the column dimension in the plane considered

β_a = 0.19

au = 66.03 mm

Additional Moment, M_{add} = Nau

M_{add} = 3.30 kNm

Additional bending on the y axis

BS8110: Cl 3.8.3.1

au = $\beta_a Kh$

$$K = \frac{N_{uz} - N}{N_{uz} - N_{bal}} \leq 1$$

$$N_{uz} = 0.45 f_{cu} A_c + 0.95 f_y A_{sc}$$

N_{uz} = 2185.94 kN

N_{bal} = $0.25 f_{cu} bd$ = 918.75 kN

K = 1.69 ≤ 1

Use K = 1.00

$$\beta_a = \frac{1}{2000}\left(\frac{l_e}{b'}\right)^2$$

Where b' is the column dimension in the plane considered

β_a = 0.19

au = 66.03 mm

Additional Moment, M_{add} = Nau

M_{add} = 3.30 kNm

Design Moment, Mx (kNm) 15.45

Design Moment, My (kNm) 15.45

BS8110: Cl 3.8.4.5	Biaxial Bending Let the x axis be critical, i.e. $Mx/h' \geq My/b'$ Design Moment $M'x = Mx + \beta(h'/b')My$	
BS8110: Table 3.22	$N/(bhf_{cu}) =$ 0.01 $\beta =$ 0.90 $M'x =$ 29.35777	
BS8110: Chart 27	$M / bh^2 =$ 0.68 $N / bh =$ 0.41 $A_{sreq}(mm^2) =$ 0.50% $A_{sreq}(mm^2) =$ 612.5	**$A_{sreq}(mm^2)$ 612.5**
	Provide 4 T 20mm diameter bars. $A_{sprov}(mm^2) =$ 1256	**$A_{sprov}(mm^2)$ 1256**

Appendix II

Revetment Wall

REFERENCES	CALCULATIONS			OUTPUT	
	LOCATION **Herstelling Sluice**				
	DESIGN OF RETAINING WALL.				
	Clay Soil				
	Height of soil retained (m)	4.2			
	Length of sheet pile (m)	12			
	Surcharge (kN/m^2) (Permanent)	0			
	Surcharge (kN/m^2) (Temporary)	0			
	Length of pile (m)	12			
	Span of pile (m)	1			
	Pile Diameter(m)	1			
	Layer 1 - Tension Crack				
	Wet Density of Soil, ϒ (kN/m^3)	16			
	Dry Density of Soil, ϒ (kN/m^3)	16			
	Effective weight of Soil, ϒ' (kN/m^3)	6.193			
	Internal Angle of Friction, ϕ (^{o})	0	0.000		
	Cohesion(kN/m^2)	15			
	Coefficient of active earth pressure, K_a	1			
	Coefficient of passive earth pressure, K_p	1			
	Elevation of top of layer	0			
	Height of layer (m)	1.88			
	Elevation at bottom of layer (m)	1.88			
	Depth to water table (active) (m)	1			
	Depth to water table (passive) (m)	3.5			
	Depth of Tension Crack (m)	1.88			
	Considering the tension crack filled with water.				
	SLIDING.				
	Forces contributing to sliding: (Sheet Pile)				
	Force due to hydrostatic pressure (kN) =	17.24			
	Force due to active earth pressure (kN) =	0.00			
	Force due to surcharge (kN) =	0		**Layer 1**	
				Total Sliding	
	Total Sliding Force (kN) =	17.24		**Force (kN)**	**17.24**
	Forces restraining wall from sliding.				
	Sheet Pile				
	Height of earth on passive side of sheet pile (m)	0			
	Force due to passive earth pressure (kN) =	0.00			
	Force due to hydrostatic pressure (kN) =	0.00			
	Force due to cohesion (kN) =	0.00		**Layer 1**	
				Total restraining	
	Total Restraining Force (kN) =	0.00		**Force (kN)**	**0.00**

Overturning.

Taking moments about the toe:

Overturning Moments.

Sheet Pile

Moment due to hydrostatic pressure (kNm)	185.32		
Moment due to active earth pressure (kNm)	0.00		
Moment due to surcharge (kNm)	0.00	**Layer 1**	
Total Overturning Moment (kNm)	185.32	**Total Overturning Moment (kNm)**	**185.32**

Restraining Moments.

Sheet Pile

Moment due to passive earth pressure (kNm)	0		
Moment due to hydrostatic pressure (kNm)	0		
Moment due to cohesion (kNm)	0	**Layer 1**	
Total restraining Moment (kNm)	0	**Total Restraining Moment (kNm)**	**0.00**

Layer 2

Wet Density of Soil, ϒ (kN/m^3)	16	
Dry Density of Soil, ϒ (kN/m^3)	16	
Effective weight of Soil, ϒ' (kN/m^3)	6.193	
Internal Angle of Friction, ϕ (^{o})	0	0.000
Cohesion(kN/m^2)	15	
Coefficient of active earth pressure, K_a	1	
Coefficient of passive earth pressure, K_p	1	
Elevation of top of layer	1.88	
Height of layer (m)	2.63	
Elevation at bottom of layer (m)	4.50	
Depth to water table (active) (m)	1	
Depth to water table (passive) (m)	3.5	

SLIDING.

Forces contributing to sliding: (Sheet Pile)

Force due to hydrostatic pressure (kN) =	0.00		
Force due to active earth pressure (kN) =	55.13		
Force due to surcharge (Perm) (kN) =	0		
Force due to overlying layers (kN) =	0.00	**Layer 2**	
Total Sliding Force (kN) =	55.13	**Total Sliding Force (kN)**	**55.13**

Forces restraining wall from sliding.			
Sheet Pile			
Height of earth on passive side of sheet pile (m)	0.30		
Force due to passive earth pressure (kN) =	0.72		
Force due to hydrostatic pressure (kN) =	4.46		
Force due to overlying layers (kN) =	0		
Force due to cohesion (kN) =	9.00	**Layer 2**	
		Total restraining	
Total Restraining Force (kN) =	14.18	**Force (kN)**	**14.18**
<u>Overturning.</u>			
Taking moments about the toe:			
Overturning Moments.			
Sheet Pile			
Moment due to hydrostatic pressure (kNm)	0.00		
Moment due to active earth pressure (kNm)	461.67		
Moment due to surcharge (kNm)	0.00		
Moment due to overlying layers (kNm)	0.00	**Layer 2**	
		Total Overturning	
Total Overturning Moment (kNm)	461.67	**Moment (kNm)**	**461.67**
Restraining Moments.			
Sheet Pile			
Moment due to passive earth pressure (kNm)	5.47		
Moment due to hydrostatic pressure (kNm)	35.06		
Moment due to overlying layers (kNm)	0		
Moment due to cohesion (kNm)	68.85	**Layer 2**	
		Total Restraining	
Total restraining Moment (kNm)	109.38	**Moment (kNm)**	**109.38**

Layer 3			
Wet Density of Soil, ϒ (kN/m^3)	16		
Dry Density of Soil, ϒ (kN/m^3)	16		
Effective weight of Soil, ϒ' (kN/m^3)	6.193		
Internal Angle of Friction, ϕ (^{o})	0	0.000	
Cohesion(kN/m^2)	15		
Coefficient of active earth pressure, K_a	1		
Coefficient of passive earth pressure, K_p	1		
Elevation of top of layer	4.50		
Height of layer (m)	5.50		
Elevation at bottom of layer (m)	10.00		
Depth to water table (active) (m)	1		
Depth to water table (passive) (m)	3.5		
SLIDING.			
Forces contributing to sliding: (Sheet Pile)			
Force due to hydrostatic pressure (kN) =	0.00		
Force due to active earth pressure (kN) =	242.00		
Force due to overlying layers (kN) =	231.00		
Total Sliding Force (kN) =	473.00	**Layer 3 Total Sliding Force (kN)**	**473.00**
Forces restraining wall from sliding.			
Sheet Pile			
Height of earth on passive side of sheet pile (m)	5.80		
Force due to passive earth pressure (kN) =	242.00		
Force due to hydrostatic pressure (kN) =	0.00		
Force due to overlying layers (kN) =	64.16		
Force due to cohesion (kN) =	165.00		
Total Restraining Force (kN) =	471.16	**Layer 3 Total restraining Force (kN)**	**471.16**
Overturning.			
Taking moments about the toe:			
Overturning Moments.			
Sheet Pile			
Moment due to hydrostatic pressure (kNm)	0.00		
Moment due to active earth pressure (kNm)	927.67		

Moment due to overlying layers (kNm)	1097.25		**Layer 3**	
			Total Overturning	
Total Overturning Moment (kNm)	2024.92		**Moment (kNm)**	**2024.92**
Restraining Moments.				
Sheet Pile				
Moment due to passive earth pressure (kNm)	927.67			
Moment due to hydrostatic pressure (kNm)	0.00			
Moment due to overlying layers (kNm)	304.75			
Moment due to cohesion (kNm)	783.75		**Layer 3**	
			Total Restraining	
Total restraining Moment (kNm)	2016.16		**Moment (kNm)**	**2016.16**
Layer 4				
Wet Density of Soil, ϒ (kN/m^3)	16			
Dry Density of Soil, ϒ (kN/m^3)	16			
Effective weight of Soil, ϒ' (kN/m^3)	6.193			
Internal Angle of Friction, ϕ (^{o})	0	0.000		
Cohesion(kN/m^2)	25			
Coefficient of active earth pressure, K_a	1			
Coefficient of passive earth pressure, K_p	1			
Elevation of top of layer	10.00			
Height of layer (m)	2.00			
Elevation at bottom of layer (m)	12.00			
Depth to water table (active) (m)	1			
Depth to water table (passive) (m)	3.5			
SLIDING.				
Forces contributing to sliding: (Sheet Pile)				
Force due to hydrostatic pressure (kN) =	0.00			
Force due to active earth pressure (kN) =	32.00			
Force due to overlying layers (kN) =	260.00			
			Layer 4	
			Total Sliding	
Total Sliding Force (kN) =	292.00		**Force (kN)**	**292.00**
Forces restraining wall from sliding.				
Sheet Pile				
Height of earth on passive side of sheet pile (m)	7.80			
Force due to passive earth pressure (kN) =	32.00			
Force due to hydrostatic pressure (kN) =	0.00			
Force due to overlying layers (kN) =	199.33			
Force due to cohesion (kN) =	100.00		**Layer 4**	
			Total restraining	
Total Restraining Force (kN) =	331.33		**Force (kN)**	**331.33**

Overturning.			
Taking moments about the toe:			
Overturning Moments.			
Sheet Pile			
Moment due to hydrostatic pressure (kNm)	0.00		
Moment due to active earth pressure (kNm)	21.33		
Moment due to overlying layers (kNm)	260.00	**Layer 4**	
Total Overturning Moment (kNm)	281.33	**Total Overturning Moment (kNm)**	**281.33**
Restraining Moments.			
Sheet Pile			
Moment due to passive earth pressure (kNm)	21.33		
Moment due to hydrostatic pressure (kNm)	0.00		
Moment due to overlying layers (kNm)	199.33		
Moment due to cohesion (kNm)	100.00	**Layer 4**	
Total restraining Moment (kNm)	320.66	**Total Restraining Moment (kNm)**	**320.66**

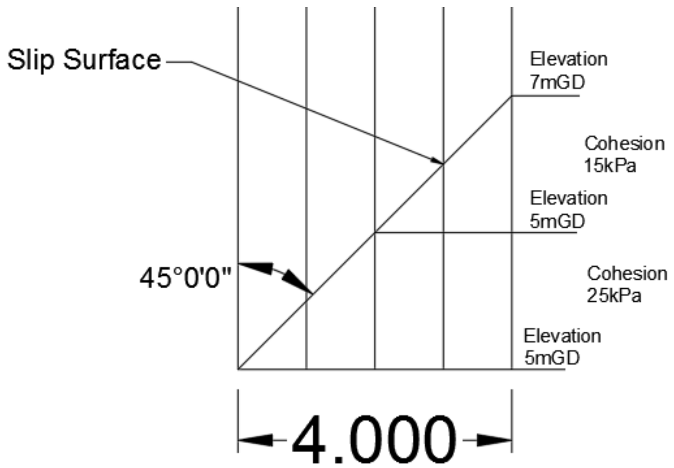
Total Sliding Forces	837.36	**Total Sliding Forces (KN)**	**837.36**
Total Restraining Forces	816.67	**Total restraining Forces (KN)**	**816.67**
Factor of safety against sliding failure: F.S. =	0.98	**Factor of safety for sliding**	**0.98**
Total Overturning Moments	2953.24	**Total Overturning Moment (KNm)**	**2953.24**
Total Restraining Moment	2446.20	**Total Restraining Moments (KN)**	**2446.20**
Factor of safety against overturning F.S. =	0.8283121	**Factor of safety for overturning**	**0.83**

Anchorage is required.

Revetment Wall Anchorage

Consider a planar slip surface extending from the base of the wall at an angle of 45°.

Consider an anchorage system in the form of 12m long steel sheet piles driven perpendicular to the revetment wall and welded both to each other and the revetment wall. Consider the length of this anchor wall to be 4m.



If welding is done for the top 4m of the steel sheet piles (down to approximately 13mGD) the resultant point of action for the anchorage force will be taken as half way down this welding, i.e. 10m above the base of the sheet piles.

Required anchorage force to stabilize wall	= (Excess overturning moment / 10m) per m length
	= 50kN per m length
Approximate length of wall	= 5m
Required anchorage force	= 250kN

Considering a 4m long anchor wall. Anchorage will be provided by the section of the wall outside of the slip surface.

Allowing for a 30% reduction in soil strength due to driving disturbance.

Total anchorage force = 0.67 * area of wall * soil shear strength

= (0.7*6*25) + (0.7*2*15)

= 126kN

Due to the angle at which the anchorage wall is required to be placed resistance from only one side of the wall will be considered since lift off of the other side may occur during movement of the wall.

Considering 3 anchor walls.

Total anchorage force = 3 * 126

= 378kN

F.S. = 378/250 = 1.5

Appendix III

Herstelling Sluice and Pump Station

2017

Sluice and Pump Station Drawings

SRKN'gineering & Associates
5/12/2017

COVER

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE &
PUMP STATION AT HERSTELLING,
E.B.D., REGION No.4

drawing title:

EAST ELEVATION OF SLUICE AND
PUMP STATION

notes:

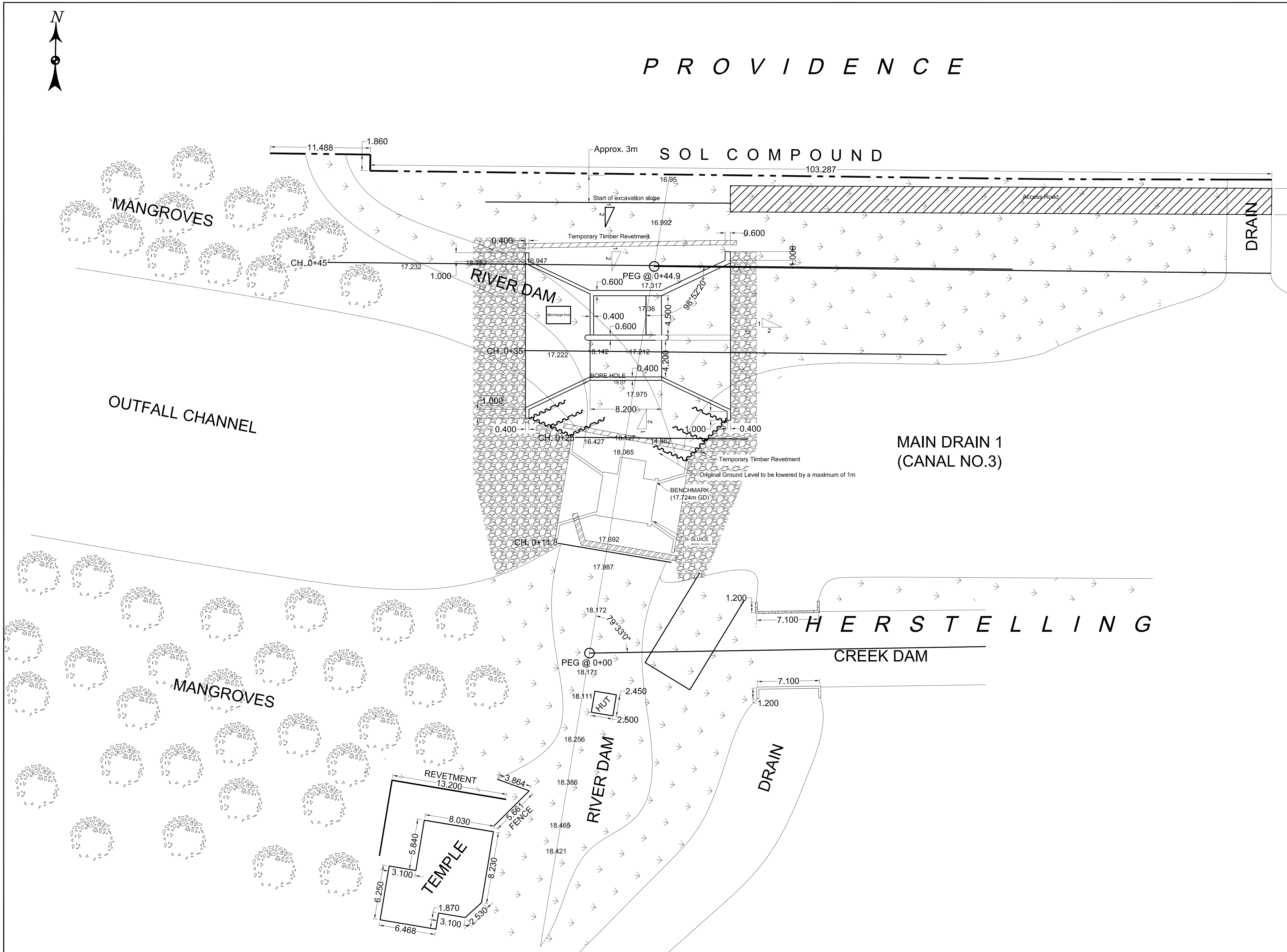
revisions

NO.	REVISIONS	DATE

scale:	approved by:
drawn by: King	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no.

SCHEDULE OF DRAWINGS

DRAWING No.	DRAWING TITLE
SRKN/2017 - 1	SITE LAYOUT
SRKN/2017 - 2	EAST ELEVATION OF SLUICE & PUMP STATION
SRKN/2017 - 3	NORTH ELEVATION OF SLUICE & PUMP STATION
SRKN/2017 - 4	NORTH ELEVATION OF SLUICE & PUMP STATION
SRKN/2017 - 5	PLAN OF SLUICE
SRKN/2017 - 6	FLOOR PLANS, BEAM LAYOUT & STAIR DETAIL
SRKN/2017 - 7	PILE & PILE CAP LAYOUT
SRKN/2017 - 8	STEEL SHEET PILE ARRANGEMENT & CORNER STEEL SHEET PILE DETAIL
SRKN/2017 - 9	SECTION B-B & DETAIL OF WEIR
SRKN/2017 - 10	SECTION B1-B1
SRKN/2017 - 11	SECTION A-A
SRKN/2017 - 12	REINFORCED CROSS SECTION A-A
SRKN/2017 - 13	SECTION C-C REINFORCEMENT DETAILS
SRKN/2017 - 14	GANTRY DETAILS & DOOR DETAILS
SRKN/2017 - 15	RAIL DETAILS, REINFORCED TIE BEAM DETAILS, PUMP HOUSE FLOOR SLAB DETAIL & WINCH BASE
SRKN/2017 - 16	BUTTRESS REINFORCEMENT DETAILS, BRIDGE CONNECTION & DETAILS
SRKN/2017 - 17	CONNECTION DETAILS
SRKN/2017 - 18	DOOR DETAILS
SRKN/2017 - 19	CONNECTION DETAILS 2
SRKN/2017 - 20	TIMBER REVETMENT
SRKN/2017 - 21	STEEL SHEET PILE REVETMENT DETAILS
SRKN/2017 - 22	HDPE PIPE CULVERT DETAILS
SRKN/2017 - 23	PLAN PROFILE
SRKN/2017 - 24	TYPICAL ROAD DESIGN



consultant:
SRKN'gineering & Associates Ltd.
107 Lamaha Street
Georgetown, GUYANA.

client:
MINISTRY OF AGRICULTURE,
N.D.I.A.
REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:
CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:
SITE PLAN

notes:

revisions

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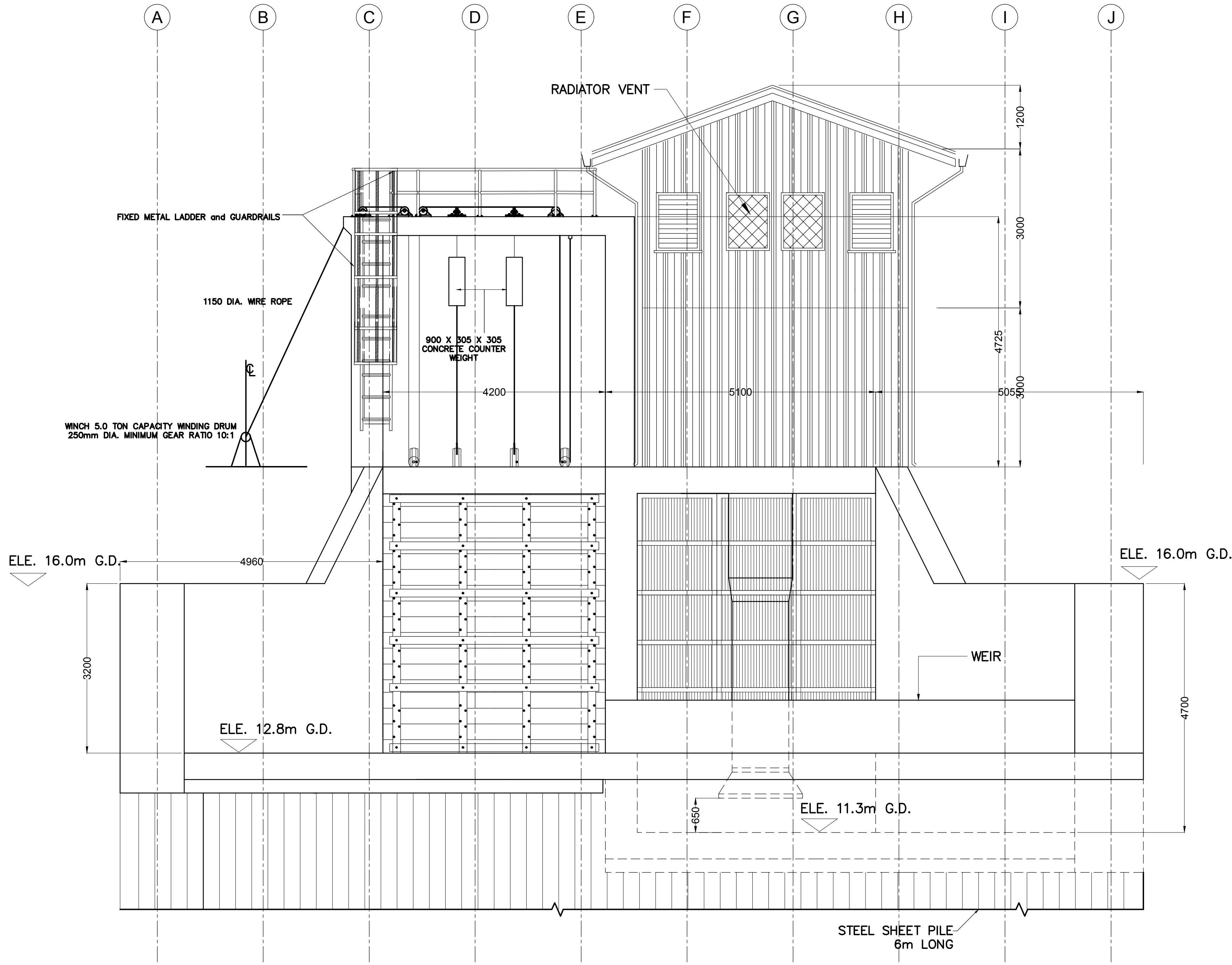
drawn by: King	surveyed by:
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 1 of 24



East Elevation of Sluice

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

EAST ELEVATION OF SLUICE AND PUMP STATION

notes:

revisions

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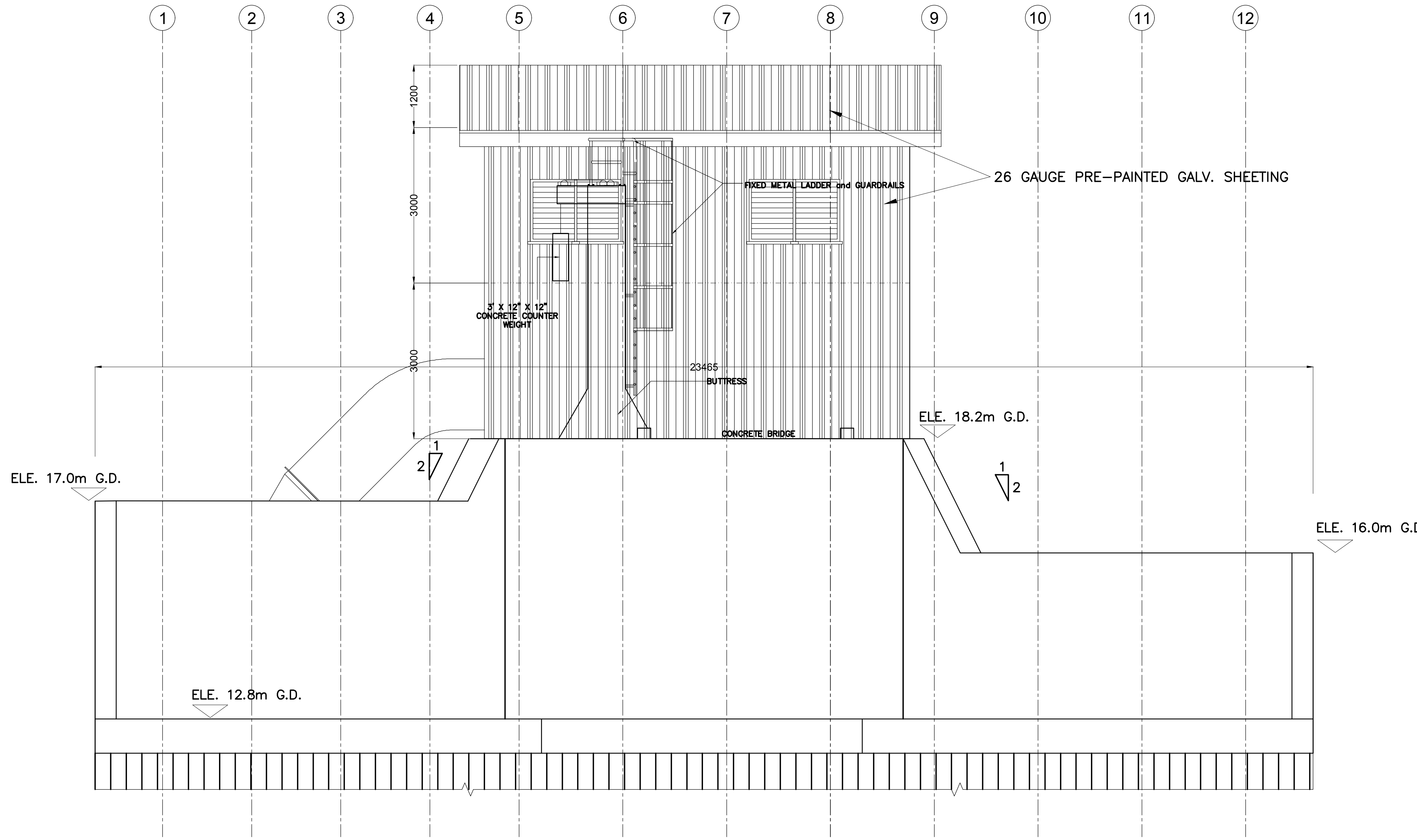
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 2 of 24



South Elevation of Sluice

consultant:
SRKN'gineering & Associates Ltd.
107 Lamaha Street
Georgetown, GUYANA.

client:
MINISTRY OF AGRICULTURE,
N.D.I.A.
REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:
CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:
SOUTH ELEVATION OF SLUICE AND PUMP STATION

notes:

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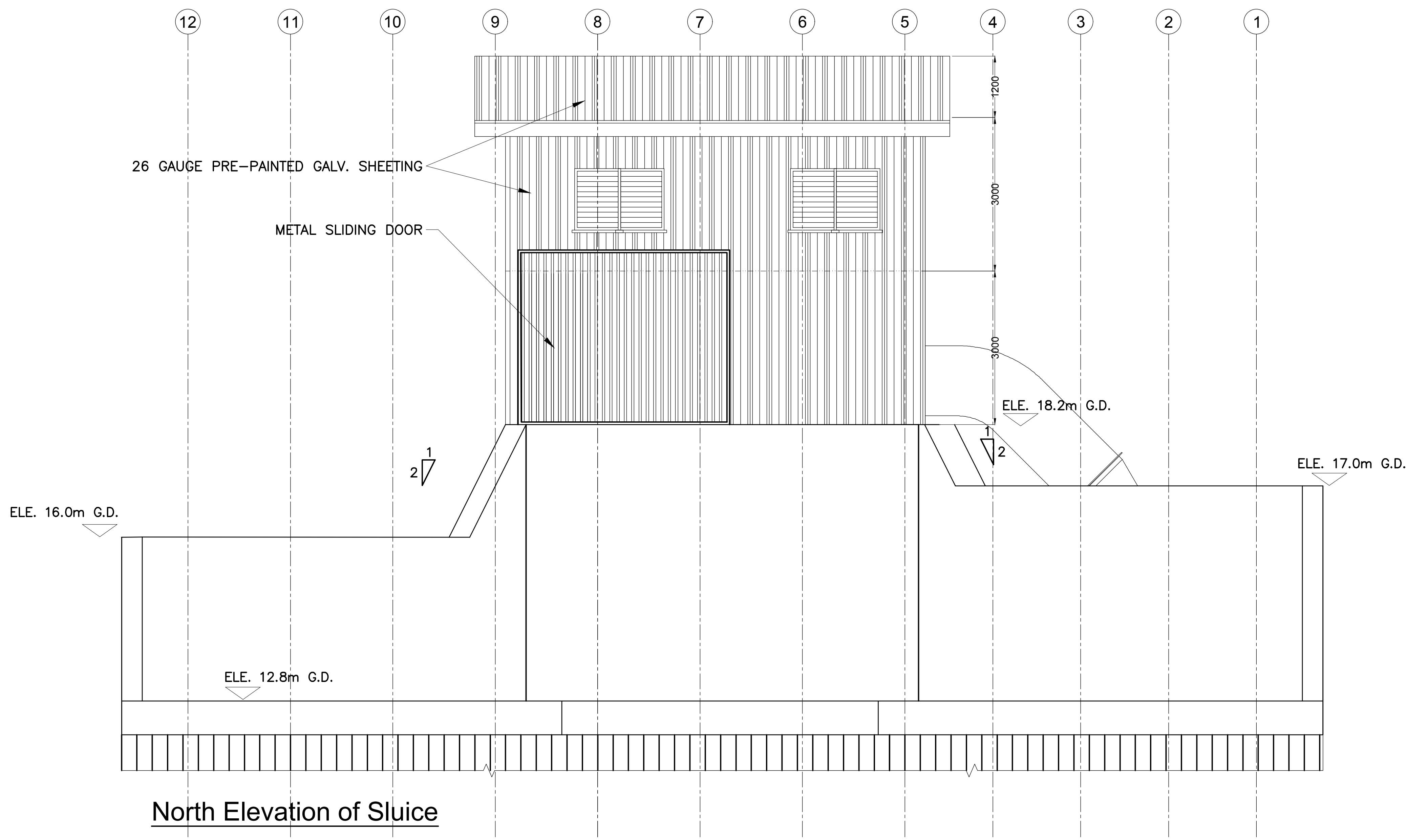
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 3 of 24



North Elevation of Sluice

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

NORTH ELEVATION OF SLUICE AND PUMP STATION

notes:

revisions

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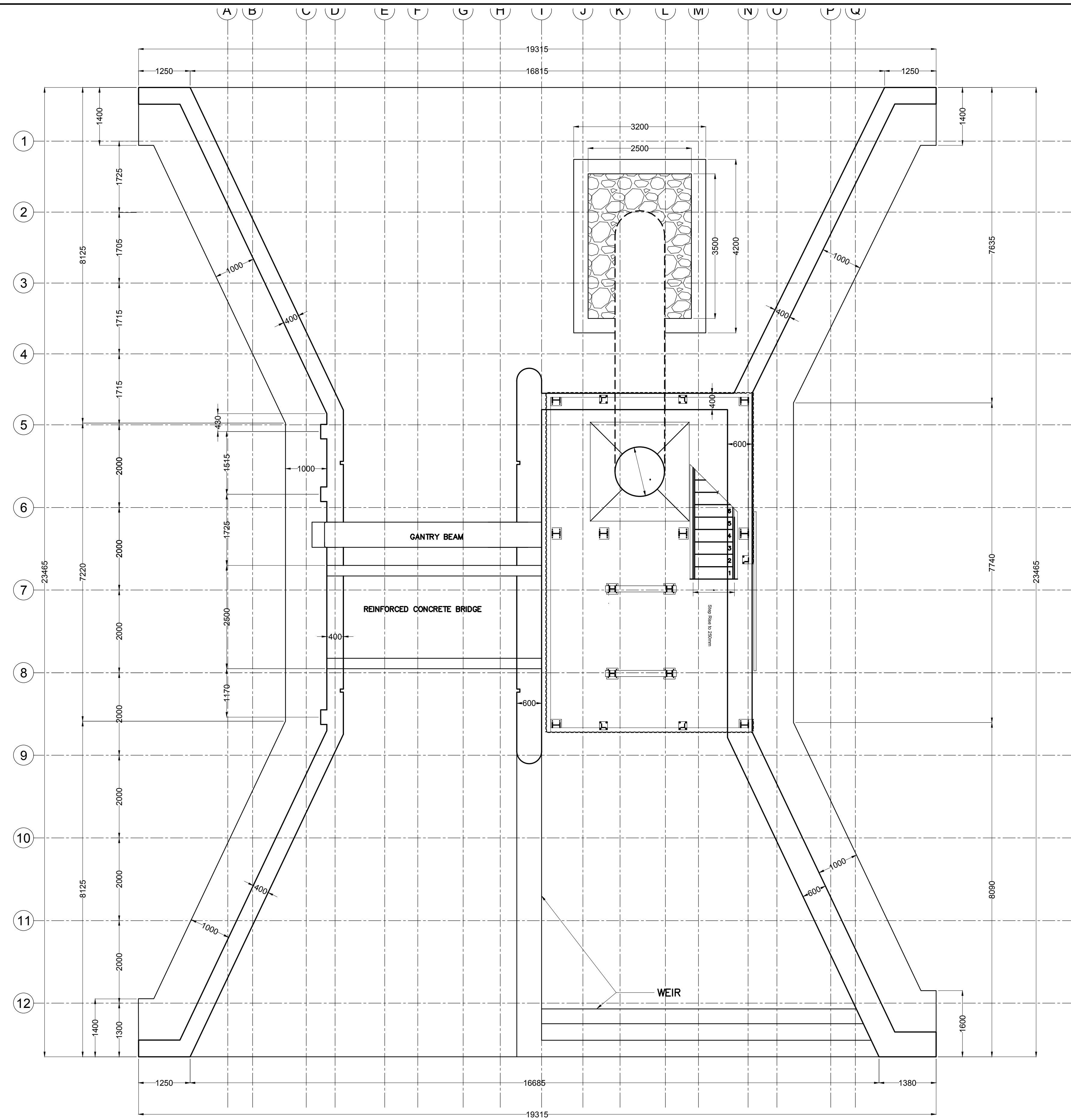
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 4 of 24



Plan of Sluice

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

PLAN OF SLUICE

notes:

revisions

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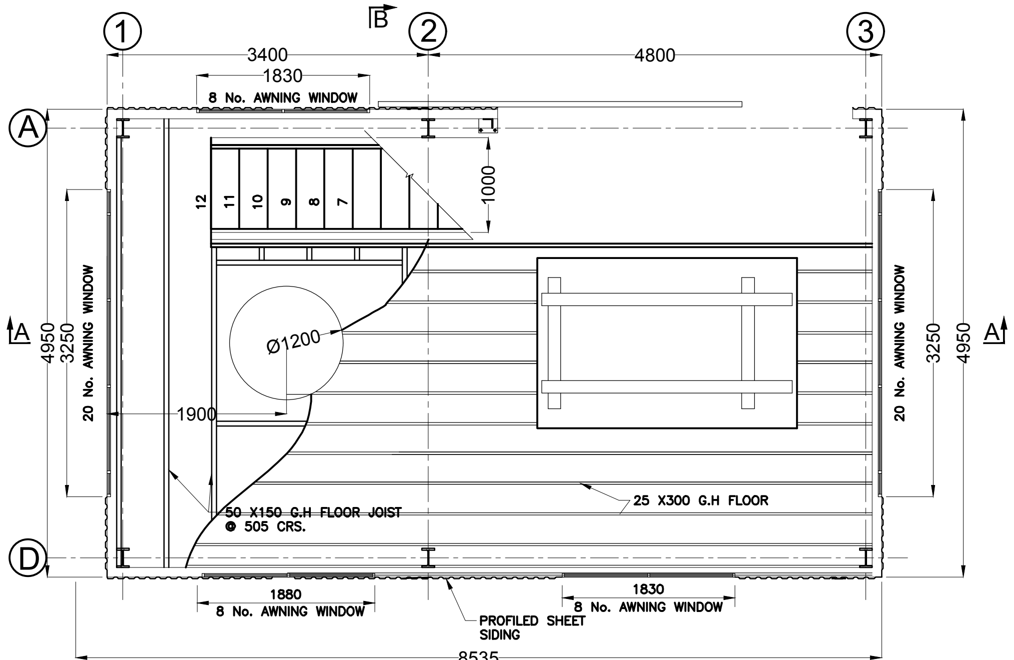
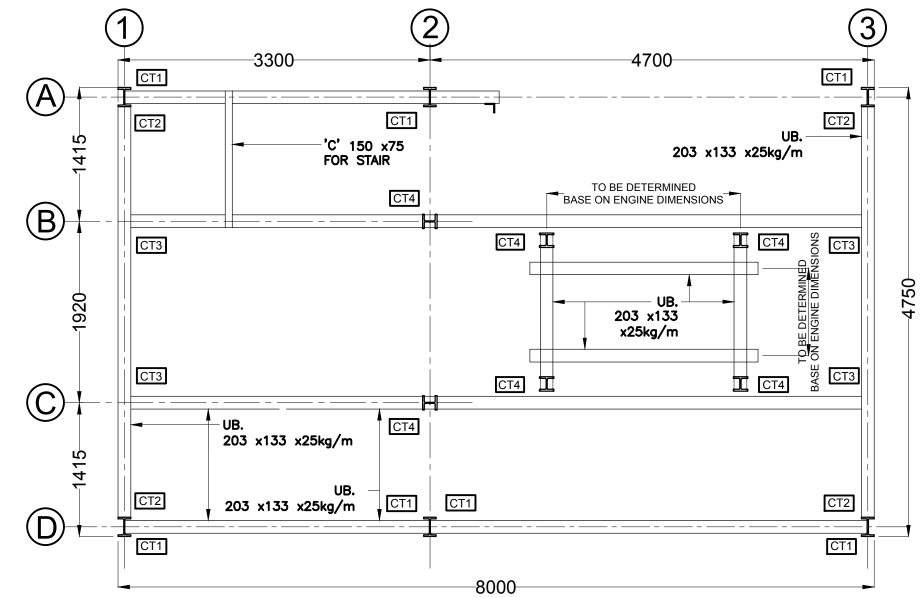
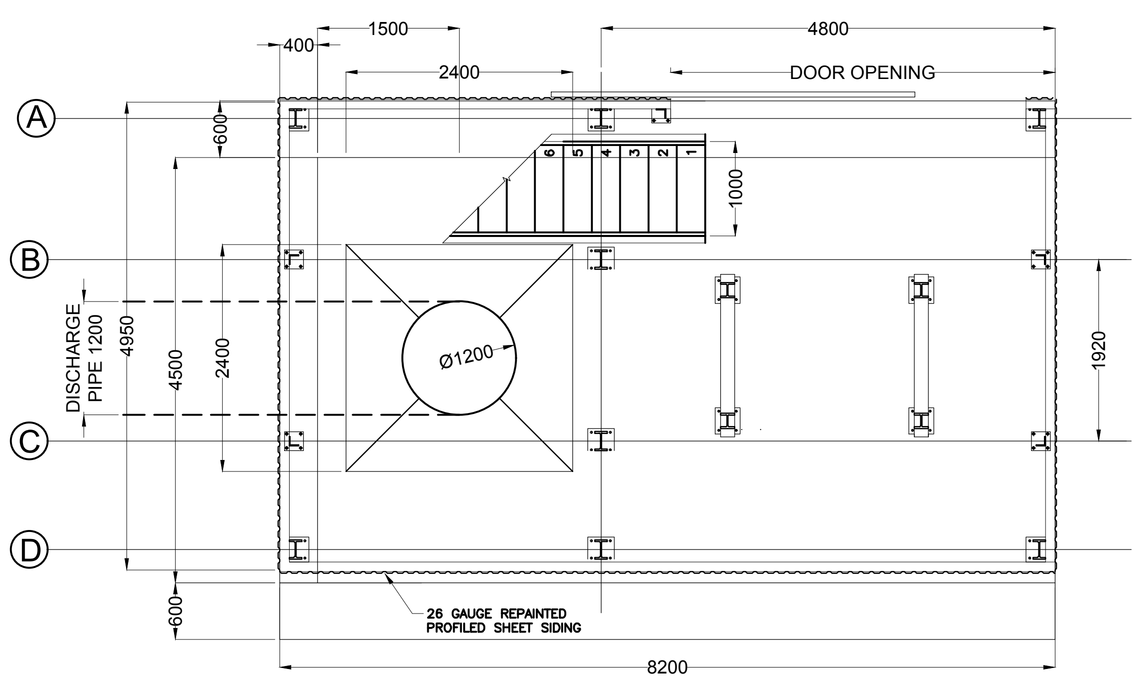


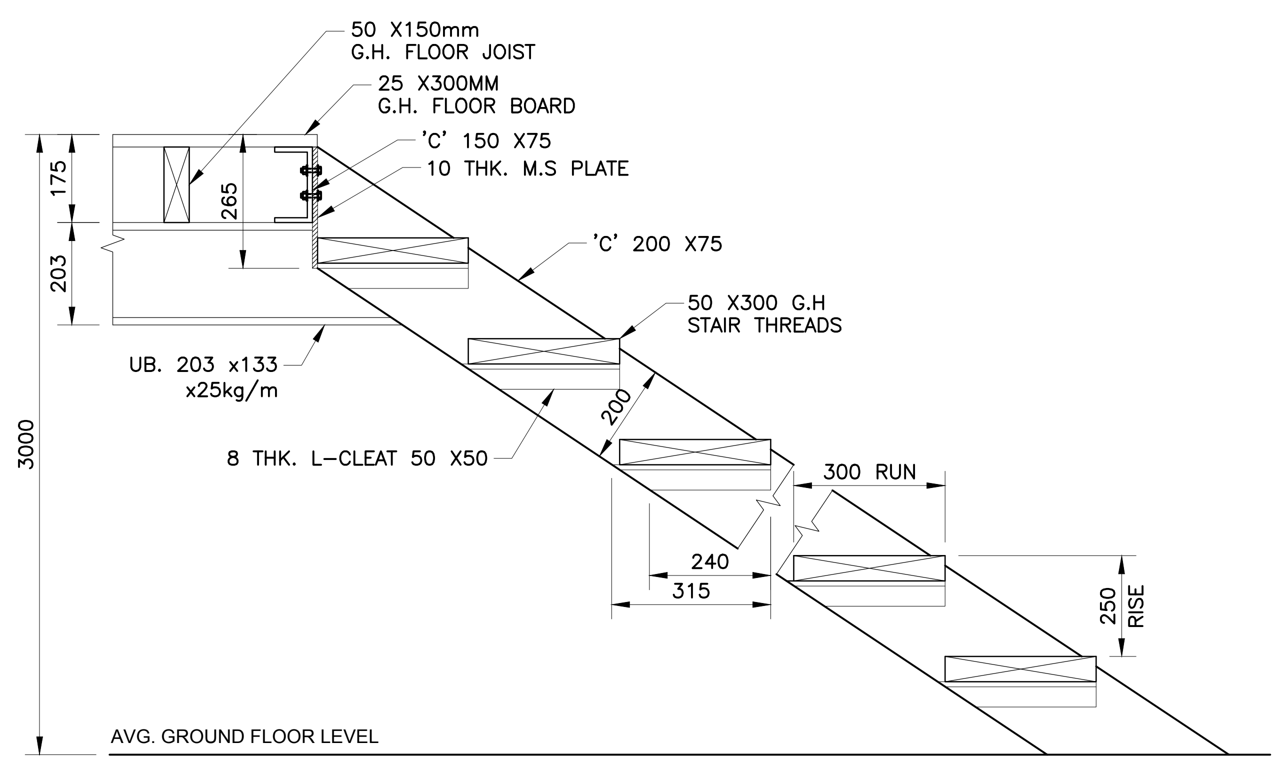
FIRST FLOOR PLAN
SCALE. 1:50



FIRST FLOOR BEAM LAYOUT
SCALE. 1:50



GROUND FLOOR PLAN
SCALE. 1:50



STAIR DETAILS
SCALE. 1:15

consultant:
SRKN'gineering & Associates Ltd.
107 Lamaha Street
Georgetown, GUYANA.

client:
MINISTRY OF AGRICULTURE, N.D.I.A.
REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:
CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:
FLOOR PLANS, BEAM LAYOUT & STAIR DETAIL

notes:

revisions

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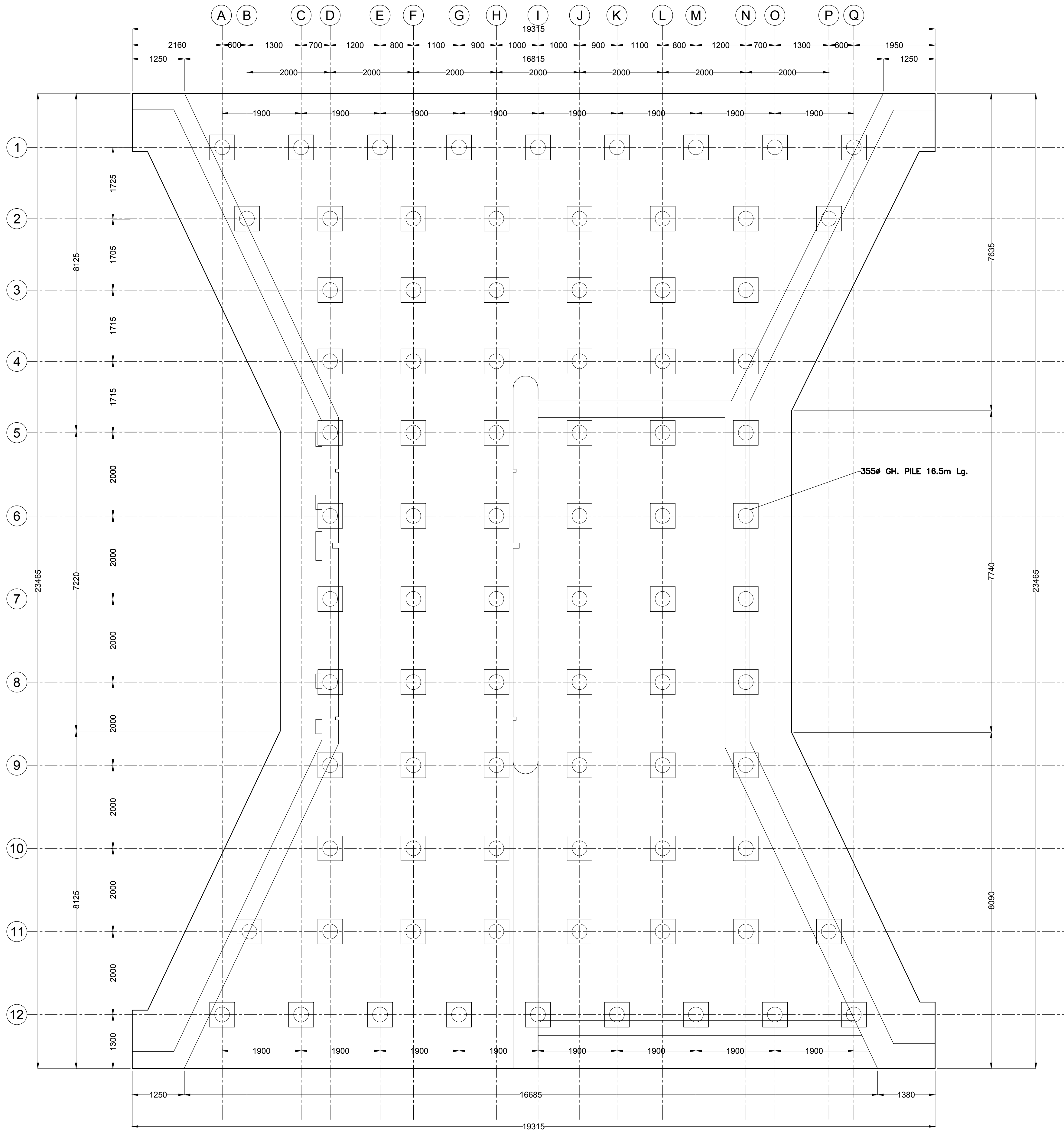
project code: SAPS-HR4-2017	drawing no. 6 of 24



Pile & Pile Cap layout

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

PILE & PILE CAP LAYOUT

notes:

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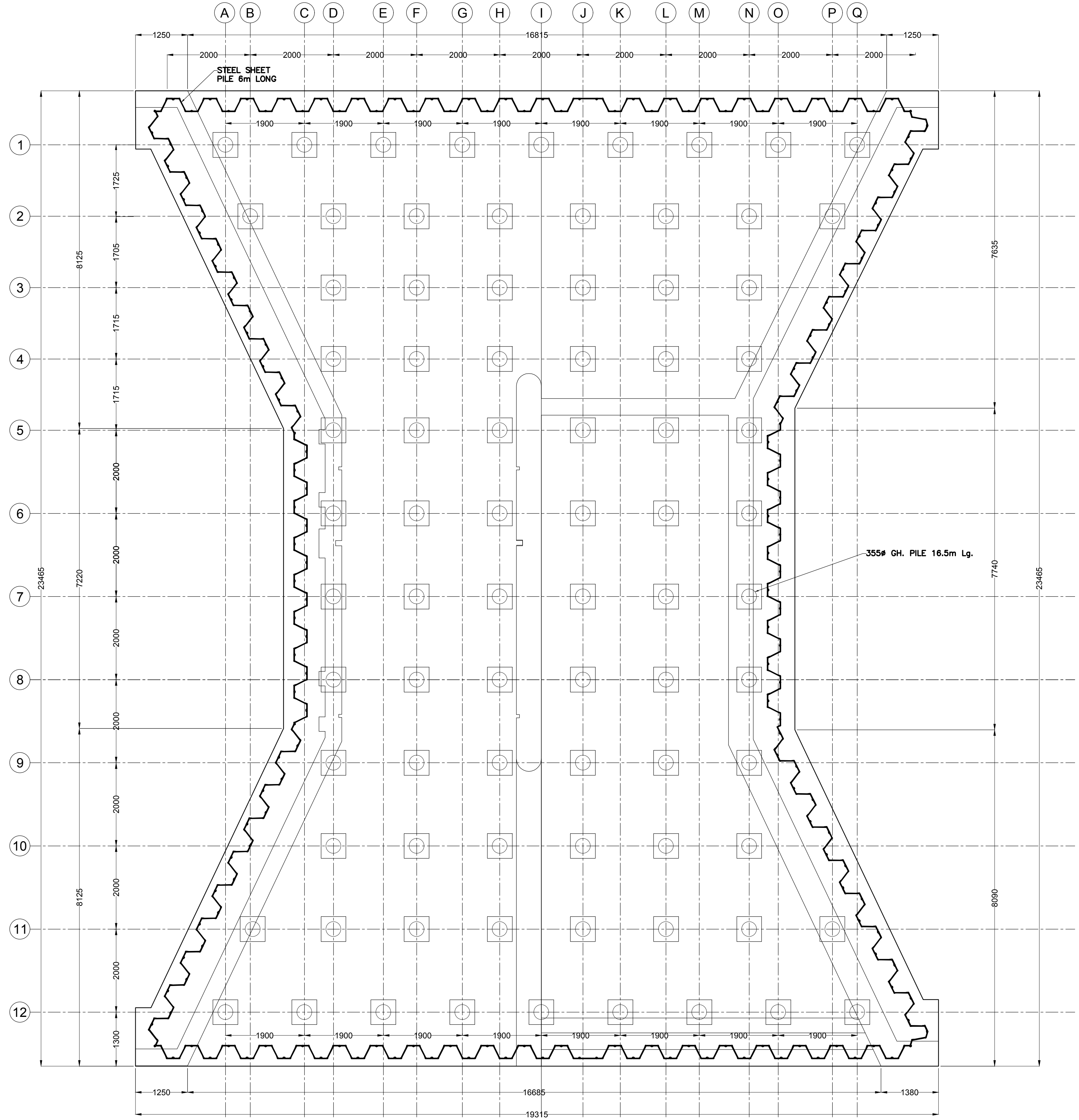
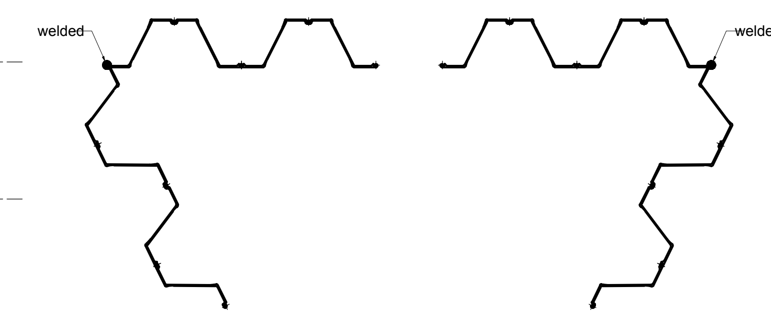
project code: SAPS–HR4–2017	drawing no. 7 of 24



Steel Sheet Pile Arrangement



CORNER STEEL SHEET PILE

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

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GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

STEEL SHEET PILE ARRANGEMENT AND CORNER STEEL SHEET PILE DETAIL

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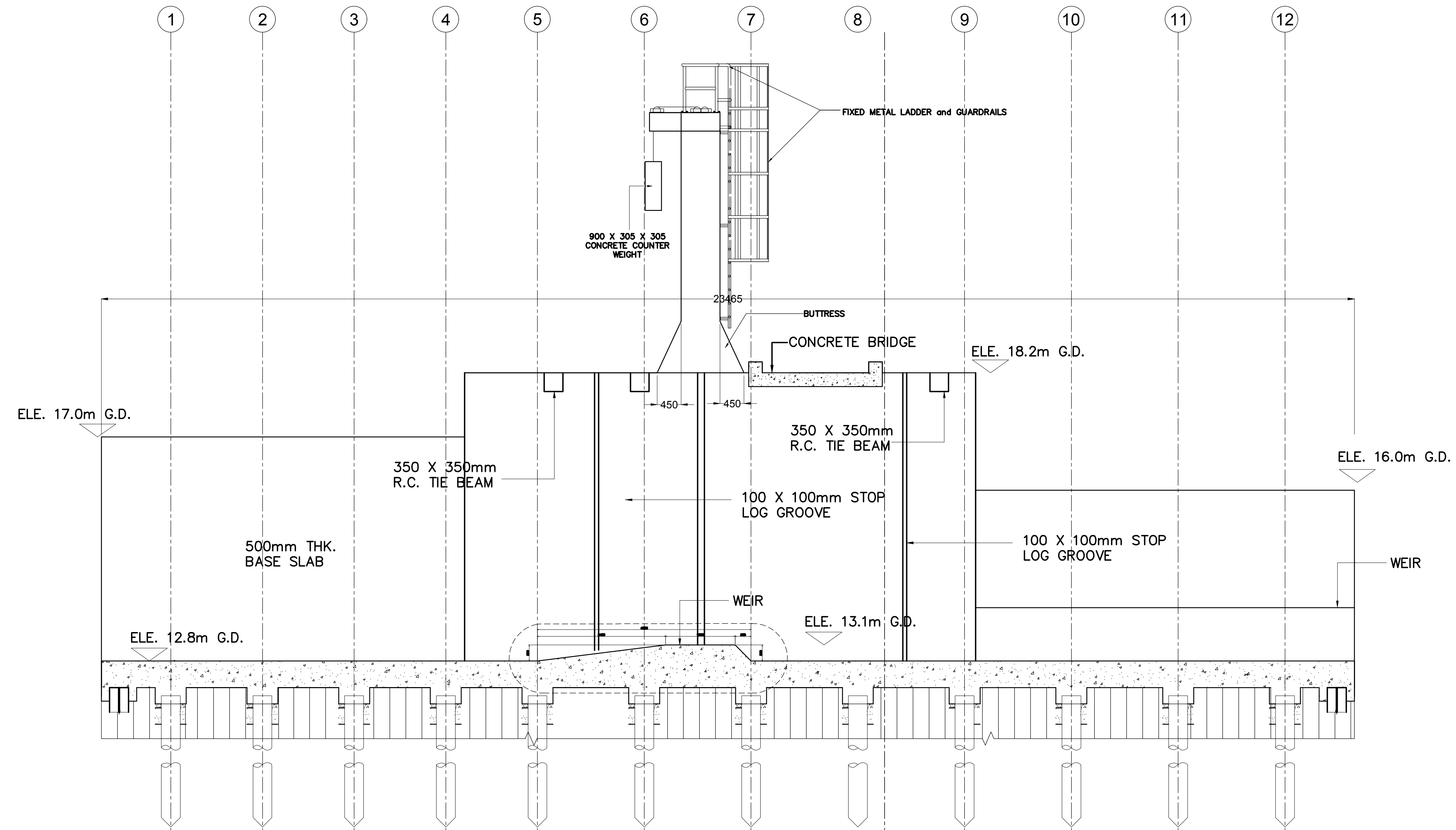
project code: SAPS–HR4–2017	drawing no. 8 of 24



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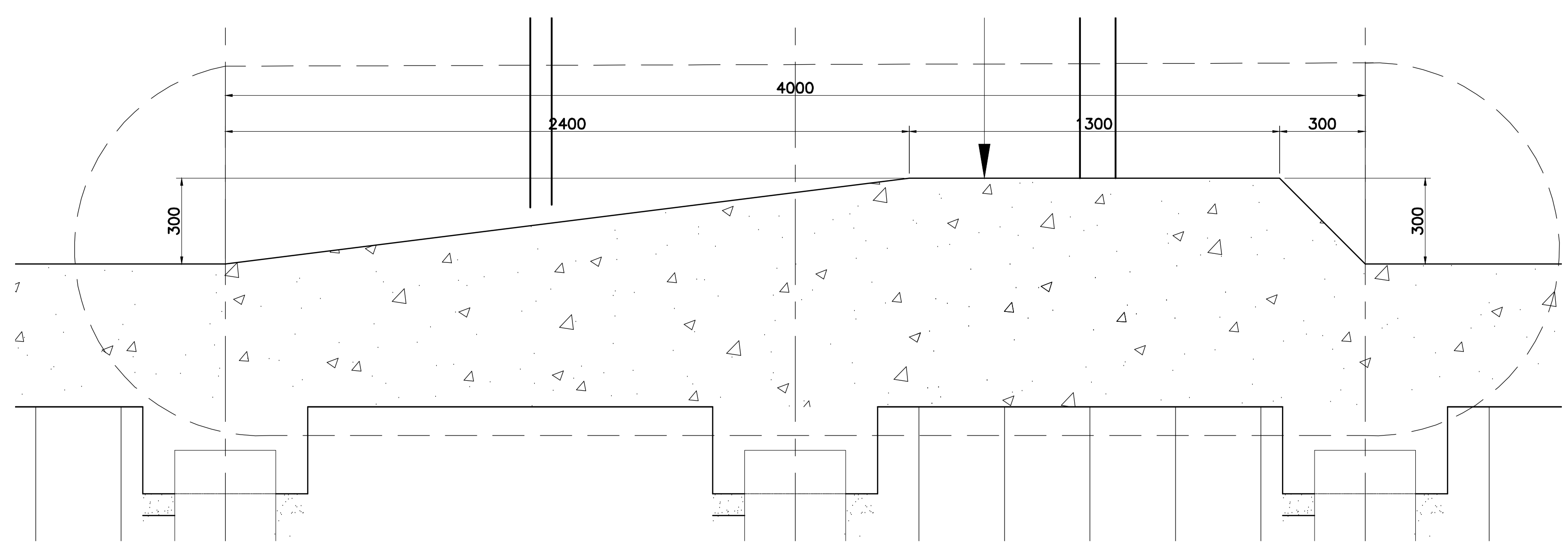

Detail of Weir

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

SECTION B-B AND DETAIL OF WEIR

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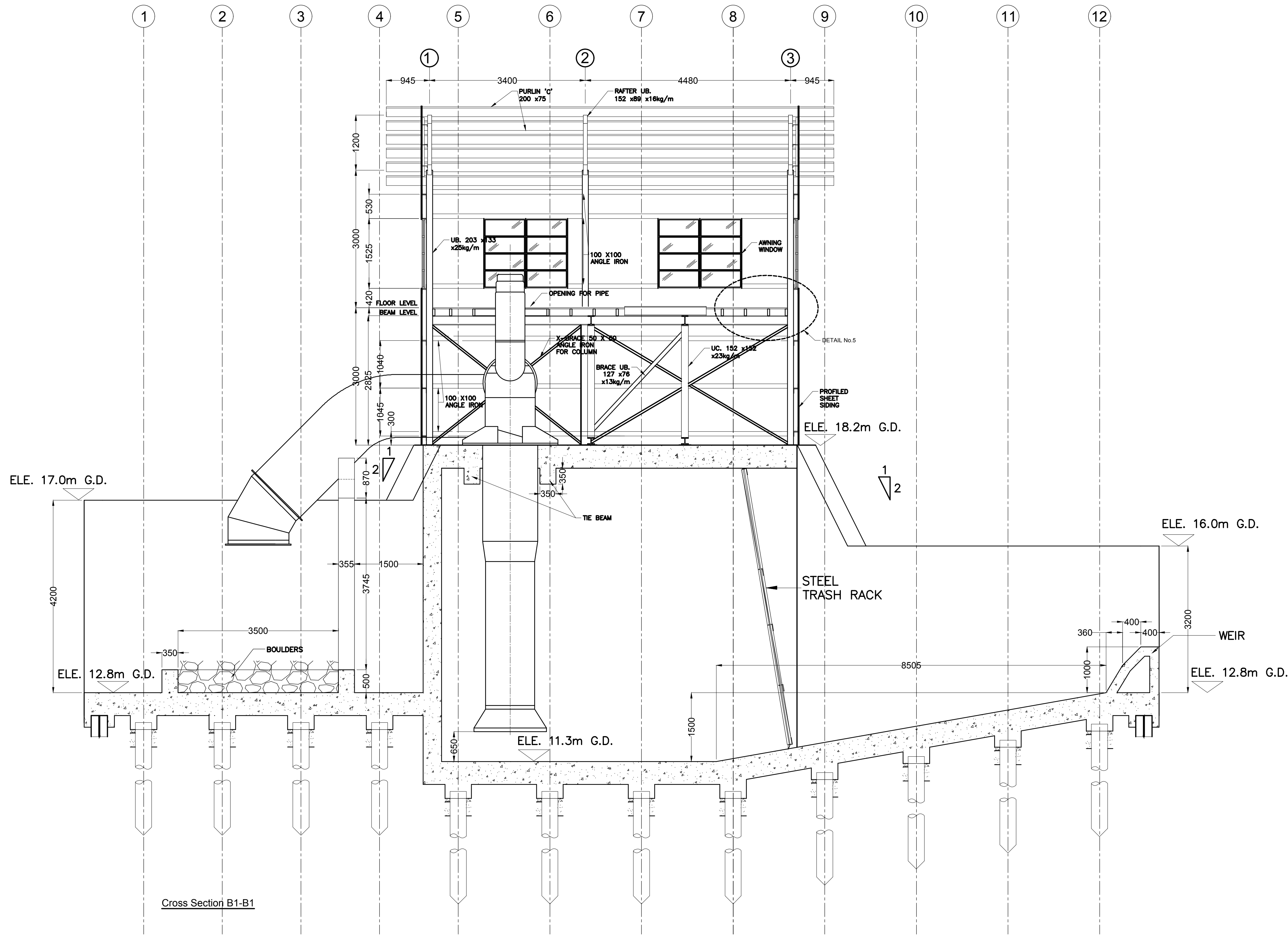

Cross Section B1-B1

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
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REGENT STREET AND VLISSENGEN ROAD
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GUYANA.

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CONSTRUCTION OF SLUICE &
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E.B.D., REGION No.4

drawing title:

SECTION B1–B1

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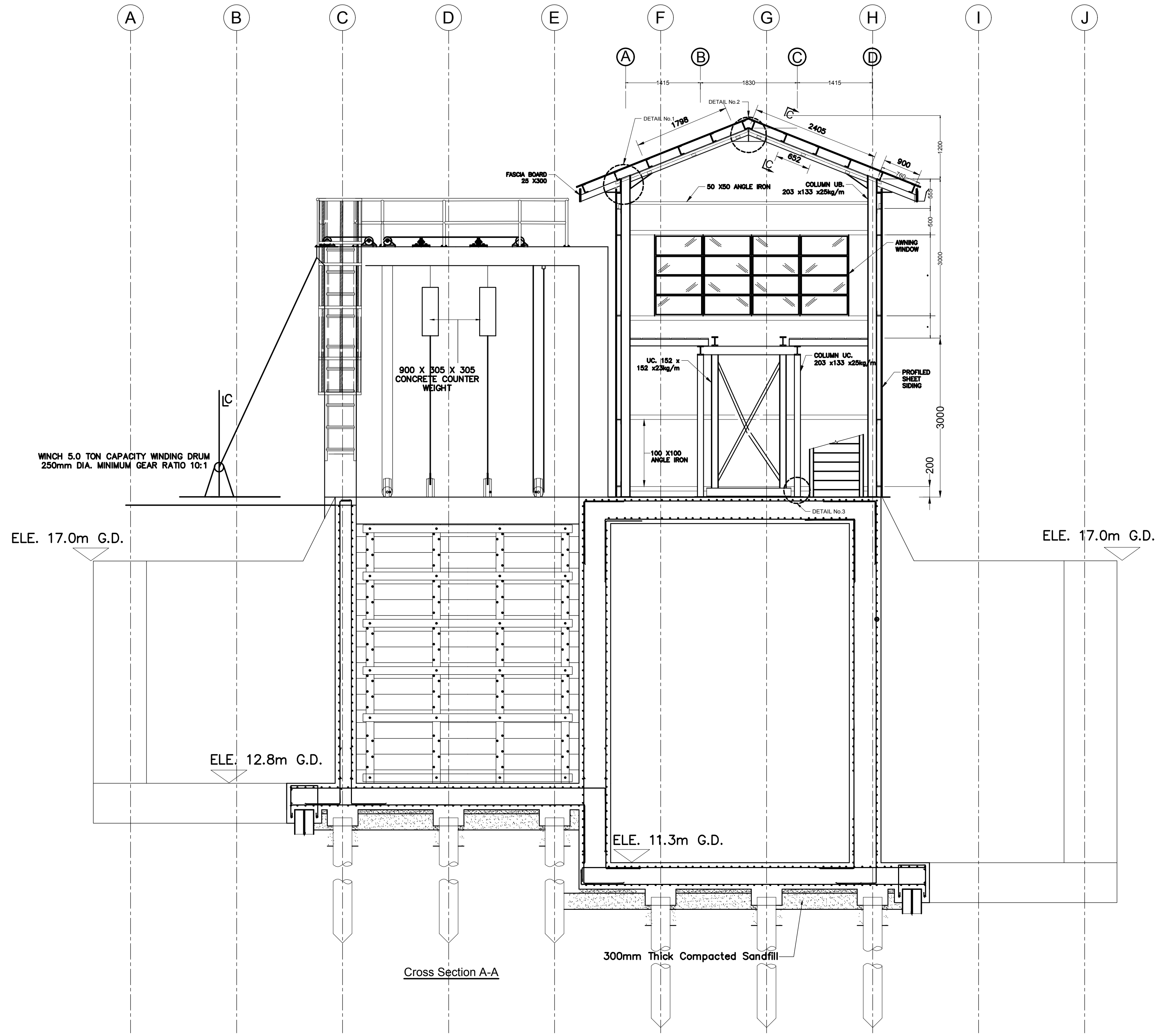

Cross Section A-A

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
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project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

SECTION A–A

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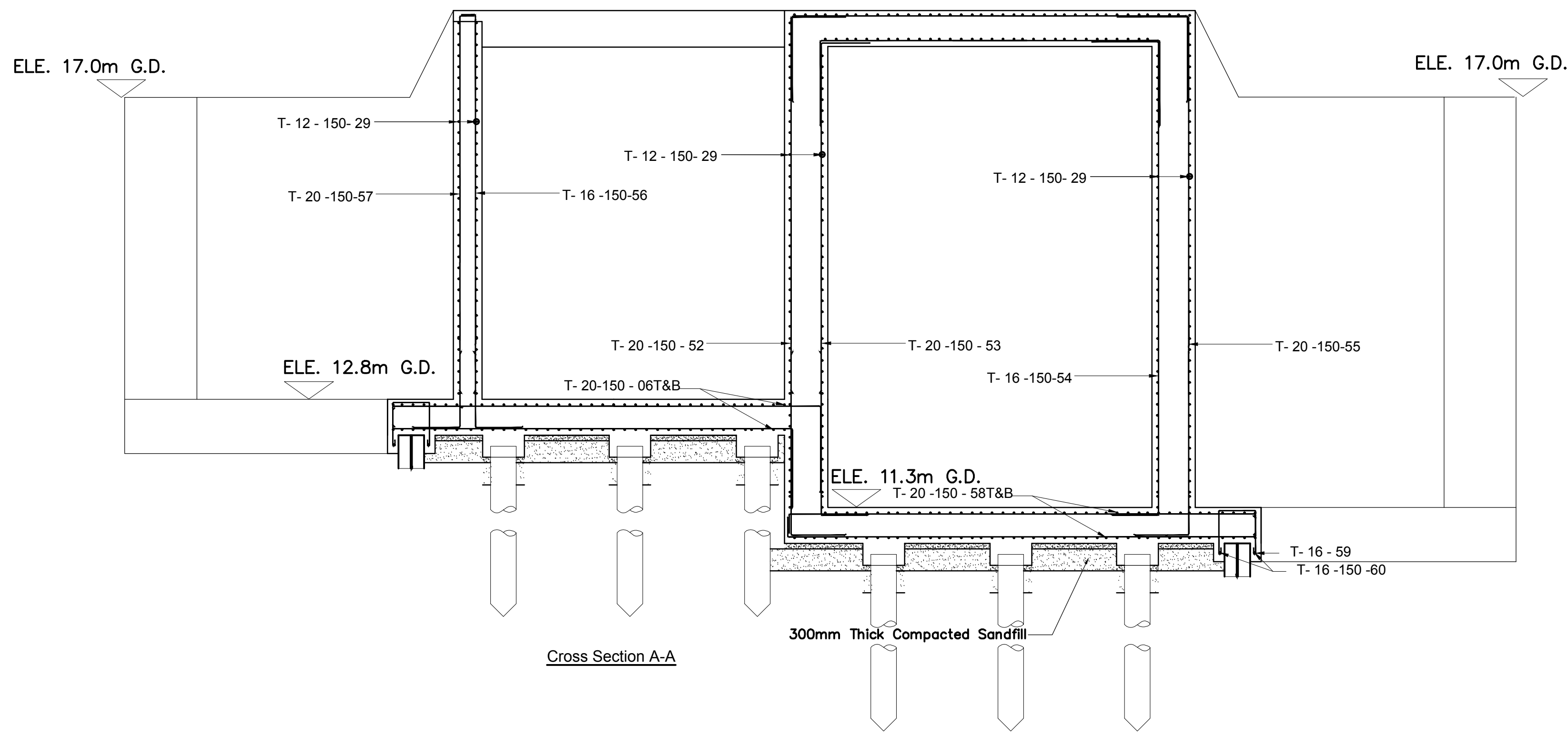
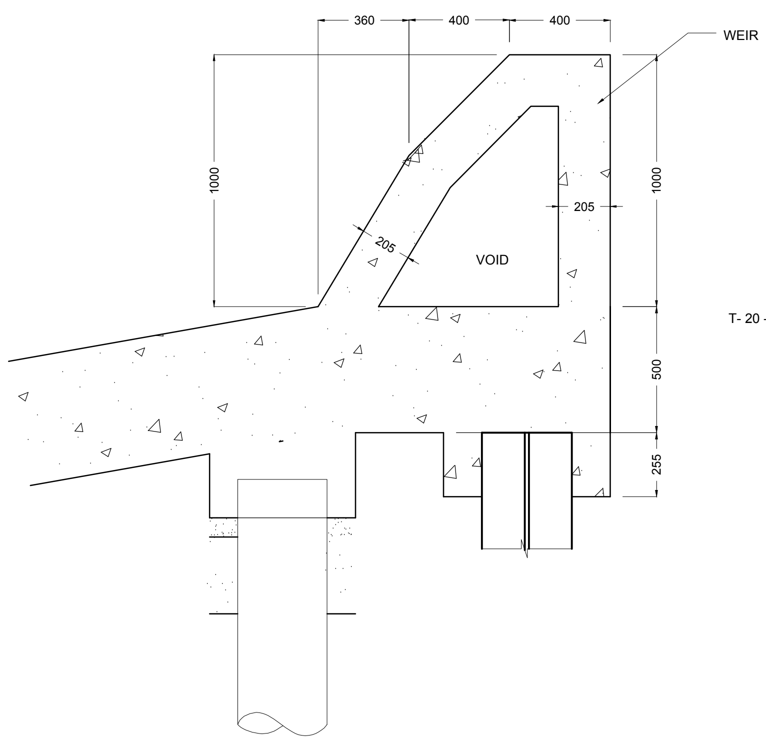
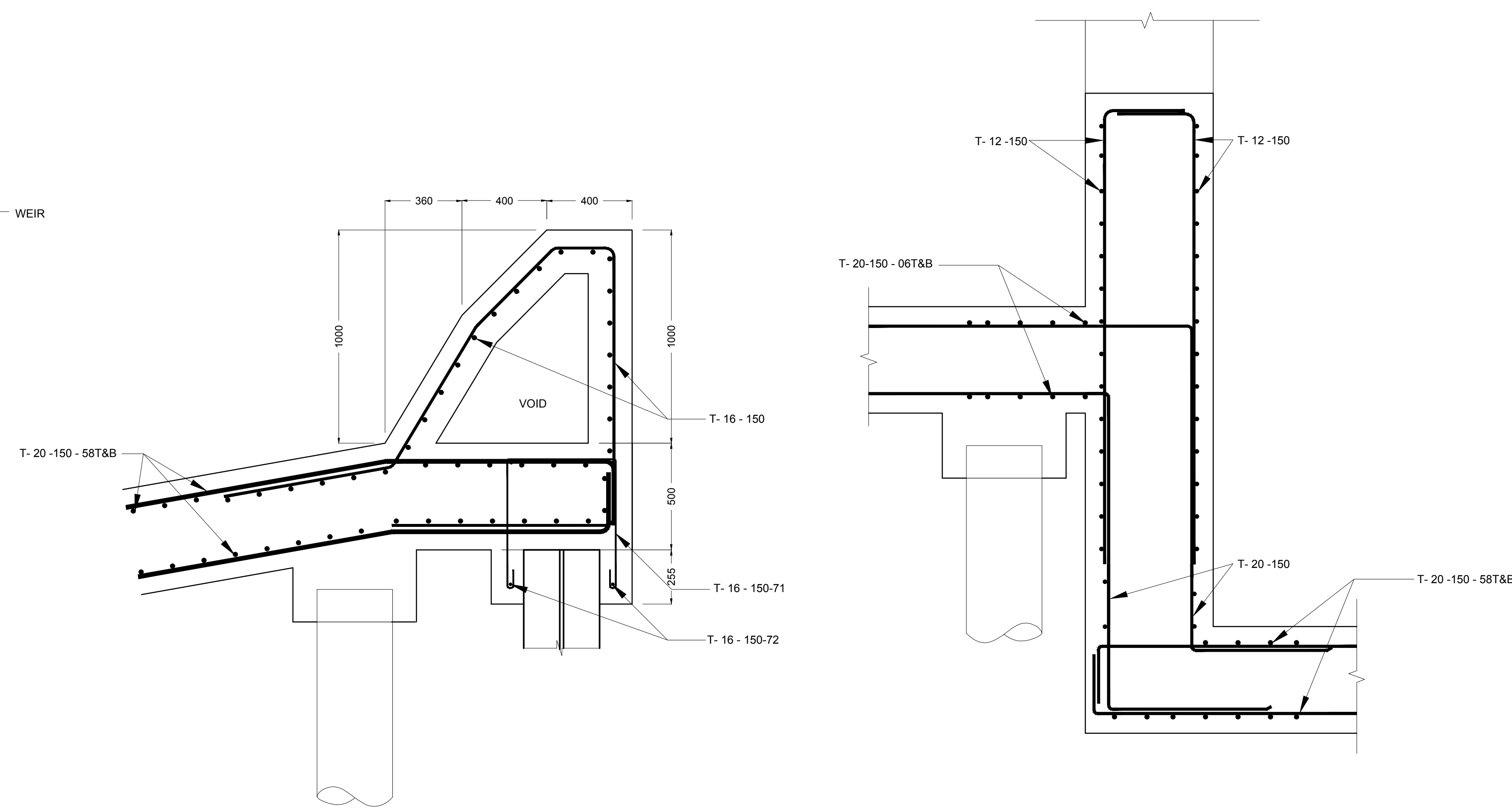
project code: SAPS–HR4–2017	drawing no. 11 of 24



Cross Section A-A



Toe, Tanking Steel Sheet Pile and Weir Details



Reinforcement of Weir Details

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

REINFORCED CROSS SECTION A-A & WEIR

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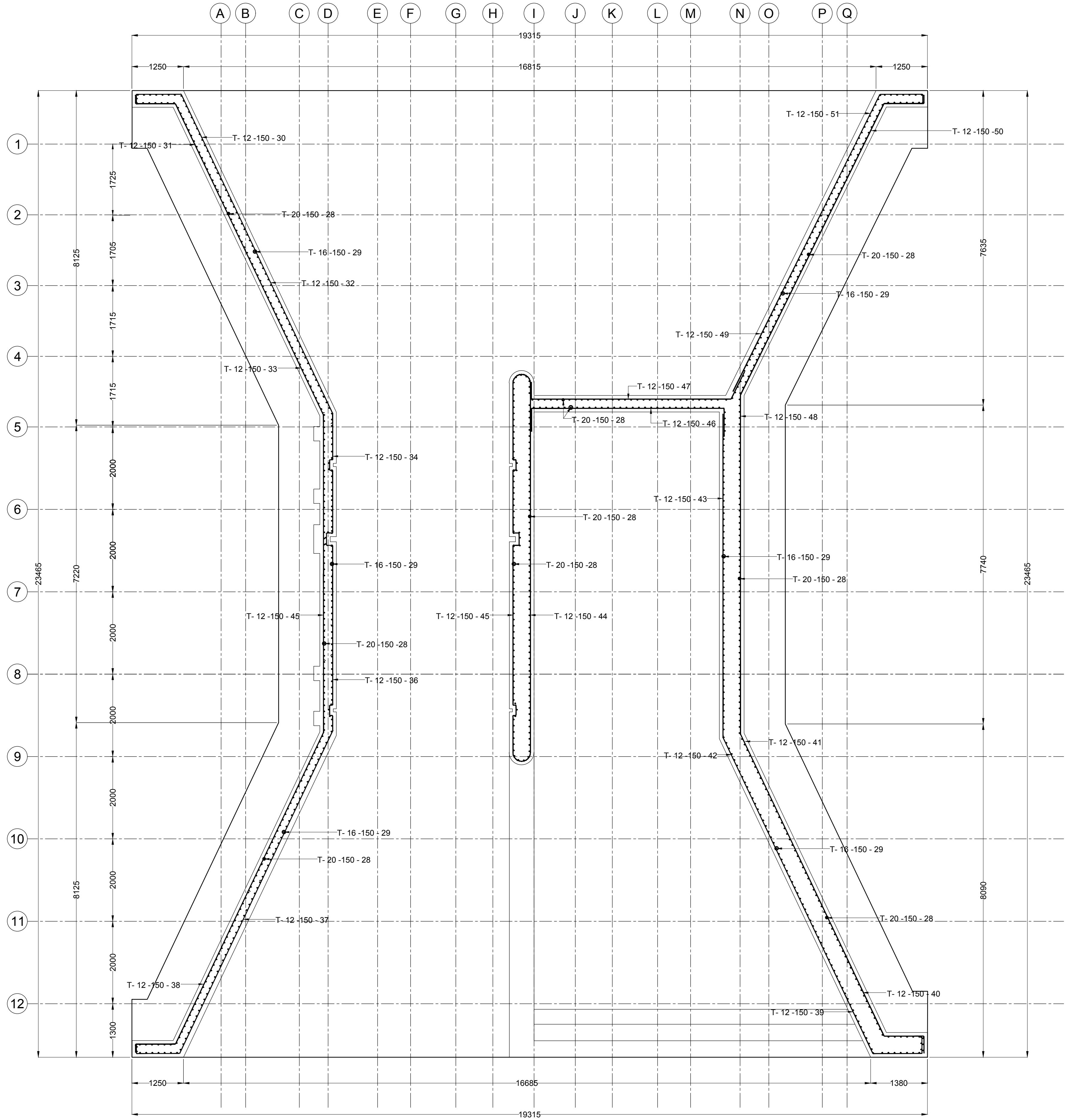

Section C-C Reinforcement Details

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

SECTION C–C REINFORCEMENT DETAILS

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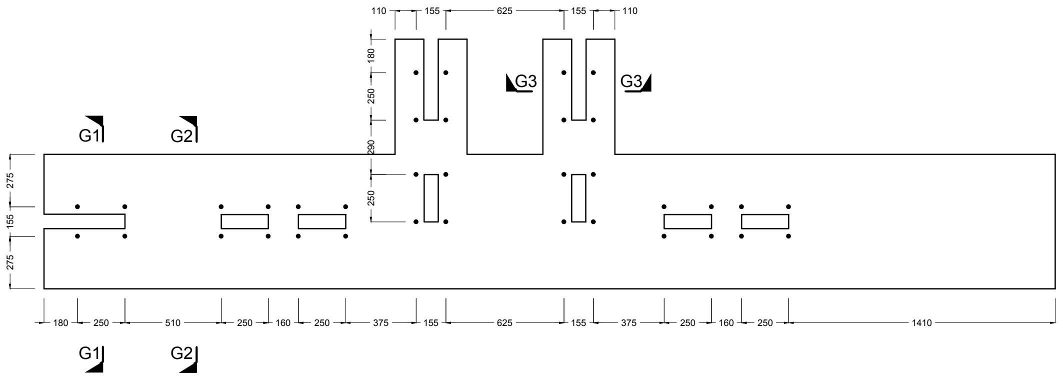
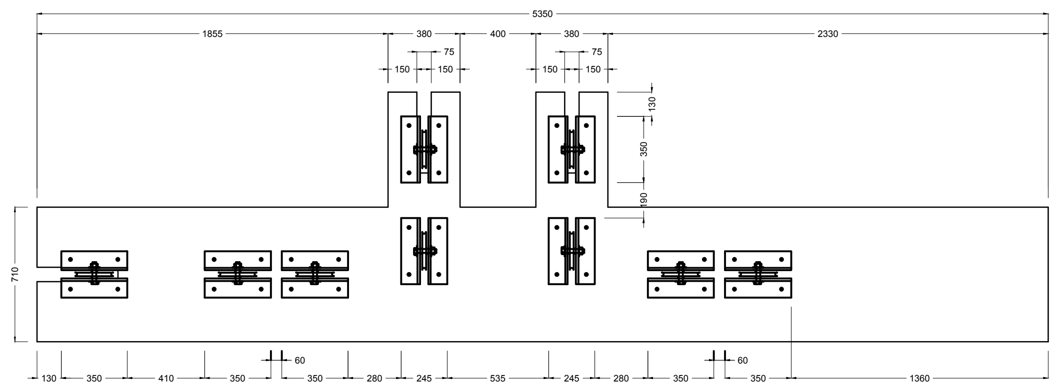


GANTRY BEAM DETAIL 2



GANTRY BEAM DETAIL 1
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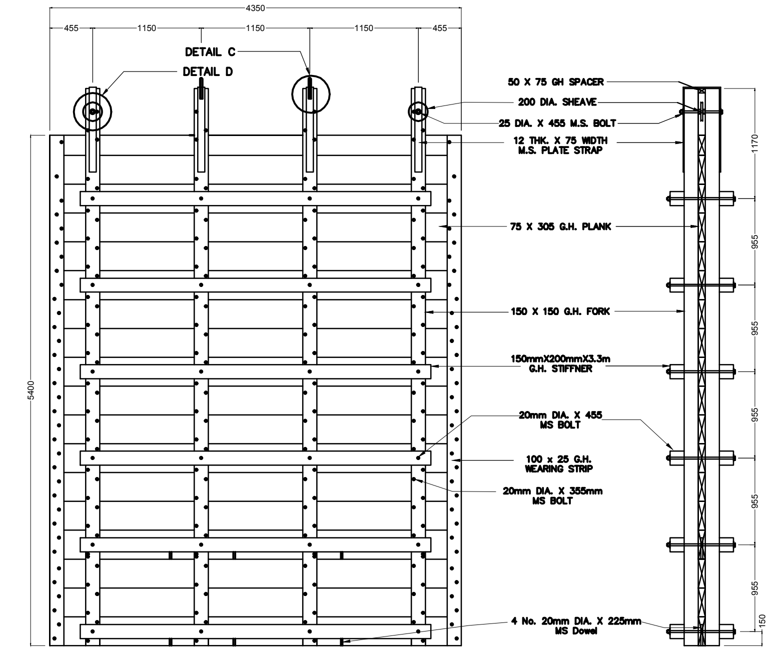

SLUICE DOOR
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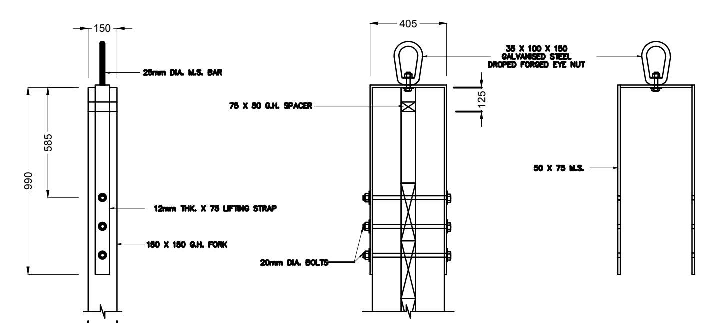
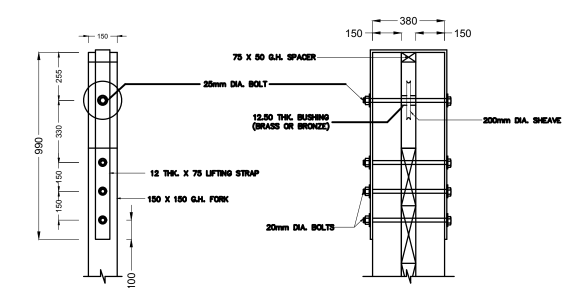


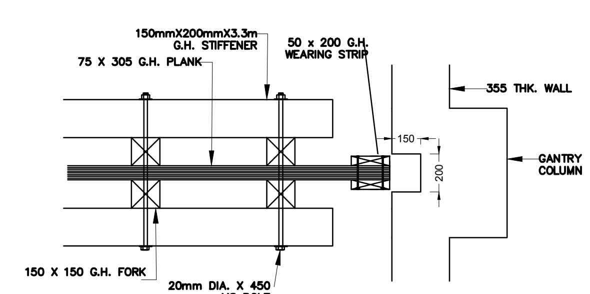
DETAIL C

LIFTING STRAP DETAIL

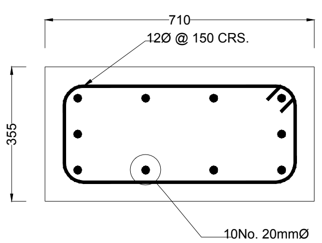


DETAIL D

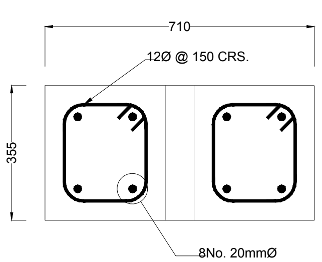
LIFTING STRAP DETAIL



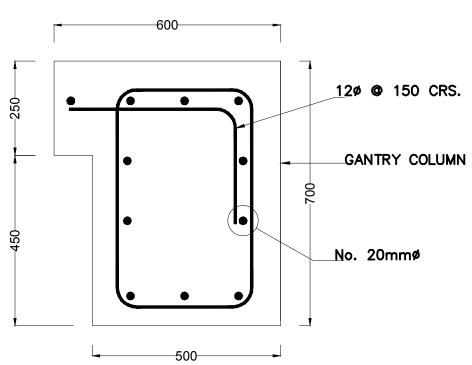
SLUICE DOOR TO WALL CONNECTION DETAIL
scale 1:40



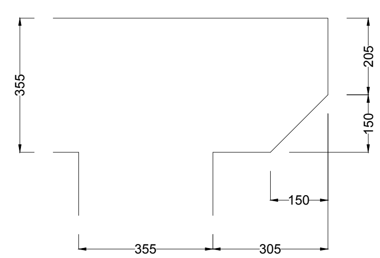
SECTION G2-G2



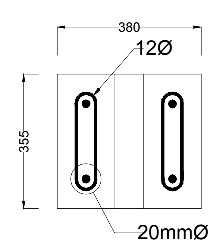
SECTION G1-G1
scale 1:20



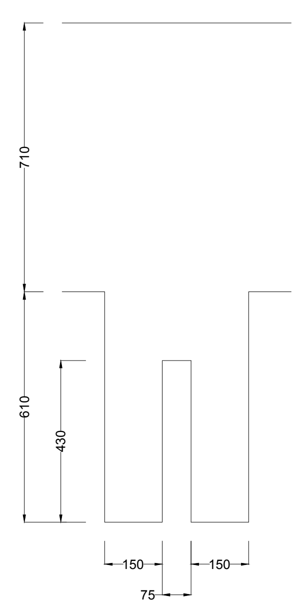
GANTRY COLUMN ABOVE WALL DETAIL



GANTRY END DETAIL



SECTION G3-G3



SECTION G3-G3 PLAN

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

GANTRY DETAILS & DOOR DETAILS

notes:

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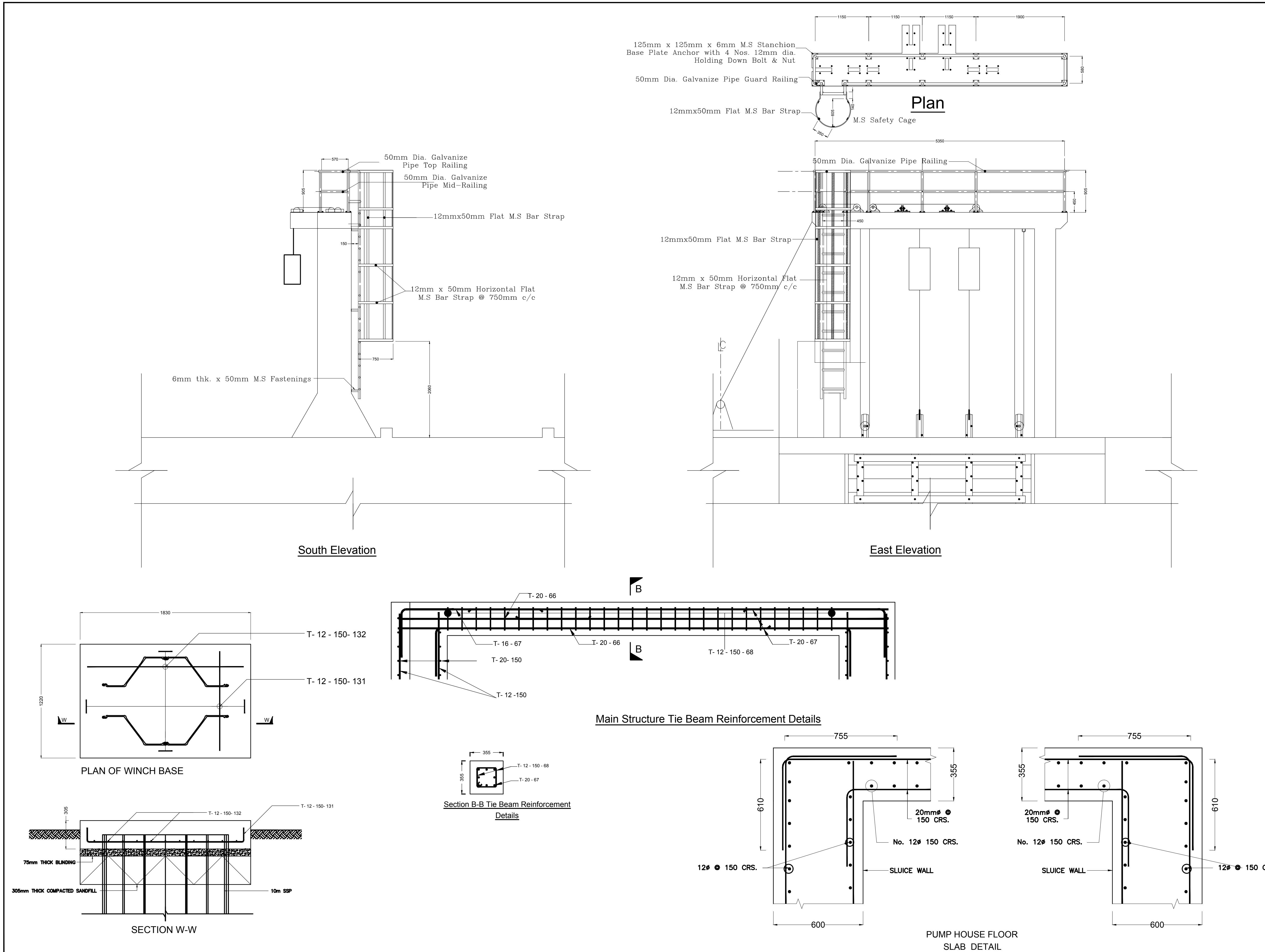

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

RAIL DETAILS, REINFORCED TIE BEAM DETAILS, PUMP HOUSE FLOOR SLAB DETAILS AND WINCH BASE

notes:

revisions

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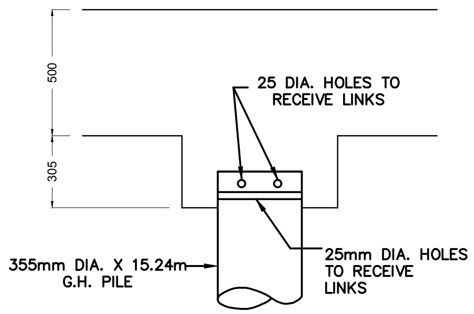
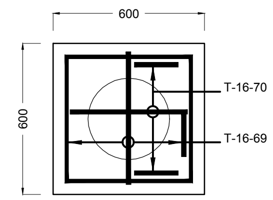
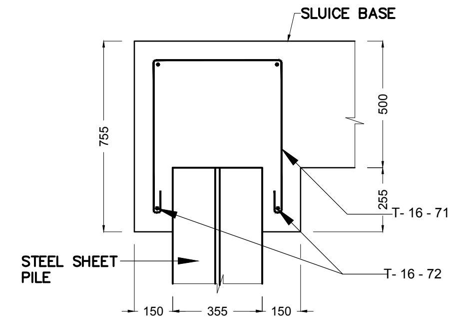
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 15 of 24



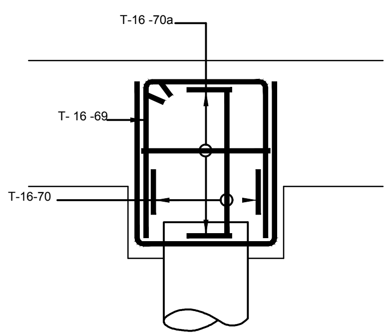
Pile Cap Details



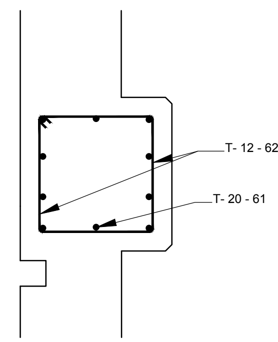
Pile Cap Plan



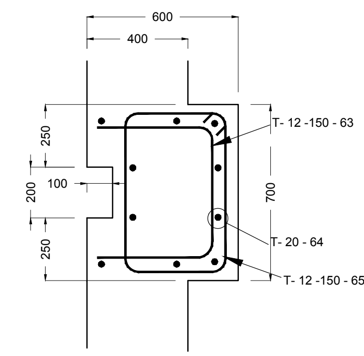
Toe and Tanking Steel Sheet Pile Details



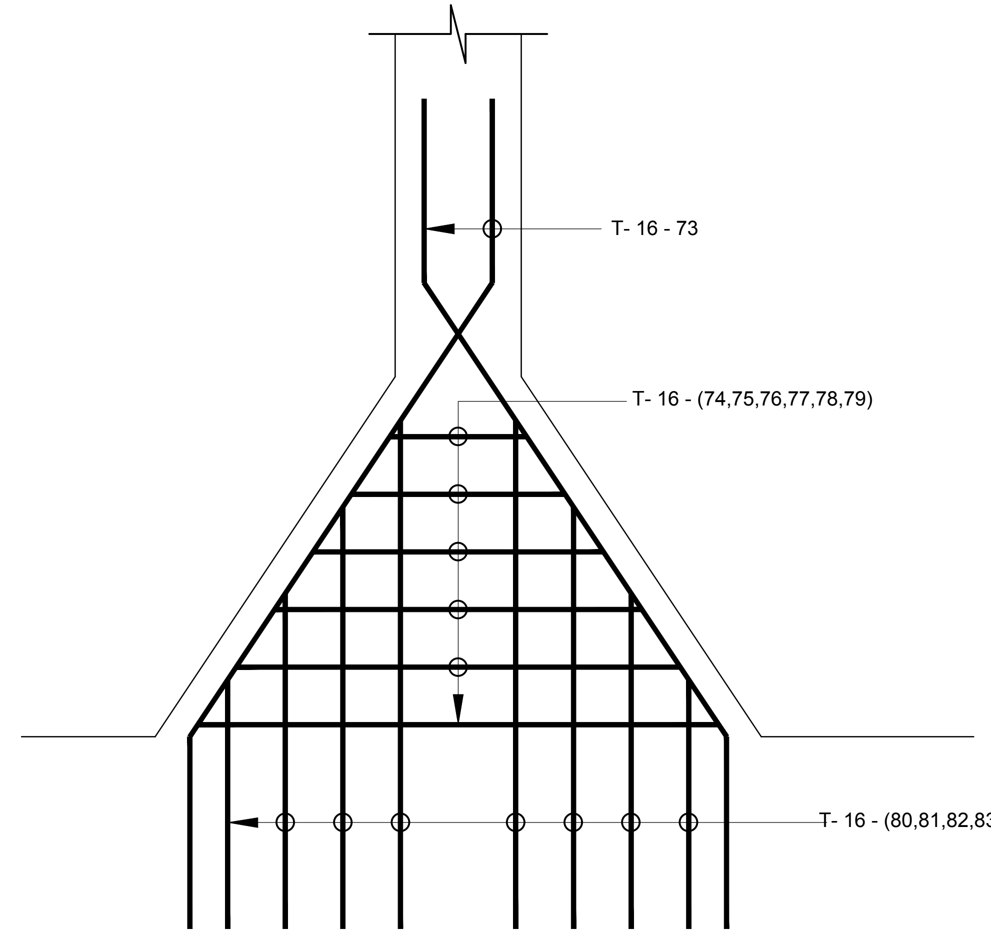
Pile Cap Reinforcement Details



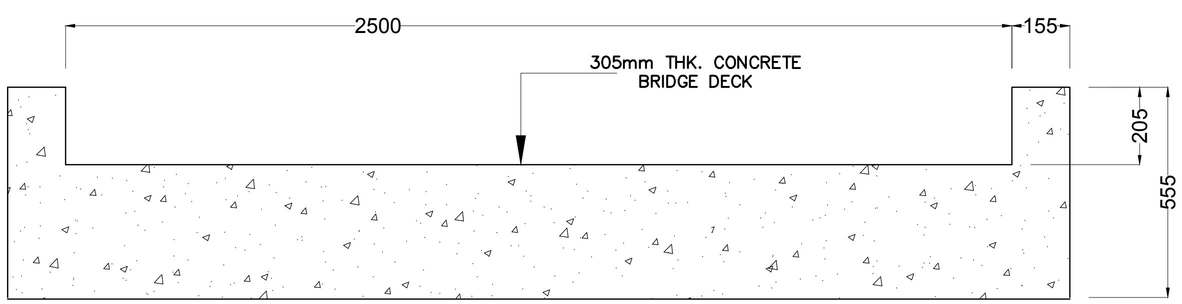
DETAIL "A"



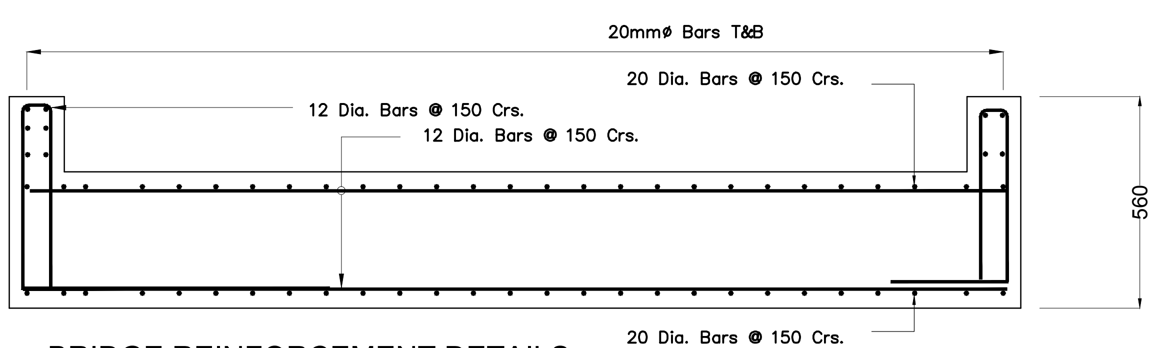
GANTRY COLUMN BELOW WALL DETAIL



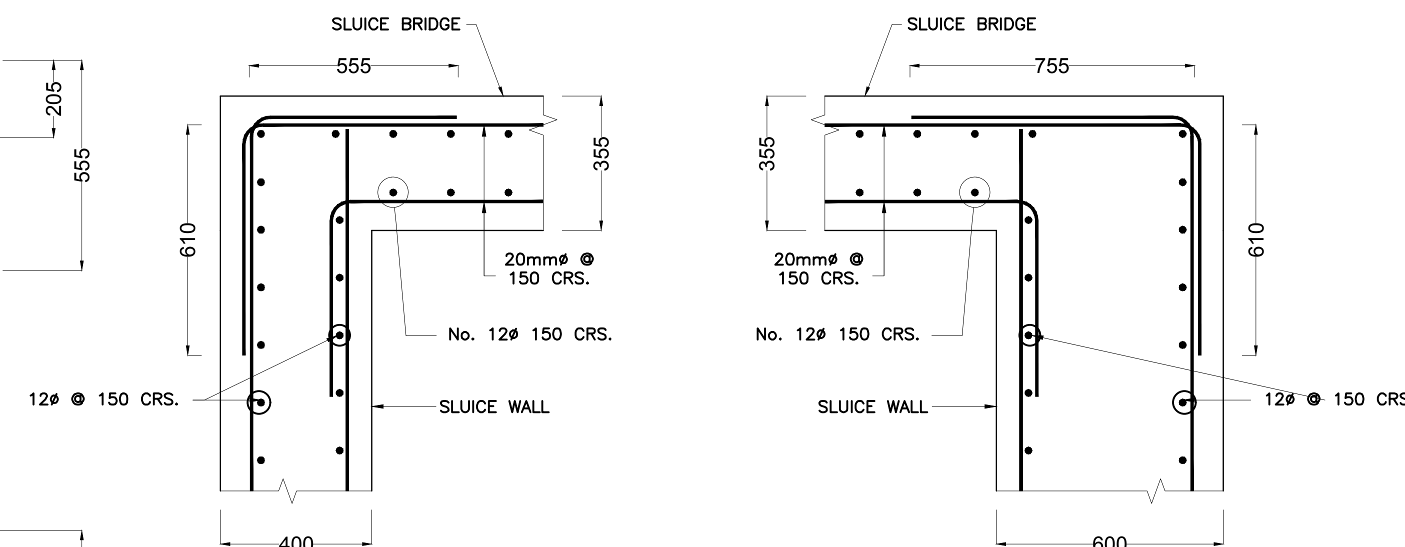
Buttress Reinforcement Details



CROSS SECTION BRIDGE



BRIDGE REINFORCEMENT DETAILS



WALL TO BRIDGE CONNECTION DETAIL

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

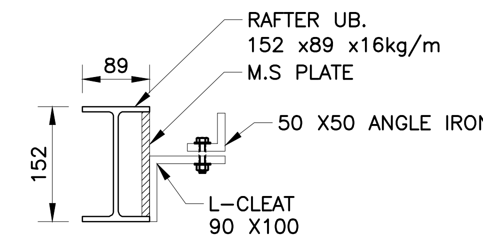
BUTTRESS REINFORCEMENT DETAILS, BRIDGE CONNECTION AND DETAILS

notes:

revisions

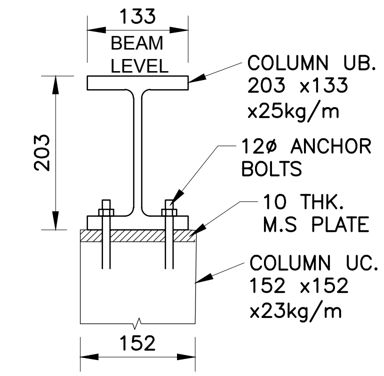
NO.	REVISIONS	DATE

scale: 1:20&1:30	approved by:
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 16 of 24



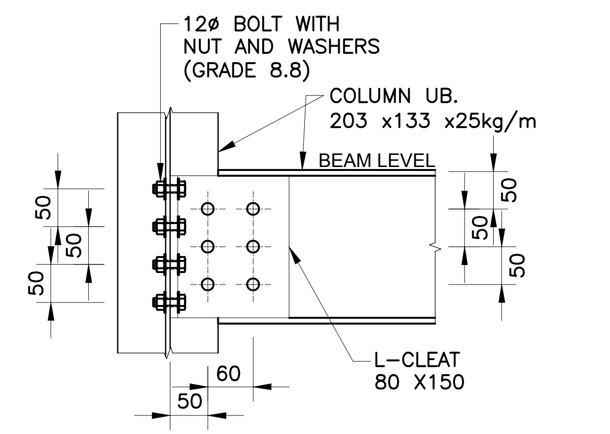
SECTION C-C

SCALE. 1:10



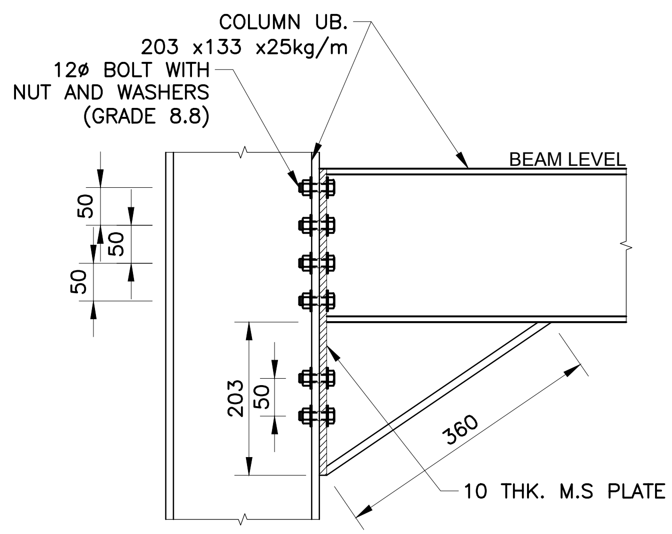
CONNECTION TYPE 4

SCALE. 1:10



CONNECTION TYPE 1

SCALE. 1:10



CONNECTION TYPE 2

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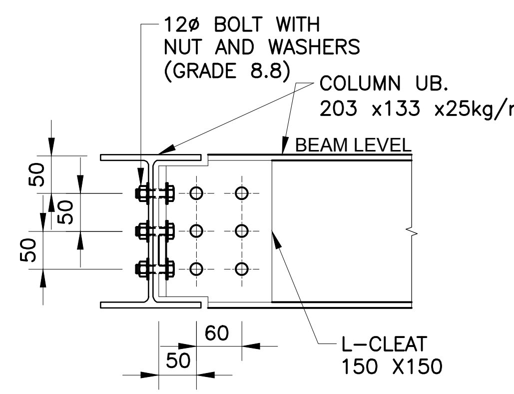

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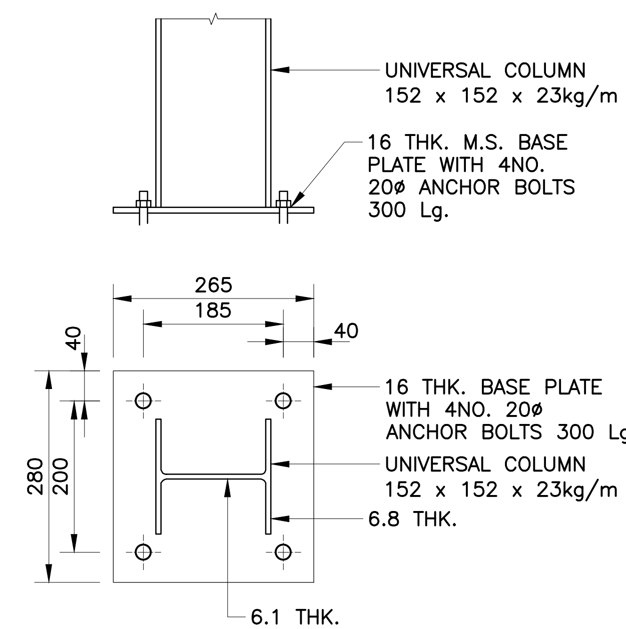
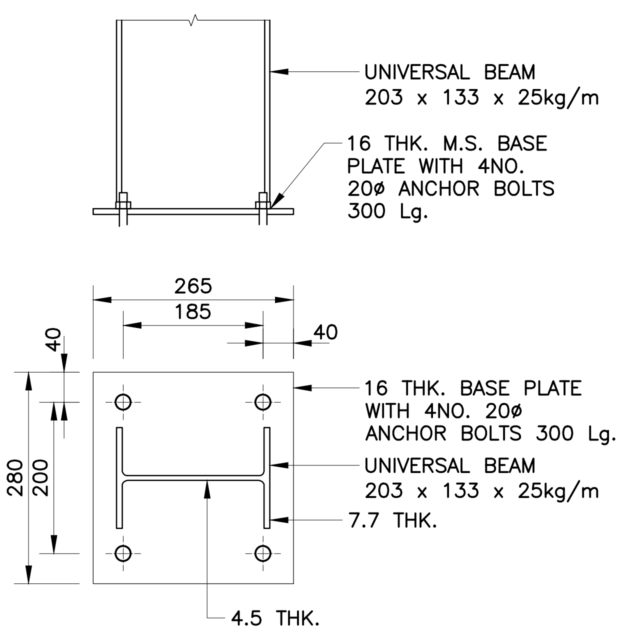
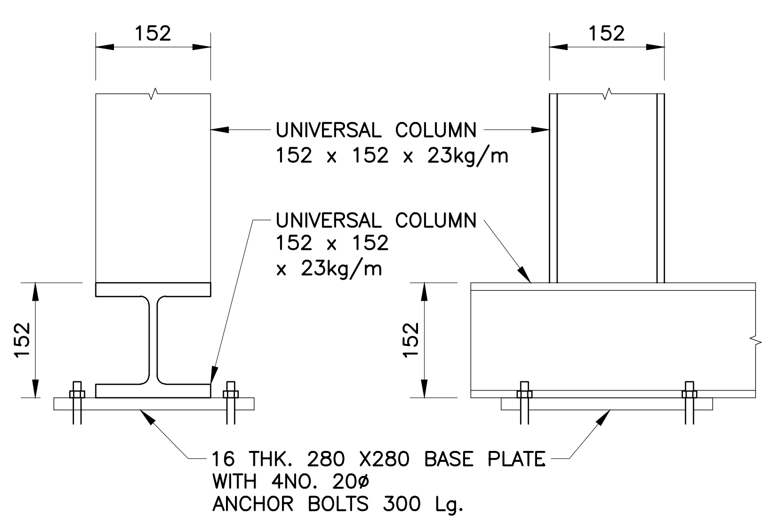


TYPE 4 DETAILS



TYPE 1 DETAILS

SCALE. 1:10



TYPE 2 DETAILS

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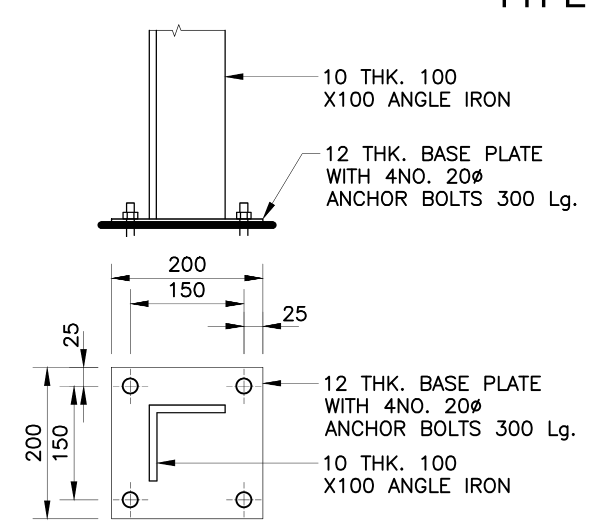

TYPE 3 DETAILS

SCALE. 1:10

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE &
PUMP STATION AT HERSTELLING,
E.B.D., REGION No.4

drawing title:

CONNECTION DETAILS

notes:

revisions

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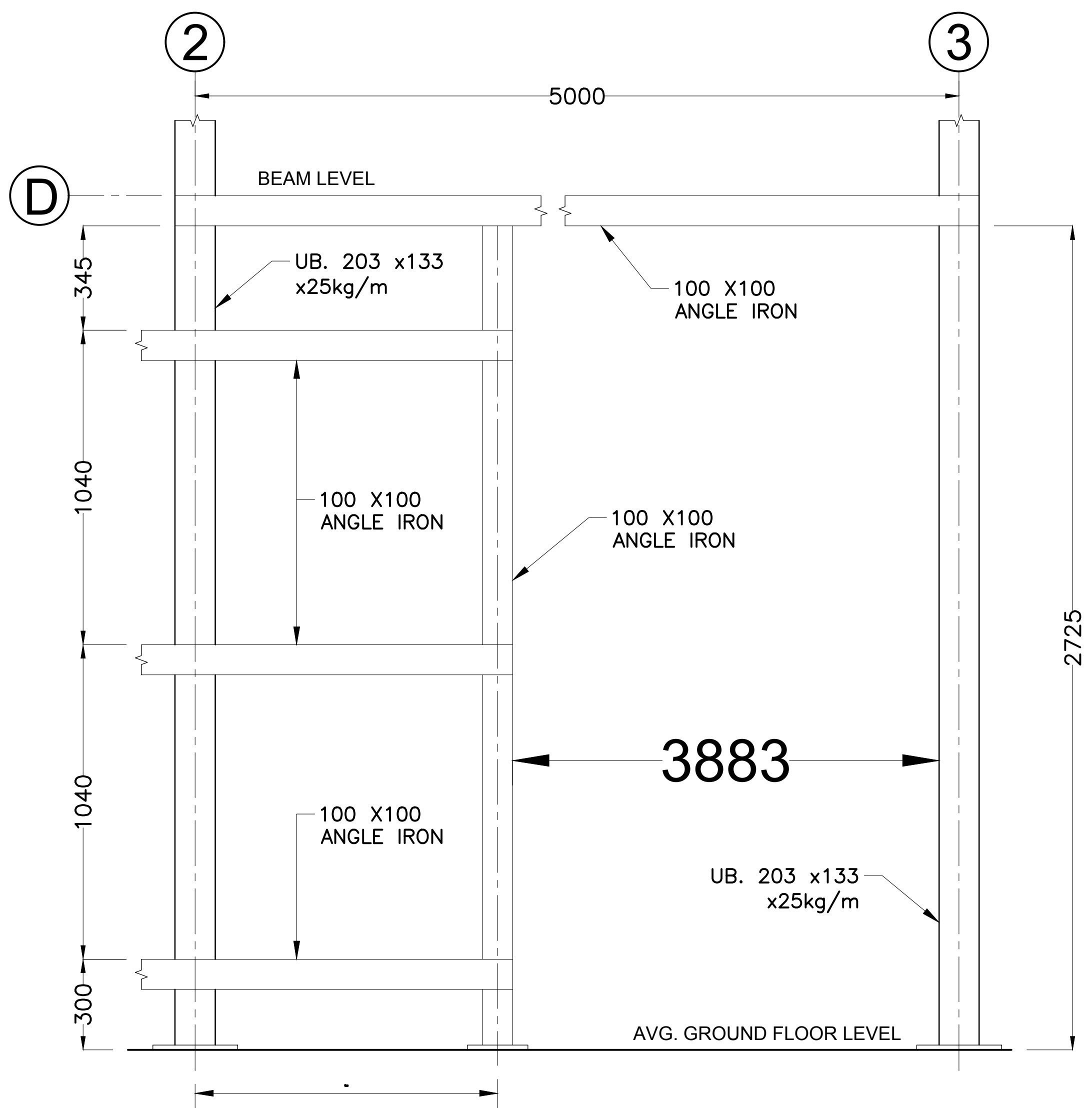
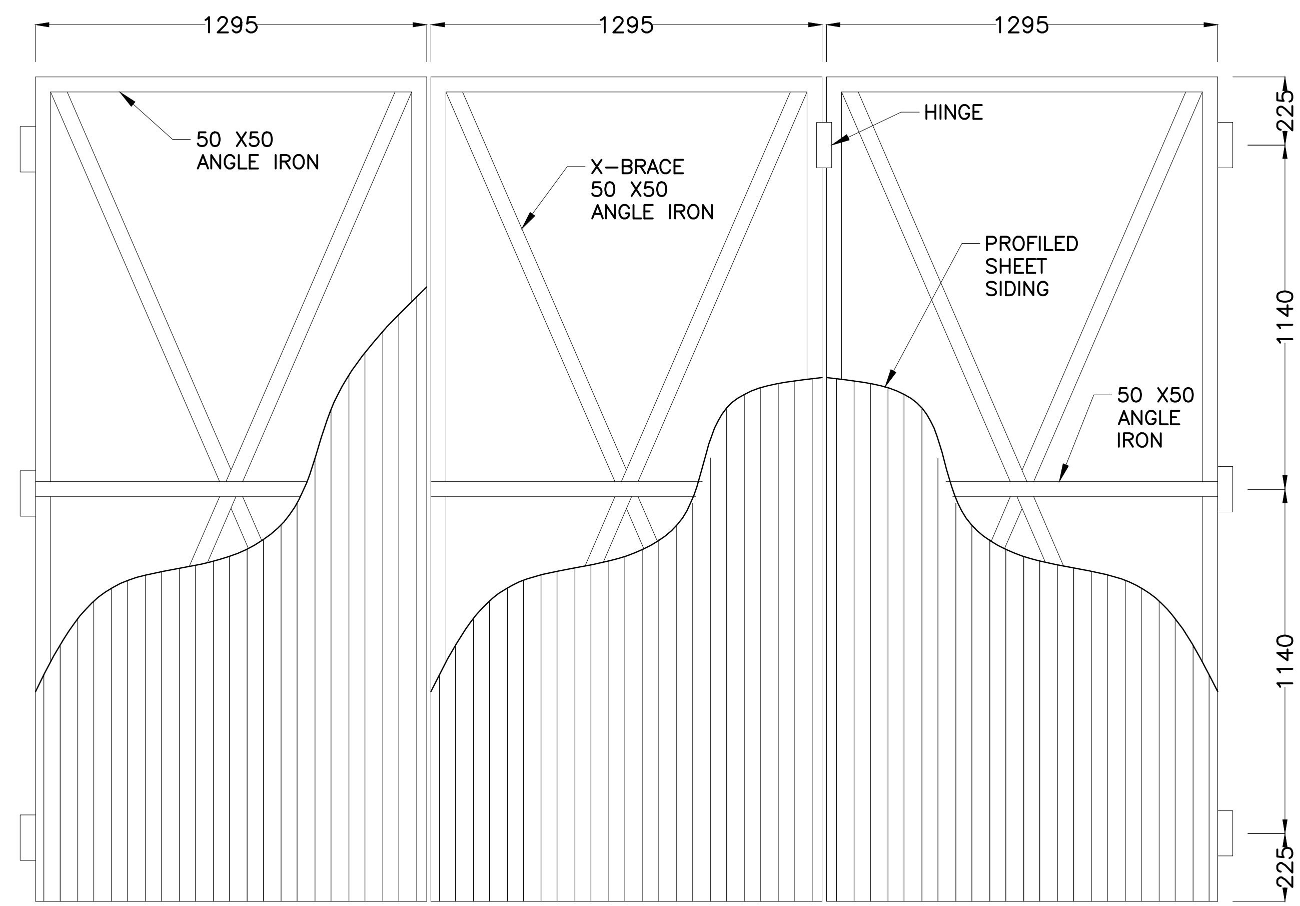
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 17 of 24



DOOR FRAME DETAILS

SCALE. 1:25



DOOR FRAME DETAILS

SCALE. 1:25

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE &
PUMP STATION AT HERSTELLING,
E.B.D., REGION No.4

drawing title:

DOOR DETAILS

notes:

revisions

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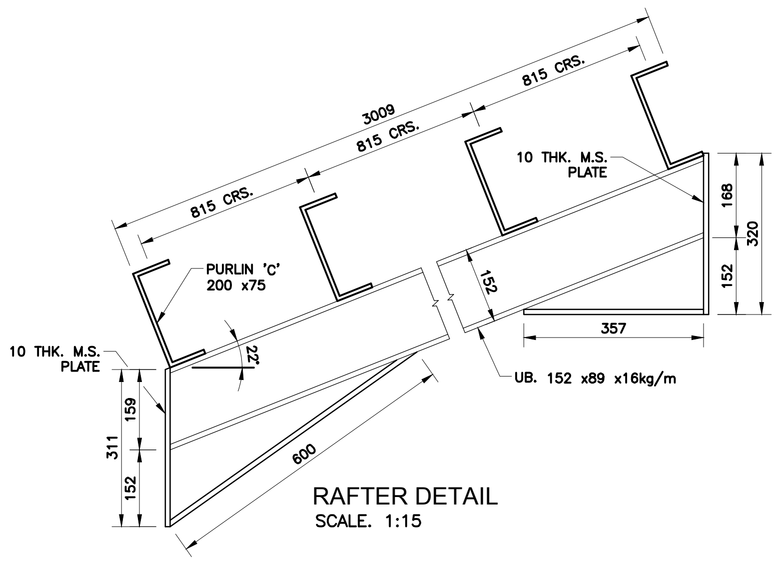
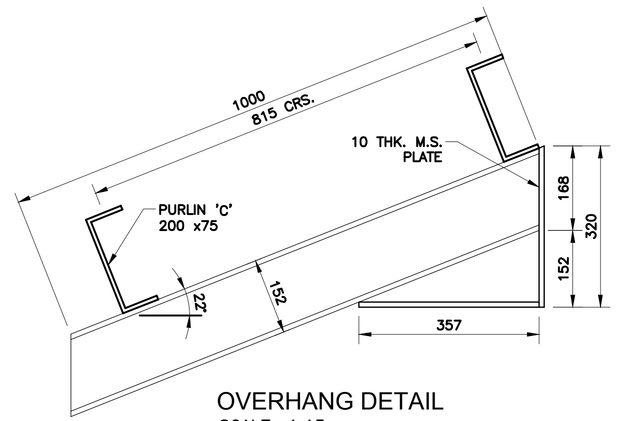
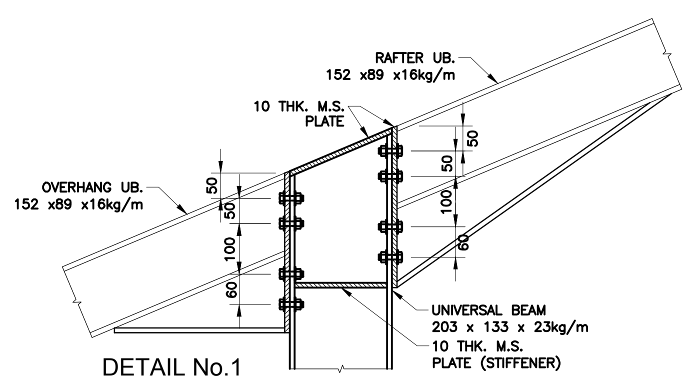
scale: 1:25	approved by:
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 18 of 24



RAFTER DETAIL
SCALE. 1:15



OVERHANG DETAIL
SCALE. 1:15



DETAIL No.1
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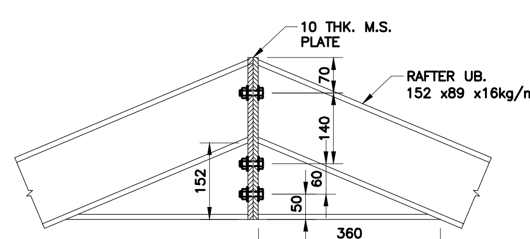

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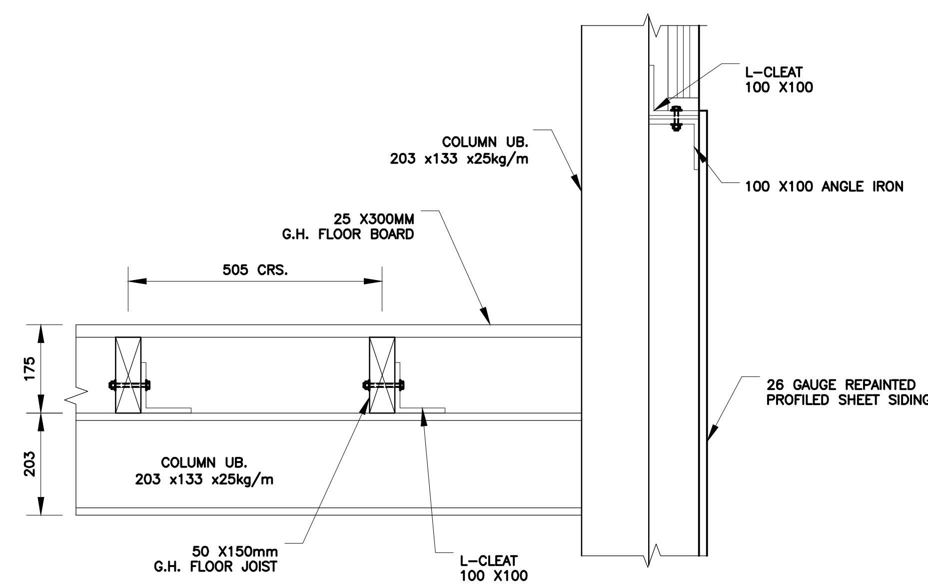


DETAIL No.5
SCALE. 1:15

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

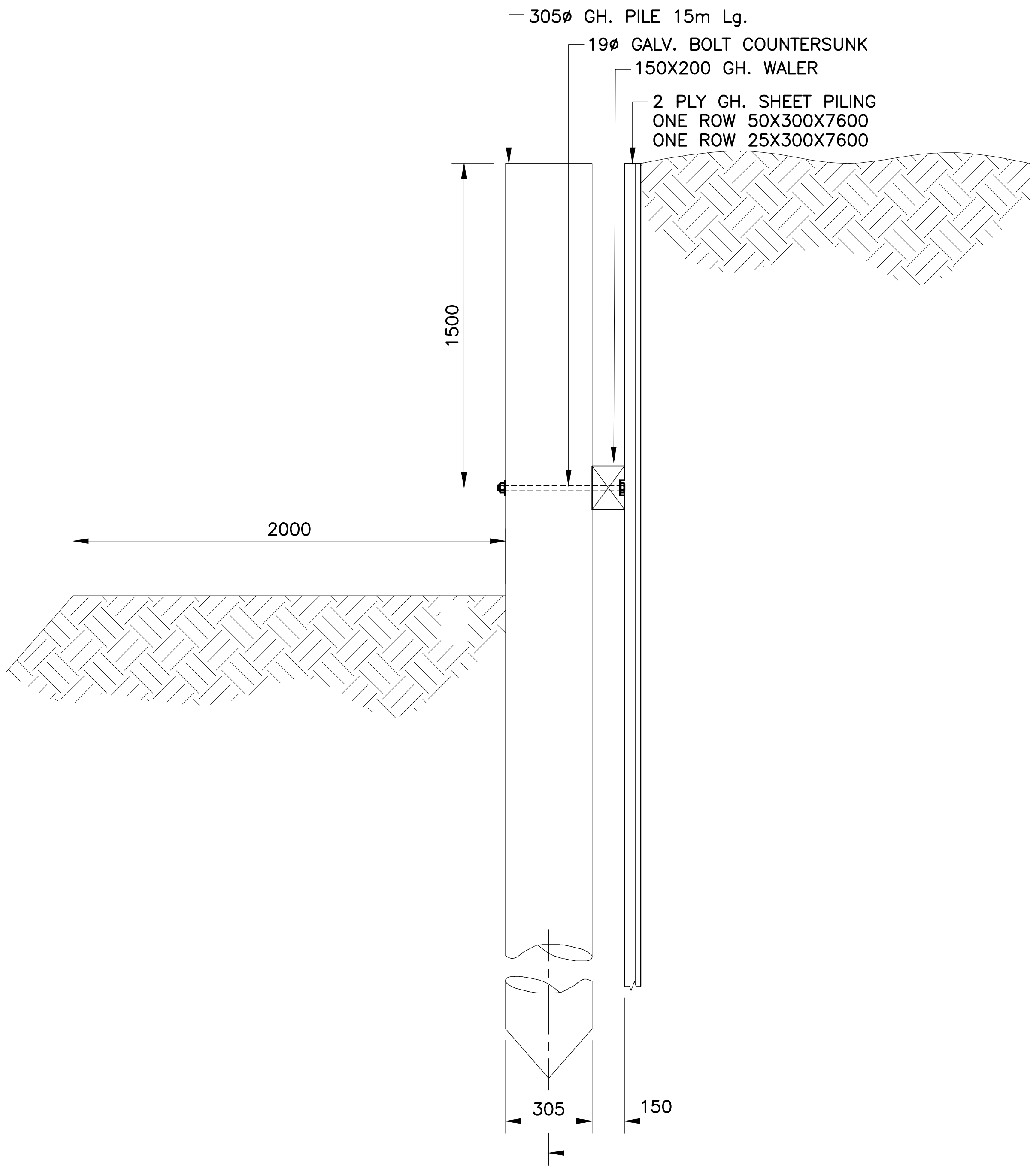
CONNECTION DETAILS 2

notes:

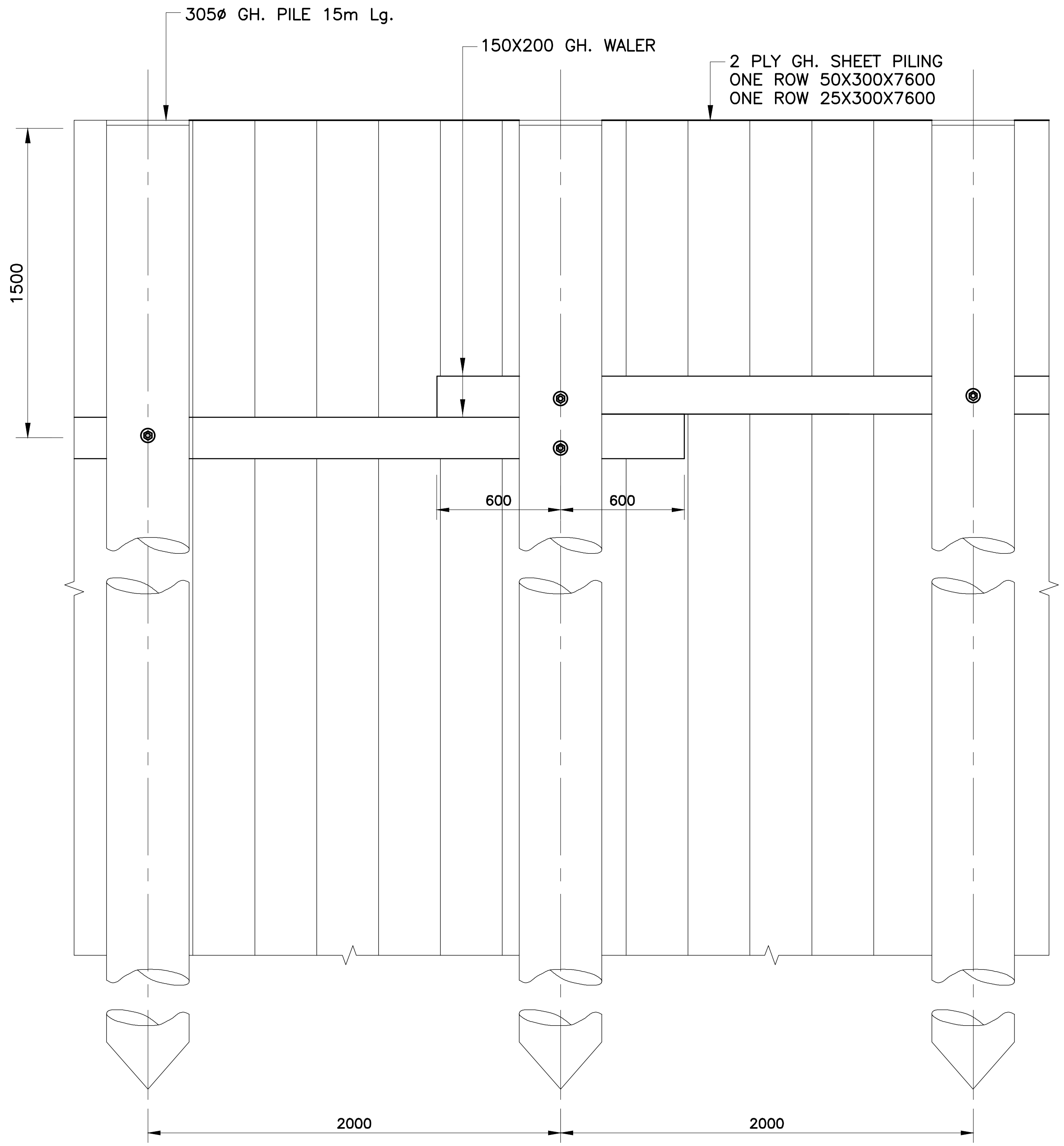
revisions

NO.	REVISIONS	DATE

scale: 1:15	approved by:
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 19 of 24



SECTION A-A
SCALE. 1:30



VIEW - 'A'
SCALE. 1:30

consultant:
SRKN'gineering & Associates Ltd.
107 Lamaha Street
Georgetown, GUYANA.

client:
MINISTRY OF AGRICULTURE,
N.D.I.A.
REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:
CONSTRUCTION OF SLUICE &
PUMP STATION AT HERSTELLING,
E.B.D., REGION No.4

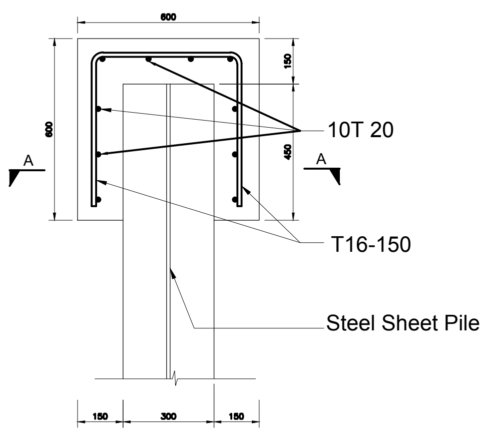
drawing title:
TIMBER REVETMENT FOR
TEMPORARY WORKS

notes:

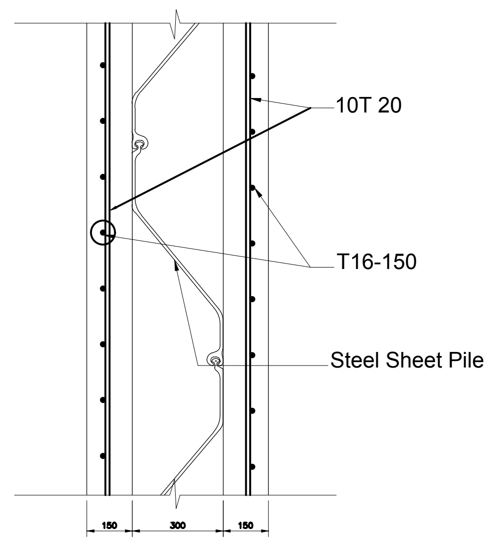
revisions

NO.	REVISIONS	DATE

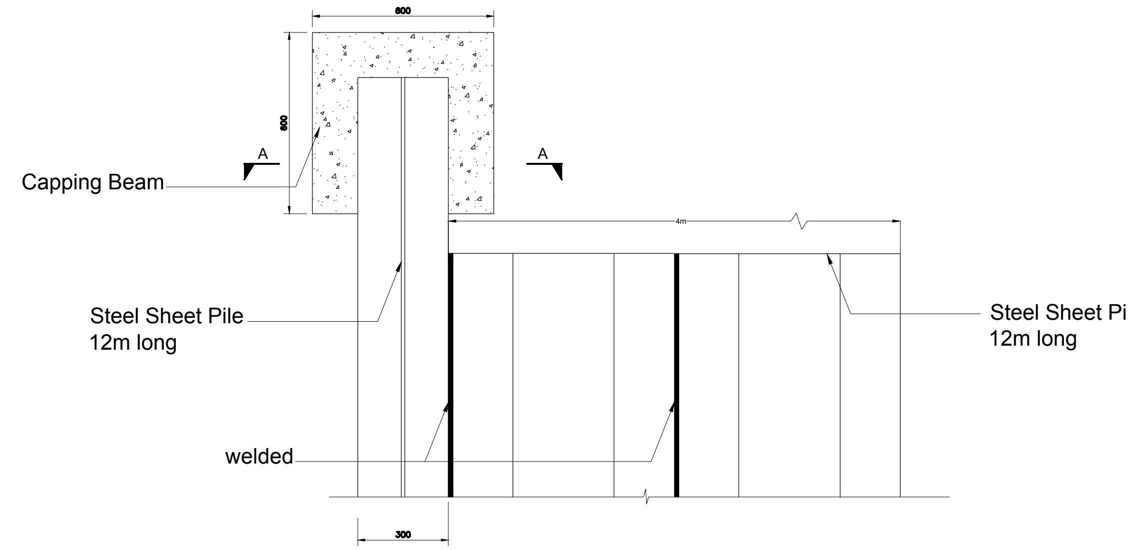
scale: 1:30	approved by:
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 20 of 24



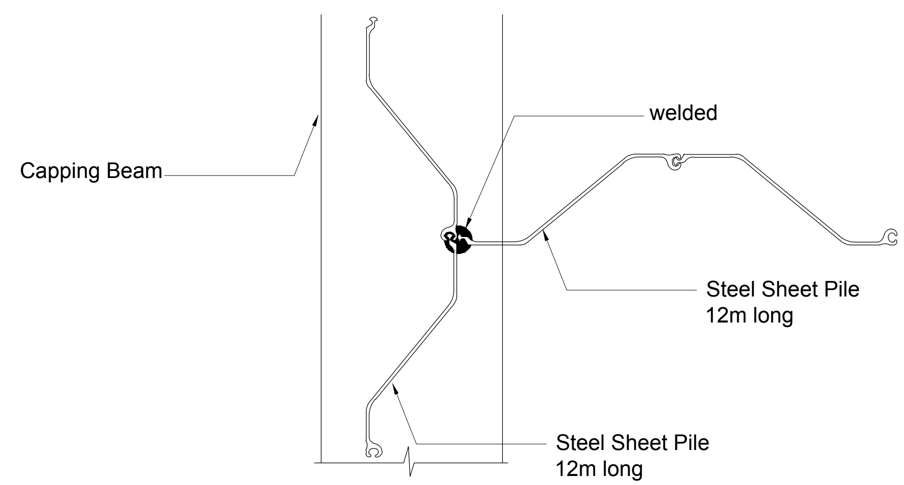
STEEL SHEET PILE CASING REINFORCEMENT DETAILS



SECTION A-A



Elevation



Plan

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
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client:

MINISTRY OF AGRICULTURE,
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REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

STEEL SHEET PILE REVETMENT

notes:

revisions

NO.	REVISIONS	DATE

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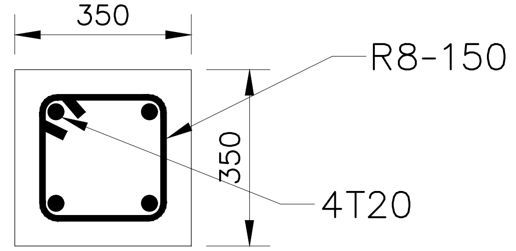
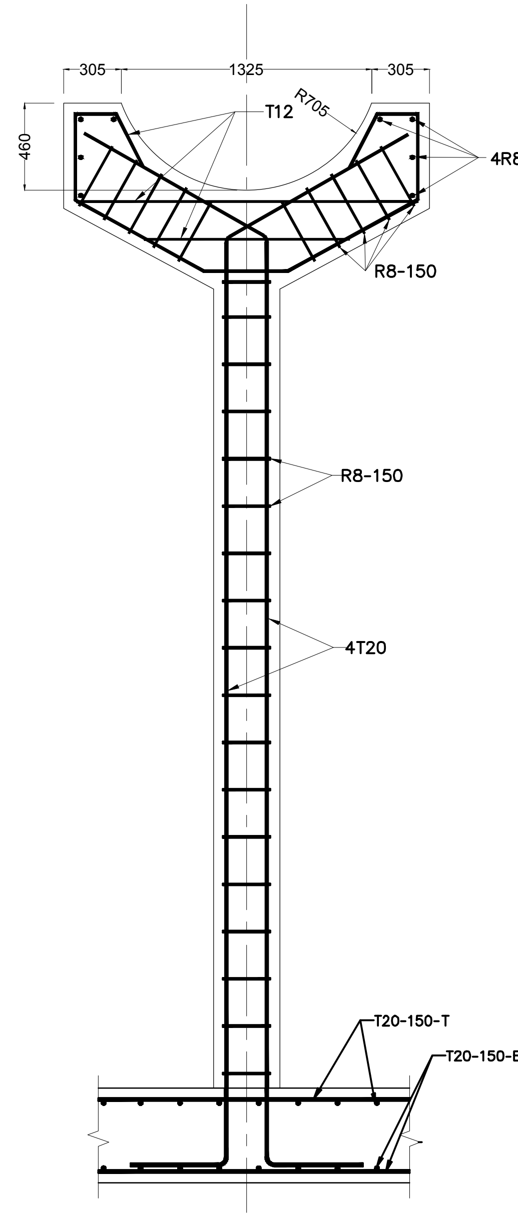
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 21 of 24



COLUMN REINFORCEMENT DETAIL

Scale: 1=15



REINFORCEMENT SECTION

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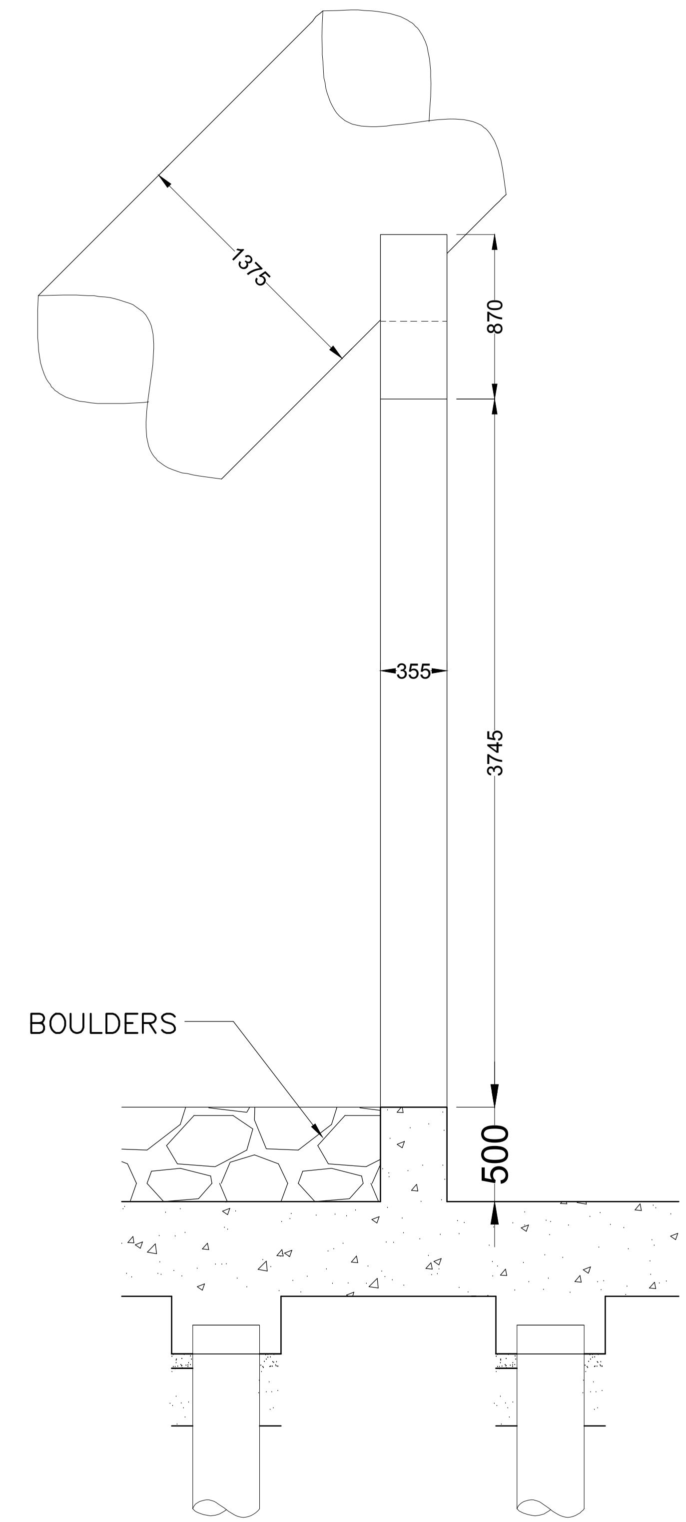

PIPE SUPPORT - LONGITUDINAL SECTION

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

PIPE SUPPORT & REINFORCEMENT

notes:

revisions

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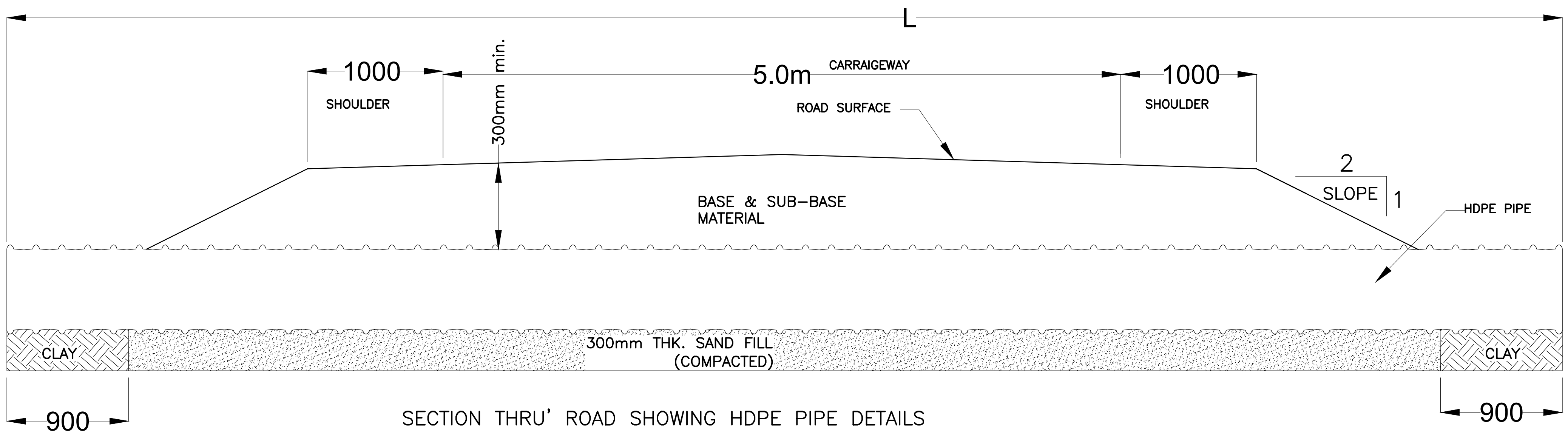
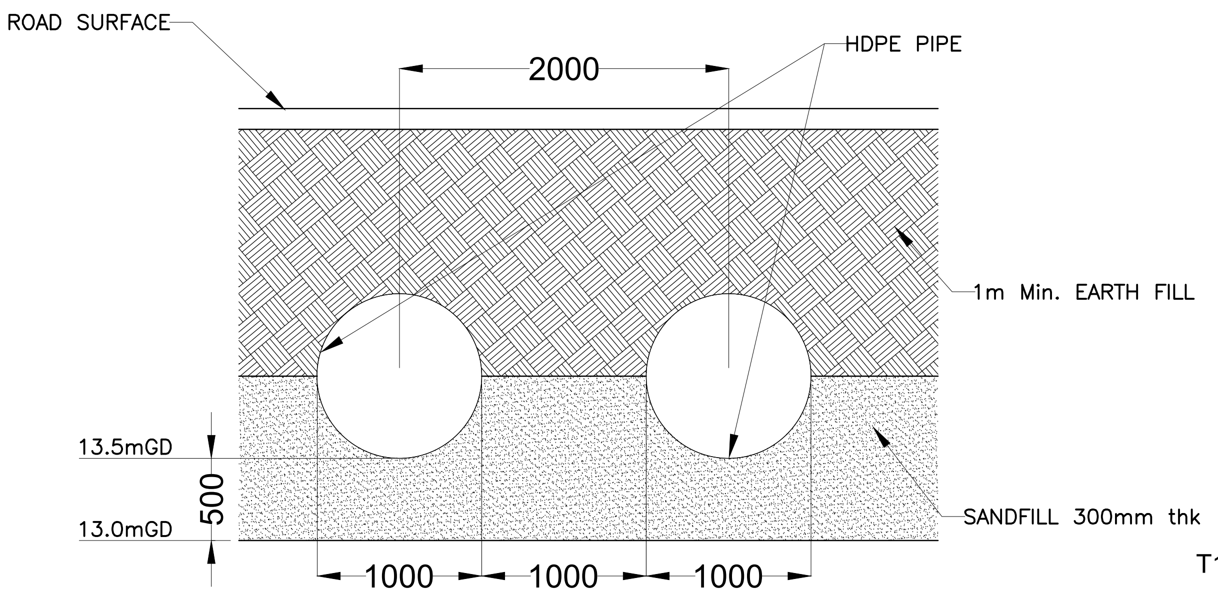
scale: 1:15&1:40	approved by:
drawn by: King	surveyed by:
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 21B of 24



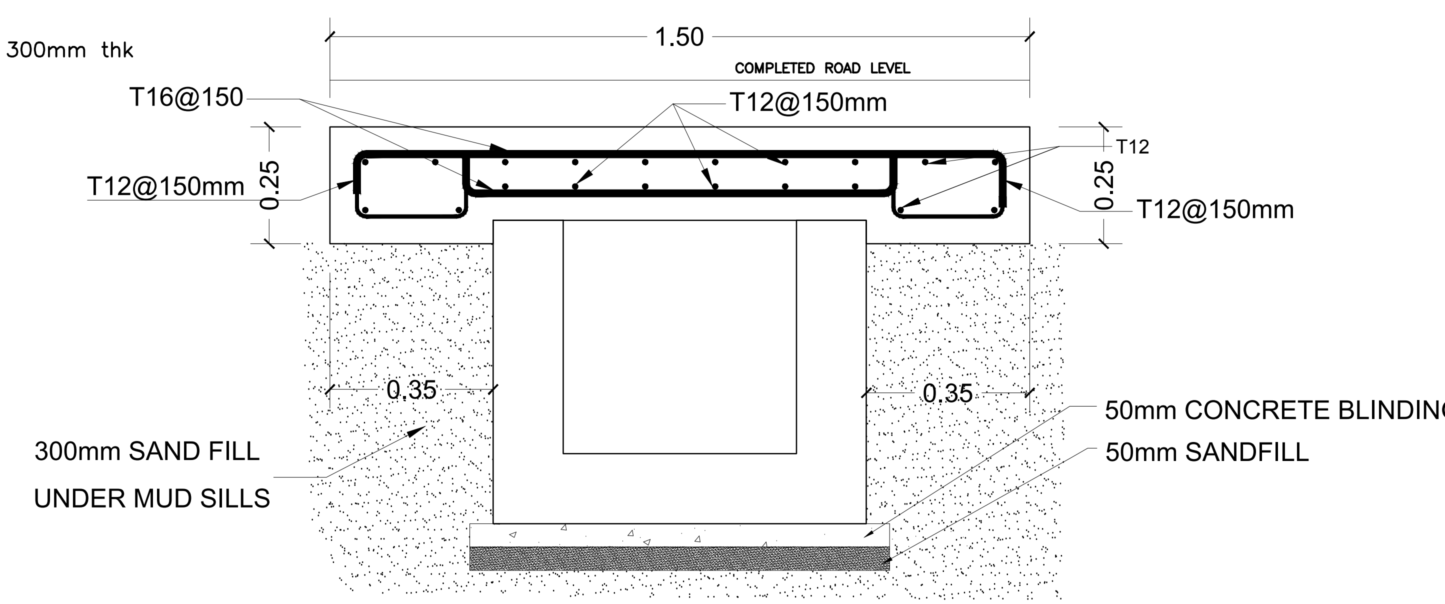
SECTION THRU' ROAD SHOWING HDPE PIPE DETAILS

CULVERT SCHEDULE

CULVERT CODE	DIAMETER mm	LENGTH (L) m	LOCATION CHAINAGE m
PC1	1000	18	0+60



END VIEW



SECTION OF CONCRETE BOX DRAIN (COVER)

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

HDPE PIPE CULVERT DETAILS

notes:

revisions

NO.	REVISIONS	DATE

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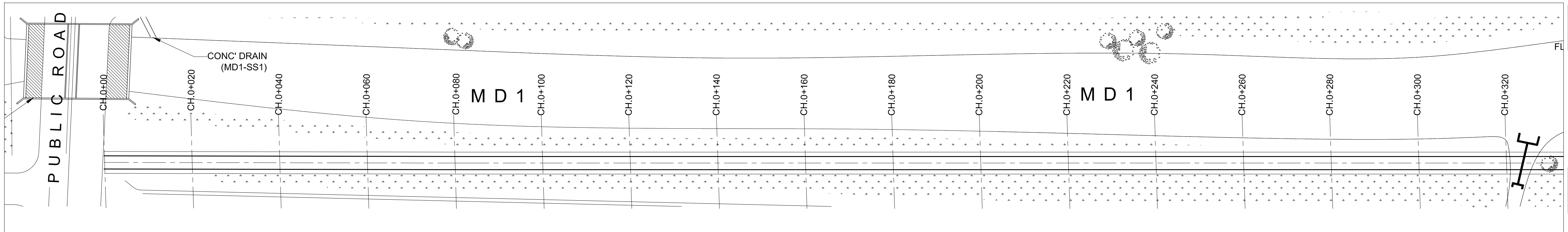
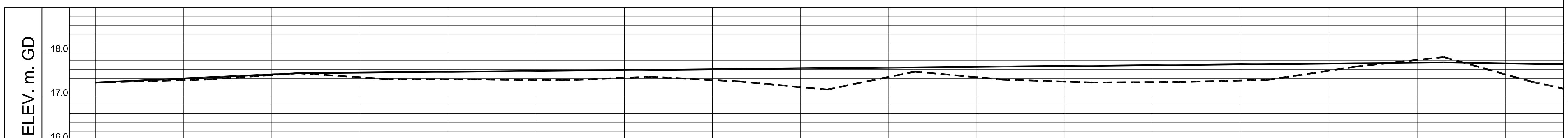
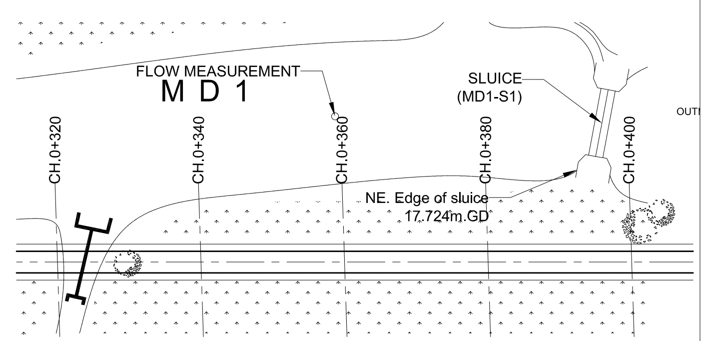
drawn by:	surveyed by:
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 22 of 24

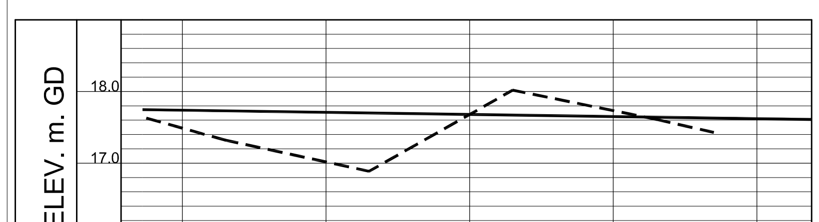




CH.(m)	0.0	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0	200.0	220.0	240.0	260.0	280.0	300.0	320.0

EXIST.ELEV. (m.GD)	DES.ELEV. (m.GD)
17.303	17.303
17.320	17.331
17.376	17.423
17.516	17.516
17.381	17.535
17.376	17.553
17.354	17.572
17.434	17.591
17.329	17.610
17.144	17.628
17.552	17.647
17.370	17.666
17.305	17.684
17.315	17.703
17.365	17.722
17.665	17.741
17.881	17.759
17.321	17.730





CH.(m)	320.0	340.0	360.0	380.0	400.0

EXIST.ELEV. (m.GD)	DES.ELEV. (m.GD)
17.321	17.730
16.887	17.700
18.019	17.670
17.611	17.641
17.429	17.629

consultant:

SRKN'gineering & Associates Ltd.
107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.
REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

PLAN PROFILE
CH 0+000 TO CH 0+420

notes:

- —DESIGNED ELEVATION
- - - - -EXISTING ELEVATION
- –ALL MEASUREMENTS ARE IN METERS UNLESS OTHERWISE STATED.
- –ALL ELEVATIONS ARE REFERENCED TO GEORGETOWN DATUM

revisions

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scale: not to scale	approved by:
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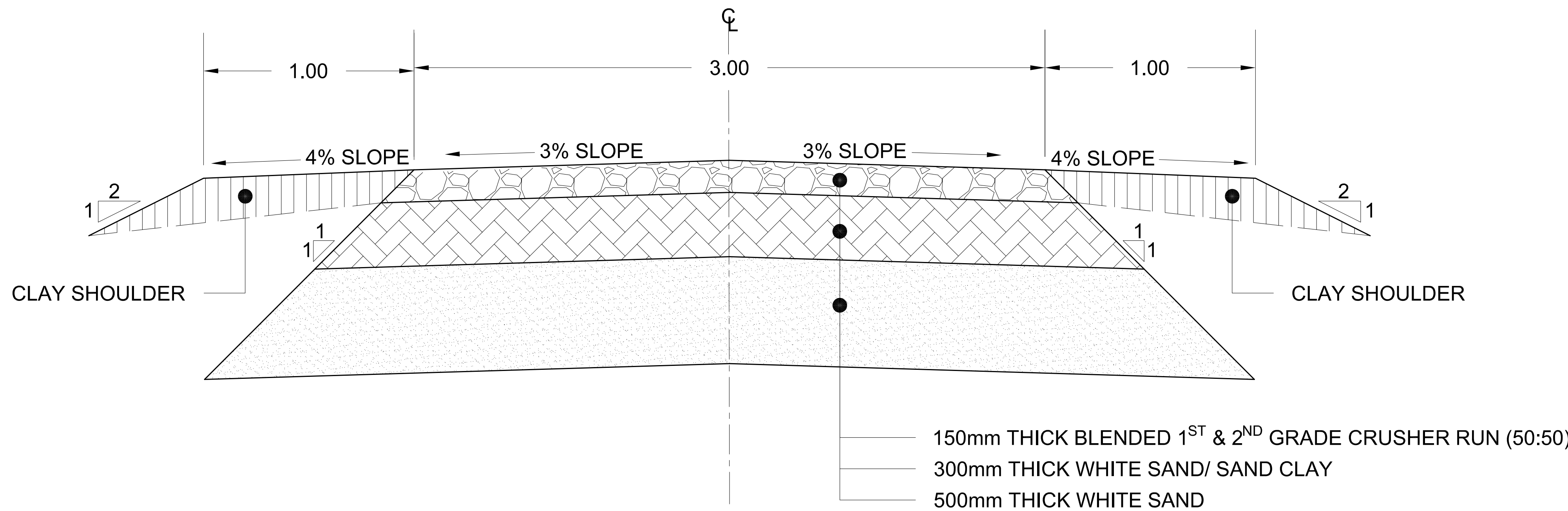
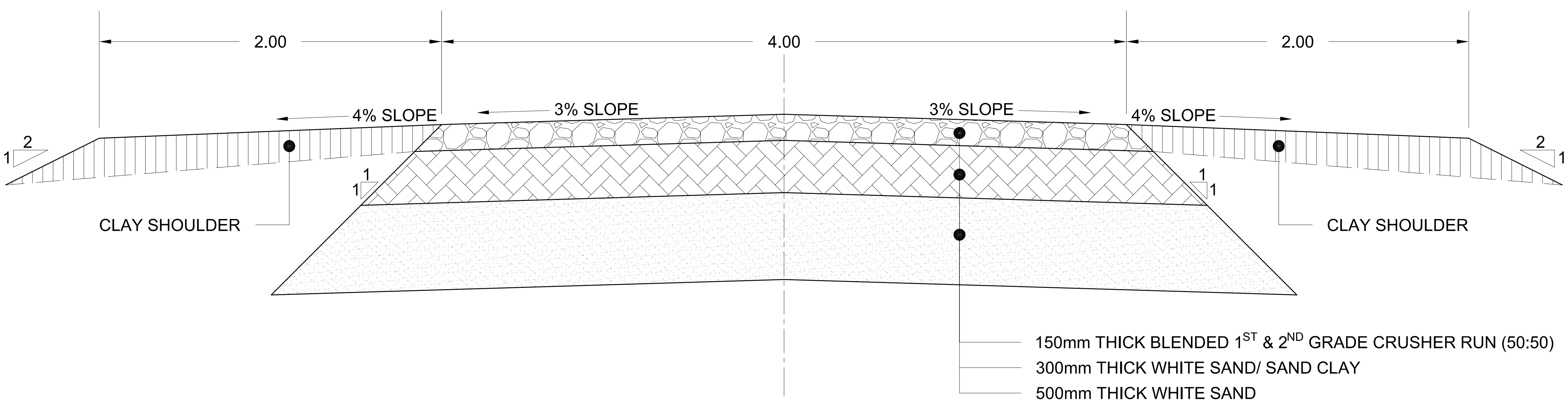
check by:	date: MAY, 2017
project code: SAPS-HR4-2017	drawing no. 23 of 24



TYPICAL DESIGN CROSS SECTION OF ROAD IN HERSTELLING



TYPICAL DESIGN CROSS SECTION OF ROAD IN HERSTELLING

consultant:

SRKN'gineering & Associates Ltd.

107 Lamaha Street
Georgetown, GUYANA.

client:

MINISTRY OF AGRICULTURE,
N.D.I.A.

REGENT STREET AND VLISSENGEN ROAD
GEORGETOWN
GUYANA.

project title:

CONSTRUCTION OF SLUICE & PUMP STATION AT HERSTELLING, E.B.D., REGION No.4

drawing title:

TYPICAL ROAD DESIGN SECTION

notes:

---------- - EXISTING ELEVATION
-ALL MEASUREMENTS ARE IN METERS UNLESS OTHERWISE STATED.
-ALL ELEVATIONS ARE REFERENCED TO GEORGETOWN DATUM

revisions

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scale: not to scale	approved by:
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check by:	date: MAY, 2017
project code: SAPS–HR4–2017	drawing no. 24 of 24