ARAB REPUBLIC OF EGYPT
MINISTRY OF WATER RESOURCES AND IRRIGATION
RESERVOIR AND GRAND BARRAGES SECTOR

THE ARAB REPUBLIC OF EGYPT
THE PROJECT FOR CONSTRUCTION OF THE NEW DIROUT GROUP OF REGULATORS

DETAILED DESIGN STUDY

FINAL REPORT

May, 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

SANYU CONSULTANTS INC.

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Preface

The Detailed Design Study on the Project for Construction of the New Dirout Group of Regulators has started on 1st July 2015. The study was executed in two (2) phases, consists of natural condition survey and basic design study as the first half, and the detailed design study as the last half. The Study was executed in the total study periods of one (1) year and 11 months, until the 7th of July 2017 when the contract period for this study terminates.

In the course of execution of the studies, the Basic Design Report was submitted at the end of July 2016, the Interim Report was submitted at the end of November 2017 as the intermediate phase of the detailed design study. The Final Report consists of the issues consistently on design, drawings, bill of quantities (BQ), construction plan, project cost estimation and draft bidding documents.

For the preparation of the Final Report, we made due consideration on the convenience and acceleration of understanding on the contents of this report by the users who will be engaged for the first time in each expected stage of the Construction Project of the New Dirout Group of Regulators, for their confirmation and understanding of the design concept on this report.

It is our great honor to be engaged in the Japanese Yen Loan Project with condition of the STEP (Special Terms for Economic Partnership) which is the first case to be applied in the irrigation sector in Japan’s Official Development Assistance. We sincerely desire that this Final Report will contribute to the high quality of works on the Construction of the New Dirout Group of Regulators, of which the implementation is expected to start in the near future.

Last of all, JICA Study Team wishes to express the sincerest appreciation to the officials concerned of the Japan International Cooperation Agency and Ministry of the Water Resources and Irrigation, the Arab Republic of Egypt who gave precious comments and guidance to the team.

May, 2017

EXECUTIVE SUMMARY

1. Outline of Design

The Dirout Group of Regulators (hereinafter referred to as "DGRs"), which is the subject of this study, is the core irrigation infrastructure to supply irrigation water to all the beneficiary area located in the middle Nile basin region. The DGRs delivers 9.6 BCM/year of irrigation water or 17% of the gross water resource of the Nile of 55.5 BCM/year taken from the Assiut Barrage into the beneficiary area of 0.6 million ha through the Ibrahimia main canal. The DGRs branches the Ibrahimia main canal into seven (7) main canals, and irrigation water is provided to the beneficiary area through these canals.

The Bahr Yusef canal is the largest canal in capacity among the seven (7) canals. Its length extends as long as 312 km and there are four (4) regulators, namely the Lahoun Regulator, the Mazoura Regulator, the Sakoula Regulator and the Dahab Regulator, all of which were rehabilitated by Japan's Grand Aid from 1995 to 2010.

The DGRs, which was constructed in 1872, is the oldest active regulator in the country, and the weirs cannot function well due to their age. The rehabilitation of the DGRs should, therefore, be urgently implemented. It is expected that the impacts of the rehabilitation of the DGRs should be significant considering the vast beneficiary area and very long canal networks by synergy with the rehabilitation of four (4) regulators in the Bahr Yusef canal.

In view of such a situation, Japan International Cooperation Agency (hereinafter referred to as "JICA") conducted the feasibility study, namely "The Preparatory Survey for the Rehabilitation and Improvement of the Dirout Group of Regulators in the Arab Republic of Egypt" (hereinafter referred to as "F/S"), in 2010 in order to formulate the rehabilitation plan of the DGRs and integrated water management plan for the operational management of the DGRs and other regulators along the Bahr Yusef canal.

The Egyptian Government requested of the Japanese Government the Official Development Assistance (hereinafter referred to as "ODA") loan, which applied Special Terms for Economic Partnership (hereinafter referred to as "STEP"), in March 2013. On March, 2015, JICA signed an ODA loan agreement for the Project for Construction of the New Dirout Group of Regulators (hereinafter referred to as "the Project") with the Egyptian Government after a series of discussions. This study will be conducted for twenty-two (22) months from July 2015 in compliance with the Record of Discussion (hereinafter referred to as "R/D") signed by JICA and the Ministry of Water Resources and Irrigation (hereinafter referred to as "MWRI") on March, 2015, in order to prepare the detailed designs and bidding of documents.

2. Design of the Regulators

2-1 Design conditions

Adherence to the Egyptian code is given first priority in the design criteria applied at the basic design and the detailed design stages for NDGRs construction project, which is supplemented by " Part No.2 Design of Hydraulic Structure, Spillways, Regulators and Barrage" used as the design criteria for the hydraulic facility in Egypt. In the absence of a policy in the Egyptian code regarding an issue, Japanese design criteria in the field of the regulators and *Design Criteria for Irrigation and Drainage, Headworks* will be referred to.

Figure 2-1 and Table 2-1 show the outline of the NDGRs

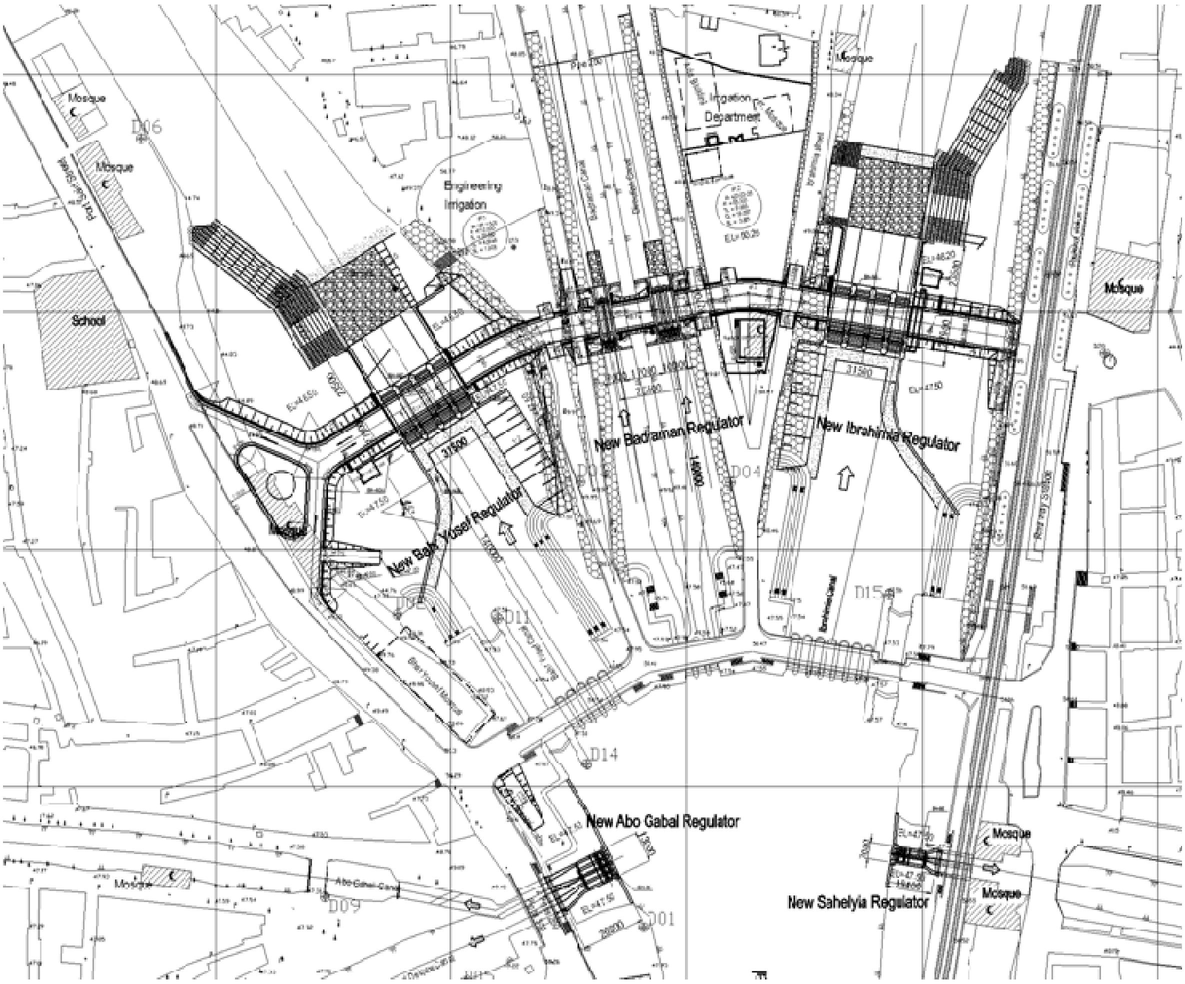


Figure 2-1 General layout of NDGRs

Table 2-1 Outline of NDGRs

Name of Regulator		Bahr Yusef	Ibrahimia	Badraman		AboGabal		Sahelyia	Remarks
Name of Canal				Badraman	Diroutiah	AboGabal	Irad Delgaw		
Design maximum discharge		227 m^3/s	186 m^3/s	9 m^3/s	12 m^3/s	7 m^3/s	9 m^3/s	5 m^3/s	Total 455m^3/s
Design minimum discharge		33.1 m^3/s	23.6 m^3/s	1.2 m^3/s	1.7 m^3/s	0.9 m^3/s	1.3 m^3/s	0.6 m^3/s	Total 62.4m^3/s
Design U/S high water level		EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	
Design U/S low water level		EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Design D/S high water level		EL45.82m	EL45.13m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Width of vent		6.00m	6.00m	2.00m	2.00m	2.00m		2.00m	
Number of vent		4	4	2	3	4		2	
Gate sill elevation		EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43.60m		EL43.00m	
Gate crest elevation		EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m		EL46.55m	
Total gate height		6.55m	6.55m	2.65m	2.35m	2.95m		3.55m	
Foundation	Main body	Cast-in-place RC pile	Cast-in-place RC pile	Raft foundation	Raft foundation	Raft foundation		Raft foundation	
	Apron	Raft foundation	Raft foundation	Raft foundation	Raft foundation	Raft foundation		Raft foundation	
	L-shape wall	Cast-in-place RC pile	Cast-in-place RC pile	-	-	-		-	
Downstream apron	Type	L-type retaining wall	L-type retaining wall	RC flume	RC flume	RC flume		RC flume	
	Length	44.25m	44.25m	23.35m	22.77m	23.87m		16.42m	Note(1)
Seepage control works		Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile		Steel sheet pile	
Bed protection works		Riprap L=30.0m (D_{50}=0.40m,W_{50}=60kg,t=1.00m)	Riprap L=30.0m (D_{50}=0.40m,W_{50}=60kg,t=1.00m)	Riprap L=15.0m (D_{50}=0.20m,W_{50}=10kg,t=0.50m)	Riprap L=15.0m	–		–	t : Thickness including gravel (0.10m)
Bank protection works	D/S	Cantilevered type/Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile wall	Cantilevered sheet pile wall	Cantilevered sheet pile wall	–		–	
		Gabion wall	Gabion wall						
	U/S	Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile	Cantilevered sheet pile wall	Cantilevered sheet pile wall	Brace type steel sheet pile wall		Brace type steel sheet pile wall	
		Wet stone pitching	Wet stone pitching						
Bridge		RC, Total width=12.5m	RC, Total width=12.5m	RC,Total width=12.5m	RC,Total width=12.5m	RC,Total width=6.0m		RC,Total width=6.0m	
Gate facility	Type	Double leaf Fixed wheel gate	Double leaf Fixed wheel gate	Single leaf Slide gate	Single leaf Slide gate	Single leaf Slide gate		Single leaf Slide gate	
	Hoist	Hydraulic cylinder	Hydraulic cylinder	Electric motor	Electric motor	Electric motor		Electric motor	
	Operation speed	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min		0.3 m/min	
	Material	Rolled steel & Stainless steel(Guide frame, bolt & nut, wheels)							
	Stoplogs	1 set	1 set	2 sets					Note(2)
		Height of one piece=1.35m&1.20m		Height of one piece=0.95m&0.85m					
Management facility		Remote control building: RC structure, 2 floors (Stoplogs storage house is established together)							Location and the area is under study
		Local control room: RC structure, 2 rooms (Bahr Yusef & Ibrahimia Regulator)							
Water level gauge		2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	3 sets (U/S:1,D/S:2)		2 sets (U/S:1,D/S:1)	Pressure type

Note: (1) Length of downstream apron for small regulators shows the distance from a gate sill to the existing structure.
(2) One set means a pair of stoplogs for upstream and downstream.
U/S:Upstream, D/S:Downstream

2-2 Operation and Maintenance of regulators

The outline of the operation and maintenance of the NDGRs are shown on the Table 2-2.

Table 2-2 Outline of operation and maintenance of NDGRs

List of operation and maintenance	Outline of operation and maintenance
Management and control of water distribution	Management and control of the water distribution which is necessary to make the yearly plan should be cooperated with the other operators at U.S. and D.S. of NDGRs. The gate operators should control the water discharge from the gates depending on the water level at U.S and D.S.
Maintenance of structures and buildings in NDGRs	In order to secure the structure and function for the longtime, the status check and the rehabilitation are important to conduct properly.
Maintenance of equipment	The equipment, i.g, observation, machine and electric facility, needs proper maintenance. The method of maintenance on the gate facilities are shown as followings; Inspection → Maintenance → Operation. Those works flow should be repeated as the cycle works. The necessary rehabilitation and overhaul to the equipment and the facility should be done if the deteriorations are discovered.
Record of inspection and check	The as build drawings and the design document should be kept in the custody so as to use as the necessity. The records of the inspection and check should be organized into the database and kept for a long term.
Management of target canal bed elevation	The sedimentation at the downstream of the gates could be made adverse effect to the gate operation such as closing completely. The canal bed level at the vicinity of the regulators should be less than the sill level of the gates.

2-3 Proposal for preservation works of the existing DGRs

(1) Prerequisites for examination of preservation measures

As the prerequisites for the proposal on the necessary and reasonable works of the preservation of the existing DGRs, the following purposes and the deterioration curve shown on Figure 2-2 should be utilized for the examination.

① To preserve the existing DGRs as a historical monument.
② To the practical functions of regulators by the removal of the gate or keeping the gates open completely.
③ To remain the bridge function with some traffic restrictions for large and heavy vehicles.

(2) Proposal for necessary survey and feasible measures based on present data

In order to explore the appropriate preservation measures, the visual inspection, the boring survey, the laboratory test and structural analysis should be done in addition to the past study and survey. The feasible measures based on the present available data are shown as followings;

- ✓ In order to reduce the burden load on the existing DGRs except for Abo Gabal and Sahelyia regulators, the passable traffic shall be restricted.
- ✓ All the gates shall be opened completely to alleviate the up-lift pressure to the basement of the regulators.
  (The necessary dredging works should be done before the gates opens.)
- ✓ The significant damage found in the past (2010) survey such as eroded and fallen out bricks inside of the vents and the apron erosion at Bahr Yusef and Ibrahimia regulators should be rehabilitated.

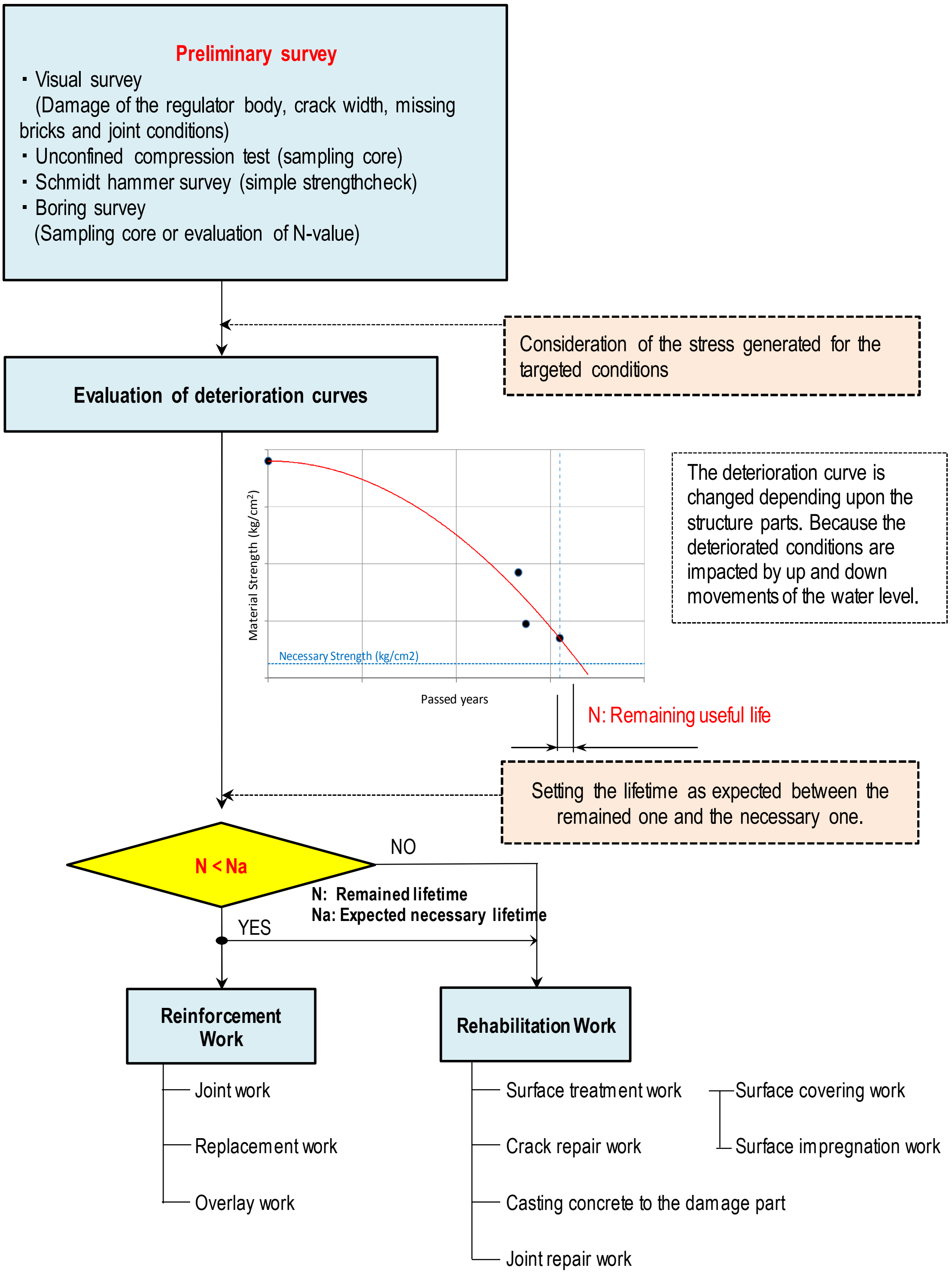


Figure 2-2. Flow of examination of appropriate measure works

2-4 Groundwater simulation analysis

(1) Purpose of analysis

The construction of NDGRs will result in a rise in canal water level, which induces rise in the groundwater level around the DGRs such as mosques, station, highways, buildings in the markets and resident area. There may be a serious concern of the damage of their structures, aggravating sanitary environment, the floating of buildings, and the deterioration of structure foundations, etc.

In this context, the aim of a groundwater simulation analysis is to predict and infer groundwater behavior after NDGRs construction, and to evaluate its environmental impact, and to provide data that is useful in deciding on the necessity and scale of mitigation measures.

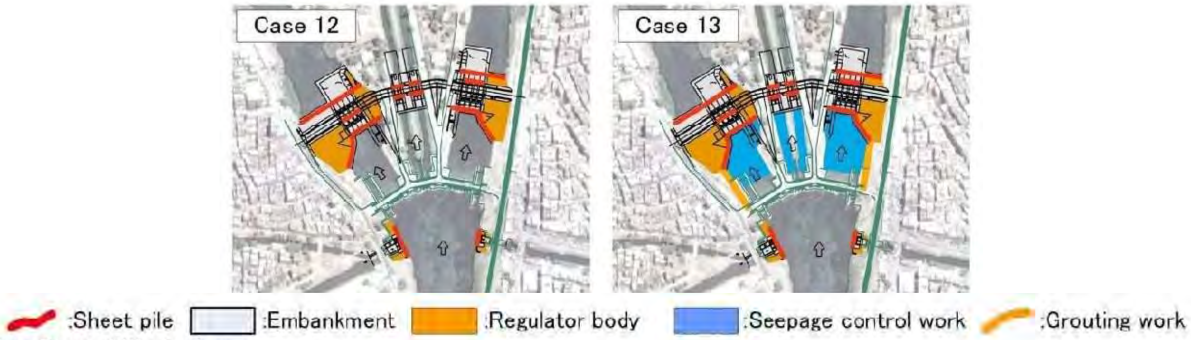
(2) Result of the analysis

The case 12 which takes sheet pile works, bank protection works and embankment works (proposed in the D/D study) restricts the risk of groundwater rise to surrounded foundation and underground structures with at most 0.3m rise in water level even beside the canals. As shown in Table 2-3, it was found that complete offset work is difficult even in the case with further seepage control works (case 13). Therefore, continuous monitoring work of groundwater and its analysis are recommended in addition to the improvement work of public sewage system to mitigate the groundwater rise caused by civilization.

Table 2-3 Simulation conditions and their results

Case	Condition					Result		
	Canal Water level	Sheet Pile	Embank ment	Seepage Control Work	Grouting	GW Rise	Inference Area	Increase in Seepage Amount
Case 12 (D/D design)	Plan	○	○	×	×	0.09m	300m (RB) 270m (LB)	39 m³/day
Case13 (Additional seepage control works)	ditto	○	○	○	○	0.06m	300m (RB) 290m (LB)	33 m³/day

Layout of seepage control works



Note: Peemeability is given as

Sheetpile: k–1.15x10^{-7} cm/sec x 1.25m thickness of wall(1 grid)

Embankment/Regulator body: k=1.15x10^{-6} cm/sec x beds' thickness underlain the stricter/embankment

Seepage Control works: k=1.15x10^{-5} cm/sec x beds' thickness underlain the stricter/embankment

Grounting: : k=1.15x10^{-5} cm/sec x 2.5 thichness of wall(1 grid)

3. Formulation of Integrated Water Management System

3-1 Target facilities to be covered with integrated water management system

In order to distribute irrigation water fairly and appropriately to the Project area, integrated water management system will be formulated for realizing wide area monitoring of irrigation water and water allocation plan. Each facility in the irrigation system consists of water diversion facilities, regulators, main canals, intakes for branch canals, branch canals, farm land and drainage canals.

In order to efficiently distribute water to 600,000 ha-irrigation area in accordance with irrigation system requirements, each facility must fulfill its function satisfactorily. The scope of integrated water management system shall be included the irrigation facilities on the main canals under the supervision of the GDWD in Assiut of MWRI and that of GDIs.

The target facility in water management covers the beginning facility of the main canal such as head regulator, the important facility for management along the main canal, and the branch canal intake with the large amount of water distribution from the main canal to the branch canal.

Table 3-1 Facilities targeted for monitoring (1/2)

Irrigation facilities			Name of the Target facilities		Number.
Regulator	Bahr Yusef canal		Dahab Regulator Sakoula Regulator Mazoura Regulator	Lahoun Regulator Abo El Shekok Regulator Regulator km39	6
	Ibrahimia canal		New Hafze Regulator Matay Regulator Maghagha Regulator	Sharahna Regulator El Gandy Regulator Ashmont Regulator	6
Branch canal	Bahr Yusef canal	Intake	Manshat EL Dahab El Hareka El Sabaa	Quftan Wesh El-Bab EL-Giza	6
		Weir	Hassan Wasef Weir		1
		Pump	New Kamdeer P.S. New Terfa P.S. Old Terfa P.S.	Old Sakoula P.S. Mazoura P.S.(2)	5
	Ibrahimia canal	Intake	Irad El Maharak El Kosia East Hafze West Hafze Adkak	Gendia Abo Shosha EL Soultany Tansa El Mansour	10
		Weir	Serry Weir	Maghagha Weir	2
Ibrahimia main canal			Ibrahimia Head Regulator		1
Lake			Quarun Lake		1
Total					38

Table 3-2 Facilities targeted for monitoring (2/2)

Irrigation facilities	Name of the Target facilities		Number
Dirout Group of Regulators	Bahr Yusef Regulator Ibrahimia Regulator Irad Delgaw Regulator Abo Gabal Regulator	Badraman Regulator Dairotiah Regulator Sahelyia Regulator	7
Total			7

3-2 Centralized management system

Remote monitoring of water level developed by the telemetry engineers and promoted by the CDT is expected to be utilized in the future following its wide dissemination because of its high expansibility and technical simplicity. Therefore, the CDT-based monitoring system shall be used continuously for the remote monitoring of the water levels at the regulators in the main canals, at the intakes of the branch canals, and for data processing that converts water levels into flow rate. The existing water management system is using the GPRS communication network system. The access point (APN), that is, the facility for implementing TCP/IP data transmission by GPRS communication, is managed by MWRI. The integrated water management system uses the same communication method and data transmission method in order to integrate with the current telemetry system, and uses the same facility of APN.

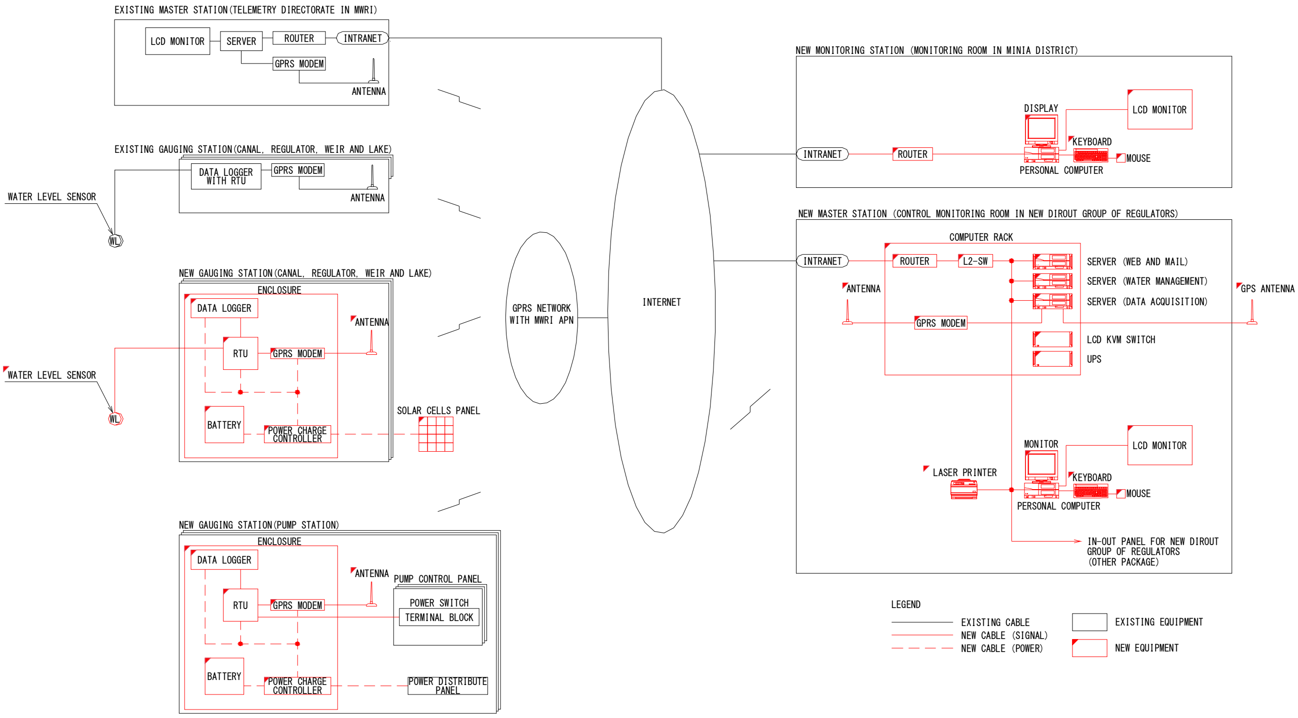


Figure 3-1 Integrated water management system composition of GPRS communication

3-3 Design of gauging station and master station

In the water level gauging station installed in the regulators or branch canal intakes, the water levels upstream and downstream of the gate are measured. The monitored water level is used for grasping the status of water distribution and future's proper gate operation.

The central monitoring station (master station) will be installed in the same building of the control house for NDGRs. The central monitoring office has a function to be collected, recorded and evaluated water level data at each gauging stations.

Table 3-3 Equipment of the gauging station

GPRS modem	Water level sensor	Protection pipe
RTU with Data logger	Enclosure	Frame of solar panel
Charge controller	Pole	Frame of enclosure
Battery	Foundation	Wiring cable
Solar panel	Junction box	

Table 3-4 Equipment of the central monitoring station (master station)

GPRS modem	Web & E-mail server	19 inch Rack
Router	KVM Switch	Monitoring terminal
L2-SW	KVM Monitor	Laser printer
Data acquisition server	Keyboard & Mouse	LCD Monitor
Water management server	UPS	

4. Construction Planning

4-1. Temporary Works

(1) Outline of the project

The construction site is located in an urban area, and the national railway and the national road run on the east and west sides, respectively, of the construction site. Both the temporary work plan and the construction plan were formulated using the field survey, the existing condition survey, and the construction equipment and materials survey, and take the actual conditions around the site into consideration.

The project consists of the following two components.

(a) Construction of the NDGRs 140 m downstream from the existing DGRs.

(b) Improvement of the communications facilities pertaining to the construction of the water distribution system.

Table 4-1. Outline of the project

Item	Structures
1) New Dirout Group of Regulators	
(a) Construction of new regulators	Construction work on six regulators
(b) Installation of gates	
Bahr Yusef	W 6.0 m × H 6.55 m, total 4 vents
Ibrahimia	W 6.0 m × H 6.55 m, total 4 vents
Abo Gabal	W 2.0 m × H 2.95 m, total 4 vents
Badraman	W 2.0 m × H 2.65 m, total 2 vents
Diroutiah	W 2.0 m × H 2.35 m, total 3 vents
Sahelyia	W 2.0 m × H 3.55 m, total 2 vents
(c) Improvement of peripheral facilities	Construction of parallel bridge Improvement of retaining walls
(d) Cofferdam works	Single and double cofferdams of steel sheet pile
2) Integrated Water Management	
(a) Main canal gates management system (b) Branch canal intake management system (c) Establishment of integrated water management centre	Monitoring system installation work Monitoring system installation work Construction of centre building

Figure 4-1 shows the layout plan of temporary works.

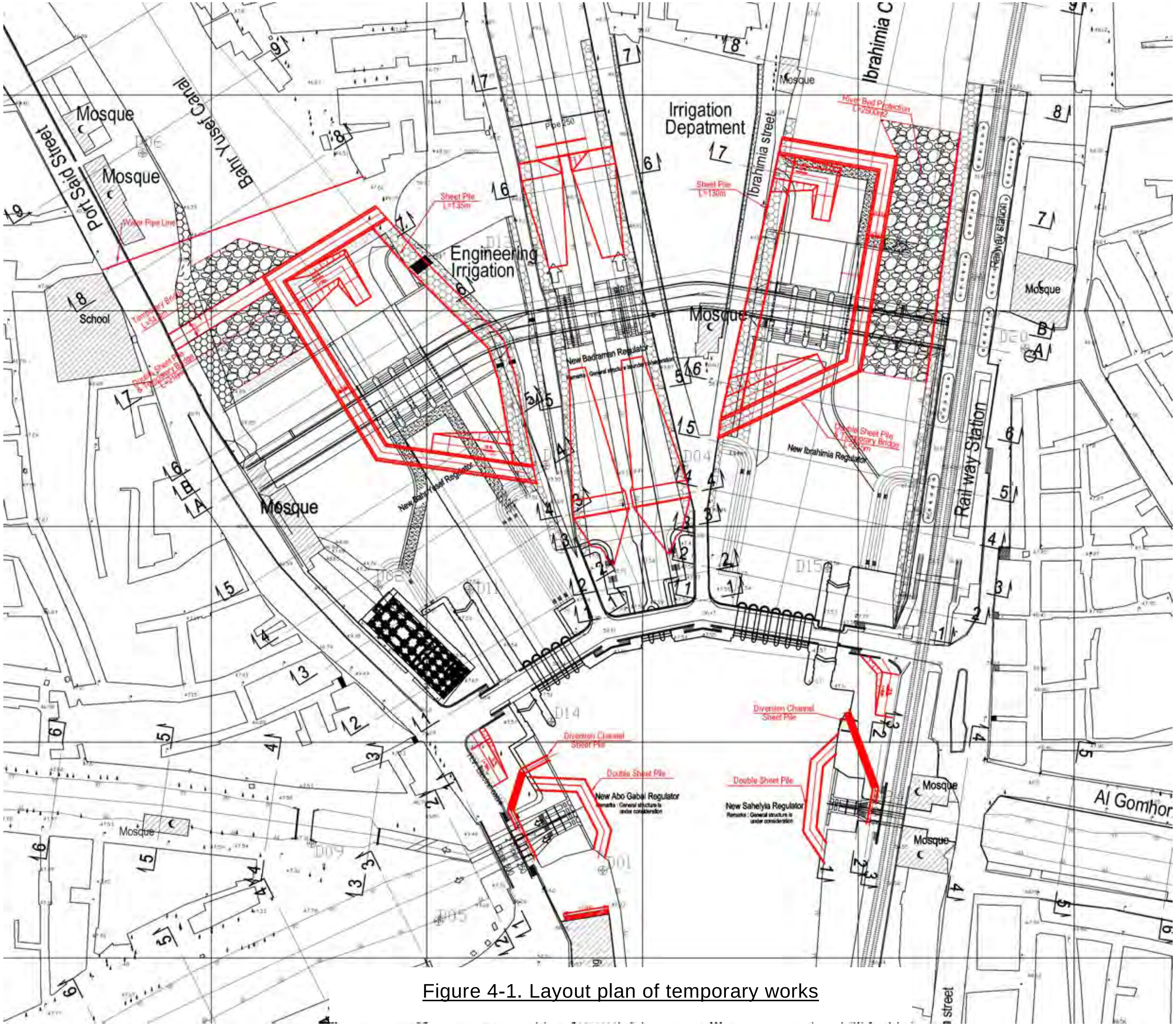


Figure 4-1. Layout plan of temporary works

4-2. Construction of the NDGRs and Water Management Facilities

In the construction of the NDGRs, the construction of Bahr Yusef regulator on the downstream side will begin first, and secondly the construction of Ibrahimia regulator will start. The construction of the other regulators, Badraman and Diroutiah, and on the upstream side, Abo Gabal and Sahelyia, will be performed in parallel with the construction of Bahr Yusef and Ibrahimia.

The construction flow of Bahr Yusef, Ibrahimia and the other regulators is as follows:

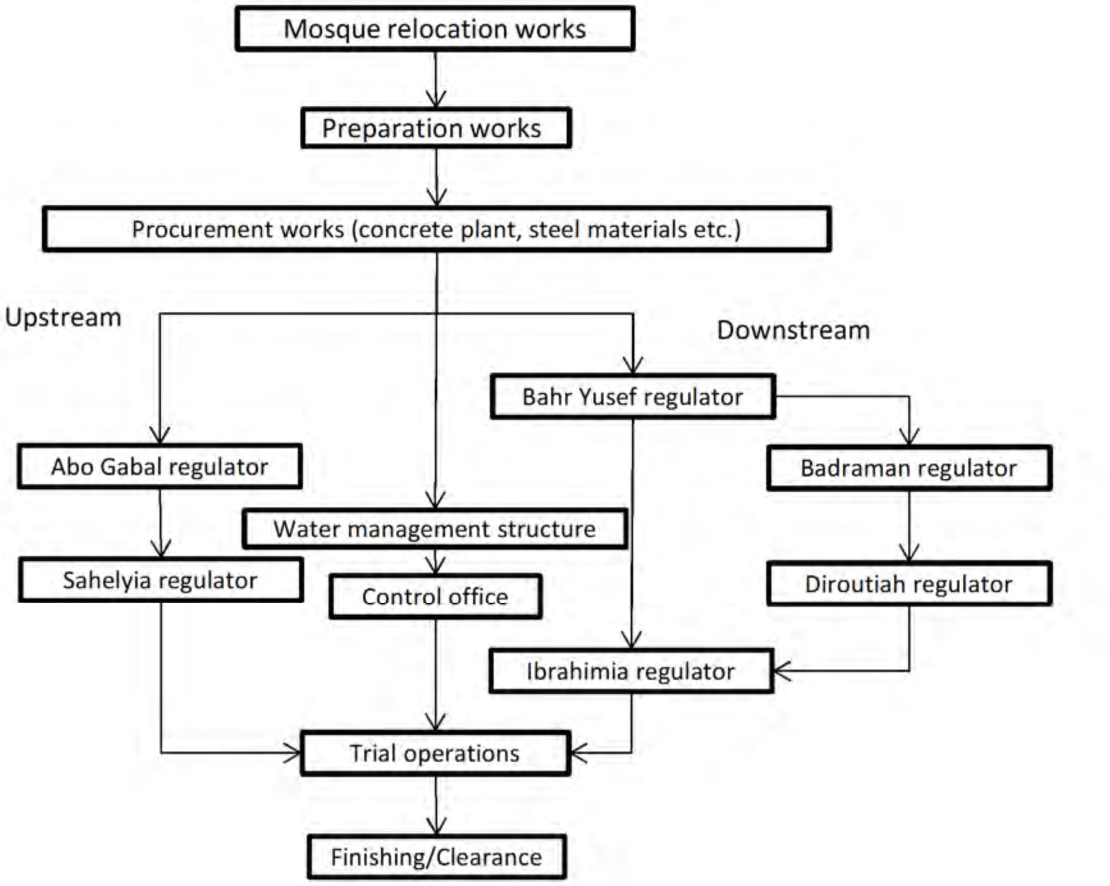


Figure 4-2. Regulator construction flow

The construction will start after the relocation of the mosque is completed by the Egypt side.

Preparation work → Temporary bridge → Double sheet coffer dam → Removal of existing facilities, Excavation inside site → Foundation piles and waterstop sheet piles → Construction of regulator structure → Installation of gates and trial operation → Removal of double sheet piles and switching diversion → Revetment work and appurtenant work (road works and electrical work) → Integrated trial operation/Operation training → Finishing/Clearing

The manufacture and transport of the gates, machinery and electrical equipment, the building work and the revetment work proceed in parallel with the construction of the structures and the installation and trial operation of the gate.

4-3. Work procedure

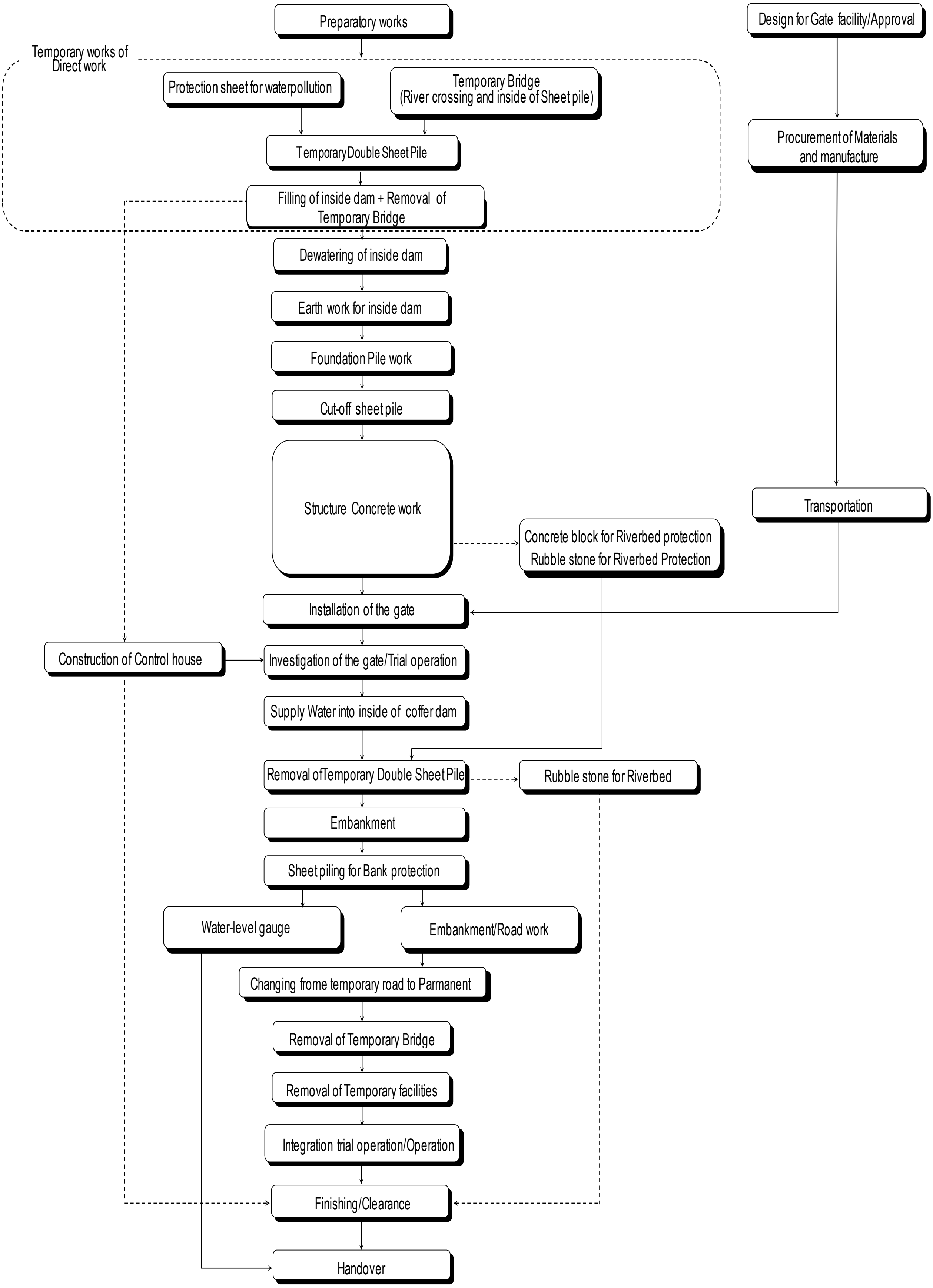
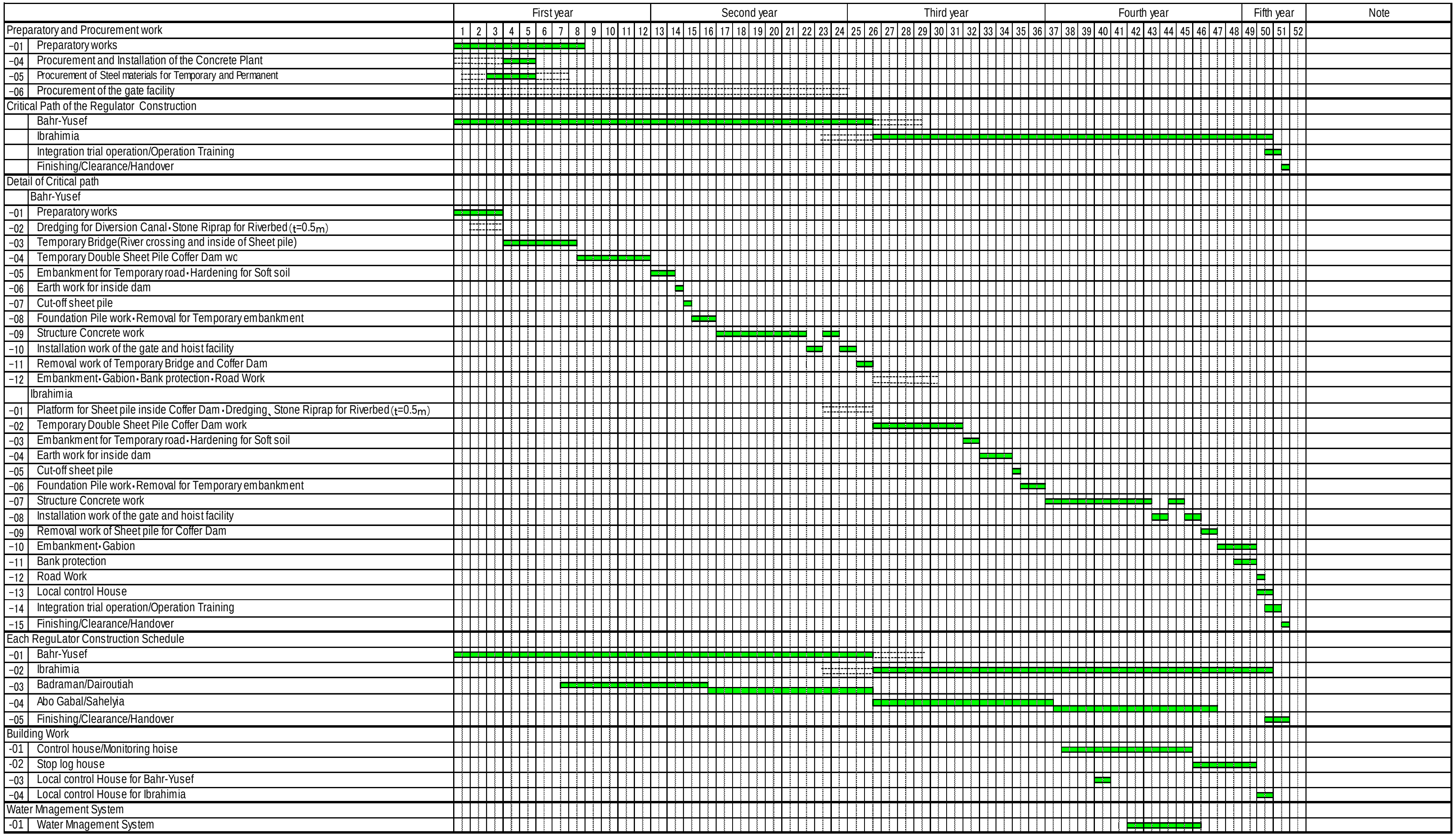


Figure 4-3. Work procedure

4-4. Construction schedule

Table 4-2. Construction schedule (large regulators)



		First year												Second year												Third year												Fourth year												Fifth year				Note
Preparatory and Procurement work		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	
−01	Preparatory works	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩																																													
−04	Procurement and Installation of the Concrete Plant	┄	┄	┄	🟩	🟩																																																
−05	Procurement of Steel materials for Temporary and Permanent	┄	┄	🟩	🟩	🟩	┄	┄																																														
−06	Procurement of the gate facility	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄	┄																													
Critical Path of the Regulator Construction																																																						
	Bahr-Yusef	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	┄	┄	┄																								
	Ibrahimia																							┄	┄	┄	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
	Integration trial operation/Operation Training																																																		🟩	🟩		
	Finishing/Clearance/Handover																																																			🟩		
Detail of Critical path																																																						
	Bahr-Yusef																																																						
−01	Preparatory works	🟩	🟩	🟩																																																		
−02	Dredging for Diversion Canal・Stone Riprap for Riverbed (t=0.5m)		┄	┄																																																		
−03	Temporary Bridge(River crossing and inside of Sheet pile)				🟩	🟩	🟩	🟩	🟩																																													
−04	Temporary Double Sheet Pile Coffer Dam wc								🟩	🟩	🟩	🟩	🟩																																									
−05	Embankment for Temporary road・Hardening for Soft soil													🟩	🟩																																							
−06	Earth work for inside dam														🟩																																							
−07	Cut-off sheet pile															🟩																																						
−08	Foundation Pile work・Removal for Temporary embankment															🟩	🟩																																					
−09	Structure Concrete work																	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩																													
−10	Installation work of the gate and hoist facility																						🟩	🟩	🟩	🟩																												
−11	Removal work of Temporary Bridge and Coffer Dam																									🟩	🟩																											
−12	Embankment・Gabion・Bank protection・Road Work																										┄	┄	┄	┄	┄																							
	Ibrahimia																																																						
−01	Platform for Sheet pile inside Coffer Dam・Dredging、Stone Riprap for Riverbed (t=0.5m)																							┄	┄	┄	┄																											
−02	Temporary Double Sheet Pile Coffer Dam work																										🟩	🟩	🟩	🟩	🟩	🟩																						
−03	Embankment for Temporary road・Hardening for Soft soil																																🟩																					
−04	Earth work for inside dam																																	🟩	🟩																			
−05	Cut-off sheet pile																																			🟩																	
−06	Foundation Pile work・Removal for Temporary embankment																																			🟩	🟩																
−07	Structure Concrete work																																					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩								
−08	Installation work of the gate and hoist facility																																											🟩	🟩	🟩	🟩							
−09	Removal work of Sheet pile for Coffer Dam																																														🟩	🟩						
−10	Embankment・Gabion																																															🟩	🟩	🟩				
−11	Bank protection																																																🟩	🟩				
−12	Road Work																																																		🟩			
−13	Local control House																																																		🟩			
−14	Integration trial operation/Operation Training																																																		🟩	🟩		
−15	Finishing/Clearance/Handover																																																			🟩		
Each ReguLator Construction Schedule																																																						
−01	Bahr-Yusef	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	┄	┄	┄																								
−02	Ibrahimia																							┄	┄	┄	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
−03	Badraman/Dairoutiah							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩																											
−04	Abo Gabal/Sahelyia																										🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩						
−05	Finishing/Clearance/Handover																																																		🟩	🟩		
Building Work																																																						
-01	Control house/Monitoring hoise																																						🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩								
-02	Stop log house																																														🟩	🟩	🟩	🟩				
-03	Local control House for Bahr-Yusef																																								🟩													
-04	Local control House for Ibrahimia																																																		🟩			
Water Mnagement System																																																						
-01	Water Mnagement System																																										🟩	🟩	🟩	🟩	🟩							

Table 4-3 Construction schedule (small regulators)

		First year												Second year												Third year												Fourth year												Fifth year				Note
Detail of Critical path for Small Regulator		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	
	Badraman																																																				
-01	Preparatory works・Temporary Embankment for Coffer Dam・Steel Sheet Pile						🟩	🟩																																												
-02	Hardning for Soft Soil・Earth Work・Cut-off Steel Sheet Pile							🟩	🟩																																											
-03	Structure Concrete work								🟩	🟩	🟩	🟩	🟩																																							
-04	Installation work of the gate and hoist facility											🟩	🟩	🟩																																						
-05	Bank Protection・Stone Riprap・Removal for Embankment for Coffer Dam & Sheet pile														🟩																																					
-06	Road Work・Trial Operatio															🟩																																				
	Diroutiah																																																				
-01	Preparatory works・Temporary Embankment for Coffer Dam・Steel Sheet Pile															🟩	🟩																																			
-02	Hardning for Soft Soil・Earth Work・Cut-off Steel Sheet Pile																🟩	🟩																																		
-03	Structure Concrete work																	🟩	🟩	🟩	🟩	🟩	🟩																													
-04	Installation work of the gate and hoist facility																					🟩	🟩	🟩																												
-05	Bank Protection・Stone Riprap・Removal for Embankment for Coffer Dam & Sheet pile																							🟩	🟩																											
-06	Road Work・Trial Operation																									🟩																										
	Abo Gabal																																																				
-01	Preparatory works・Embankment for Access Road・Sheet pile for Coffer Dam & Temporary Canal																									🟩	🟩																									
-02	Hardning for Soft Soil・Earth Work・Cut-off Steel Sheet Pile																											🟩																								
-03	Structure Concrete work																												🟩	🟩	🟩	🟩	🟩	🟩																		
-04	Installation work of the gate and hoist facility																																🟩	🟩	🟩																	
-05	Bank Protection・Stone Riprap・Removal for Embankment for Coffer Dam & Sheet pile																																		🟩	🟩																
-06	Trial Operation																																				🟩															
	Sahelyia																																																				
-01	Preparatory works・Embankment for Access Road・Sheet pile for Coffer Dam & Temporary Canal																																				🟩	🟩														
-02	Hardning for Soft Soil・Earth Work・Cut-off Steel Sheet Pile																																						🟩													
-03	Structure Concrete work																																							🟩	🟩	🟩	🟩	🟩								
-04	Installation work of the gate and hoist facility																																												🟩							
-05	Bank Protection・Stone Riprap・Removal for Embankment for Coffer Dam & Sheet pile																																												🟩	🟩						
-06	Trial Operation																																														🟩					
	Water Management System																																																				
	Civil works																																																				
-01	Assiut (4 sites)																																									🟩										
-02	West Minia (6 sites)																																									🟩	🟩									
-03	East Minia (8 sites)																																									🟩	🟩									
-04	Beni suef and Fayoum (8 sites)																																									🟩	🟩									
	Electrical works																																																				
-01	Master station (Dirout)																																											🟩	🟩							
-02	Monitoring station (Minia)																																											🟩	🟩							
-03	Assiut (4 sites)																																											🟩								
-04	West Minia (6 sites)																																											🟩	🟩							
-05	East Minia (8 sites)																																											🟩	🟩							
-06	Beni suef and Fayoum (8 sites)																																											🟩	🟩							
-07	Software development in cairo																																🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									
-08	Commissioning test																																													🟩						

5. Project Cost Estimation

5-1. Criteria and manual of project cost estimation

(1) Time of cost estimation January 2017

(2) Expected commencement date February 2018

(3) Exchange rate the average rate for the three months from February to April 2017

1USD = ¥113.34, 1EUR = ¥121.26, 1LE = ¥6.49

(4) Indirect cost

- Indirect cost for Civil and Temporary Works : 35% of each direct cost
- Indirect cost for Gate Manufacture : 3% of the direct cost

(5) Unit price of manpower, materials, and rental fee of heavy equipment etc.

- Procured from Japan: 90% of the average price between two books for monthly unit price published in Japan. When there was any item not described on the two books, competitive estimations from three companies were applied.
- Procured in Egypt: 100% of the average price of the competitive estimations from three companies

(6) Price escalation

- Price escalation rate for LC :
  total ratio is 18.9% (17.2% of recent price escalation + 1.0% per year during construction)
- Price escalation rate for FC :
  total ratio is 4.2% (1.6% per year during construction)

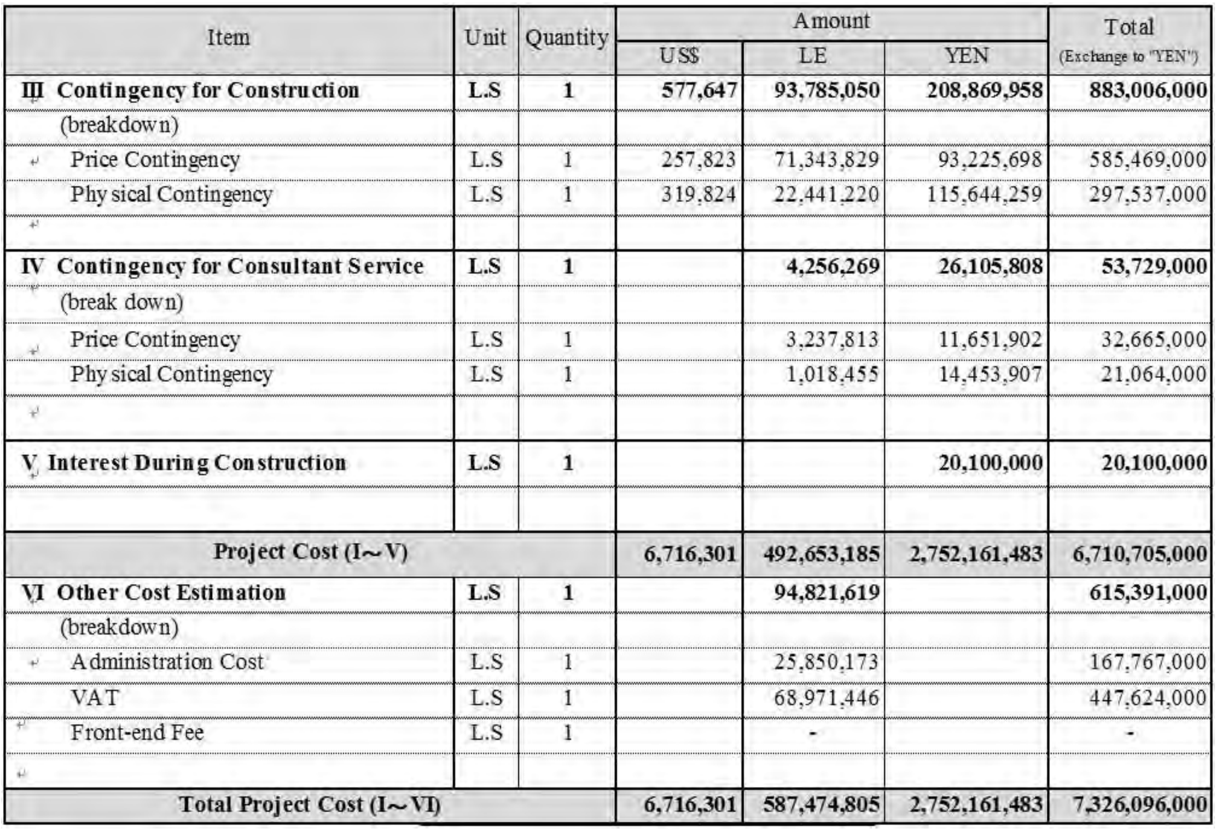
(7) Depreciation ratio for temporary steel material 50%

5-2. Estimation of the project cost

Table 5-1. Construction and project cost estimation (1/2)

Item	Unit	Quantity	Amount			Total
			US$	LE	YEN	(Exchange to "YEN")
I Construction Cost	**L.S**	**1**	**6,138,654**	**377,480,579**	**2,219,659,487**	**5,365,263,000**
(breakdown)						
A. Civil Works	L.S	1	1,422,252	213,048,447	1,870,904,765	3,414,787,000
B. Temporary works	L.S	1	4,309,402	117,144,168	348,754,722	1,597,447,000
C. Building works	L.S	1		4,589,565		29,786,000
D. Integrated Water Management System	L.S	1		42,698,399		277,112,000
E. Dispute Board	L.S	1	407,000			46,129,000
II Consultant Service	**L.S**	**1**		**17,131,288**	**277,426,230**	**388,607,000**

Table 5-2. Construction and project cost estimation (2/2)



Item	Unit	Quantity	Amount			Total
			US$	LE	YEN	(Exchange to "YEN")
Ⅲ Contingency for Construction	**L.S**	**1**	**577,647**	**93,785,050**	**208,869,958**	**883,006,000**
(breakdown)						
Price Contingency	L.S	1	257,823	71,343,829	93,225,698	585,469,000
Physical Contingency	L.S	1	319,824	22,441,220	115,644,259	297,537,000
Ⅳ Contingency for Consultant Service	**L.S**	**1**		**4,256,269**	**26,105,808**	**53,729,000**
(break down)						
Price Contingency	L.S	1		3,237,813	11,651,902	32,665,000
Physical Contingency	L.S	1		1,018,455	14,453,907	21,064,000
Ⅴ Interest During Construction	**L.S**	**1**			**20,100,000**	**20,100,000**
Project Cost (Ⅰ～Ⅴ)			**6,716,301**	**492,653,185**	**2,752,161,483**	**6,710,705,000**
Ⅵ Other Cost Estimation	**L.S**	**1**		**94,821,619**		**615,391,000**
(breakdown)						
Administration Cost	L.S	1		25,850,173		167,767,000
VAT	L.S	1		68,971,446		447,624,000
Front-end Fee	L.S	1		-		-
Total Project Cost (Ⅰ～Ⅵ)			**6,716,301**	**587,474,805**	**2,752,161,483**	**7,326,096,000**

Table 5-3 the Ratio for STEP Loan

Item	Grade	Detail	Unit	Quantity	Amount
A-11. Gate manufactures and works					
1. Gate manufacture	gate leaf	6.0×6.55	L.S	2.0	324,769,300
	gate guide		L.S	2.0	272,305,220
	hoisting device	hydraulic	L.S	2.0	846,320,100
	remote operation system		L.S	2.0	228,439,580
1. Installation for manufactures	Japanese mechanical engineer		day	1,050.0	31,403,295
	Japanese electrical engineer f		day	1,050.0	35,009,415
sub-total					1,738,246,910
A-12. Expense of the machine and facilities					
1. Rent fee for heavy equipment	2). Vibration hunmer (1)	Hydraulic, 232KW	day	1,507.0	42,926,895
sub-total					42,926,895
B-1. Temporary Coffer Dam					
1. Double sheet pile	14). Japanese sheet pile opera		day	2,190.0	79,914,195
sub-total					79,914,195
B-8. Transportation / Shipment					
	B-8-13. packing	951.0 F/T	L.S	1.0	12,754,883
	B-8-14. loading		L.S	1.0	7,095,825
	B-8-15. ocean transpotation		F/T	951.0	26,190,947
sub-total					46,041,655
Total					1,907,129,655

Ratio of the goods and services to be procured from Japan

1) Construction Cost 5,365,263 10^3 YEN

2) Cost of the goods and services to be procured from Japan 1,907,130 10^3 YEN

2)／1)＝ 35.5% ＞30%

6. Draft Bidding Documents

6-1. Contents of Works for the Preparation of Bidding Documents

6-1-1. Regulation and framework of procurement of public works in the Egyptian government

In Egypt, procurement of public works is made based on the Law No.89 of 1998 and its implementation regulations (Ministerial Decree No. 1367 of 1998), commonly referred to as "Tenders Law". Based on this law, executing agencies of public works prepare bidding documents, and execute pre-qualification, tendering and evaluation, and contract negotiations and signing.

According to the assessment of the procurement process of public works in Egypt, in the "Public Procurement Sector Assessment -Review of Laws and Practice in the SEMED Region," which was published by EBRD in 2013, there is no independent authority to handle claims related to public works, and there is also no single entity to formulate policies and execute government procurement process/procedures, even though transparency and efficiency are somewhat secure.

6-1-2. Differences between the regulations of the Egyptian government and JICA's guidelines for procurement under Japanese ODA Loans

At the early stage of works and discussions for the preparation of draft Bidding Documents for NDGRs project, the differences between laws and regulations related to procurement in Egypt and JICA's Procurement Guideline (*Handbook: Guideline for Procurement under Japanese ODA Loans* April 2012) were discussed (Refer to Table 1-2.1 of main report of "Vol. IV DRAFT BIDDING DOCUMENTS".)

In Article 4.7 of the Minutes of Discussions dated 21 May 2014 on the Loan Agreement for NDGRs, it was agreed that JICA Guidelines shall be applied for the procurements in this project. While JICA Guideline shall prevail, requests from RGBS to follow the Egyptian laws were also reflected in the documents as much as possible.

6-2. Preparation of Draft Bidding Documents

6-2-1. Contents of draft bidding documents

At the early stage of the preparation works on the draft Bidding Documents, RGBS made request to JICA to change the procurement process so as to combine the pre-qualification and bidding process to be made simultaneously, and bidding documents shall be made as "PQ-embedded bidding documents". This request was based on their intention to shorten the procurement process on the civil works contract. The team considered this issue as appropriate request, however the final decision shall be made by the direct discussion between RGBS and JICA. Under such circumstance, two patterns of draft Bidding Documents (PQ-embedded Documents, and separated PQ/Bidding Documents) were prepared, however discussions thereafter were made basically on PQ-embedded Documents.

For this issue, RGBS requested the study team to maintain both patterns for the decision in future. Therefore, PQ embedded Documents are adopted as the final product as part of the Final Report, and separated PQ/Bidding Documents are also submitted but only in electric file.

6-2-2. Contents of discussions and understanding with Egyptian side on draft Bidding Documents (except technical specifications)

The contents of discussions during ‘8th Assignment’ and ‘9th Assignment’ on the draft Bidding Documents, including initial presentation from the team, comments from RGBS, information from JICA Egypt Office, conclusion as of 24 February, comments from JICA thereafter, and conclusion as of 24 April, were summarized in Table 2-2.1 of the main report “Vol. IV DRAFT BIDDING DOCUMENTS”.

After the completion of ‘9th Assignment’, final comments were provided by RGBS on 10 May 2017 and by JICA on 19 May 2017. By reflecting these comments, the draft Bidding Documents were finalized as part of the Final Report of the Study. The summary of said comments and reflection on the final draft Bidding Documents are summarized in Table 2-2.2 of the main report “Vol. IV DRAFT BIDDING DOCUMENTS”.

6-2-3. Draft bidding documents (technical specifications)

As for the technical specifications, an integral part of draft Bidding Documents, discussions with RGBS were started on ‘8th Assignment’ in February 2017. After the confirmation of structure and contents, actual works on the preparation of technical specifications were started.

The contents of technical specifications are as follows:

1) General Provisions

2) General Technical Specifications
    - Civil Works
    - Mechanical and Electrical Works

3) Particular Technical Specifications
    - Civil Works
    - Mechanical and Electrical Works

For the preparation of technical specifications, attentions were paid on the consideration of fair risk allocation among contract parties, and also consistency with contents of general conditions of contract.

7. Environmental and Social Consideration

During the F/S of the Project in 2010, the EIA Report was prepared and it was approved by EEAA in the same year. The Report mentions the environmental monitoring in pre-construction stage, however, the monitoring implementation organization is not specified. Therefore, this matter was discussed at the 25th TAC Meeting, and it was concluded that the S/V consultant will be in charge of monitoring in the stage, which means that it is necessary to add the monitoring activities to the current TOR of the S/V consultant. On the other hand, environmental monitoring in construction stage and operation stage are to be done by the contractor and MWRI, respectively.

As a result of review of the EIA Report, some of the monitoring items are to be clarified or modified. According to EEAA, it is not needed to get re-approval of the EIA Report, as far as the project components, scale of the structures, location and so on are not changed, and the EIA Report of the Project is still effective. In addition, if necessary, it is possible to modify the proposed environmental monitoring items and methods, under the condition that the reason for the modification is described. Still, it is noted that monitoring groundwater level and groundwater quality shall be implemented since the approval letter of the EIA report mentions the necessity of the monitoring of those items.

The Environment WG reviewed and examined the EIA report, focusing on the Environmental Evaluation, Environmental Management Plan and Monitoring Plan. According to realistic probability and necessity, some monitoring items are cancelled or added with those reasons. Moreover, frequency, sampling points, methodologies of monitoring and implementation organization are clarified through the discussion among the WG members.

As a point of concern in terms of environmental and social consideration, mosque transfer is planned for the Project implementation. There are three affected mosques that are requested to be resettled. New locations of the two mosques out of them, which are under control of the Ministry of Awqaf, have been fixed, and they will be relocated prior to the construction works. On the other hand, the last mosque, under the management of MWRI, is planned to be shifted within the area owned by MWRI in the construction stage. It is needed to monitor whether the transfer of those mosques is implemented as planned.

The groundwater monitoring results indicates that groundwater levels are significantly influenced by change of the water levels of Bahr Yusef canal and Ibrahimia canal. It is, therefore, necessary to monitor change of the groundwater level continuously, especially, those of BH-N10, BH-N11, BH-N12 and BH-N13, which correspond to the change of water level of the canals. Furthermore, the total (fecal) coliform was detected in the groundwater, and the cause is probably seepage from the sewage. Therefore, it is needed to improve current sewage treatment system.

Through of the Project implementation, it is proposed to establish the Security Management Committee, which coordinates, assesses various issues to maintain security of the project. It is proposed that the committee consists of RGBS staff of Dirout and Cairo, S/V consultant and the Contractor. Proposed major tasks of the committee are; 1) supervision of monitoring and examination of monitoring result, 2) taking measures if some problems are identified, 3) handling of complaints from the people, 4) Identification and counting of those who catch fish around the Dirout Regulators and their legalities, and taking measures, and 5) reporting, recording and information sharing, especially, any issues identified and measured taken.

8. Mathematical Model Analysis

8-1. Water Surface Profile Analysis

(1) Objectives of Analysis

The objective is to calculate the water surface profile impacted by the construction of NDGRs in order to check the discharge ability of the Ibrahimia canal. The analysis is conducted by one-dimensional unsteady flow analysis using the Ibrahimia canal cross-section given in measurement results.

(2) Result of Analysis

Given by 0.20m increase of water level at the existing DGRs due to the new operation water level of the NDGRs, the water surface profile is impacted to the D.S. of Ibrahimia intake from the existing DGRs. The difference between water levels, however, is only 0.05 m at the upstream. Therefore, it was found that there is no large impact to the operation of the Ibrahimia intake besides the discharge capacity of the Ibrahimia canal is enough in the new conditions (new water level and new discharge volume) to the NDGRs.

8-2. Mathematical Model Analysis

(1) Objectives of Analysis

Since the NDGRs is required to divert accurately and stably the water to the seven main canals through the five regulators, those regulators should be secured for the necessary hydraulic function and capability. In order to clarify those capabilities, the mathematical model is applied. The sediment and the scouring phenomena around the NDGRs, furthermore, should be analyzed based on the result of the flow conditions analysis taken into consideration the gate operation by overflow and underflow.

In this report, the former analysis is regarded as the "Flow Analysis" and another is regarded as the "Riverbed Variation Analysis". As for the riverbed analysis, the present available data is utilized for the analysis. The followings show the result of analysis.

(2) Result of Analysis

・Flow Analysis

It was found that the five regulators of the NDGRs have enough capability to divert to the seven canals properly. Under the conditions of existing canal sections, the maximum velocity on the bottom layer around the D.S. of the NDGRs is 0.8~1.0 m/s in the Bahr Yusef canal and 0.8 m/s in the Ibrahimia canal. As for the analysis to the planned canal sections, some uneven tendencies are observed among each vent in the distribution velocity of the new Ibrahimia regulator, but all of those are less than the allowable velocity (Va=2.00 m/sec). Accordingly, there is no hydraulically serious problem to the NDGRs.

・Riverbed Variation Analysis

There is the tendency of sedimentation between the existing DGRs and the NGDRs due to the low water velocity. As for new Abo Gabal and Sahelyia regulators which are located on the U.S of existing regulators, the sedimentation around the new intake tend to decrease after NDGRs construction, but still remains the same tendency. Accordingly, the removal works to the sedimentation should be maintained periodically as maintenance works after the construction of NDGRs.

8-3. Integrated Evaluation of Hydraulic Model Test

(1) Objectives of Integrated Evaluation

As for the physical hydraulic model test conducted by HRI according to the contract with MWRI, the test condition should have the consistency with the mathematical analysis conducted by the D/D consultants in the test conditions. In this context, the objective is to organize and adjust the conditions between the physical hydraulic model test and mathematical model analysis by providing the information and advice on the hydraulic model experiments.

The target of the evaluation in this report is the 3D physical hydraulic model test for the flow condition in the vicinity of the NDGRs and the 2D physical hydraulic model test for the river bed protection of NDGRs. The evaluations are targeted for the two tests above.

(2) Result of Integrated Evaluation

As a result of consideration based on the recommendation of the physical hydraulic model test, the following recommendations are applied to the design of the NDGRs.

3D physical hydraulic model test

As a result of the 3D physical hydraulic model test, the embankment bank protection should be done at the D.S. of the left bank of the new Bahr Yusef regulator and the D.S. of the right bank of the new Ibrahimia regulator in order to alleviate the stagnant area (with slow vortex current)

2D physical hydraulic model test

As a result of the 2D physical hydraulic model test, the following design specification are identified and applied to the design of the NDGRs.

1）Length of bed protection
  - ✓ Large regulators (Bahr Yusef and Ibrahimia) : 30m
  - ✓ Small regulators (Badraman): 15m
  - ✓ Small regulators (Abo Gabal and Sahelyia) : no need

2）Type of bed protection
  - ✓ Ripraps

Table of Contents

Abbreviations

ADCP : Acoustic Doppler Current Profiler
APN : Access Point Name
ASTM : American Society for Testing and Materials
BC : Boundary Condition
BH : Borehole
B/D : Basic Design
CDSSD : Central Directorate of Studies, Specifications and Designs
CDT : Central Directorate for Telemetry
CDWD : Central Directorate of Water Distribution
CRI : Construction Research Institute
D/D : Detailed Design
DGRs : Dirout Group of Regulators
DO : Dissolved Oxygen
DS : Downstream
EBRD : European Bank for Reconstruction and Development
EC : Electrical Conductivity
ECRI : Environment and Climate changes Research Institute
EEAA : Egyptian Environmental Affairs Agency
EGSA : Egyptian General Survey Authority
EIA : Environmental Impact Assessment
EL : Elevation
EMP : Environmental Management Plan
EMoP : Environmental Monitoring Plan
ENR : Egyptian National Railways
FC : Foreign Currency
FDM : Finite Difference Method
FHT : Falling Head Test
F/S : Feasibility Study
GDIs : General Directorates of Irrigations
GDWD : General Directorate for Water Distribution
GPRS : General Packet Radio Service
GPS : Global Positioning System
GW : Groundwater
HAD : High Aswan Dam
HCWW : Holding Company for Water & Wastewater
HD : High Definition
HPPEA : Hydro Power Plants Executive Authority
H-Q : Height-Quantity
HRI : Hydraulic Research Institute
ID : Irrigation Department
IIS : Irrigation Improvement Sector
IMF : International Monetary Fund
IP : Internet Protocol
KfW : Kreditanstalt für Wiederaufbau (German government-owned development bank)
KVM : Keyboard, Video, Mouse
JICA : Japan International Cooperation Agency

JIS : Japanese Industrial Standards
L2SW : Layer 2 Switch
LC : Local Currency
LCD : Liquid Crystal Display
LE : Livre Égyptienne (Egyptian Pound)
LLT : Lateral Load Test
MCCB : Molded Case Circuit Breaker
MD : Minutes of Discussion
MED : Mechanical and Engineering Department
MEE : Ministry of Electricity and Energy
MERE : Ministry of Electricity & Renewable Energy
MMA : Mathematical Model Analysis
MOT : Ministry of Transport
MWRI : Ministry of Water Resources and Irrigation
N : Number of Blows (value for SPT)
NDGRs : New Dirout Group of Regulators
NTP : Network Time Protocol
NWRC : National Water Research Center
ODA : Official Development Assistance
O&M or O/M : Operation and Maintenance
PDCA : Plan-Do-Check-Act cycle
pH : Potential Hydrogen
PHMT : Physical Hydraulic Model Test
PIU : Project Implementation Unit
PQ : Prequalification
Q3D : Quasi-3 Dimensional
RC : Reinforced Concrete
RD : Record of Discussion
RGBS : Reservoirs and Grand Barrages Sector
RTA : River Transport Authority
RTU : Remote Terminal Unit
SCADA : Supervisory Control and Data Acquisition
SEMED : Southern and Eastern Mediterranean
SMC : Security Management Committee
SPT : Standard Penetration Test
STEP : Special Terms for Economic Partnership
TAC : Technical Advisory Committee
TBM : Temporary Benchmark
TCP : Transmission Control Protocol
TDS : Total Dissolved Solids
TSS : Total Soluble Salts
UNESCO : United Nations Educational, Scientific and Cultural Organization
US : Upstream
VAT : Value Added TAX
VGA : Video Graphics Array
WG : Working Group
WL : Water Level

Unit

BCM : billion cubic meter
cm : centimeter
fed : feddan (1fed ≒ 0.42ha)
ft : feet
g : gram
ha : hectare
hr : hour
kg : kilogram
km : kilometer
kN : kilo newton
kV : kilo volt
kVA : kilo volt ampere

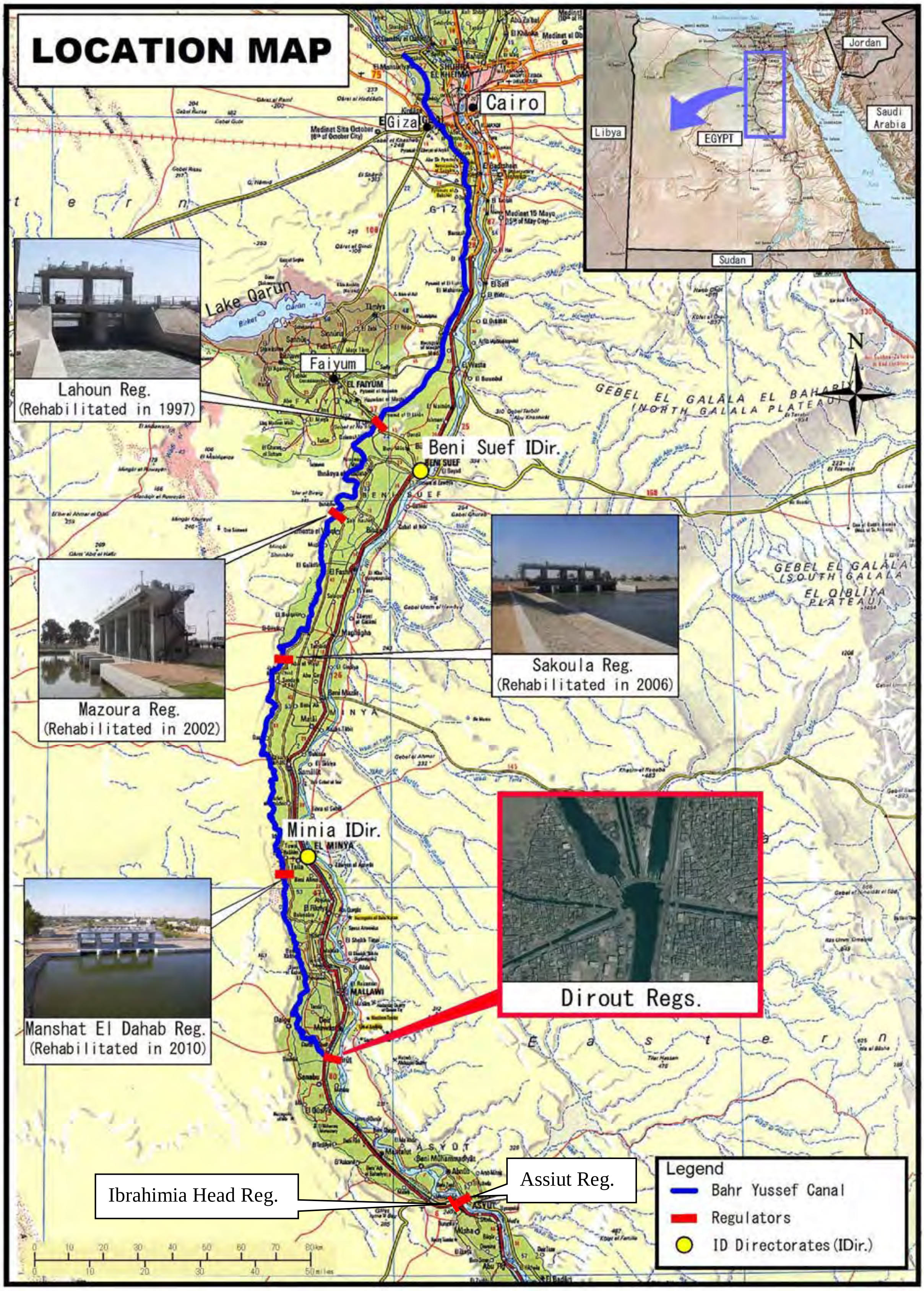
ℓ : liter
lb : pound
MPa : mega pascal
m : meter
MCM : million cubic meter
min : minute
mm : millimeter
N : newton
% : percentile
s : second
t : ton

Currency Exchange Rate (average from Feb. 2017 to Apr. 2017)

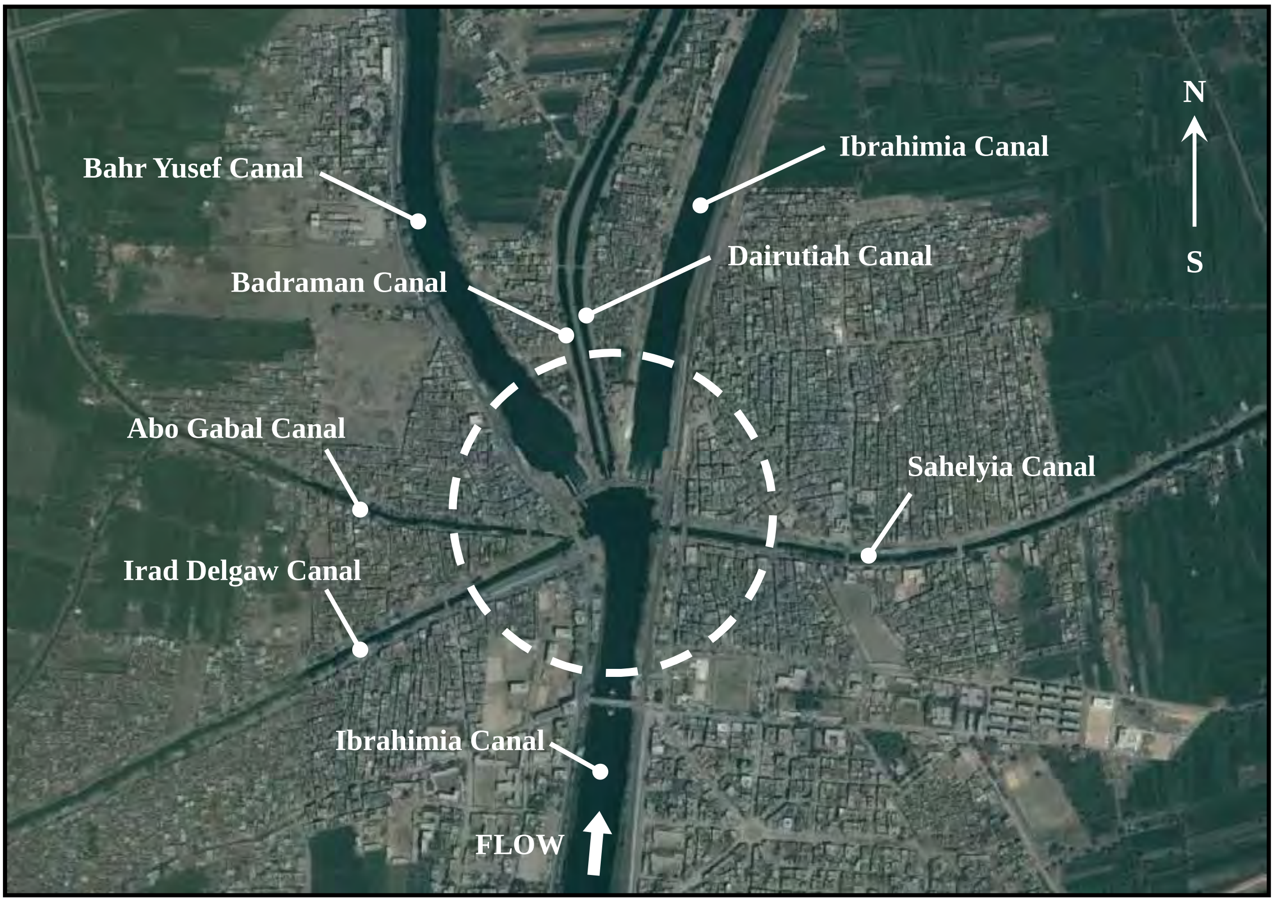
Egyptian Pound (EGP or LE) : 6.49 JPY/LE
Japanese Yen (JPY)
US Dollar (USD) : 113.34 JPY/USD
Euro (EUR) : 121.26 JPY/EUR

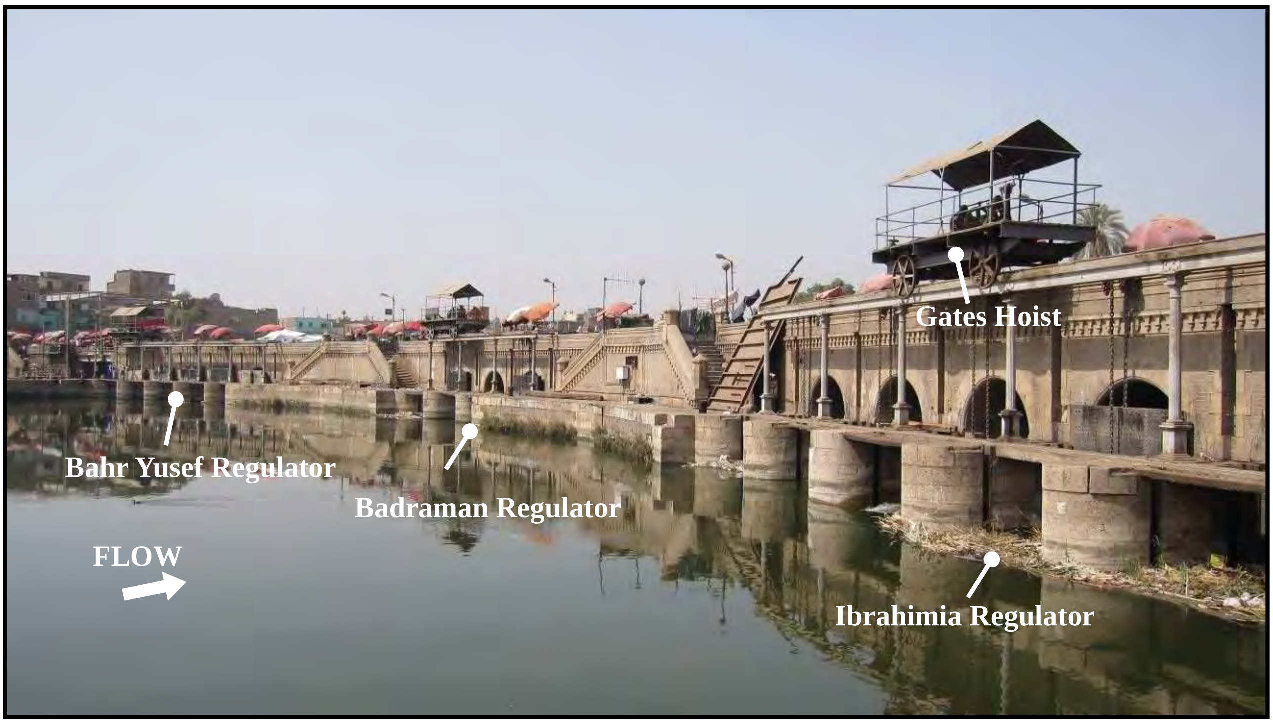
PROJECT LOCATION MAP

- PROJECT FOR CONSTRUCTION OF DIROUT GROUP OF REGULATORS -



PANORAMIC LANDSCAPE OF DIROUT GROUP OF REGULATORS





Project Photo

Photo1：Existing DGRs (Ibrahimia Regulator)

view from downstream

Photo2：Existing DGRs (Bahr Yusef Regulator)

view from downstream

Photo3 : Current Gate Operation (with a log to push the gate)

Photo4：Dredging (upstream of DGRs)

Photo5 : Distant view of Double leaf gates (Dahab Regulator)

Photo6：Near view of Double leaf gates (Dahab Regulator)

Photo7：Steel double sheet pile method (Dahab Regulator)

Photo8：Steel double sheet pile method (Dahab Regulator)

Photo9：TAC kick-off meeting

Photo10：Three Parties Agreement

Photo11：On-water boring on NDGRs axis

Photo12：Proposed borrow pit

Photo13：Ceremony to put the corner stone for NDGRs

Photo14：JICA Egypt office project inspection

Photo15：Inspection of the Japanese Embassy

Volume I DESIGN OF REGULATORS

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Volume I – DESIGN OF REGULATORS

1. Outline of Design

1-1 Design conditions

(1) Design discharge for each regulator

Maximum design discharge for NDGRs was decided at the 6th TAC meeting. Maximum design discharge at this stage should take into account not only previous discharge which was applied in the F/S stage, but also the future demand on irrigation water. Discharge of Ibrahimia regulator in NDGRs, is accordingly upgraded to 186m^3/s from 161.6m^3/s. All design discharges are shown on Table 1-1.1. Design discharges of diversion works provided by the Egyptian side were applied to the diversion works in the construction stage.

Table 1-1.1 Design discharge

NDGR	Canal	Design Max. Discharge Qmax (m^3/s)	Design Min. Discharge Qmin (m^3/s)	Design Discharge for temporary works Qtem (m^3/s)	Note
Ibrahimia Reg.	Ibrahimia	186	23.6	162	
Bahr Yusef Reg.	Bahr Yusef	227	33.1	185	
Badraman Reg.	Badraman	9	1.2	6	
	Diroutiah	12	1.7	10	
Abo Gabal Reg.	Abo Gabal	7	0.9	2	
	Irad Delgaw	9	1.3	6	
Sahelyia Reg.	Sahelyia	5	0.6	3.5	

(2) Design water level

"Unusual" and "normal" water levels should be taken into account in the design water level on the NDGRs as stipulated at the 6th TAC meeting as follows.

According to the 1962 drawings of the existing rehabilitation plan, a high water level (H.W.L) of 47.00m was shown at the upstream. As this water level was designed before the construction of the Aswan High Dam, Nile and canal waters were not controlled by the dam. Today, water levels are controlled and floods do not occur under normal conditions. However, the inoperative Ibrahimia intake at the upstream which causes over-inflow to the NDGRs, requires the evaluation of the design water level in emergency situations. Accordingly, WL 47.00mas design at High High Water Level (H.H.W.L) should be applied for the emergency case, and in addition, WL 46.30m as design at HWL should be applied.

CDWD of MWRI provided the conditions of the downstream water level, and design should comply with these water levels. In addition, since each cross section of the existing canals does not have the necessary flow capacity, the upgrading works should be conducted as a different project to achieve the provided water levels. Reference 1-1.1 shows the H-Q curve at an existing cross section of Bahr Yusef and Ibrahimia canals. Table 1-1.2 shows the full design water level of each canal.

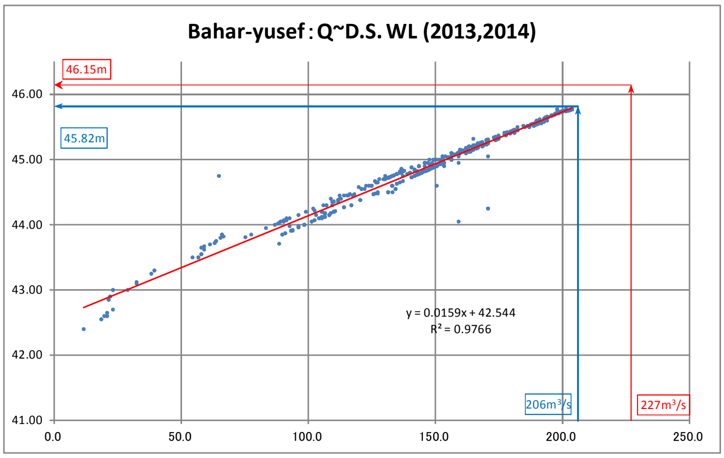
Table 1-1.2 Design water levels

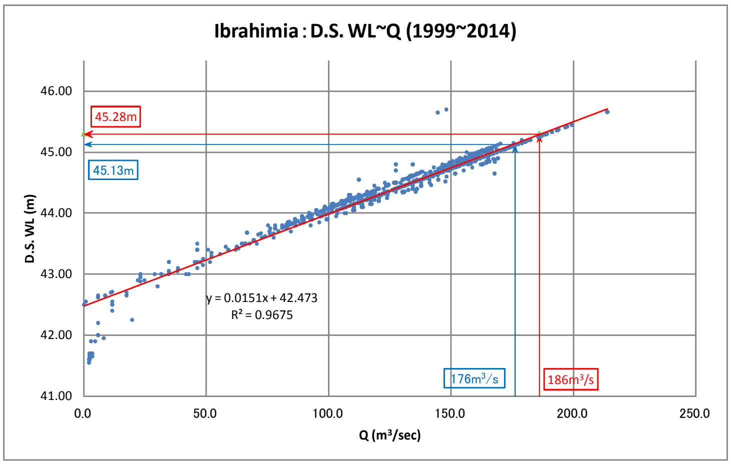
Regulator name	Canal name	US.HHWL (m)	US.HWL (m)	US.LWL (m)	US.LLWL (m)	DS.HWL (m)
Ibrahimia Reg.	Ibrahimia	47.00	46.30	45.90	—	45.13
Bahr Yusef Reg.	Bahr Yusef	47.00	46.30	45.90	—	45.82
Badraman Reg.	Badraman	47.00	46.30	45.90	—	45.90
	Diroutiah	47.00	46.30	45.90	—	45.90
Abo Gabal Reg.	Abo Gabal	47.00	46.30	45.90	44.30	45.90
	Irad Delgaw	47.00	46.30	45.90	44.30	45.90
Sahelyia Reg.	Sahelyia	47.00	46.30	45.90	44.30	45.90

Note 1: Upstream water level shows at upstream of the existing DGRs

Note 2: US. LLWL is taken from the actual records for the past five years as the available water level at Abo Gabal and Sahelyia regulators after the winter closure. Refer to reference Figure 1-1.2.

※Reference 1-1.1：H-Q curve at Bahr Yusef and Ibrahimia canal

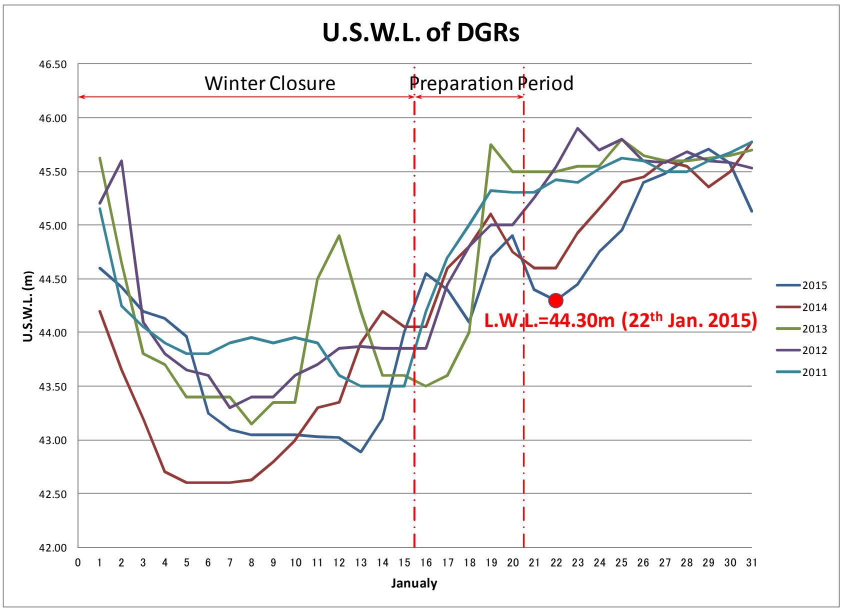




※Reference 1-1.2：Consideration of unusual upstream water level (US.LLWL)

The lowest upstream water level (US.LLWL) should be chosen from the five years record of just after the preparation period from 2011 to 2015 (see the graph below). As the result of the evaluation, US.LLWL should be determined as follows:

US.LLWL=44.30m (22th Jan 2015)



(3) Design of related facilities

Although no decision regarding the navigation lock and mini hydro power facilities was made at the F/S stage, after discussions between related Ministries, the Egyptian side decided that these facilities were unnecessary for the project.

a) Navigation lock

Neither navigation lock has been operated in the existing Bahr Yusef and Ibrahimia regulators in DGRs so far. Discussions at F/S stage deemed a navigation lock for the new Bahr Yusef regulator to be unnecessary, but encouraged the planning of the new Ibrahimia regulator.

At the 7th TAC meeting, discussions between MWRI and RTA concluded that no navigation locks need to be planned for the new Ibrahimia and the new Bahr Yusef regulators.

b) Mini hydro power generation

Mini hydro power generation was unable to generate the necessary electric power, due to the negative water level difference in F/S stage, and as such, the Egyptian side decided that that mini hydro power generation was unnecessary for the project. In this study, that conclusion was reviewed and agreed in the 6th TAC meeting. MWRI submitted an official letter stating that mini hydro power generators are infeasible and would not be constructed in NDGRs to MERE, the authority in charge of hydro power generation in Egypt.

1-2 Reference code

In the Arab Republic of Egypt (hereinafter referred to as Egypt), all irrigation facilities constructed based on the project plan and detailed design under MWRI management are required to follow the Egyptian code.

The Egyptian code is the design criteria for water resources development and irrigation works, and is accountable to NWRC. The contents of the parts of the Egyptian code relevant to the project are shown below.

Table 1-2.1 Contents of Egyptian code

Egyptian Code	Chapter
Operation of the Irrigation and Drainage Network part 1	1. Irrigation of the Agricultural Land
	2. Drainage of the Agricultural Land
Operation of the Irrigation and Drainage Network part 2	3. Horizontal expansion
	4. Water Resources Development
	5. Maintenance Work
	6. Hydrology Torrents Management
	7. Survey Works
Civilian Facilities on Irrigation and Drainage part 1	1. Irrigation Networks Lining
	2. Water Installations Intersecting
	3. Outfalls
	4. Weirs
	5. Regulators (Barrage) and Gates
	6. Dams
	7. Sluice gates Navigation
	8. Hydroelectric Power Plants
Civilian Facilities on Irrigation and Drainage part 2	9. Pump Stations
	10. Wells
	11. Bridges
	12. Tunnels
Irrigation and Drainage Mechanical works	1. Pumps
	2. Internal Combustion Engines
	3. Transmission and Power rate
	4. Valves and Gates
	5. Mechanical, Chemical and Cathodic Protections
	6. Selection and Testing of Materials
	7. Mechanical Equipment for Maintenance of Water Ways
	8. Advance for Irrigation Equipment
	9. Monitoring Water Quality in Streams Equipment
Irrigation and Drainage Electrical works	1. Electric Stations
	2. Electric Transformers and Accessories
	3. Keys, Electrical Connection and Electrical Fittings
	4. Circles and Control Devices in Electric Motors
Irrigation and Drainage Electrical works	5. Terms Implementation of Electric Works
	6. Power Supply Emergency Systems

Egyptian Code	Chapter
	7. Grounding
	8. Irrigation Equipment Powered by Electricity
Shore Protection Techniques	1. Natural Factor Affecting the Costal and Beach Areas
	2. Research Studies, Field work, Hydraulic Models and
	3. Facilities, Shore Protection Plan and its Impact on the
	4. Designer Protection
	5. Shore Protection and Maintenance Facilities

Adherence to the Egyptian code was given first priority in the design criteria applied at the basic design and the detailed design stages for NDGRs construction project. In the absence of a policy in the Egyptian code regarding an issue, Japanese design criteria in the field of the regulators and *Design Criteria for Irrigation and Drainage, Headworks* will be referred to.

The design criteria adopted for the study, is defined in chapter five "*Regulators (Barrage) and Gates in the Civilian Facilities on Irrigation and Drainage.*" Part one of the chapter consists of following items:

5-1	Definition
5-2	Gate Types
5-3	Mutual affect between the Hydraulic Structure and Water Channel
5-4	Regulator Design
5-5	Gates
5-6	References

In the Japanese Criteria, the methodology for the design of the headworks is defined with great attention to theory and method. In the Egyptian code, the maximum velocity allowed at the vents is defined as follows with limited expansion and details.

Small scale regulators	1 - 1.5 m/sec
Large scale regulators (barrage)	1.5 - 2 m/sec
Barrage on Rivers	2.5 – 3.5 m/sec

To fill the gaps in the details left by the Egyptian code, the RGBS recommended the textbook *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrage*, for design works.

Adherence to the Egyptian code was given first priority in defining the hydraulic dimensions at the Basic Study stage, the textbook only providing supplemental criteria.

1-3 Outline of facilities

Figure 1-3.1 and Table 1-3.1 show the outline of the NDGRs

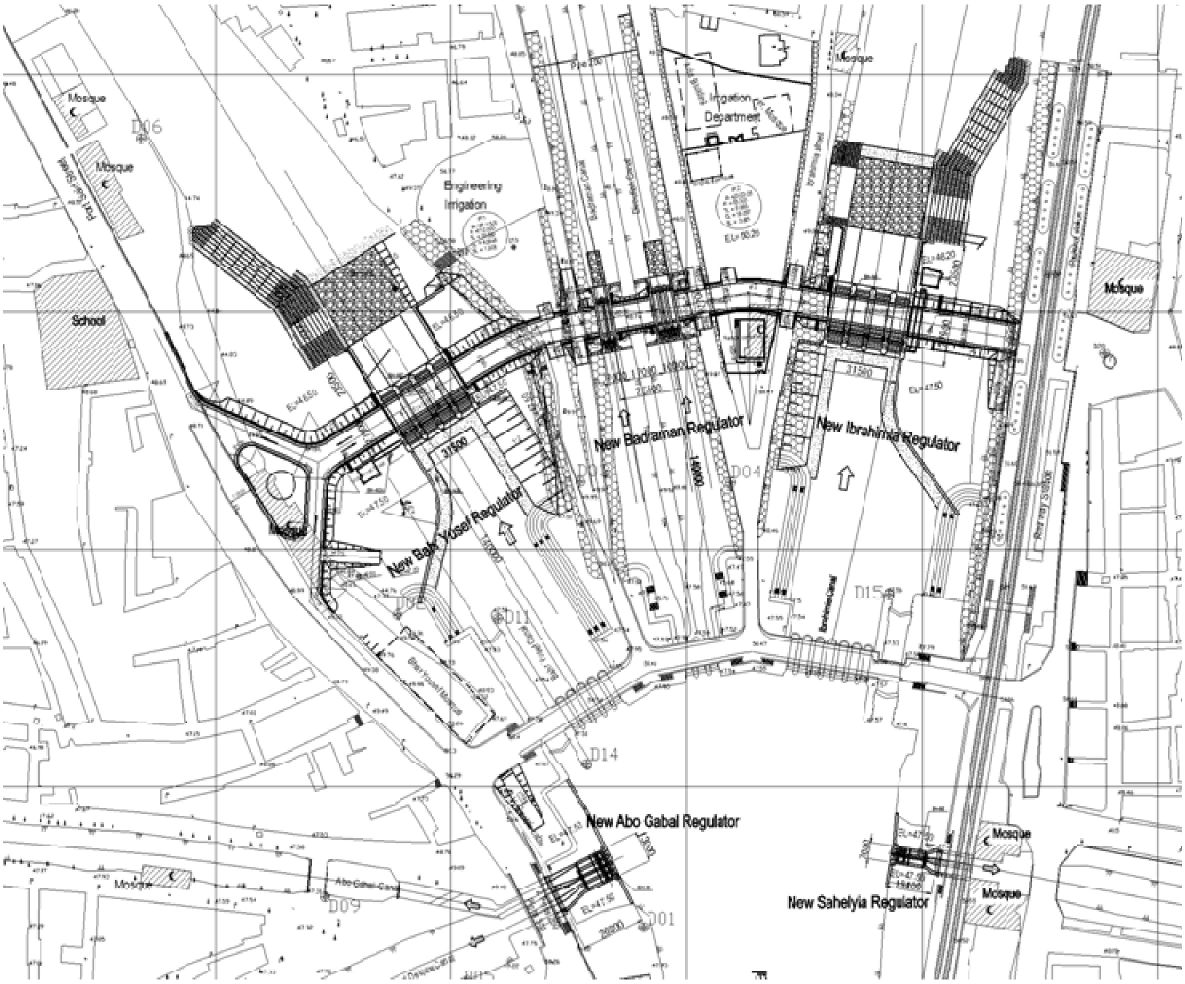


Figure 1-3.1 General layout of NDGRs

Table 1-3.1 Outline of NDGRs

Name of Regulator		**Bahr Yusef**	**Ibrahimia**	**Badraman**		**AboGabal**		**Sahelyia**	**Remarks**
Name of Canal				**Badraman**	**Diroutiah**	**AboGabal**	**Irad Delgaw**		
Design maximum discharge		227 m^3/s	186 m^3/s	9 m^3/s	12 m^3/s	7 m^3/s	9 m^3/s	5 m^3/s	Total 455m^3/s
Design minimum discharge		33.1 m^3/s	23.6 m^3/s	1.2 m^3/s	1.7 m^3/s	0.9 m^3/s	1.3 m^3/s	0.6 m^3/s	Total 62.4m^3/s
Design U/S high water level		EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	
Design U/S low water level		EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Design D/S high water level		EL45.82m	EL45.13m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Width of vent		6.00m	6.00m	2.00m	2.00m	2.00m		2.00m	
Number of vent		4	4	2	3	4		2	
Gate sill elevation		EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43.60m		EL43.00m	
Gate crest elevation		EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m		EL46.55m	
Total gate height		6.55m	6.55m	2.65m	2.35m	2.95m		3.55m	
Foundation	Main body	Cast-in-place RC pile	Cast-in-place RC pile	Raft foundation	Raft foundation	Raft foundation		Raft foundation	
	Apron	Raft foundation	Raft foundation	Raft foundation	Raft foundation	Raft foundation		Raft foundation	
	L-shape wall	Cast-in-place RC pile	Cast-in-place RC pile	-	-	-		-	
Downstream apron	Type	L-type retaining wall	L-type retaining wall	RC flume	RC flume	RC flume		RC flume	
	Length	44.25m	44.25m	23.35m	22.77m	23.87m		16.42m	Note(1)
Seepage control works		Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile		Steel sheet pile	
Bed protection works		Riprap L=30.0m (D$_{50}$=0.40m,W$_{50}$=60kg,t=1.00m)	Riprap L=30.0m (D$_{50}$=0.40m,W$_{50}$=60kg,t=1.00m)	Riprap L=15.0m (D$_{50}$=0.20m,W$_{50}$=10kg,t=0.50m)	Riprap L=15.0m	–		–	t : Thickness including gravel (0.10m)
Bank protection works	D/S	Cantilevered type/Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile wall	Cantilevered sheet pile wall	Cantilevered sheet pile wall	–		–	
		Gabion wall	Gabion wall						
	U/S	Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile	Cantilevered sheet pile wall	Cantilevered sheet pile wall	Brace type steel sheet pile wall		Brace type steel sheet pile wall	
		Wet stone pitching	Wet stone pitching						
Bridge		RC, Total width=12.5m	RC, Total width=12.5m	RC,Total width=12.5m	RC,Total width=12.5m	RC,Total width=6.0m		RC,Total width=6.0m	
Gate facility	Type	Double leaf Fixed wheel gate	Double leaf Fixed wheel gate	Single leaf Slide gate	Single leaf Slide gate	Single leaf Slide gate		Single leaf Slide gate	
	Hoist	Hydraulic cylinder	Hydraulic cylinder	Electric motor	Electric motor	Electric motor		Electric motor	
	Operation speed	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min		0.3 m/min	
	Material	Rolled steel & Stainless steel(Guide frame, bolt & nut, wheels)							
	Stoplogs	1 set	1 set	2 sets					Note(2)
		Height of one piece=1.35m&1.20m		Height of one piece=0.95m&0.85m					
Management facility		Remote control building: RC structure, 2 floors (Stoplogs storage house is established together)							Location and the area is under study
		Local control room: RC structure, 2 rooms (Bahr Yusef & Ibrahimia Regulator)							
Water level gauge		2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	2 sets (U/S:1,D/S:1)	3 sets (U/S:1,D/S:2)		2 sets (U/S:1,D/S:1)	Pressure type

Note: (1) Length of downstream apron for small regulators shows the distance from a gate sill to the existing structure.

(2) One set means a pair of stoplogs for upstream and downstream.

U/S:Upstream, D/S:Downstream

2. Topographic and Geological Outline

2-1 Topographic feature

The flood plain of the Nile has been formed by Nile sedimentation onto the eroded limestone plateau which was aggraded in early Eocene time. The flood plain is mainly composed of silt and sand, and is suitable for agriculture due to its fertility. According to an old map of the area (*Carte topographique de l'Égypte et de plusieurs parties des pays limitrophes*, 1826), Dirout El-Shareef city, which is 2.7km north of Dirout city, was situated along the original Bahr Yusef river (Figure 2-1.1 and Figure 2-1.2). This indicates that much excavation and reclamation work has been implemented around the target area in order to divert the water from the Ibrahimia canal into the Bahr Yusef river as Bahr Yusef canal.

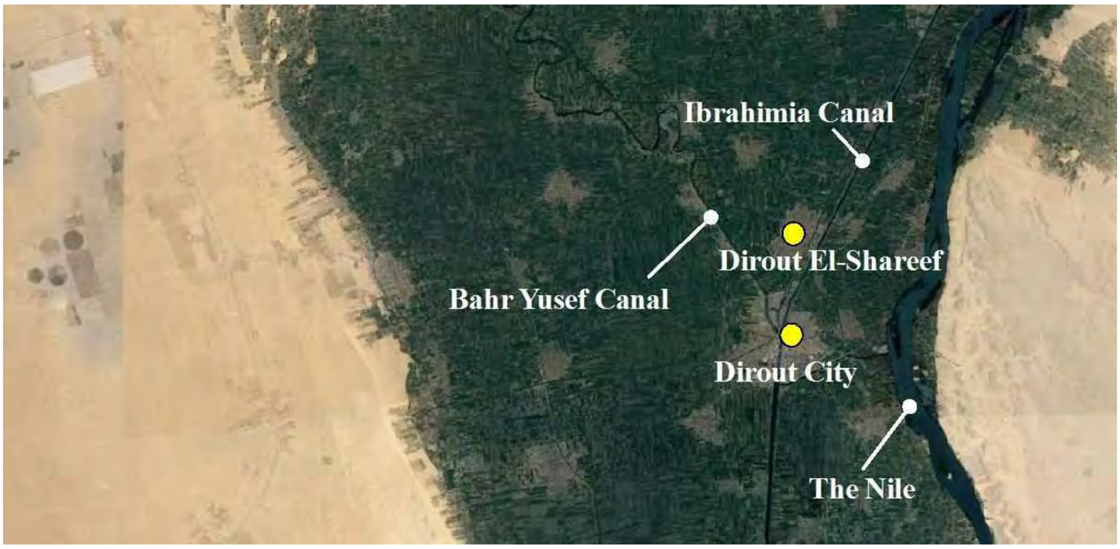


Figure 2-1.1 Satellite picture (Dirout to Malawi)

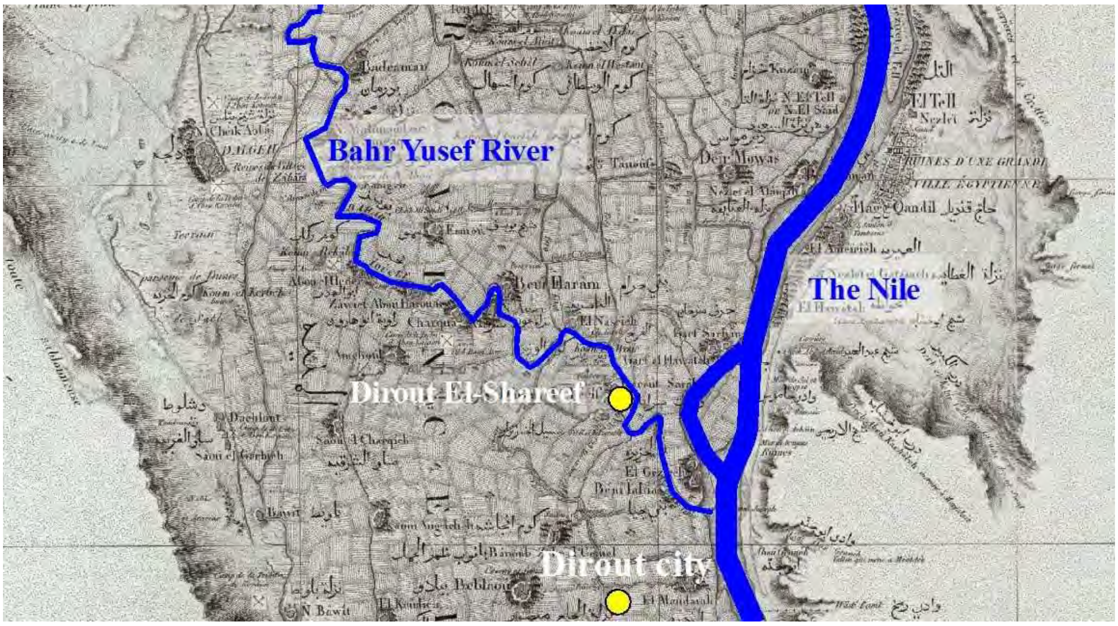


Figure2-1.2 Antique map (1826, Dirout to Malawi)

(Source: *Carte topographique de l'Égypte et de plusieurs parties des pays limitrophes*, 1826)

2-2 Geological feature

Geological structures around Dirout city feature an erosion valley striding over 15km to 20km beyond the river terrace developed over different geological times. Diluvium formation which formed the river terrace is consequently seen under the river Nile, but alluvium sediments is covered in the study area which is beside the current river Nile. The condition of Nile deposits depends on changes in hydraulic gradient caused by eustasy, and changes in the river course caused by tectonism (shown on Figure 2-2.1).

The geological field survey of the study area corresponds to the Neonile or Prenile description (Said 1993). Table 2-2.1 shows the features for those units.

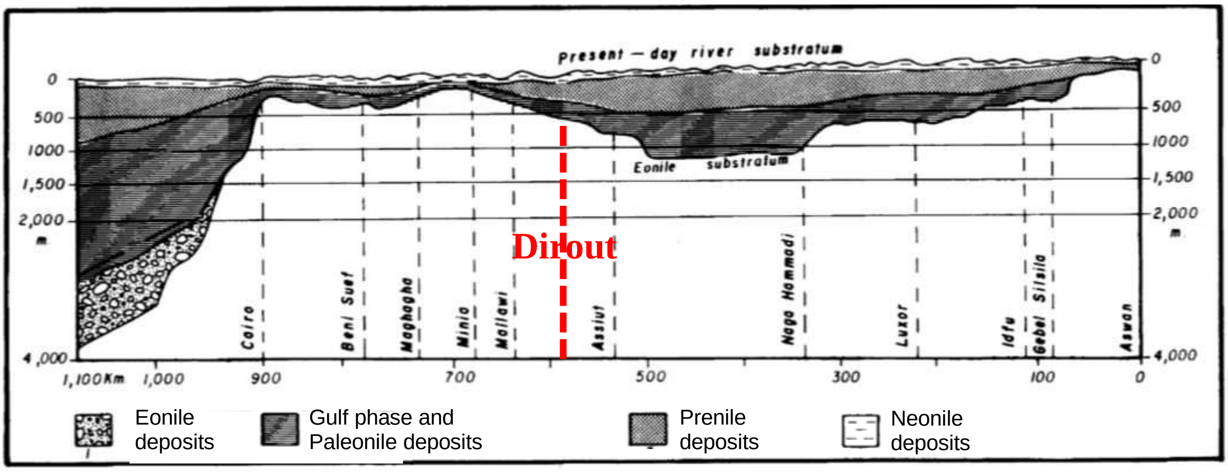


Figure 2-2.1 Geological profile of the Nile（Aswan to Mediterranean sea）

(Source: Rushdi Said *The River Nile*, 1993)

Table 2-2.1 Description of flood sediments

Unit	Remarks (Stratigraphication and distribution)
Neonile	This river system is the current condition of the Nile (0.4Ma-present), and is categorized into 4 types of deposits, α, β, γ, and δ-Neonile considering the regression/transgression cycle. They are mainly composed of riverine (flood) deposits (silt and sand, and occasional gravel) and inter-fingered dune sand.
Prenile	It is mainly composed of two types of sand layers, one for cross-bedding riverine sand, and another for inter-bedding dune sand in the middle Pleistocene (0.8 – 0.4Ma). The deposit from this river system includes mollusca and fauna which indicate that this river system is connected to Ethiopia (Said 1990). This river system conveyed massive amounts of sand on the Nile valley which resulted in considerably thick sand layer even in Upper Egypt.

2-3 Borehole logs

The location of borehole and borehole logs which relate the foundation properties for B/D stage are shown in the following figures. (See the *Field Survey Report* (April 2016) of the D/D study in regard with the detail information for the past boring surveys).

a) Location of the survey

The boring survey was carried out at fifteen borehole points in order to clarify the change in stratigraphy on the new axis, and the soil properties were determined through in-situ and laboratory tests. The results support the design of main regulators, navigation locks, piers, sheet piles, and all related structures in the construction of NDGRs. A location map for the boreholes is shown in Figure 2-3.1.

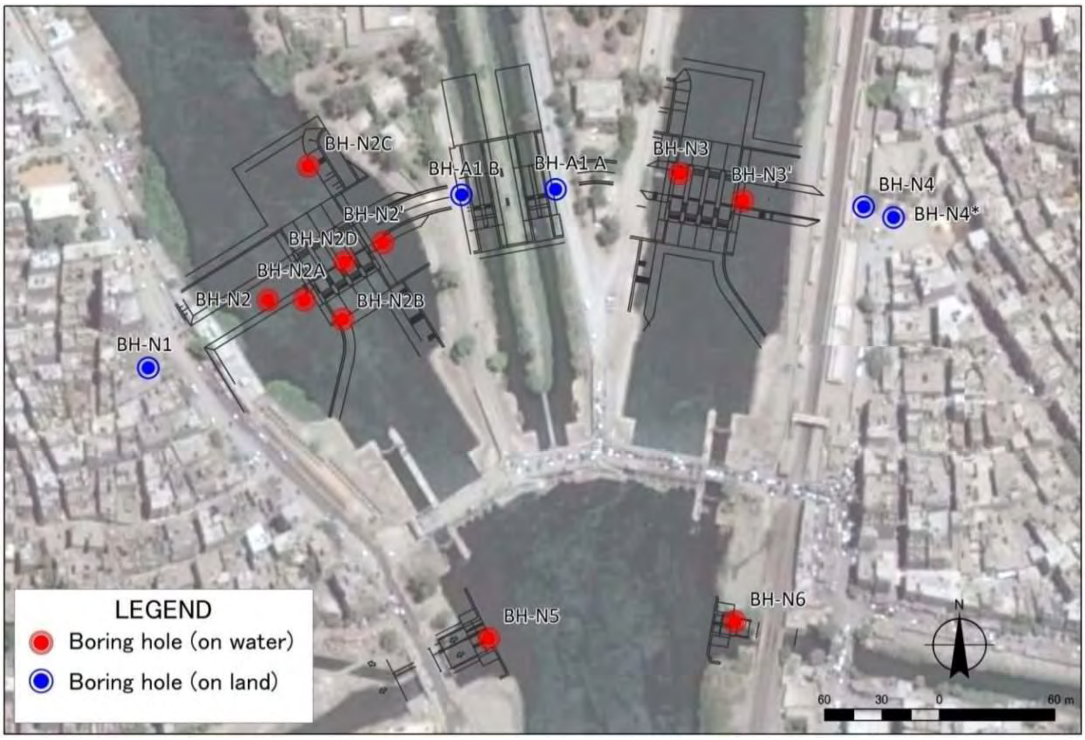


Figure 2-3.1 Location map of boreholes on NDGRs

b) Borehole logs

Figures 2-3.2 to 2-3.5 show the geological cross-sectional maps of the regulators and SPT values. Figures 2-3.6 to 2-3.19 show all 15 borehole logs on the new Bahr Yusef, Badraman, Diroutiah, and Ibrahimia regulators.

According to the borehole logs obtained in the survey, thick silt layer is overlain at the depth of 10m, changing from silt to sand with depth. Coarse facies intercalated with granule and pebble are dominant at the bottom of the boreholes. This upper silt may be correlated to γ-Neo-Nile (or δ-Neo-Nile) sub-stage, and the lower part of the sandy layer succession can be compared with a part of γ-Neo-Nile sequence[1] (or δ-Neo-Nile). It should be remarked that a loose backfill layer (containing mainly unconsolidated silt to clay, and traces of brick particles) exists under the new Bahr Yusef regulator. That backfill layer is classified into two layers, top and bottom, with an interbedded silt layer with a trace of shell fragments.

---

[1] Sediment sequence: A succession of geologic events, processes, or layers, arranged in chronologic order to show their relative position and age with respect to geologic history as a whole. In the Dirout area in particular, sediment layer(s) indicate a transgressive deposit, consisting of low lying gravel overlain by a finer layer of sand/silt on the surface. This is influenced by past sedimentation in response to a seawater rise after the middle Pleistocene time.

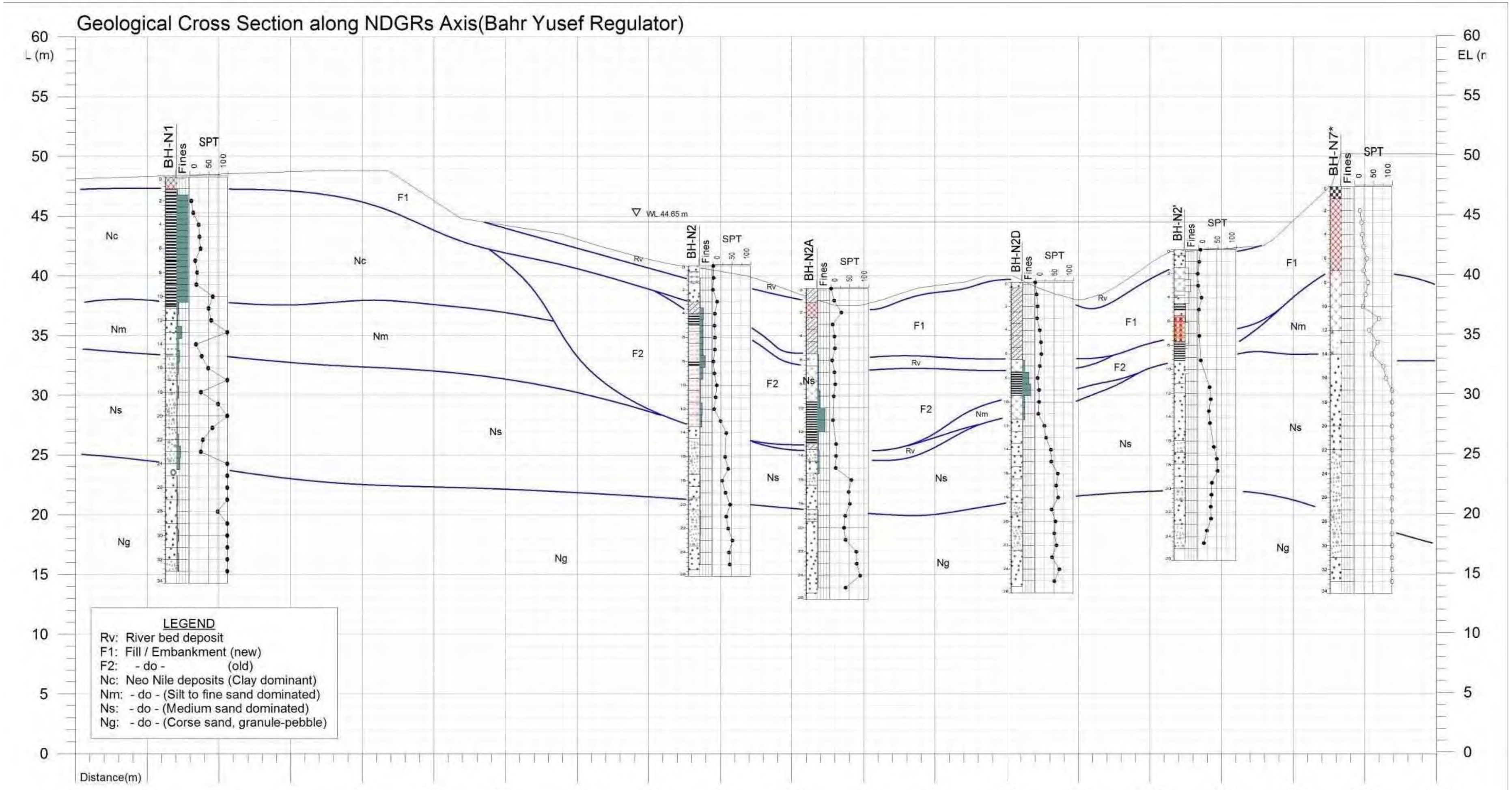


Figure 2-3.2 Geological cross-sectional map (New Bahr Yusef regulator)

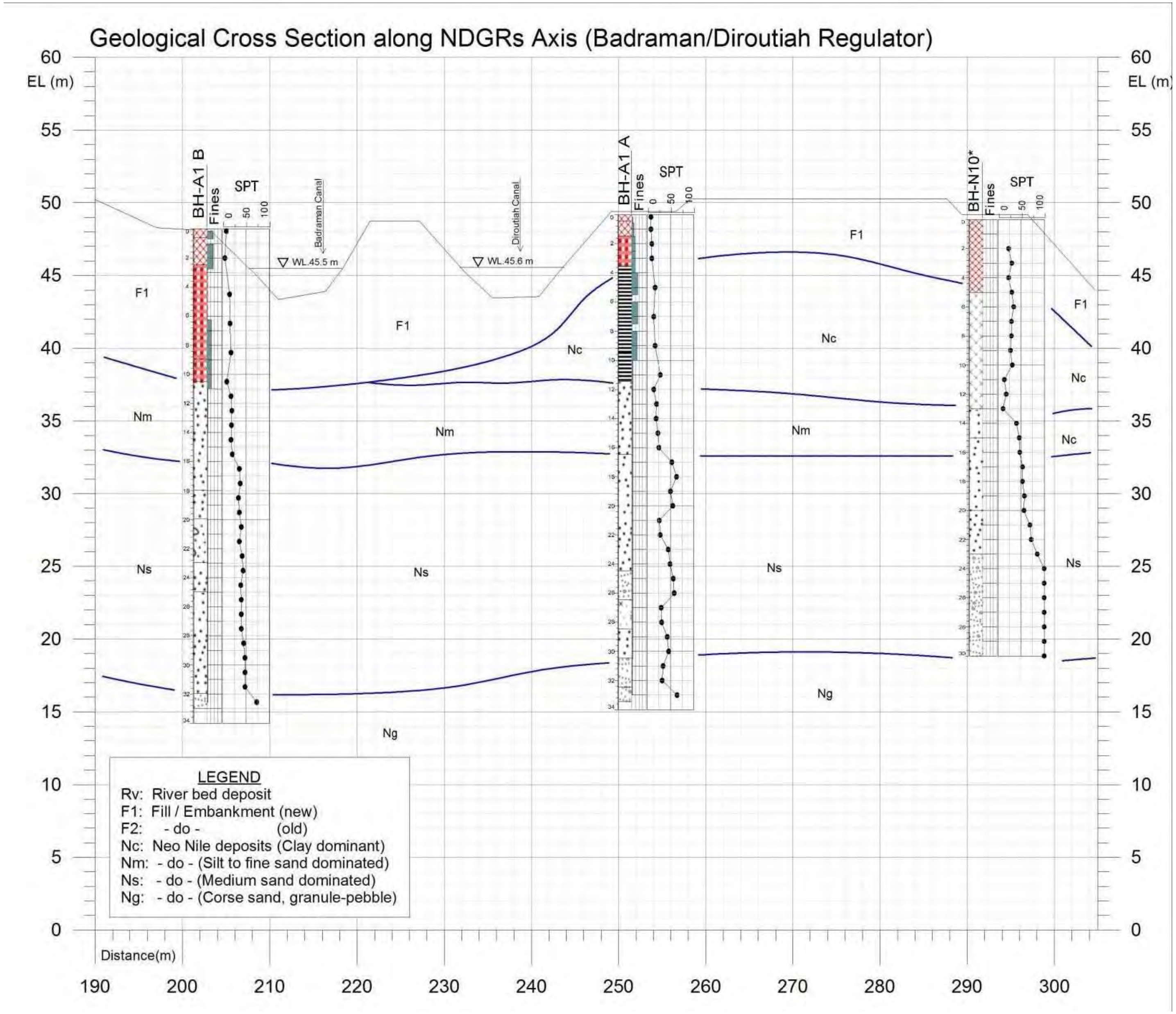


Figure 2-3.3 Geological cross-sectional map (New Badraman to Diroutiah regulators)

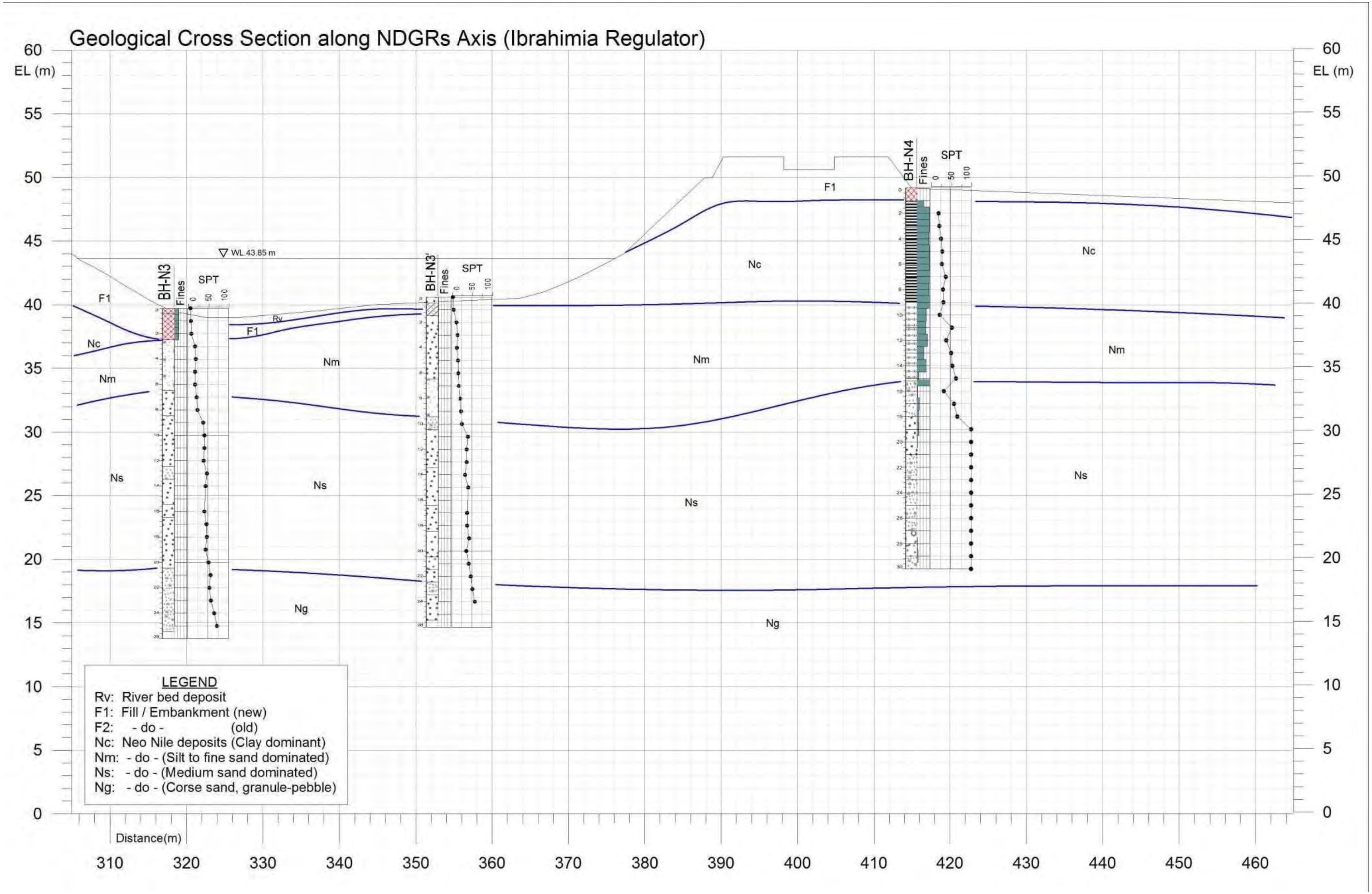
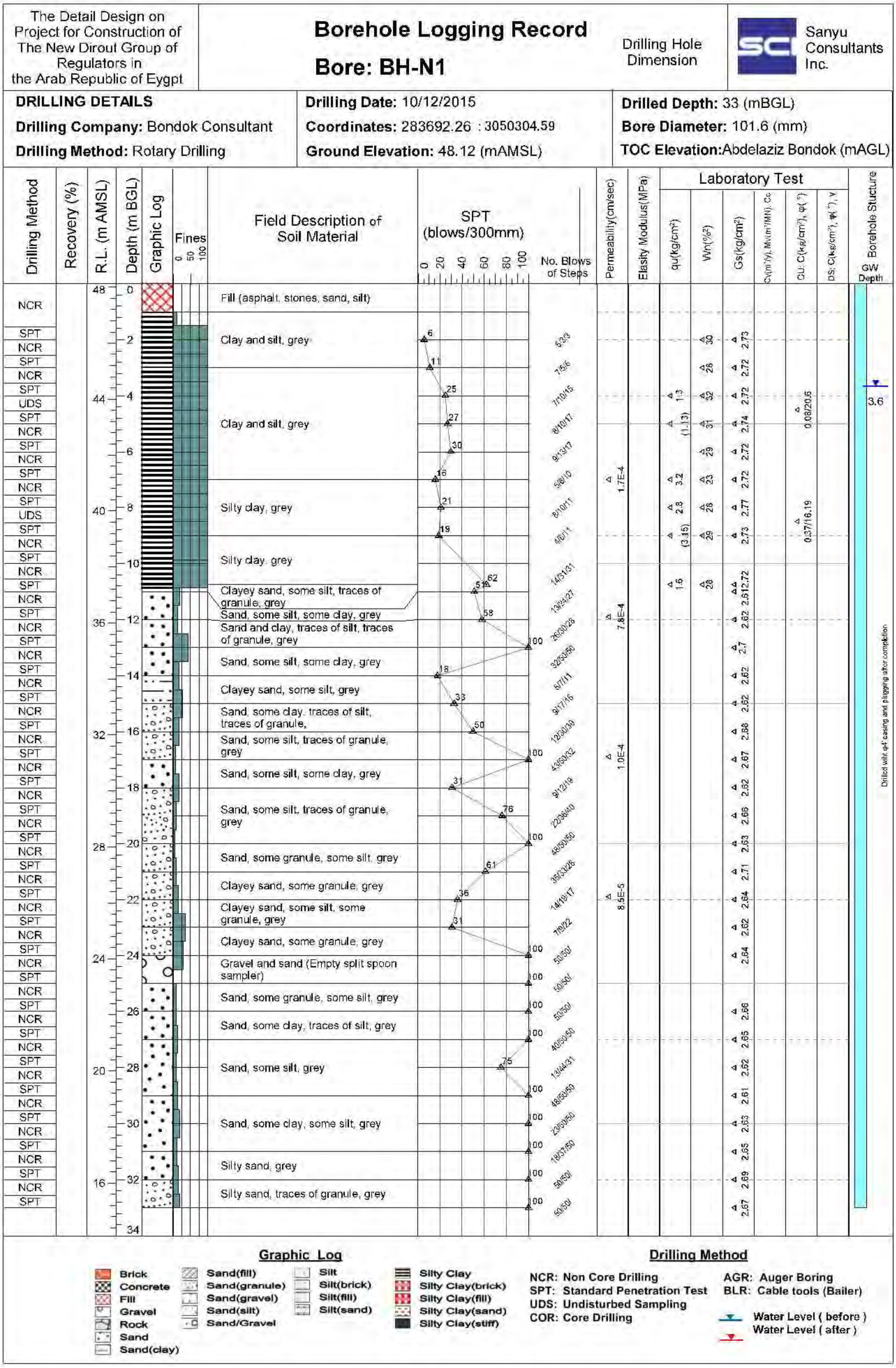


Figure 2-3.4 Geological cross-sectional map (New Ibrahimia regulator)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N1

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Bondok Consultant

Drilling Method: Rotary Drilling

Drilling Date: 10/12/2015

Coordinates: 283692.26 : 3050304.59

Ground Elevation: 48.12 (mAMSL)

Drilled Depth: 33 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: Abdelaziz Bondok (mAGL)

Fill (asphalt, stones, sand, silt)

Clay and silt, grey

Clay and silt, grey

Silty clay, grey

Silty clay, grey

Clayey sand, some silt, traces of granule, grey

Sand, some silt, some clay, grey

Sand and clay, traces of silt, traces of granule, grey

Sand, some silt, some clay, grey

Clayey sand, some silt, grey

Sand, some clay, traces of silt, traces of granule,

Sand, some silt, traces of granule, grey

Sand, some silt, some clay, grey

Sand, some silt, traces of granule, grey

Sand, some granule, some silt, grey

Clayey sand, some granule, grey

Clayey sand, some silt, some granule, grey

Clayey sand, some granule, grey

Gravel and sand (Empty split spoon sampler)

Sand, some granule, some silt, grey

Sand, some clay, traces of silt, grey

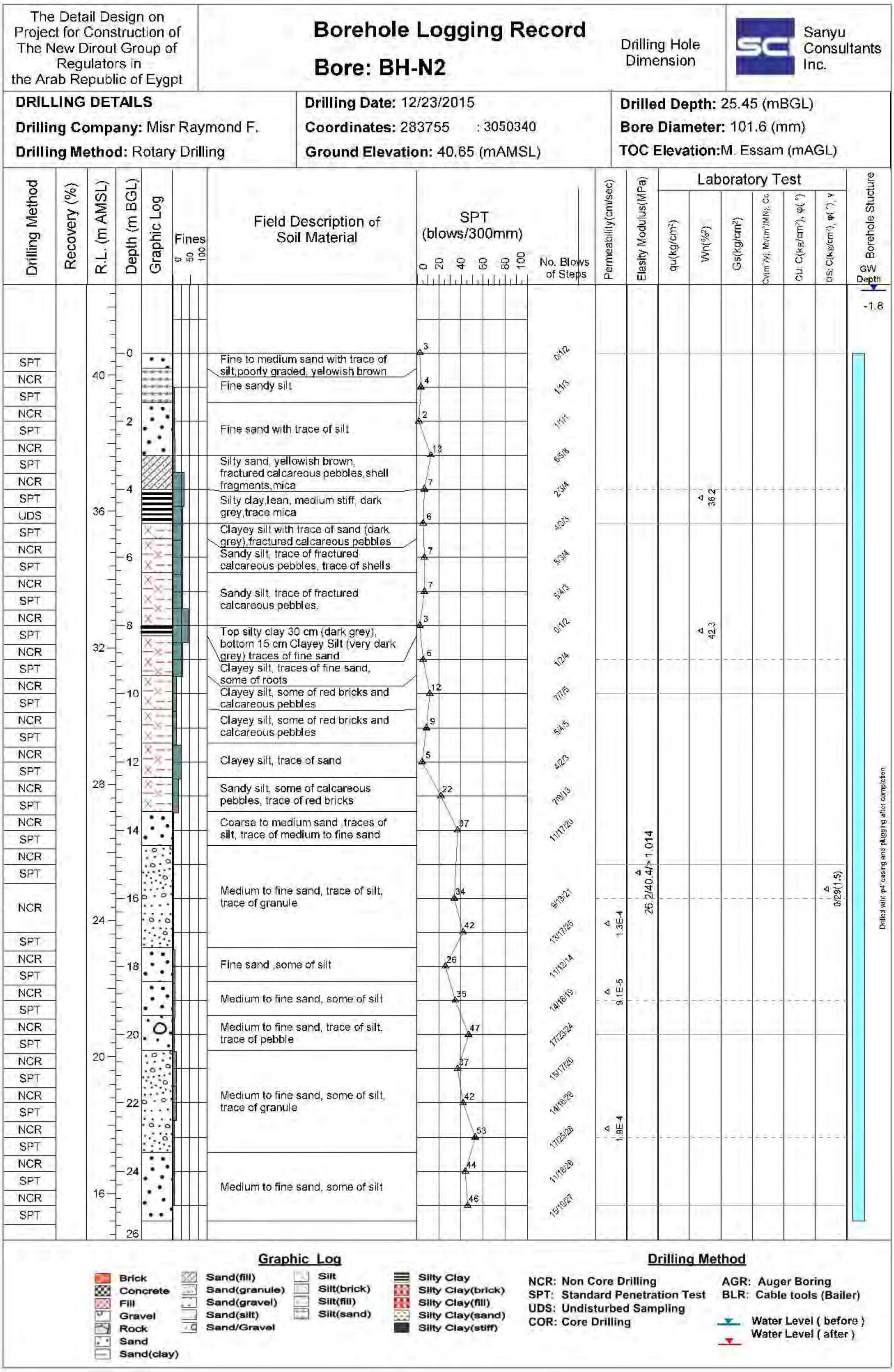
Sand, some silt, grey

Sand, some clay, some silt, grey

Silty sand, grey

Silty sand, traces of granule, grey

Figure 2-3.5 Borehole log (BH-N1)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N2

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS
Drilling Company: Misr Raymond F.
Drilling Method: Rotary Drilling
Drilling Date: 12/23/2015
Coordinates: 283755 : 3050340
Ground Elevation: 40.65 (mAMSL)
Drilled Depth: 25.45 (mBGL)
Bore Diameter: 101.6 (mm)
TOC Elevation:M. Essam (mAGL)

Field Description of Soil Material:

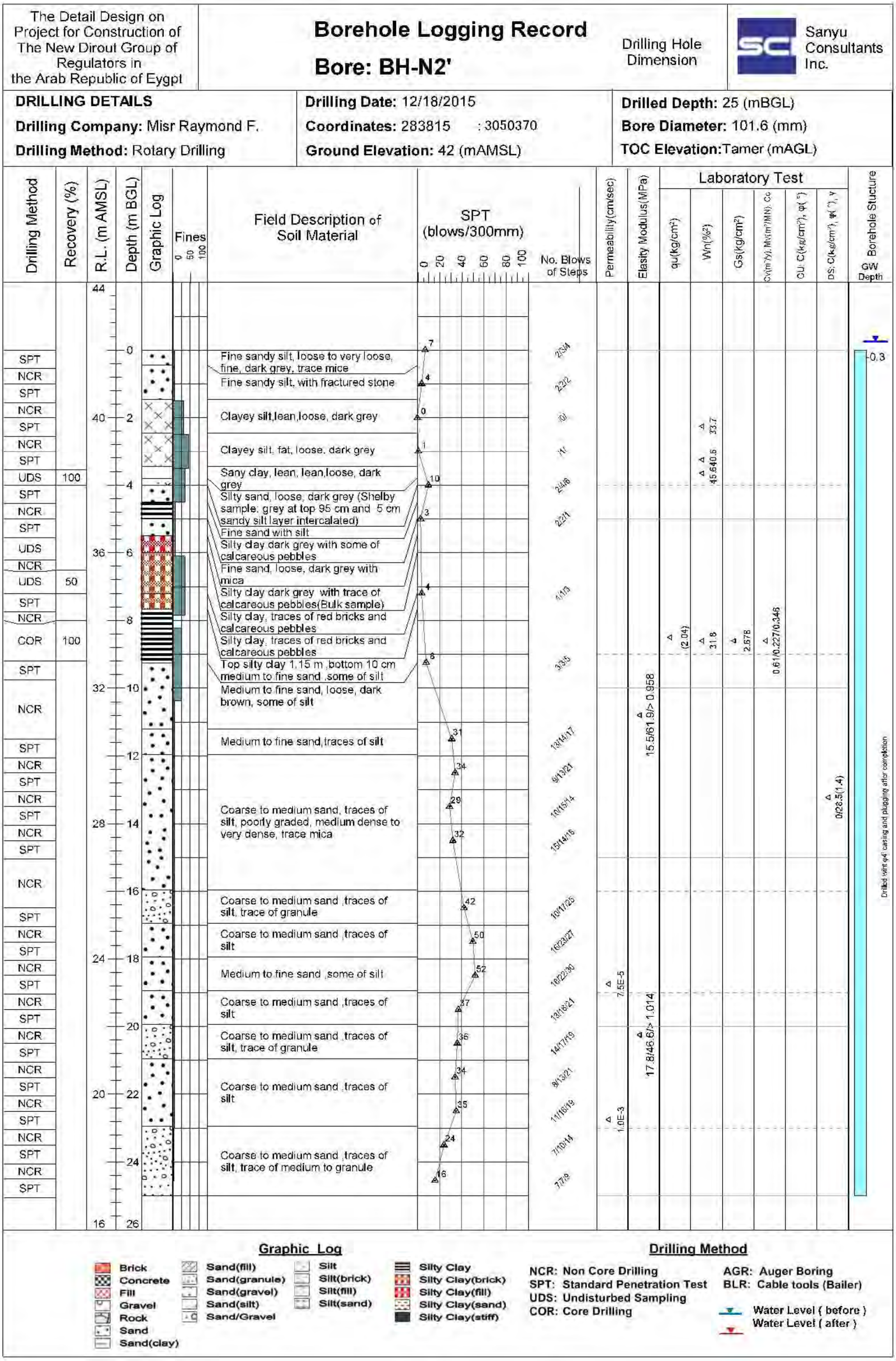
- Fine to medium sand with trace of silt,poorly graded, yelowish brown
- Fine sandy silt
- Fine sand with trace of silt
- Silty sand, yellowish brown, fractured calcareous pebbles,shell fragments,mica
- Silty clay,lean, medium stiff, dark grey,trace mica
- Clayey silt with trace of sand (dark grey),fractured calcareous pebbles
- Sandy silt, trace of fractured calcareous pebbles, trace of shells
- Sandy silt, trace of fractured calcareous pebbles.
- Top silty clay 30 cm (dark grey), bottom 15 cm Clayey Silt (very dark grey) traces of fine sand
- Clayey silt, traces of fine sand, some of roots
- Clayey silt, some of red bricks and calcareous pebbles
- Clayey silt, some of red bricks and calcareous pebbles
- Clayey silt, trace of sand
- Sandy silt, some of calcareous pebbles, trace of red bricks
- Coarse to medium sand ,traces of silt, trace of medium to fine sand
- Medium to fine sand, trace of silt, trace of granule
- Fine sand ,some of silt
- Medium to fine sand, some of silt
- Medium to fine sand, trace of silt, trace of pebble
- Medium to fine sand, some of silt, trace of granule
- Medium to fine sand, some of silt

SPT (blows/300mm)	No. Blows of Steps
3	0/1/2
4	1/1/3
2	1/1/1
13	6/5/8
7	2/3/4
6	4/3/3
7	5/3/4
7	5/4/3
3	0/1/2
6	1/2/4
12	7/7/5
9	5/4/5
5	4/2/3
22	7/9/13
37	11/17/20
34	9/13/21
42	13/17/25
26	11/12/14
35	14/16/19
47	17/23/24
37	15/17/20
42	14/16/26
53	17/25/28
44	11/18/26
46	15/19/27

Drilled with φ4' casing and plugging after completion

Drilling Method
NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.6 Borehole log (BH-N2)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N2'

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 12/18/2015

Coordinates: 283815 : 3050370

Ground Elevation: 42 (mAMSL)

Drilled Depth: 25 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: Tamer (mAGL)

Field Description of Soil Material

Fine sandy silt, loose to very loose, fine, dark grey, trace mice

Fine sandy silt, with fractured stone

Clayey silt,lean,loose, dark grey

Clayey silt, fat, loose, dark grey

Sany clay, lean, lean,loose, dark grey

Silty sand, loose, dark grey (Shelby sample: grey at top 95 cm and 5 cm sandy silt layer intercalated)

Fine sand with silt

Silty clay dark grey with some of calcareous pebbles

Fine sand, loose, dark grey with mica

Silty clay dark grey with trace of calcareous pebbles(Bulk sample)

Silty clay, traces of red bricks and calcareous pebbles

Silty clay, traces of red bricks and calcareous pebbles

Top silty clay 1.15 m ,bottom 10 cm medium to fine sand ,some of silt

Medium to fine sand, loose, dark brown, some of silt

Medium to fine sand,traces of silt

Coarse to medium sand, traces of silt, poorly graded, medium dense to very dense, trace mica

Coarse to medium sand ,traces of silt, trace of granule

Coarse to medium sand ,traces of silt

Medium to fine sand ,some of silt

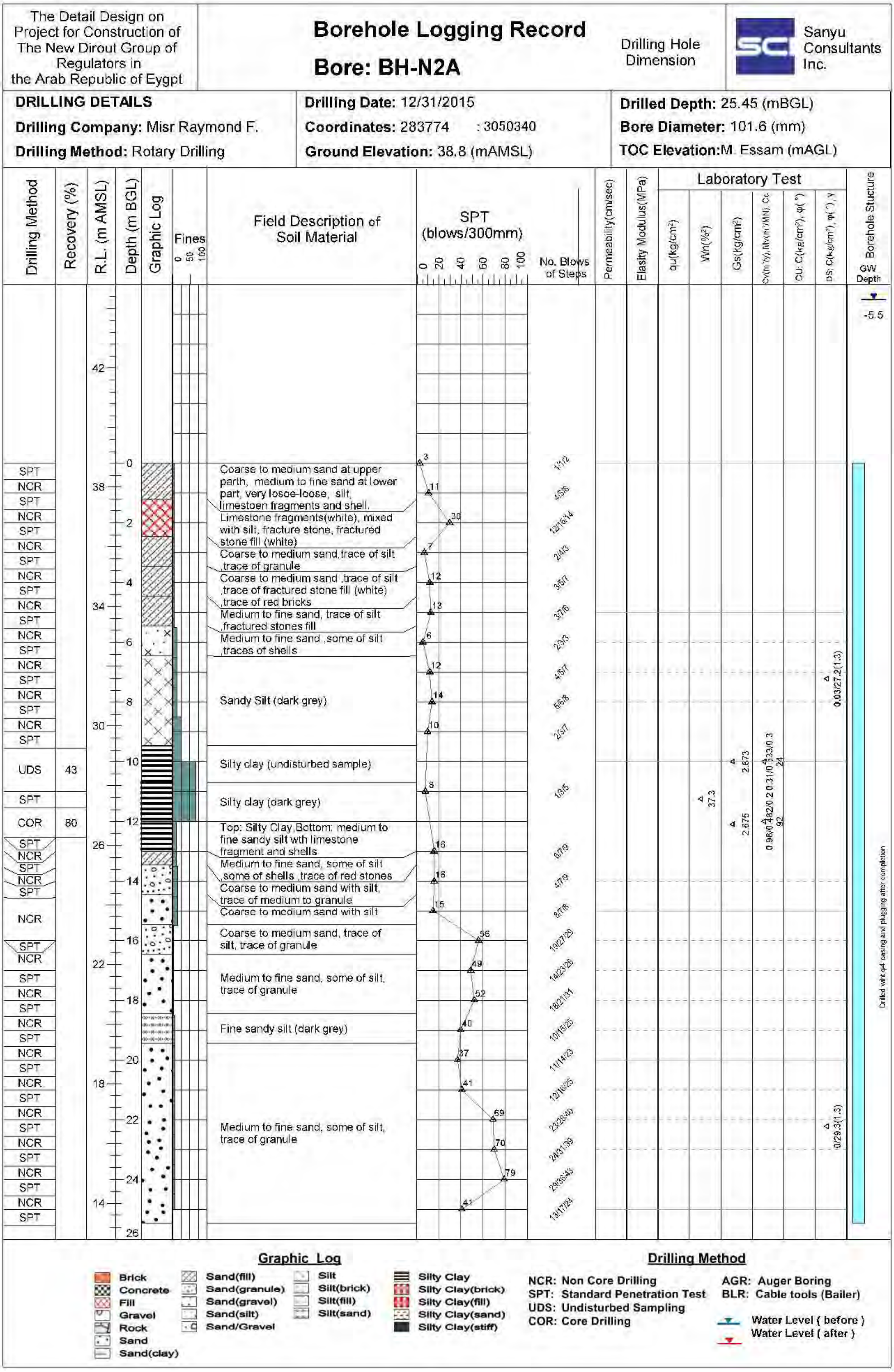
Coarse to medium sand ,traces of silt

Coarse to medium sand ,traces of silt, trace of granule

Coarse to medium sand ,traces of silt

Coarse to medium sand ,traces of silt, trace of medium to granule

Figure 2-3.7 Borehole log (BH-N2')



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N2A

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 12/31/2015

Coordinates: 283774 : 3050340

Ground Elevation: 38.8 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: M. Essam (mAGL)

Depth (m BGL)	Drilling Method	SPT	No. Blows of Steps
0	SPT	3	1/1/2
	NCR		
1	SPT	11	4/5/6
	NCR		
2	SPT	30	12/16/14
	NCR		
3	SPT	7	2/4/3
	NCR		
4	SPT	12	3/5/7
	NCR		
5	SPT	13	3/7/6
	NCR		
6	SPT	6	2/3/3
	NCR		
7	SPT	12	4/5/7
	NCR		
8	SPT	14	5/6/8
	NCR		
9	SPT	10	2/3/7
10	UDS (Recovery 43)		
11	SPT	8	1/3/5
12	COR (Recovery 80)		
13	SPT	16	6/7/9
	NCR		
14	SPT	16	4/7/9
	NCR		
15	SPT	15	8/7/8
	NCR		
16	SPT	56	10/27/29
	NCR		
17	SPT	49	14/23/26
	NCR		
18	SPT	52	18/21/31
	NCR		
19	SPT	40	10/15/25
	NCR		
20	SPT	37	11/14/23
	NCR		
21	SPT	41	12/16/25
	NCR		
22	SPT	69	23/29/40
	NCR		
23	SPT	70	24/31/39
	NCR		
24	SPT	79	29/36/43
	NCR		
25	SPT	41	13/17/24

Field Description of Soil Material:

- Coarse to medium sand at upper parth, medium to fine sand at lower part, very losoe-loose, silt, limestoen fragments and shell.
- Limestone fragments(white), mixed with silt, fracture stone, fractured stone fill (white)
- Coarse to medium sand,trace of silt ,trace of granule
- Coarse to medium sand ,trace of silt ,trace of fractured stone fill (white) ,trace of red bricks
- Medium to fine sand, trace of silt ,fractured stones fill
- Medium to fine sand ,some of silt ,traces of shells
- Sandy Silt (dark grey)
- Silty clay (undisturbed sample)
- Silty clay (dark grey)
- Top: Silty Clay,Bottom: medium to fine sandy silt wth limestone fragment and shells
- Medium to fine sand, some of silt ,some of shells ,trace of red stones
- Coarse to medium sand with silt, trace of medium to granule
- Coarse to medium sand with silt
- Coarse to medium sand, trace of silt, trace of granule
- Medium to fine sand, some of silt, trace of granule
- Fine sandy silt (dark grey)
- Medium to fine sand, some of silt, trace of granule

Graphic Log

Brick
Concrete
Fill
Gravel
Rock
Sand
Sand(clay)
Sand(fill)
Sand(granule)
Sand(gravel)
Sand(silt)
Sand/Gravel
Silt
Silt(brick)
Silt(fill)
Silt(sand)
Silty Clay
Silty Clay(brick)
Silty Clay(fill)
Silty Clay(sand)
Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.8 Borehole log (BH-N2A)

The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N2B

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS	**Drilling Date:** 1/5/2016	**Drilled Depth:** 25.45 (mBGL)
Drilling Company: Misr Raymond F.	**Coordinates:** 283794 : 3050330	**Bore Diameter:** 101.6 (mm)
Drilling Method: Rotary Drilling	**Ground Elevation:** 39.63 (mAMSL)	**TOC Elevation:** M. Essam (mAGL)

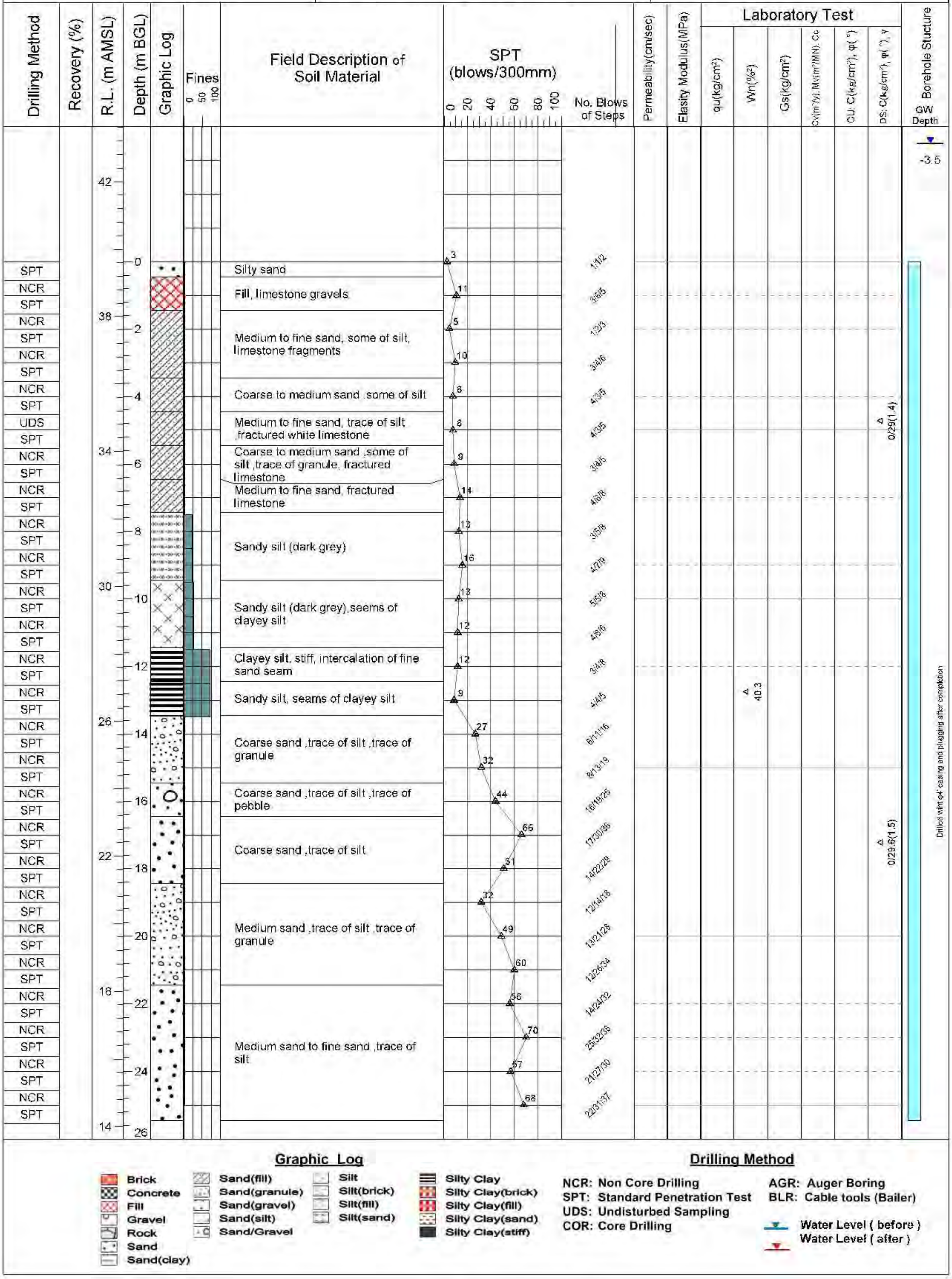


Figure 2-3.9 Borehole log (BH-N2B)

The Detail Design on
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Borehole Logging Record

Bore: BH-N2C

Drilling Hole
Dimension

Sanyu
Consultants
Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 1/3/2015

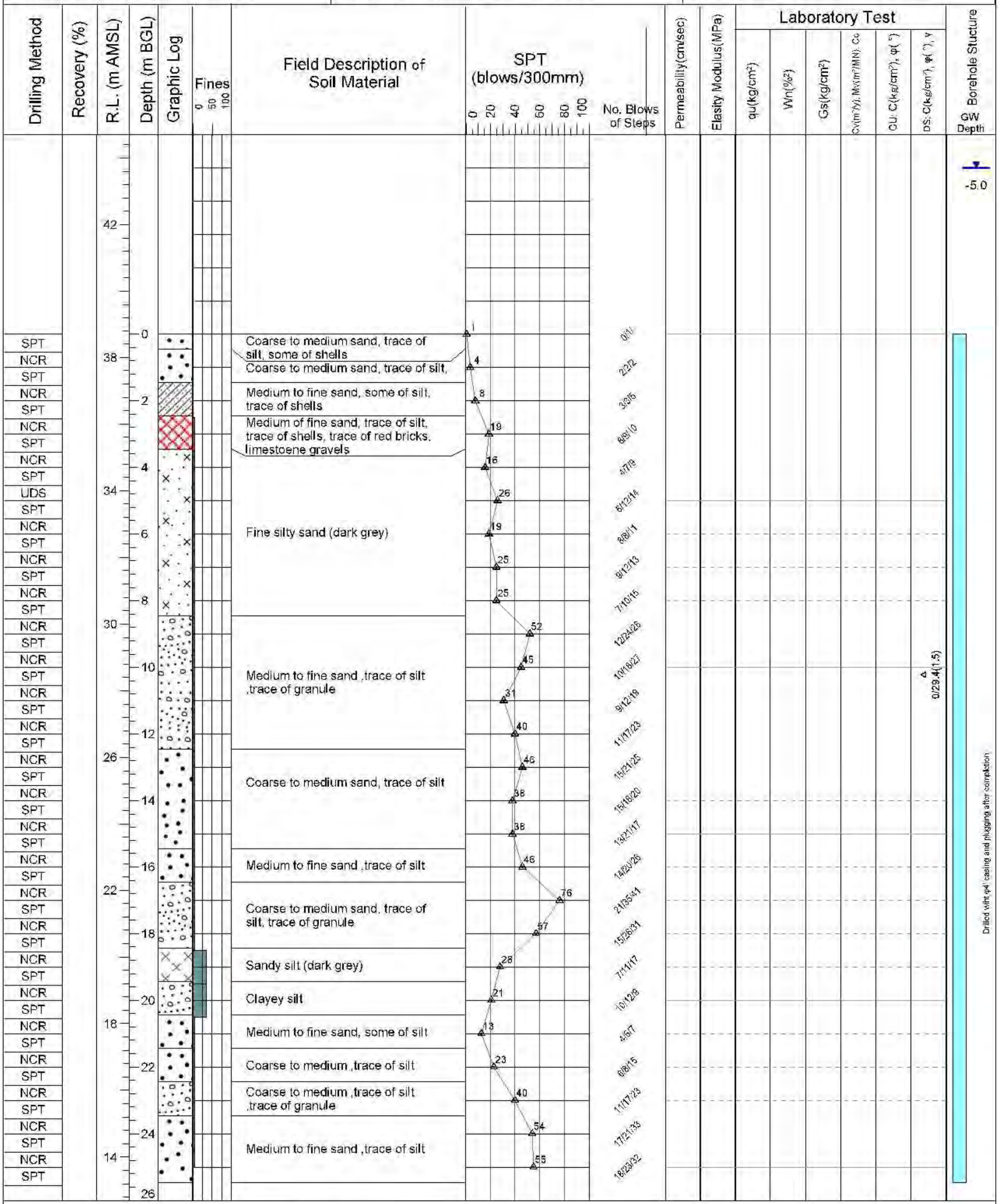
Coordinates: 283776 : 3050410

Ground Elevation: 38.7 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation:M. Essam (mAGL)



Graphic Log

🟥 Brick
▩ Concrete
▨ Fill
Gravel
Rock
Sand
Sand(clay)
Sand(fill)
Sand(granule)
Sand(gravel)
Sand(silt)
Sand/Gravel
Silt
Silt(brick)
Silt(fill)
Silt(sand)
Silty Clay
Silty Clay(brick)
Silty Clay(fill)
Silty Clay(sand)
Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.10 Borehole log (BH-N2C)

The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N2D

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 1/8/2015

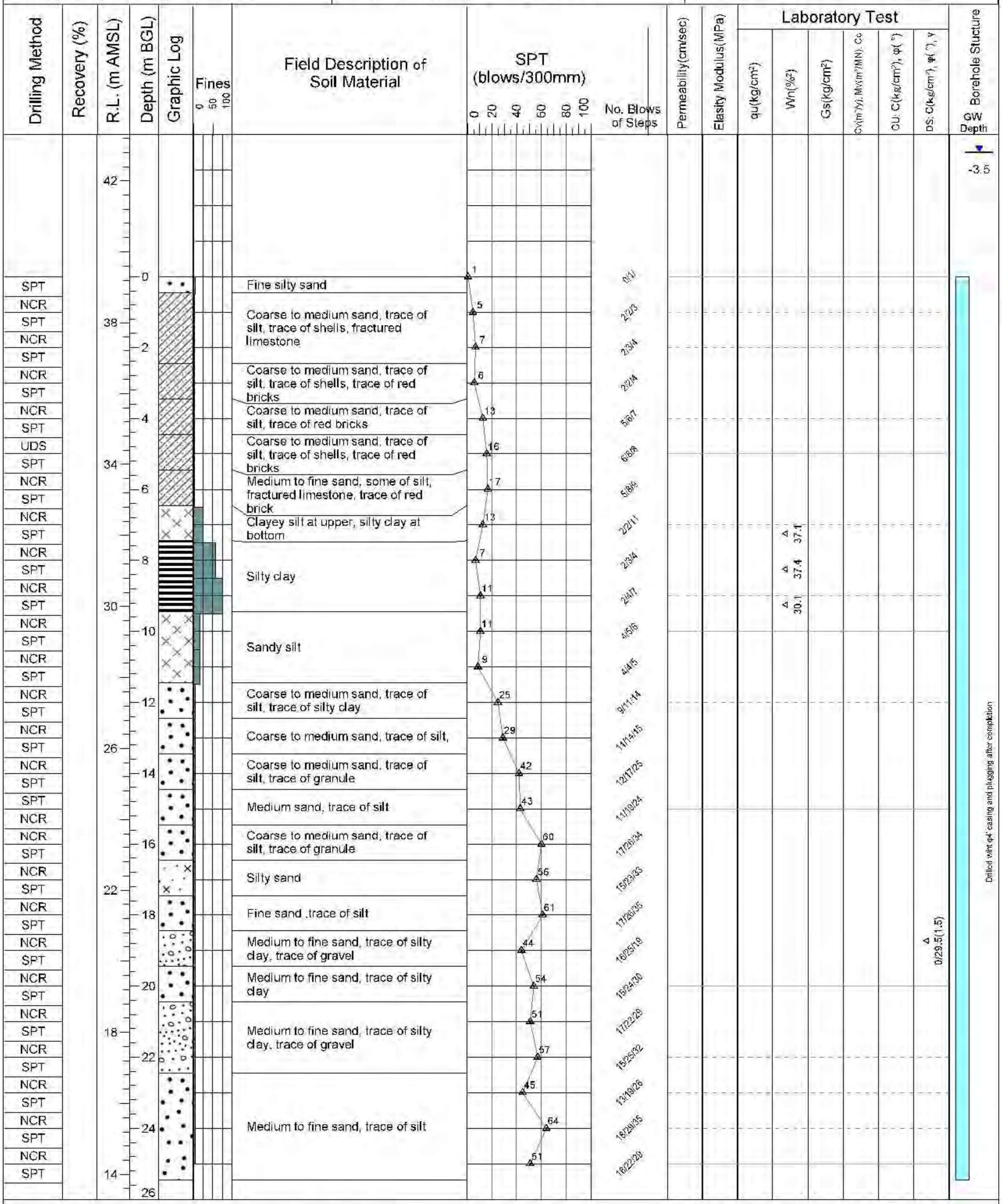
Coordinates: 283795 : 3050360

Ground Elevation: 39.3 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: M. Essam (mAGL)



Drilling method (top to bottom): SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, UDS, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, SPT, NCR, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT, NCR, SPT

Field Description of Soil Material:

- Fine silty sand
- Coarse to medium sand, trace of silt, trace of shells, fractured limestone
- Coarse to medium sand, trace of silt, trace of shells, trace of red bricks
- Coarse to medium sand, trace of silt, trace of red bricks
- Coarse to medium sand, trace of silt, trace of shells, trace of red bricks
- Medium to fine sand, some of silt, fractured limestone, trace of red brick
- Clayey silt at upper, silty clay at bottom
- Silty clay
- Sandy silt
- Coarse to medium sand, trace of silt, trace of silty clay
- Coarse to medium sand, trace of silt,
- Coarse to medium sand, trace of silt, trace of granule
- Medium sand, trace of silt
- Coarse to medium sand, trace of silt, trace of granule
- Silty sand
- Fine sand ,trace of silt
- Medium to fine sand, trace of silty clay, trace of gravel
- Medium to fine sand, trace of silty clay
- Medium to fine sand, trace of silty clay, trace of gravel
- Medium to fine sand, trace of silt

1	0/1/1
5	2/2/3
7	2/3/4
6	2/2/4
13	5/6/7
16	6/8/8
17	5/8/9
13	2/2/11
7	2/3/4
11	2/4/7
11	4/5/6
9	4/4/5
25	9/11/14
29	11/14/15
42	12/17/25
43	11/19/24
60	17/26/34
56	15/23/33
61	17/26/35
44	16/25/18
54	15/24/30
51	17/22/29
57	15/25/32
45	13/19/26
64	18/29/35
51	16/22/29

Graphic Log

- Brick
- Concrete
- Fill
- Gravel
- Rock
- Sand
- Sand(clay)
- Sand(fill)
- Sand(granule)
- Sand(gravel)
- Sand(silt)
- Sand/Gravel
- Silt
- Silt(brick)
- Silt(fill)
- Silt(sand)
- Silty Clay
- Silty Clay(brick)
- Silty Clay(fill)
- Silty Clay(sand)
- Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.11 Borehole log (BH-N2D)

The Detail Design on
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The New Dirout Group of
Regulators in
the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N3

Drilling Hole
Dimension

Sanyu
Consultants
Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 2/5/2016

Coordinates: 283970 : 3050406

Ground Elevation: 39.7 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation:M. Essam (mAGL)

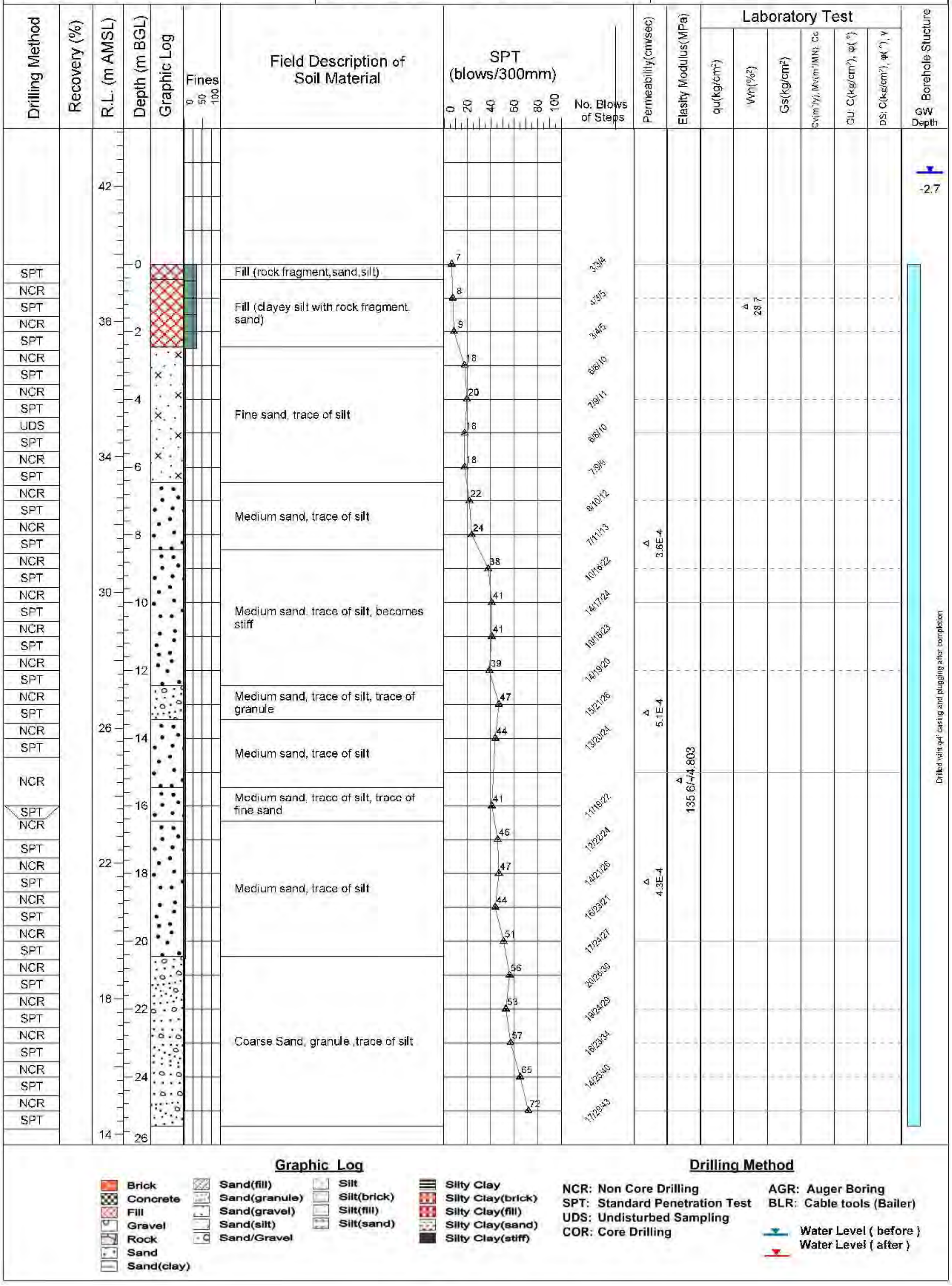
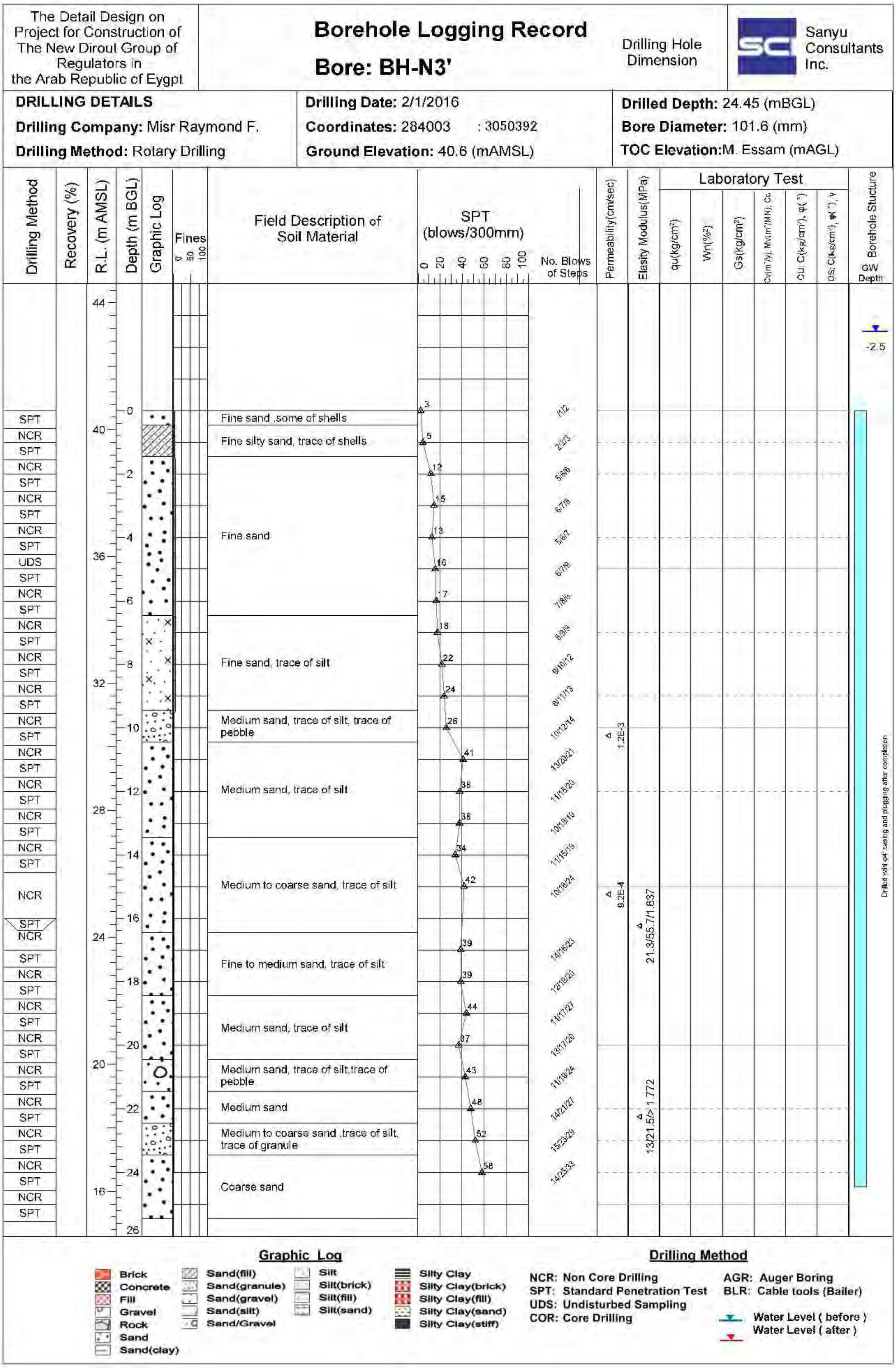


Figure 2-3.12 Borehole log (BH-N3)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N3'

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 2/1/2016

Coordinates: 284003 : 3050392

Ground Elevation: 40.6 (mAMSL)

Drilled Depth: 24.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: M. Essam (mAGL)

Field Description of Soil Material	SPT (blows/300mm)	No. Blows of Steps
Fine sand ,some of shells	3	1/1/2
Fine silty sand, trace of shells	5	2/2/3
Fine sand	12 15 13 16 17	5/6/6 6/7/8 5/6/7 6/7/9 7/8/9
Fine sand, trace of silt	18 22 24	8/9/9 9/10/12 8/11/13
Medium sand, trace of silt, trace of pebble	26	10/12/14
Medium sand, trace of silt	41 38 38	13/20/21 11/18/20 10/19/19
Medium to coarse sand, trace of silt	34 42	11/15/19 10/18/24
Fine to medium sand, trace of silt	39 39	14/16/23 12/19/20
Medium sand, trace of silt	44 37	11/17/27 13/17/20
Medium sand, trace of silt,trace of pebble	43	11/19/24
Medium sand	48	14/21/27
Medium to coarse sand ,trace of silt, trace of granule	52	15/23/29
Coarse sand	58	14/25/33

Graphic Log

🟥 Brick	▨ Sand(fill)	☐ Silt	▤ Silty Clay
▩ Concrete	☐ Sand(granule)	☐ Silt(brick)	▦ Silty Clay(brick)
▨ Fill	☐ Sand(gravel)	☐ Silt(fill)	▦ Silty Clay(fill)
☐ Gravel	☐ Sand(silt)	☐ Silt(sand)	▒ Silty Clay(sand)
☐ Rock	☐ Sand/Gravel		■ Silty Clay(stiff)
☐ Sand			
☐ Sand(clay)			

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling

AGR: Auger Boring
BLR: Cable tools (Bailer)

Water Level (before)
Water Level (after)

Figure 2-3.13 Borehole log (BH-N3')

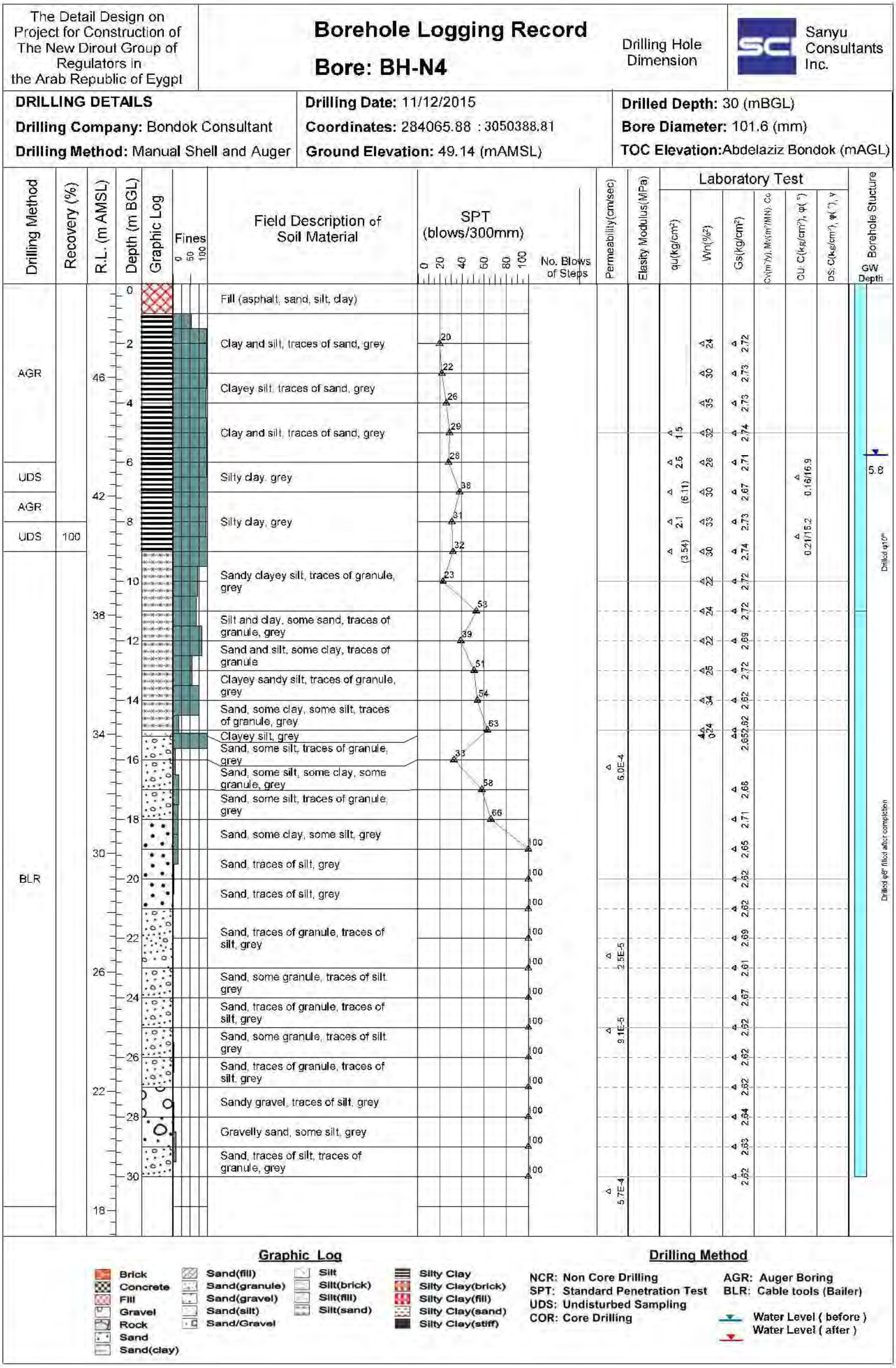
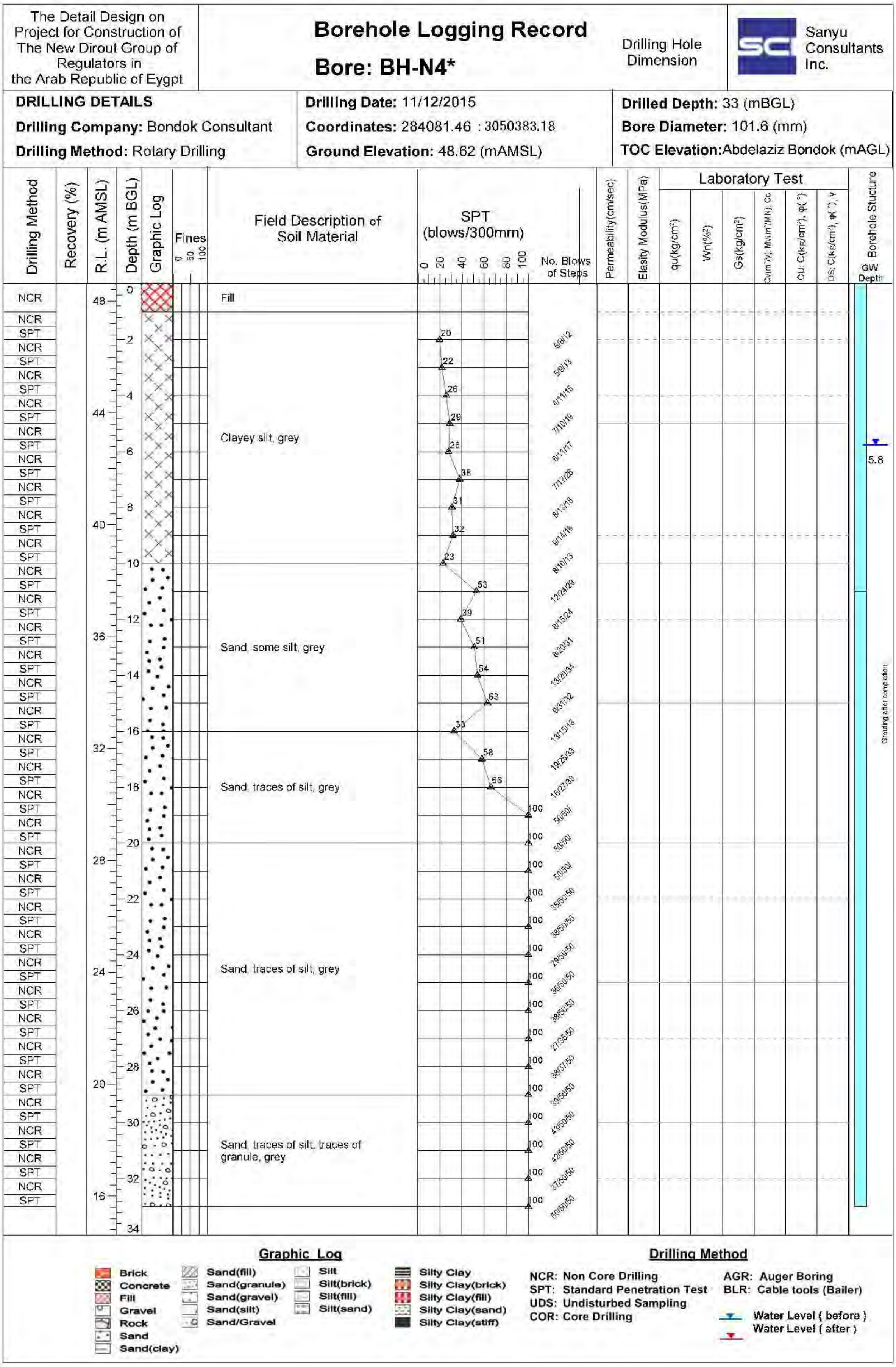


Figure 2-3.14 Borehole log (BH-N4)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N4*

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS	**Drilling Date:** 11/12/2015	**Drilled Depth:** 33 (mBGL)
Drilling Company: Bondok Consultant	**Coordinates:** 284081.46 : 3050383.18	**Bore Diameter:** 101.6 (mm)
Drilling Method: Rotary Drilling	**Ground Elevation:** 48.62 (mAMSL)	**TOC Elevation:** Abdelaziz Bondok (mAGL)

Field Description of Soil Material:

- Fill
- Clayey silt, grey
- Sand, some silt, grey
- Sand, traces of silt, grey
- Sand, traces of silt, grey
- Sand, traces of silt, traces of granule, grey

SPT (blows/300mm)	No. Blows of Steps
20	6/8/12
22	5/9/13
26	4/11/15
29	7/10/19
28	6/11/17
38	7/12/26
31	8/13/18
32	9/14/18
23	8/10/13
53	12/24/29
39	8/15/24
51	8/20/31
54	13/20/34
63	9/31/32
33	13/15/18
58	19/25/33
66	16/27/39
100	50/50/
100	50/50/
100	50/50/
100	35/50/50
100	38/50/50
100	29/50/50
100	36/50/50
100	38/50/50
100	27/35/50
100	38/37/50
100	39/50/50
100	43/50/50
100	42/50/50
100	37/50/50
100	50/50/50

GW Depth: 5.8

Grouting after completion

Graphic Log

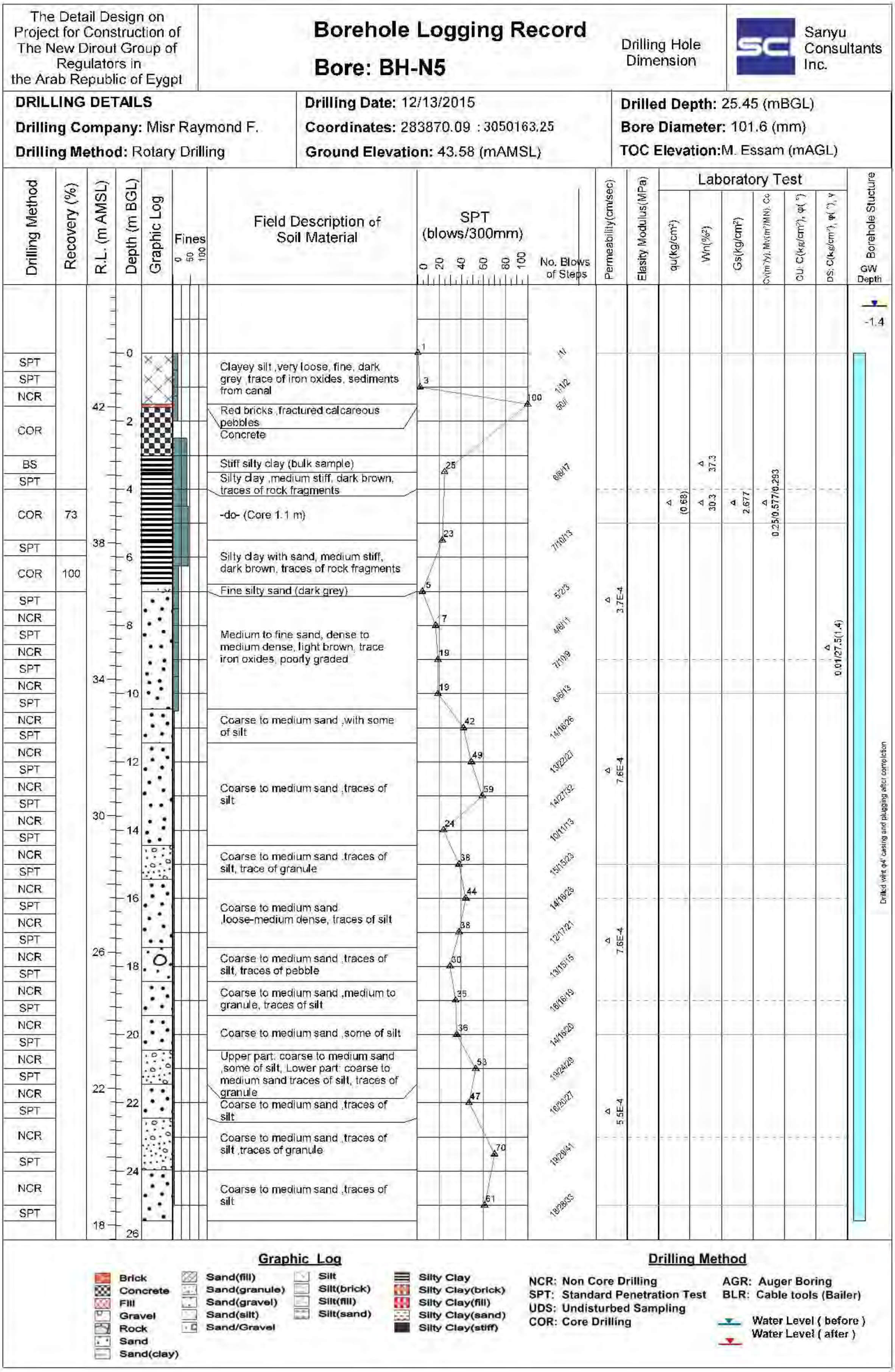
- Brick
- Concrete
- Fill
- Gravel
- Rock
- Sand
- Sand(clay)
- Sand(fill)
- Sand(granule)
- Sand(gravel)
- Sand(silt)
- Sand/Gravel
- Silt
- Silt(brick)
- Silt(fill)
- Silt(sand)
- Silty Clay
- Silty Clay(brick)
- Silty Clay(fill)
- Silty Clay(sand)
- Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)

Water Level (before)
Water Level (after)

Figure 2-3.15 Borehole log (BH-N4*)



The Detail Design on Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N5

Drilling Hole Dimension

Sanyu Consultants Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 12/13/2015

Coordinates: 283870.09 : 3050163.25

Ground Elevation: 43.58 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation: M. Essam (mAGL)

Field Description of Soil Material

- Clayey silt ,very loose, fine, dark grey ,trace of iron oxides, sediments from canal
- Red bricks ,fractured calcareous pebbles
- Concrete
- Stiff silty clay (bulk sample)
- Silty clay ,medium stiff, dark brown, traces of rock fragments
- -do- (Core 1.1 m)
- Silty clay with sand, medium stiff, dark brown, traces of rock fragments
- Fine silty sand (dark grey)
- Medium to fine sand, dense to medium dense, light brown, trace iron oxides, poorly graded
- Coarse to medium sand ,with some of silt
- Coarse to medium sand ,traces of silt
- Coarse to medium sand ,traces of silt, trace of granule
- Coarse to medium sand ,loose-medium dense, traces of silt
- Coarse to medium sand ,traces of silt, traces of pebble
- Coarse to medium sand ,medium to granule, traces of silt
- Coarse to medium sand ,some of silt
- Upper part: coarse to medium sand ,some of silt, Lower part: coarse to medium sand traces of silt, traces of granule
- Coarse to medium sand ,traces of silt
- Coarse to medium sand ,traces of silt ,traces of granule
- Coarse to medium sand ,traces of silt

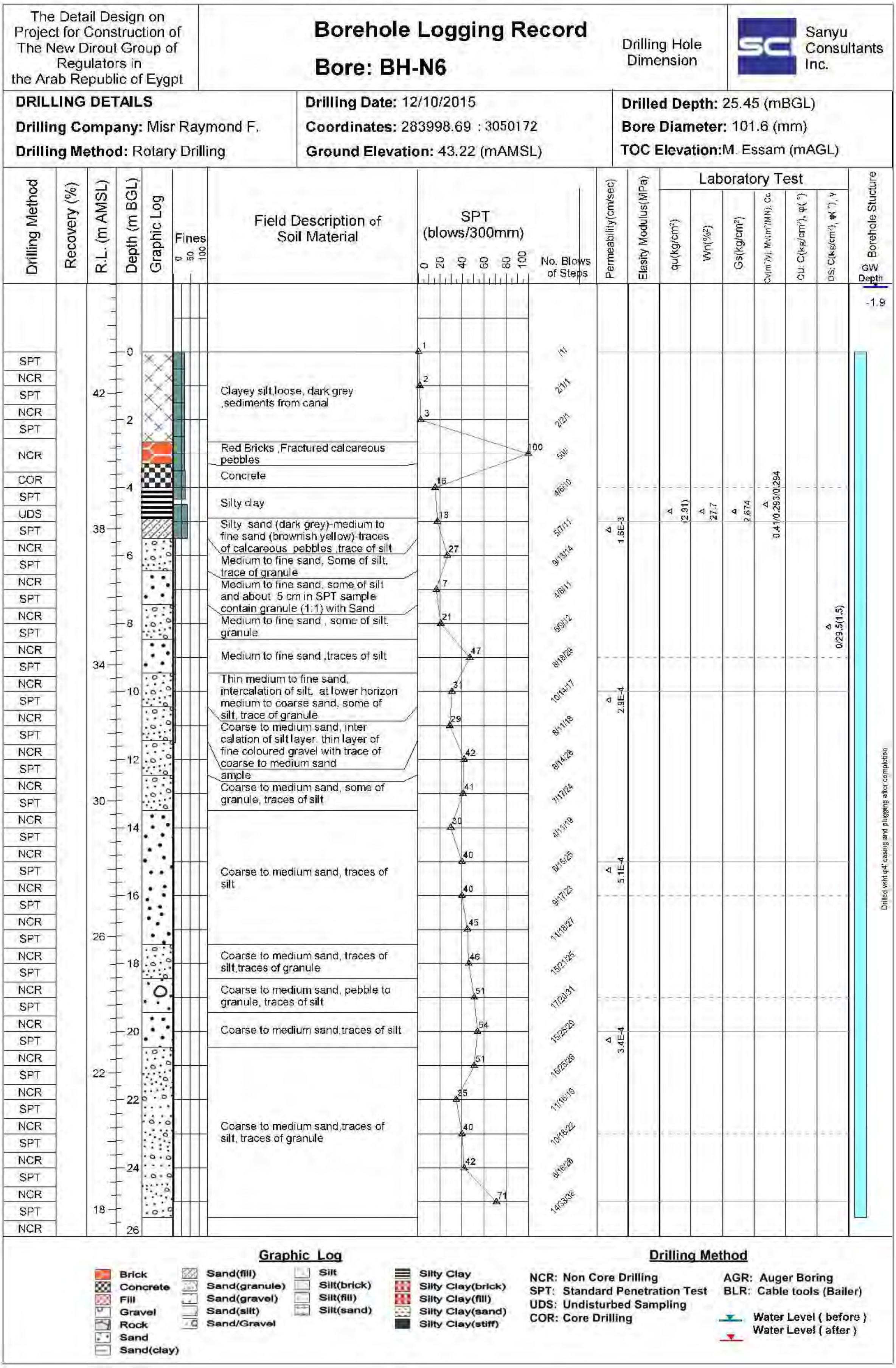
Graphic Log

- ▨ Brick
- ▨ Concrete
- ▨ Fill
- ▨ Gravel
- ▨ Rock
- ▨ Sand
- ▨ Sand(clay)
- ▨ Sand(fill)
- ▨ Sand(granule)
- ▨ Sand(gravel)
- ▨ Sand(silt)
- ▨ Sand/Gravel
- ▨ Silt
- ▨ Silt(brick)
- ▨ Silt(fill)
- ▨ Silt(sand)
- ▨ Silty Clay
- ▨ Silty Clay(brick)
- ▨ Silty Clay(fill)
- ▨ Silty Clay(sand)
- ▨ Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.16 Borehole log (BH-N5)



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Regulators in
the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-N6

Drilling Hole
Dimension

Sanyu
Consultants
Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 12/10/2015

Coordinates: 283998.69 : 3050172

Ground Elevation: 43.22 (mAMSL)

Drilled Depth: 25.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation:M. Essam (mAGL)

Field Description of Soil Material

Clayey silt,loose, dark grey ,sediments from canal

Red Bricks ,Fractured calcareous pebbles

Concrete

Silty clay

Silty sand (dark grey)-medium to fine sand (brownish yellow)-traces of calcareous pebbles ,trace of silt

Medium to fine sand, Some of silt, trace of granule

Medium to fine sand, some of silt and about 5 cm in SPT sample contain granule (1:1) with Sand

Medium to fine sand , some of silt, granule

Medium to fine sand ,traces of silt

Thin medium to fine sand, intercalation of silt, at lower horizon medium to coarse sand, some of silt, trace of granule

Coarse to medium sand, inter calation of silt layer. thin layer of fine coloured gravel with trace of coarse to medium sand ample

Coarse to medium sand, some of granule, traces of silt

Coarse to medium sand, traces of silt

Coarse to medium sand, traces of silt,traces of granule

Coarse to medium sand, pebble to granule, traces of silt

Coarse to medium sand,traces of silt

Coarse to medium sand,traces of silt, traces of granule

Drilled wiht φ4' casing and plugging after completion

Graphic Log

🟥 Brick	▨ Sand(fill)	☐ Silt	☰ Silty Clay
▦ Concrete	▨ Sand(granule)	☐ Silt(brick)	▦ Silty Clay(brick)
▨ Fill	▨ Sand(gravel)	☐ Silt(fill)	▦ Silty Clay(fill)
☐ Gravel	☐ Sand(silt)	☐ Silt(sand)	▨ Silty Clay(sand)
▨ Rock	▨ Sand/Gravel		■ Silty Clay(stiff)
▨ Sand			
☐ Sand(clay)			

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling

AGR: Auger Boring
BLR: Cable tools (Bailer)

Water Level (before)
Water Level (after)

Figure 2-3.17 Borehole log (BH-N6)

The Detail Design on
Project for Construction of
The New Dirout Group of
Regulators in
the Arab Republic of Egypt

Borehole Logging Record

Bore: BH-A1 A

Drilling Hole
Dimension

Sanyu
Consultants
Inc.

DRILLING DETAILS

Drilling Company: Misr Raymond F.

Drilling Method: Rotary Drilling

Drilling Date: 2/10/2016

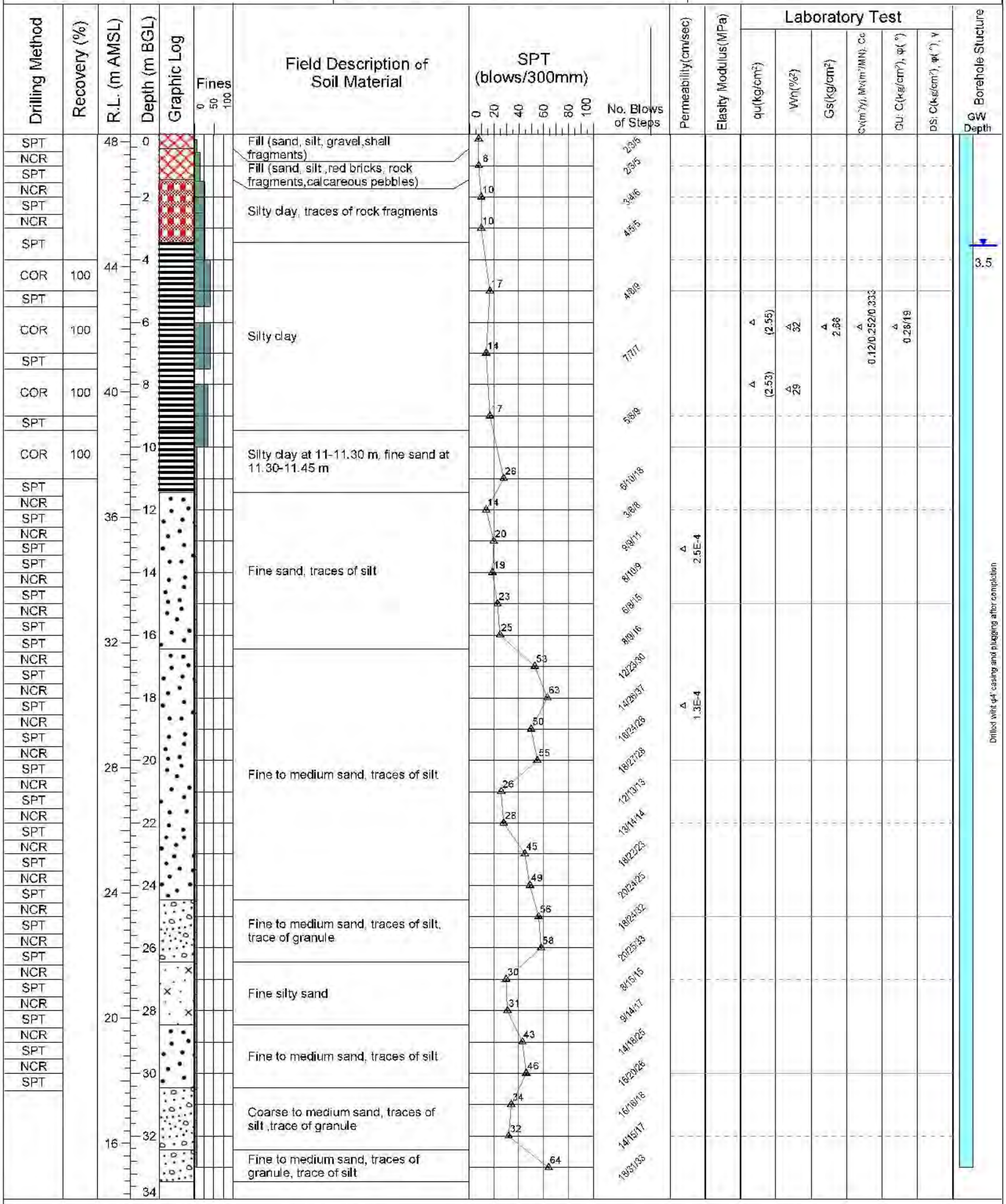
Coordinates: 283905 : 3050398

Ground Elevation: 48.236 (mAMSL)

Drilled Depth: 33.45 (mBGL)

Bore Diameter: 101.6 (mm)

TOC Elevation:M. Essam (mAGL)



Fill (sand, silt, gravel,shall fragments)

Fill (sand, silt ,red bricks, rock fragments,calcareous pebbles)

Silty clay, traces of rock fragments

Silty clay

Silty clay at 11-11.30 m, fine sand at 11.30-11.45 m

Fine sand, traces of silt

Fine to medium sand, traces of silt

Fine to medium sand, traces of silt, trace of granule

Fine silty sand

Fine to medium sand, traces of silt

Coarse to medium sand, traces of silt ,trace of granule

Fine to medium sand, traces of granule, trace of silt

Graphic Log

- Brick
- Concrete
- Fill
- Gravel
- Rock
- Sand
- Sand(clay)
- Sand(fill)
- Sand(granule)
- Sand(gravel)
- Sand(silt)
- Sand/Gravel
- Silt
- Silt(brick)
- Silt(fill)
- Silt(sand)
- Silty Clay
- Silty Clay(brick)
- Silty Clay(fill)
- Silty Clay(sand)
- Silty Clay(stiff)

Drilling Method

NCR: Non Core Drilling
SPT: Standard Penetration Test
UDS: Undisturbed Sampling
COR: Core Drilling
AGR: Auger Boring
BLR: Cable tools (Bailer)
Water Level (before)
Water Level (after)

Figure 2-3.18 Borehole log (BH-A1A)

The Detail Design on
Project for Construction of
The New Dirout Group of
Regulators in
the Arab Republic of Eygpt

Borehole Logging Record

Bore: BH-A1 B

Drilling Hole
Dimension

Sanyu
Consultants
Inc.

DRILLING DETAILS	**Drilling Date:** 2/13/2016	**Drilled Depth:** 33 (mBGL)
Drilling Company: Misr Raymond F.	**Coordinates:** 283856 : 3050395	**Bore Diameter:** 101.6 (mm)
Drilling Method: Rotary Drilling	**Ground Elevation:** 49.181 (mAMSL)	**TOC Elevation:** M.Rizk (mAGL)

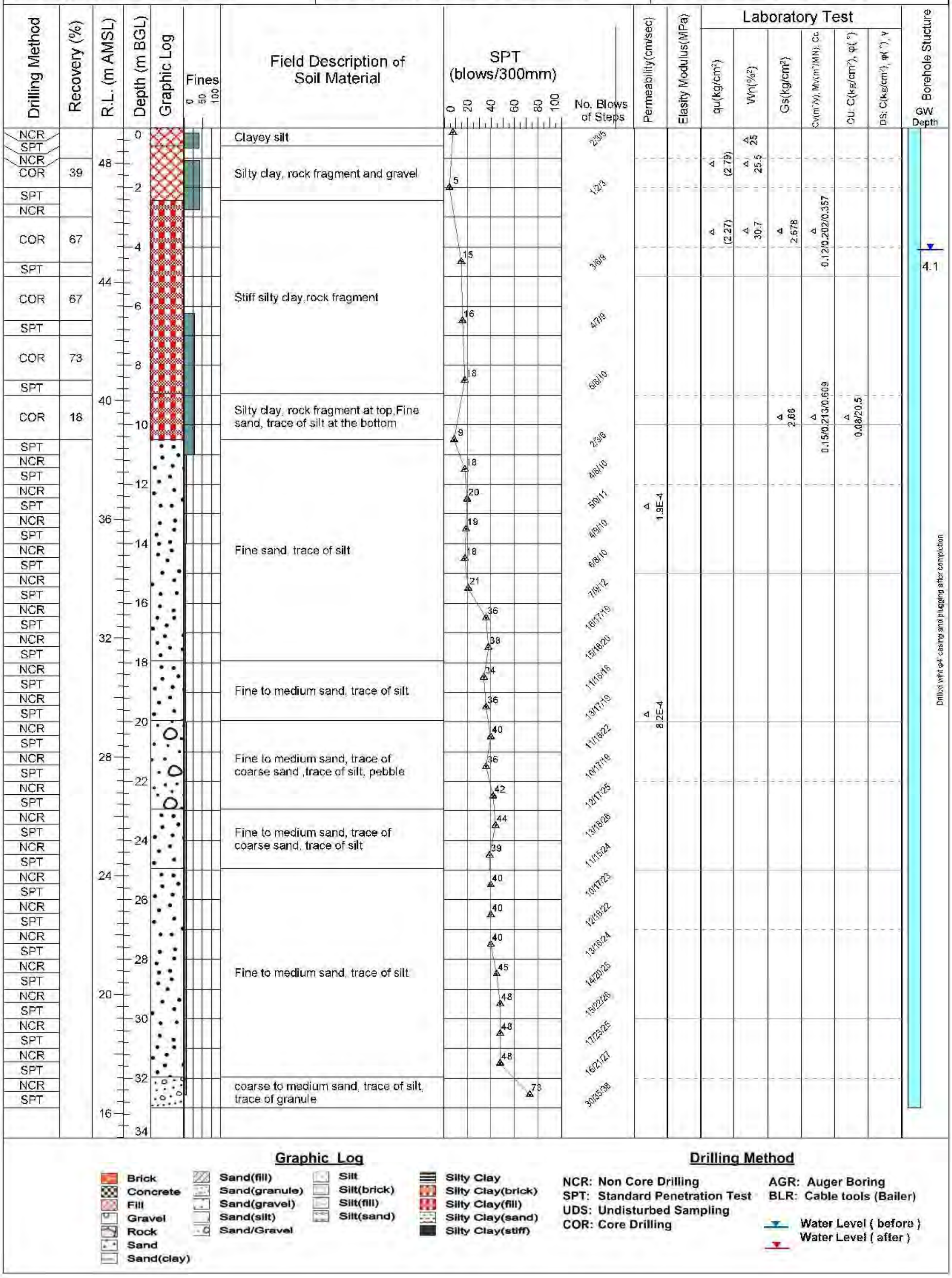


Figure 2-3.19 Borehole log (BH-A1B)

3. Hydraulic Dimensions and Calculation

3-1 Purpose

In order to clarify the flow capacity of the canal, a non-uniform flow analysis was applied under design conditions. Effective waterhead, is the difference between the upstream of the high water level (US.HWL) and the downstream of the high water level (DS.HWL).

In the evaluation of the analysis, the calculated water level at the end of the upstream must be lower than US.HWL under the conditions of the maximum discharge flow, with DS.HWL as the starting point for calculations. A water head shortage is found when US. HWL is calculated.

3-2 Hydraulic calculation (Non-uniform flow analysis)

(1) Method of analysis

Tracking the water surface in non-uniform flow is carried out by solving the basic equations of non-uniform flow, using the stepwise calculation method, or the graphical method. Calculations are carried out from a given point; toward the upstream side in the case of steady flow to the downstream side in the case of rapid flow.

Stepwise calculation method assumes the water depths at successive points from a given point, and the calculation proceeds verifying the energy by applying Bernoulli’s theory. This method has many merits: (1) calculation can be carried out at any cross-section regardless of rate of flow, (2) losses other than those incurred by friction can be calculated. It is therefore the most widely used computerized method. By dividing the water channel into ideal calculation sections and applying boundary conditions at the nodes, the calculation is carried out to obtain the successive shape of the water surface so that Bernoulli’s equation is satisfied in each section. Applying Bernoulli’s equation to cross-sections I and II in Figure 3-2.1, the following equations are obtained.

$$h_1+\frac{\alpha\cdot Q^2}{2g\cdot A_1{}^2}+z_1+h_f=h_2+\frac{\alpha\cdot Q^2}{2g\cdot A_2{}^2}+z_2$$

$$h_f=\frac{Q^2\cdot l}{2}\left(\frac{n_1{}^2}{R_1{}^{4/3}A_1{}^2}+\frac{n_2{}^2}{R_2{}^{4/3}A_2{}^2}\right)$$

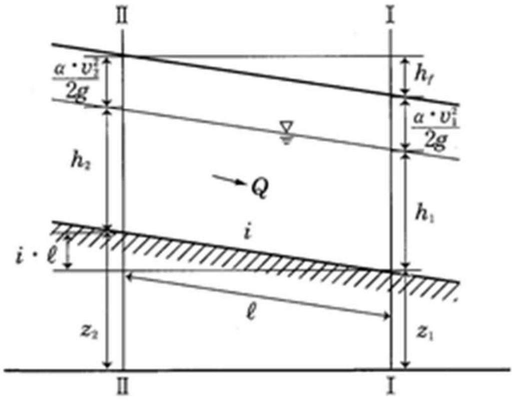


Figure 3-2.1 Explanatory drawing for non-uniform flow calculation

Where, z: Height from bedrock to bottom of water channel (m)

h : Water depth (m)

Q : Discharge (m^3/s)

v : Flow velocity (Q/A) (m/s)

i : Slope of the water channel bottom

h_f : Water head loss produced at cross-sections I, II (m)

ℓ : Slope length between cross-sections I to II (m)

R : Hydraulic radius (m)

A : Area of cross-section of water (m^2)

n : Roughness coefficient

g : Gravitational acceleration 9.8 (m/s^2)

α : Energy correction function

Subscripts 1, 2: indicate values at cross-sections 1 and 2 respectively.

When the energy at cross-section I is given, the water depth is calculated at cross-section II so that adding the hydraulic head loss between cross-sections I and II to the height of this energy line gives the height at cross-section II.

(2) Result of calculations

The result of required upstream-water level calculations by non-uniform analysis is shown on Table 3-2.1.

Table 3-2.1 Result of calculation by non-uniform analysis

Reg.name	**Bahr Yusef**	**Ibrahimia**	**Badraman**		**Abo Gabal**		**Sahelyia**
Canal name			**Badraman**	**Diroutiah**	**Abo Gabal**	**Irad Delgaw**	
Qmax	227 m^3/s	186 m^3/s	9 m^3/s	12 m^3/s	7 m^3/s	9 m^3/s	5 m^3/s
DS.HWL	45.82 m	45.13 m	45.90 m	45.90 m	45.90 m	45.90 m	45.90 m
Required US. water level (calculated WL)	46.00 m	45.22 m	45.96 m	45.95 m	45.94 m	45.95 m	45.93 m
US.HWL	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m
Judgment	**O.K**	**O.K**	**O.K**	**O.K**	**O.K**	**O.K**	**O.K**

4. Determining the Regulator Axis

4-1 Background related to determining the regulator axis

(1) Review of the regulators axis selection in the F/S stage

When the regulator axis was studied in F/S stage in 2010, there were two examination steps; namely, preliminary and detailed examinations.

1) 1st Step: Preliminary examination

In the beginning, the following three locations (plans) were compared.

- **Plan A**: The same location of the DGRs (rehabilitation of DGRs)
- **Plan B**: Upstream of DGRs (new construction)
- **Plan C**: Downstream of DGRs (new construction)

As the result of preliminary examination, NDRGs shall be constructed downstream of DGRs, which means that Plan C will be adopted.

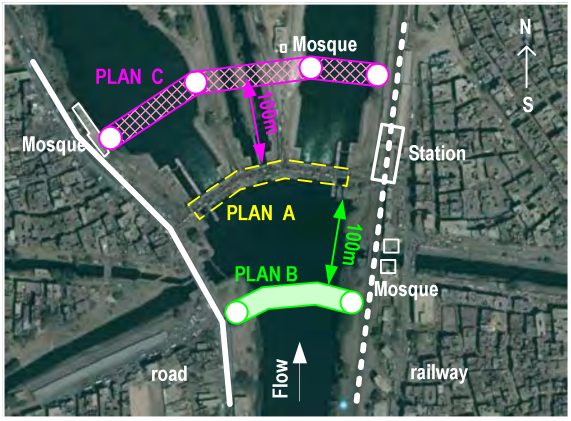


Figure 4-1.1 Preliminary layout of NDGRs' axis

2) 2nd Step: Detailed examination

In the detailed examination, layouts of the regulator axis were selected taking the following points into consideration:

- To secure enough space for the construction yard with due consideration given to the condition of site,
- To secure easy maintenance and effective operations as proper water diversion works (regulators),
- To mitigate negative impacts of the construction of NDGRs on the DGRs,
- To select locations for the new Sahelyia and Abo Gabal regulators that will solve the sedimentation issue.

Figure 4-1.2 Layout of NDGRs' axis in the detailed examination stage

In the context of the above matters, the following three locations (plans) were compared.

Plan C-1: This layout is approximately 100m downstream of DGRs, and the new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.

Plan C-2: This layout is approximately 140m downstream of DGRs, and the new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.

Plan C-3: The layouts of NDGRs are scattered. The Bahr Yusef and Badraman regulators are approximately 600m downstream of DGRs, and Ibrahimia regulator is approximately 1,000m downstream of DGRs. The new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.

The assessment symbols are as follows:

●: advantage

×: disadvantage.

Plan C-1: 100m downstream of DGRs

● This plan has the advantage of having proper distribution functions as an integrated regulator, as well as the stability of the structure, and ease of construction.

× The temporary cofferdam touches DGRs, so the apron and navigation lock on DGRs need to be partially demolished before the construction of NDGRs.

Plan C-2: 140m downstream of DGRs (adopted)

● This plan has the advantage of having proper distribution functions as an integrated regulator, as well as structural stability, and ease of construction (same as Plan C-1).

● Additionally, the temporary cofferdam does not reach to the DGRs in order to construct the NDGRs. This plan preserves the DGRs as historical monuments.

Plan C-3: 600-1,000m downstream of DGRs

● Set further downstream from Plan C-2, this plan is 600m-1,000m downstream of DGRs and avoids densely-populated area.

× The maintenance bridge on each regulator is not continuous. Therefore, it takes extra time to reach each regulator, making it difficult to maintain NDGRs properly.

× Gate operation could be a difficult to regulate discharge as new regulators are substantially away from diversion place of DGRs. Discharge will therefore not be controlled by regulator gates of NDGRs, but by the dischargeable capacity of DGRs vents. This causes unexpected backwater to move upstream of NDGRs.

× The low elevation 140m ahead of the downstream requires the building of an embankment along the canal from the NDGRs to DGRs against the raised water level, because of the expansion of the backwater area. This would increase costs and affect the surrounding area through possible seepage.

3) Conclusion of F/S stage

As a result of detailed examination, it was decided that NDGRs would be build 140m downstream of DGRs as confirmed by TAC on 30th March, 2010, thereby adopting Plan C-2.

(2) Request for supplemental examination at the Basic Design stage

During the study on the basic design stage, the Egyptian side requested that impacts on existing DGRs in the construction stage be avoided, and suggested a plan in which the wire axis be set 150m downstream from the existing DGRs. The D/D consultants agreed to conduct a supplemental examination of the plan above and compare between the 140m and 150m plans.

4-2 Location of regulator axis

As the result of these deliberations, NDGRs will be located 140m downstream of the existing DGRs, and Sahelyia and Abo Gabal regulators will be located in front of the existing ones. This is in conformity with the decision at F/S stage approved at the 6th TAC meeting.

(1) Effect on existing DGRs

Double sheet piles for the cofferdam could mitigate the negative impacts to the DGR foundations in the construction stage. The embedded length of this sheet pile shall be secured to the necessary length to avoid the influence of piping and seepage underneath the DGRs onto the construction yard. The following formula from the Japanese design criteria will be used for the examination to mitigate the negative impacts.

$F = L1 / h1$ and $L2 / h2 \geqq Fs$

where,

L1 and L2: Creep (seepage) length

h1: Water depth

h2: Difference length between water level and level of construction yard

F: Safety factor

Fs: Required safety factor

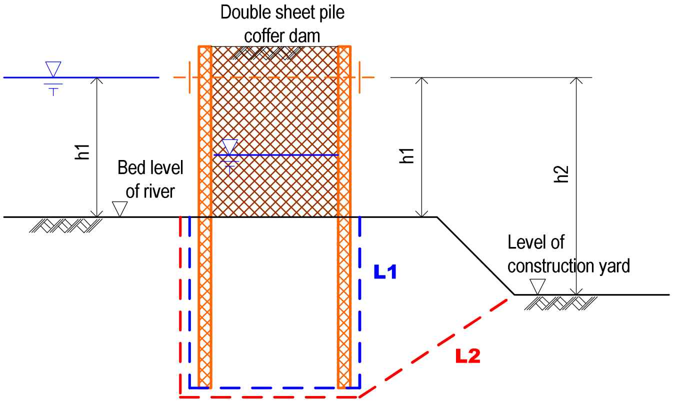


Figure 4-2.1 Schematic sketch for calculation

No negative impacts of piping and seepage were observed during construction in the four previous Japanese grant aid projects along the Bahr Yusef canal. The stability of the existing regulator was secure, including the exiting one located just beside the double sheet pile cofferdam.

Therefore, no negative impacts such as piping and seepage are expected. Monitoring instruments/devices that inspect the stability of DGRs, are expected to be installed at the construction stage.

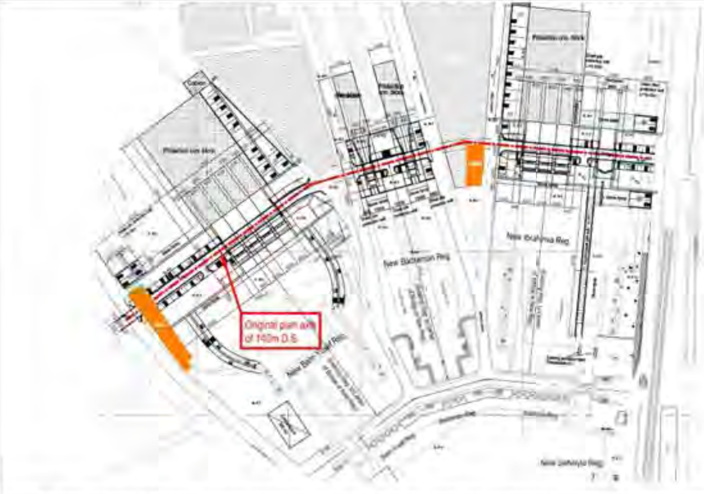
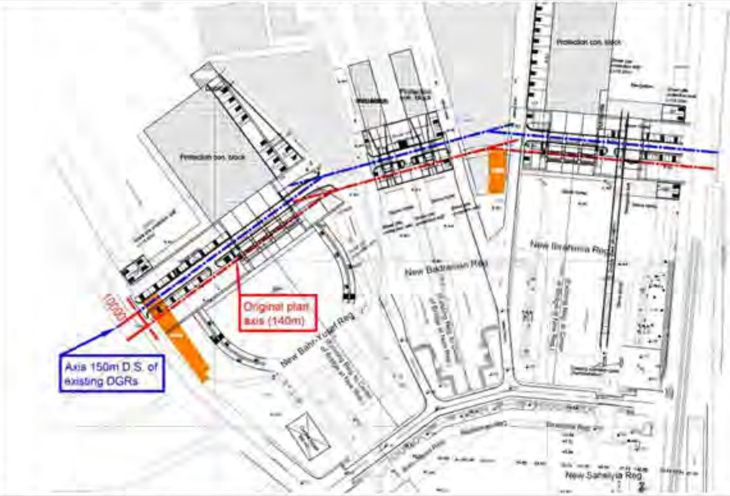
(2) Impact on groundwater

Comparing the impact on groundwater between 140m D/S which was applied in F/S stage (Plan 1) and 150m D/S which was suggested in B/D stage (Plan 1), it was expected that the Plan 1 has an advantage due to smaller upstream pooled area which makes smaller impact on the groundwater.

(3) Result

Following the evaluation, Table 4-2.1 shows the general advantage of 140m axis to 150m axis.

Table 4-2.1 Comparison of NDGRs' axis between 140m and 150m downstream of DGRs

Items	Plan 1 : NDGRs at 140m downstream of DGRs	Plan 2 : NDGRs at 150m downstream of DGRs
Figure of Layout		
1. Impact of hydraulic features on DRGs	- Flow velocity upstream of NDGRs is reduced and smaller than that downstream of NDGRs, because of the development of the basin (impounded) area and generally stable water level upstream. Therefore, DGRs would not be affected by the high flow velocity. **Point: 2**	- Same as plan 1 **Point: 2**
2. Impact of geological features on groundwater	- Basin area upstream of NDGRs will affect the vicinity of NDGRs. According to simple analysis, the affected area is assumed as per "Attached comparison tables." - Smaller negative impact compared to Plan2 dues to smaller upstream pooled aera. **Point: 2**	- Basin area upstream of NDGRs will affect to the vicinity of NDGRs. According to the simple analysis, the affected area is assumed as per "Attached comparison tables." - Comparing between plan 1 and plan 2, show that the area affected by seepage in plan 2 is larger than that in plan 1. **Point: 1**
3. Impact on construction plan	- Protection works such as sheet-piles for seepage shall be measured. **Point: 2**	- Protection works such as sheet-piles for seepage shall be measured. - The necessary area for the protection works is larger than that in plan 1, because of the larger area affected by seepage in plan 2. Accordingly, protection works in plan 2 shall be at least 20m longer (10m x 2) than those in plan 1, therefore increasing construction costs. **Point: 1**

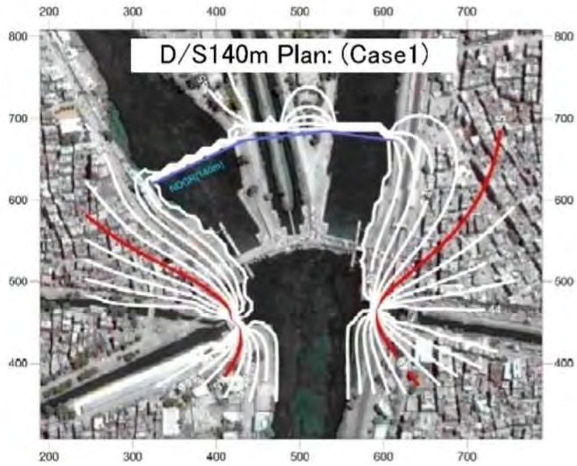
4. Impact on vicinity	- Two mosques shall be relocated to other areas to avoid impact by construction work. - The residential area downstream of the right bank of the Bahr Yusef canal, which is close to the Irrigation Department, may be affected by the temporary cofferdam. **Point: 1**	- Two mosques shall be relocated to other areas to avoid impact by construction work. - The residential area downstream of the right bank of the Bahr Yusef canal, which is close to the Irrigation Department, may be affected by the temporary cofferdam. However, as the affected area is larger than that in plan 1, therefore increasing the construction costs. **Point: 0**
5. Comprehensive evaluation	**Total point : 7** **Recommended** - The DGRs building according to both plans yields similar hydraulic impact, but the lesser effect of seepage in plan 1 gives it an advantage over plan 2, as does the lower construction cost for protection works. **Recommending the adoption of plan 1 for construction works 140m downstream of DGRs**	**Total point : 4** **Not Recommended** - The DGRs building according to both plans yields similar hydraulic impact, but the greater effect of seepage in plan 2 puts it at a disadvantage versus plan 1, as do the higher construction cost for protection works.

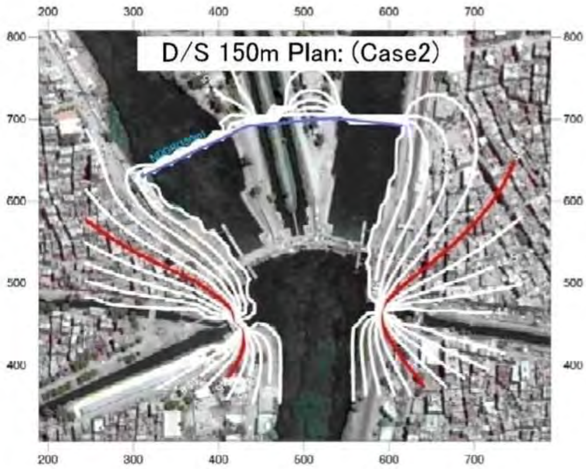
1) Maximum point shall be 2 points in conformity with the number of plans.

2) No item shall be given more weight in order to evaluate fairly.

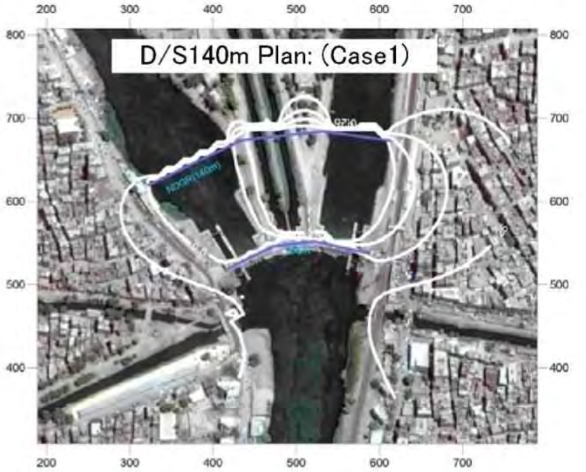
- **Attached comparison tables**

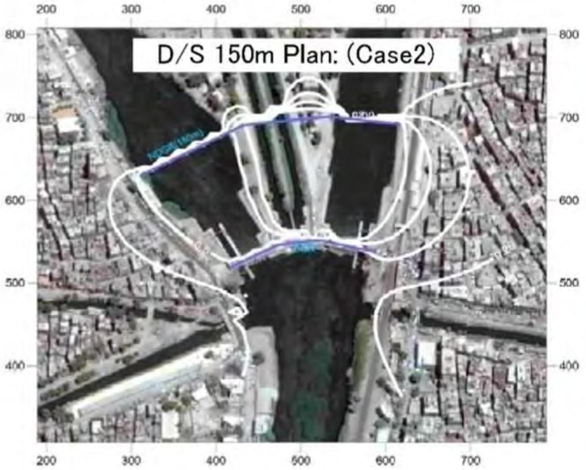
Estimated Water Head (ELm)
(at present condition, after construction of D/S140m & 150m Plan)

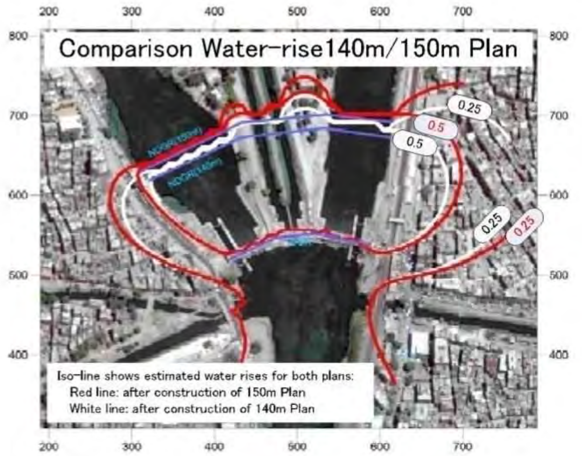




Estimated Water Rise (m)
(after construction of D/S 140m & 150m Plan and thier Comparison)







5. Weir Type

5-1 Determining weir type

Weirs are either of the fixed type constructed on the rock layer, or the floating type constructed on the permeable layer. In the project, since the geological conditions are mainly sand and clay, the floating type weirs should be used in the NDGRs.

In the design of floating type, it is important to maintain the stability of the foundation, and avoid the rising of piping and scouring at the canal bed.

5-2 Study of gate and hoist type

5-2-1 Size of target gates

Based on the results of hydraulic and structural design of weir body, the target gate facility sizes are as follows.

There are eight gates for the large scale regulators (Bahr Yusef and Ibrahimia regulators) and eleven for the small scale regulators (Sahelyia, Badraman and Abo Gabal regulators).

Table 5-2.1 Size of gates for the two large scale regulators

Name of regulator	**Bahr Yusef**	**Ibrahimia**
Clear span	6.00m	6.00m
Gate height	6.55m	6.55m
Area of a leaf	39.3m^2	39.3m^2
Gate sill elevation	EL40.00m	EL40.00m
Gate crest elevation	EL46.55m	EL46.55m
Number of gate	4	4

Table 5-2.2 Size of gates for the three small scale regulators

Name of regulator	Sahelyia	Badraman		Abo Gabal	
Name of canal	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal
Clear span	2.00m	2.00m	2.00m	2.00m	2.00m
Gate height	3.55m	2.35m	2.65m	2.95m	2.95m
Area of a leaf	7.10m^2	4.70m^2	5.30m^2	5.90m^2	5.90m^2
Gate sill elevation	EL43.00m	EL44.20m	EL43.90m	EL43.60m	EL43.60m
Gate crest elevation	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m
Number of gate	2	3	2	2	2

5-2-2 Large scale regulators

(1) Type of gate structure

Bahr Yusef and Ibrahimia regulator are the important facilities which control about 90% of the total discharge from all the DGRs though gate functions. Therefore, the appropriate selection of gate type significantly impacts the functioning of all the regulators and their future maintenance. Generally, gate types are classified by: the movement of the gate, the structure of gate leaf, the form of discharge, the type of hoist, etc. The fixed wheel vertical lift gate is the most suitable for both regulators in terms of regulator scale, Japanese and Egyptian experience, reliability, etc.

Although a radial gate was selected for the Naga Hammadi Barrage (clear span 17m x height 13.5m x 7 gates) and Assiut Barrage (clear span 17m x height 9.6m x 8 gates) which are now under construction, they are constructed in the Nile River and their scale and functions are different from those of DGR. A fixed wheel gate was selected for the Ibrahimia head regulator (clear span 5m x height 5m x 9 gates) which was recently renovated.

Figure 5-2.1 Examples of gate facilities in Egypt

From left: Assiut Barrage (Radial gate), Ibrahimia head regulator (fixed wheel gate), El Dahab regulator (overflow double leaf gate)

The four regulators constructed by Japanese grant aid project along the Bahr Yusef canal, have overflow double leaf gates. These consist of two leaves and can easily control discharge and water levels. This type of gate was expected to be selected for use on the Bahr Yusef and Ibrahimia regulators, as they utilize Japanese technology and comply with STEP.

The discharge flow features of the double leaf gate were compared to those of single leaf gate, under the design conditions of discharge and canal water level. Studies clarified that control by overflow or underflow volume was greater using double leaves, as was accuracy and stable water diversion. The decision to adopt a double leaf overflow gate was made in the 10th TAC meeting held on January 31and February 7, 2016.

(2) Hoist type

Wire-rope winding type hoisting equipment, widely used in Japan was used in the four regulators constructed in the Bahr Yusef canal by the Japanese grant aid project. On the other hand, the hydraulic cylinder type has become popular in Egypt and was used in projects like the Ibrahimia head regulators, the Naga Hammadi Barrage, and the new Assiut Barrage.

Therefore, three types of hoists can be used with a double leaf gate, (1) electric wire rope winding type, (2) hydraulic cylinder direct attached type, and (3) hydraulic cylinder wire rope winding type. Upon comparison, the hydraulic cylinder direct attached type was found to be the most suitable, especially for future ease of maintenance works and landscape, and was therefore selected for use in the 10th TAC meeting.

Table 5-2.3 Comparison of discharge control between single and double leaf gate (1/2)

(1/2)

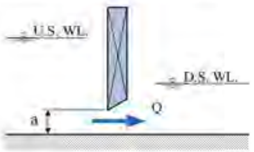
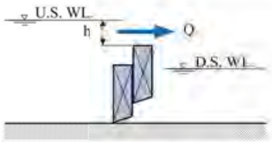
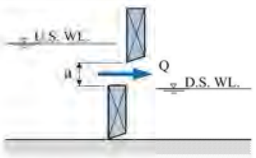
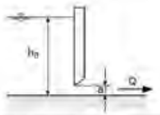
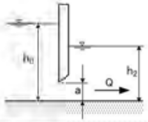
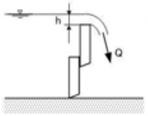
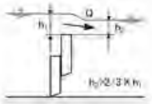
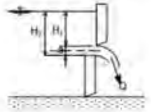
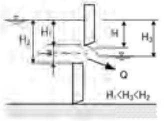
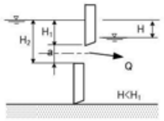
Description		Single Leaf-gate		Double Leaf-gate				
		(Under-flow control)		(Over-flow control)		(Orifice-flow control)		
Schematic drawing								
Structural feature		1)The gate consists of one gate leaf, and it has skin plate which is supported by steel beams to resist the water pressure. 2)Thickness of gate leaf is constant from the bottom to the top, arrangement of main girder is variable.		1)The gate consists of two gate leaves, a lower gate and an upper gate. Each gate leaf has skin plate which is supported by steel beams to resist the water pressure. 2)Generally, the water pressure acting on the upper leaf is smaller than the lower gate, therefore, the thickness of the upper gate is thinner than that of the lower gate. 3)The height of the upper gate can be designed within a half of water head.		1)The gate consists of two gate leaves, a lower gate and an upper gate. Each gate leaf has skin plate which is supported by steel beams to resist the water pressure. 2)Generally, The water pressure acting on the upper leaf is smaller than the lower gate, therefore, the thickness of the upper gate is thinner than that of the lower gate.		
Hydraulic feature	**General**	1)Form of flow is classified in free flow and submerged flow depending on the water level. 2)Fluctuation of discharge for the change of gate openings is larger than that of over flow type. The ability to control discharge accurately is inferior to the over-flow control. 3)High velocity of flow usually occurs and this might cause abrasion of apron concrete .		1)Form of flow is classified in complete overflow and submerged overflow depending on the water level and opening. 2)Fluctuation of discharge for the change of gate openings is smaller than that of under flow type. High accurate control of discharge is possible. 3)Discharge from under flow is also possible according to the purpose.		1)Fluctuation of discharge for the change of gate openings is larger than that of over flow type. 2)Discharge from under flow is also possible according to the purpose.		
	Form of flow	**Free outflow**	**Submerged flow**	**Complete overflow**	**Submerged overflow**	**Free orifice flow**	**Incomplete submerged orifice flow**	**Complete submerged orifice flow**
								
		$Q=CaB(2gh_0)^{1/2}$ Q :Discharge (m^3/s) C :Coefficient of discharge a :Opening (m) B :Span length (m) h_0 :Upstream water depth (m)	$Q=C_1aB(2gh_0)^{1/2}$ Q :Discharge (m^3/s) C_1 :Coefficient of discharge a :Opening (m) B :Span length (m) h_0 :Upstream water depth (m)	$Q=CBh^{3/2}$ Q :Discharge (m^3/s) C :Coefficient of discharge B :Span length (m) h :Overflow depth (m)	$Q=CBh_1(h_1-h_2)^{1/2}$ Q :Discharge (m^3/s) C :Coefficient of discharge B :Span length (m) h_1, h_2 : cf. fig. (m)	$Q=2/3CB(2g)^{1/2}(H_2^{1/2}-H_1^{3/2})$ Q :Discharge (m^3/s) C :Coefficient of discharge B :Span length (m) H_1, H_2 : cf. fig. (m)	$Q=CaB(2gH)^{1/2}$ Q :Discharge (m^3/s) C :Coefficient of discharge a :Opening (m) B :Span length (m) H :cf. fig. (m)	$Q=CaB(2gH)^{1/2}$ Q :Discharge (m^3/s) C :Coefficient of discharge a :Opening (m) B :Span length (m) H :Water level difference (m)
		・Discharge volume Q is the function of h_0 and a. ・Minimum clearance for the opening (a) is 0.10m owing to self-exiting vibration (It occurs under the condition in smaller clearance than 0.10m).	・It is hard for the stable discharge control because C_1 is affected by three variables (h_1, h_2 and a). ・It is also unclear in the demarcation between free and submerged outflow.	・Discharge volume Q is the function of only one variable, overflow depth h ; therefore, discharge control is the simplest to operate because it is hydraulically superior condition. ・Besides, this method has the best accuracy in discharge control.	・Discharge volume Q is the function of h_1 and h_2 . ・It is clear in the demarcation between complete overflow and submerged overflow.	・Discharge volume Q is the function of H_1 and H_2 (or H_1 and a). ・Minimum clearance for gate opening a is 0.10m owing to self-exiting vibration (It occurs under the condition in smaller clearance than 0.10m).	・Discharge volume Q is the function of H (water depth from the downstream vena contracta and a) . ・It is irrational to calculate Q around the boundary between complete and imcomplete submerged flow owing to the inconsistency in those equations .	・Discharge volume Q is the function of H (difference in water level between H_1 and H_2) and a , which is relatively stable in this condition.

Table 5-2.4 Comparison of discharge control between single and double leaf gate (2/2)

(2/2)

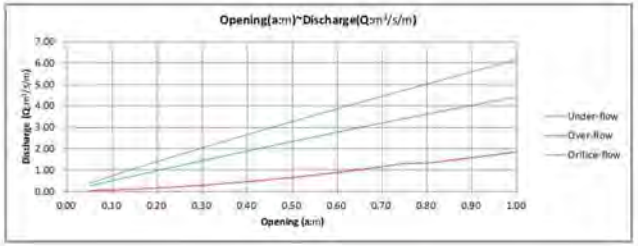
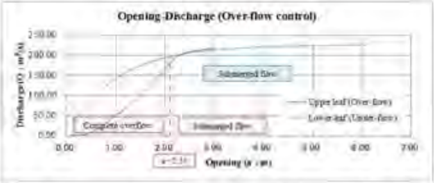
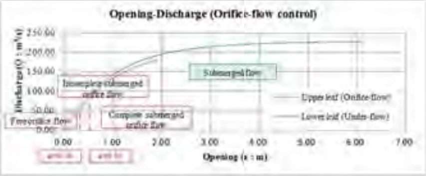
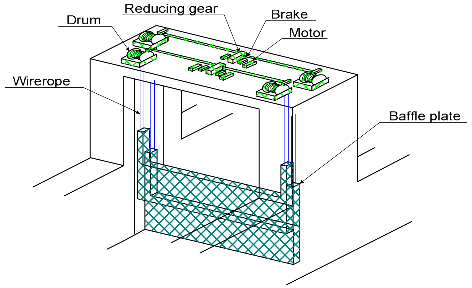
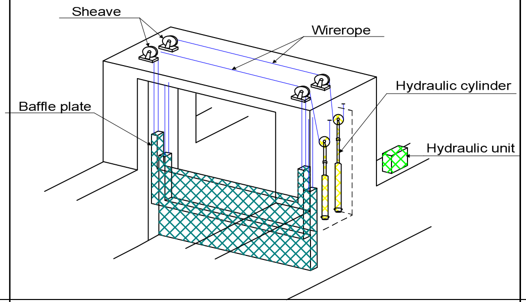
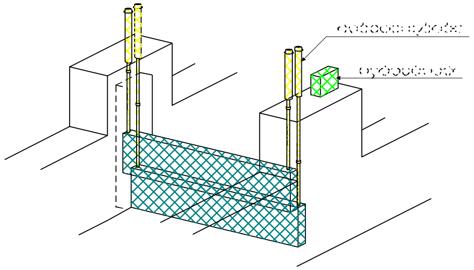
Description		Single Leaf-gate	Double Leaf-gate	
		(Under-flow control)	(Over-flow control)	(Orifice-flow control)
Hydraulic feature	General verification results of hydraulic consideration	General verification results of hydraulic consideration in unit gate length among three discharge control methods which are under-flow control (free outflow), over-flow control (complete overflow), and orifice-flow control (free orifice flow)). This figure also indicates that over-flow control (complete overflow) has smallest discharge volume change, in response to the change in gate opening, which means the over-flow control is superior method to the others in discharge volume control (Under-flow control (free outflow) is the has the biggest discharge volume change among three methods).		
	Verification results of hydraulic consideration in the case of the Bahr-Yusef Reg.			
		・It is not subject to gate opening and is always submerged flow owing to high downstream water level. ・Minimum discharge volume (at minimum gate clearance, 0.10m) is about 10m^3/s. ・When the discharge volume is more than 150m^3/s, difference in discharge volume by gate opening is stable.	・Boundary between complete overflow and submerged flow is when the opening is 2.10m. ・Under the condition that the discharge volume is less than 110m^3/s, over-flow is superior to under-flow in accurate discharge control. ・Discharge volume control with highest accuracy can be possible when over-flow control by upper leaf and under-flow control by lower leaf are properly applied depending on gate opening.	・Orifice flow control has equivalent property to under-flow control ・Under the condition that opening a is more than 1.90m, the solution in discharge volume is irrational. ・This method has unstable water state in small opening condition. ・Considering the conditions above, there is no merit to apply this method.
Hoisting equipment		1)Both hydraulic cylinder type and wire rope winding type are applicable.	1)Both hydraulic cylinder type and wire rope winding type are applicable. 2)In the case that hook type of gate is installed for upper leaf and combined with lower gate, one set of hoisting device is used. 3)Installing two sets of hoisting equipment can make gateposts shorter by shortening apparent gates height when they are fully open.	1)Both hydraulic cylinder type and wire rope winding type are applicable. 2)Two sets of hoisting devices are necessary to operate each leaf. 3)Installing two sets of hoisting equipment can make gateposts shorter by shortening apparent gates height when they are fully open.
Maintenance		1)Periodical inspection and maintenance are possible by lifting up the gates.	1)Periodical inspection and maintenance are possible by lifting up the gates. 2)The number of items to be inspected is larger than that of single leaf type.	1)Periodical inspection and maintenance are possible by lifting up the gates. 2)The number of items to be inspected is larger than that of single leaf type.
Comprehensive Evaluation		**Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDGRs.** **This type is inferior to over-flow control in this point.**	**Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDGRs.** **This type is superior to other types in this point.**	**Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDGRs.** **This type is inferior to over-flow control in this point.**
		△	◎	×

Table 5-2.5 Comparison of hoist types for the large scale regulators

		Wire rope winding type （Electric motor）		Oil-hydraulic cylinder			
				Wire rope winding type		Direct attached type	
Schematic drawing							
General characteristics		1)This type is widely used for any lifting heights and loads except a case that requires closing pressure. 2)There are several sub-styles with different combinations of wiring and number of drums. 3)In case double leaf gate, wiring and placement of hoisting devices become complicated. 4)It is impossible to push down the gate leaf by the force of hoist.		1)The gate leaf is operated by hydraulic cylinder through wirerope. 2)It is possible to install the hydraulic cylinder in a remote place from the gate leaf. 3)The structure of hoisting device is usually complicated. 4)It is better not use this type for a gate of large lifting height and large load because of difficulties in terms of structure. 5)It is impossible to push down the gate leaf by the force of hoist.		1)A hydraulic cylinder rod is attached directly to the leaf and the leaf is operated by pressurized oil. 2)This type is widely used for high pressure gates. 3)It is advantageous when the opening of the gate leaf must be strictly adjusted or when the hoisting device should be installed in a narrow space. 4)Not only pulling up the gate leaf but also pushing down it is possible by the force of hoist.	
Main components of the facility	Gate leaf	Gate leaf (Rolled steel) Roller Watertight rubber		Gate leaf (Rolled steel) Roller Watertight rubber		Gate leaf (Rolled steel) Roller Watertight rubber	
	Guide frame (Stainless steel)	Guide frame (Stainless steel)		Guide frame (Stainless steel)		Guide frame (Stainless steel)	
	Hoisting device	Sheave Brake Wire rope Motor Bearing of motor Clutch Reduction gear		Sheave Wire rope Hydraulic pump Valve Bearing of motor Cylinder (SUS) Cylinder packing		Hydraulic pump Valve Bearing of motor Cylinder (SUS) Cylinder packing	
Functional characteristics	Civil structure	Since baffle plate is required at the both edges of the gate leaf to protect wire rope and to avoid vibration of it, the height of pier becomes higher.	+	Since baffle plate is required at the both edges of the gate leaf to protect wire rope and to avoid vibration of it, the height of pier becomes higher.	+	Baffle plate is not required at the both edges of the gate leaf because the cylinder rods are made of stainless steel and have high stiffness. For this reason, the height of pier can be lowered and the structure is relatively simple.	++
	Discharge control	When double leaf gate type is applied, overflow control as well as underflow control is possible.	+	When double leaf gate type is applied, overflow control as well as underflow control is possible.	+	When double leaf gate type is applied, overflow control as well as underflow control is possible.	+
	Arrangement and space for hoist	Wide space is necessary to install the equipment.	+	There is a flexibility of placement.	++	Since the number of hoisting parts is few, necessary space for installation is small.	+++
	Maintenance	1)Necessary inspection and maintenance items are largest.	+	1)Necessary inspection and maintenance items are larger. 2)Oil leakage must be monitored and avoided. Maintenance of hydraulic oil as well as packing is very important.	+	1)Compared with mechanical type, necessary inspection items are small. 2)Oil leakage must be monitored and avoided. Maintenance of hydraulic oil as well as packing is very important.	+
	Landscape	High piers and complicated hoisting devices affect landscape.	+	The height of piers is higher than that of hydraulic cylinder type.	++	The height of pier is shortest and hoisting devices are compact.	++
Approximate cost of hoisting device (Gate size;B=8m x H=6.55m)		2.1 Million USD/set	+	1.8 Million USD/set	++	1.5 Million USD/set	+++
Recommendation						Recommended plan by JICA survey team	

Note: +++:Excellent ++:Good +:Average

5-2-3 Small scale regulators

(1) Structural type of gate

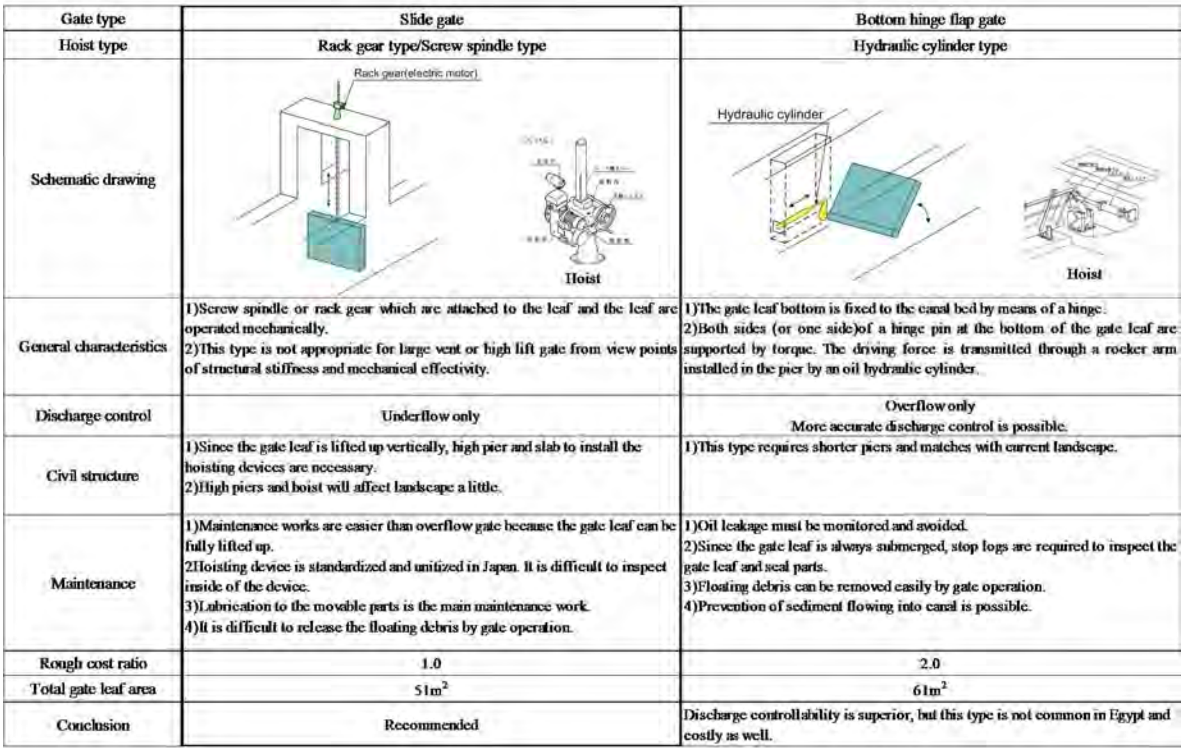
Badraman, Sahelyia, and Abo Gabal regulators divert into two canals except for the Sahelyia regulator. Considering their design discharge, gate height and width are 10m^3/s, 3.0m and 2.0 m respectively, those regulators are classified as a small gate group with less than 10m^2 of gate leaf area. The type of large gate is mainly the slide gate and the bottom hinge flap gate. The former's gate leaf moves up and down, and the latter’s is moved by rotating on its hinge

The double leaf gate could be used with the small regulator, but the lower accuracy of operation as a result of the small discharge excludes it as a suitable choice.

After considering the merits and demerits of both gates as shown in Table 5-2.6, the slide type gate was approved at the 11th TAC based on cost and ease of maintenance. The hinge flap gate type was better at operating the water levels and discharge volume, but was not recommended because it had not been used in Egypt before.

As for the number of spindles; the two spindles type was approved at the 22nd TAC meeting.

Table 5-2.6 Comparison table of gate types for the small scale regulators



Gate type	Slide gate	Bottom hinge flap gate
Hoist type	Rack gear type/Screw spindle type	Hydraulic cylinder type
Schematic drawing		
General characteristics	1)Screw spindle or rack gear which are attached to the leaf and the leaf are operated mechanically. 2)This type is not appropriate for large vent or high lift gate from view points of structural stiffness and mechanical effectivity.	1)The gate leaf bottom is fixed to the canal bed by means of a hinge. 2)Both sides (or one side)of a hinge pin at the bottom of the gate leaf are supported by torque. The driving force is transmitted through a rocker arm installed in the pier by an oil hydraulic cylinder.
Discharge control	Underflow only	Overflow only More accurate discharge control is possible.
Civil structure	1)Since the gate leaf is lifted up vertically, high pier and slab to install the hoisting devices are necessary. 2)High piers and hoist will affect landscape a little.	1)This type requires shorter piers and matches with current landscape.
Maintenance	1)Maintenance works are easier than overflow gate because the gate leaf can be fully lifted up. 2Hoisting device is standardized and unitized in Japan. It is difficult to inspect inside of the device. 3)Lubrication to the movable parts is the main maintenance work. 4)It is difficult to release the floating debris by gate operation.	1)Oil leakage must be monitored and avoided. 2)Since the gate leaf is always submerged, stop logs are required to inspect the gate leaf and seal parts. 3)Floating debris can be removed easily by gate operation. 4)Prevention of sediment flowing into canal is possible.
Rough cost ratio	1.0	2.0
Total gate leaf area	51m^2	61m^2
Conclusion	Recommended	Discharge controllability is superior, but this type is not common in Egypt and costly as well.

(2) Hoist type

The hoist type of slide gate is best suited for the rack gear type as it is simply built and therefore easier to maintain. Models that close by force or close by self-weight are also available. After considering the appropriate number of shafts connecting to the gate leaf with regard to the clear span width or horizontal to vertical ratio, the Egyptian government and the Design WG found two shafts were best at promoting high stability during operation.

Table 5-2.7 Selection of hoist type

Gate type	Scale of gate	Hoist type	
		Rack type	Wire rope winch type
Wheel gate	Small scale	○	▵
	Medium scale	○	○
	Large scale	△	○
Slide gate		○	×

Note: ○ : Appropriate to use

× : Inappropriate to use

▵ : Appropriate to use depending on occasions

Source: *Guidelines on sluice gates* (Japanese)

6. Width and Number of Vents

Discharge volume of NDGRs determines vent width and number. The Bahr Yusef and Ibrahimia regulators are defined as the large regulars and the Sahelyia, Badraman, and Abo Gabal regulators are defined as the small regulars.

6-1 Two large scale regulators

(1) Procedure of study

A comparative study on the various combinations of width to number of vents was carried out as follows.

a) Assumptions on width and number of vents

The width or the clear span length of vents for large regulators constructed on the main canal is generally 4-6m according to the Egyptian textbook, *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrages*. A width of 8m was selected based on a feasibility study as well as the specifications of existing regulators along the Bahr Yusef canal like El Dahab regulator which was constructed by a Japanese grant aid projects. Therefore vents 4,5,6,7 and 8m in width were considered, and the number of vents adjusted accordingly. Given the importance of the Bahr Yusef and Ibrahimia canals, and the importance of distributing risk in the event that one of the gates fails to operate, as well as a discussion between the Egyptian government and the survey team at the 10th TAC meeting, the minimum number of vents was set at three.

b) Hydraulic analysis by non-uniform flow calculation

The capacity of assumed flow section against the design maximum flow discharge was verified by non-uniform calculations on the condition that all the gates of new regulators are fully opened. The starting water level just downstream of the new regulators was the maximum water level which the Water Distribution Directorate in RGBS was able to provide.

Table 6-1.1 Conditions of hydraulic calculation

	Bahr Yusef regulators	Ibrahimia regulators
Design discharge	227m^3/s	186m^3/s
Water level at the starting point	45.82m	45.13m
Design upstream water level	46.30m	46.30m

c) Hydraulic judgment

If the calculated water level upstream of existing regulators is below the design intake water level (46.30m), the cross section of the new regulators is assumed to be enough to discharge the design volume. In addition, some relevant conditions in the Egyptian code needed to be met. The conditions to be examined are as follows.

- Check 1 : Capacity of design discharge flow
  Calculated water level at the upstream of existing regulators≤WL.46.30m
- Check 2 : The maximum allowable velocity (Vr) through vents
  $2\ V_{DS} < Vr < 3\ V_{DS}$
  where, Vr: Velocity through vents (Vr =1.00-2.00 m/s)

V_{DS} : Velocity of channel downstream (m/s)

- Check 3 : Flow area

$(A_{DS} - Are) / A_{DS} \leq 40\%$

where, Are : Area of the water way through the openings (m^2)

A_{DS} : Area of the canal cross section downstream the structure (m^2)

- Check 4 : The maximum allowable heading-up

$$h = \frac{V_{US}{}^2}{2gC^2}\left(\left(\frac{A_{US}}{A_r}\right)^2 - 1\right) \leq 10\ cm$$

where, V_{US}: Velocity in channel without regulator (m/s)

A_{US}: Cross section area of flow without regulator (m^2)

Ar: Regulator vent area (m^2)

C: Factor depends on the vent width

g : Acceleration of gravity (=9.8m/s^2)

d) Comprehensive evaluation

A comprehensive evaluation of the combinations of the number and width of vents which meet the aforementioned hydraulic requirements was made to judge economy, discharge controllability, ease of maintenance, etc.

The costs of major civil works and gate facilities were roughly estimated as part of the economic evaluation.

(2) Result of study

For the comparative study, three combination were used, namely, 5m in width with 5 vents, 6m in width with 4 vents, and 8m in width with 3 vents, for both the Bahr Yusef and Ibrahimia regulators.

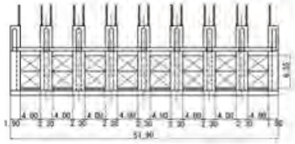
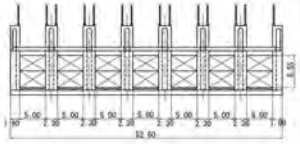
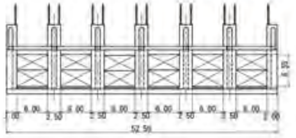
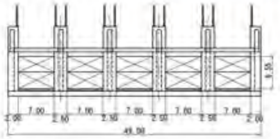
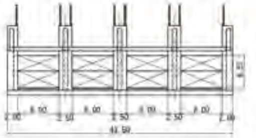
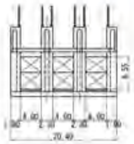
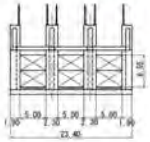
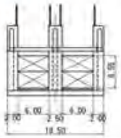
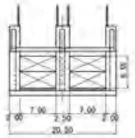
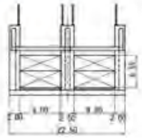
8m width was found to be the most economical and superior size in reducing construction area because the fewer number of piers results in the smallest total regulators width. However, the large regulators constructed on the main canals in Egypt, are within the 4-6m range, as described in the textbook. The exceptions to this rule are the four regulators constructed through the Japanese grant aid projects. The RGBS requested that what was successfully used in the past, in terms of operability and maintenance, be repeated. Consequently, the 6m wide vent, which is the second most economical choice, was selected for the Bahr Yusef and Ibrahimia regulators at the 10th TAC meeting.

Table 6-1.3 shows the results of an initial comparative study in which the Egyptian code is ignored to review feasibility. Table 6-1.4 shows the final version of the comparison which was approved by TAC in discussions between the survey team and the Egyptian government. Table 6-1.2 shows the design of vents on the large regulator.

Table 6-1.2 Design of vents on the large regulators

	New Bahr Yusef	New Ibrahimia
Vent width	6.00m	6.00m
No. of vents	4 vents	4 vents
Sill level	EL.40.00m	EL.40.00m

Table 6-1.3 Number and width of vents for the large scale regulators (initial results)

Width of vent(m)			4.00		5.00		6.00		7.00		8.00	
Total gate height(m)			6.55		6.55		6.55		6.55		6.55	
Bahr Yusef Regulator	Hydraulic calculation	Number of vent	7	8	6	7	5	6	4	5	3	4
		U.S.WL. (m)	46.32	46.30	46.31	46.30	46.31	46.29	46.32	46.30	46.35	46.30
		Judgement(≤46.30m)	Not available	Available	Not available	Available	Not available	Available	Not available	Available	Not available	Available
	Schematic drawing											
	Total width (m)		51.90		52.60		52.50		49.00		43.50	
Ibrahimia Regulator	Hydraulic calculation	Number of vent	2	3	2	3	2	3	2	3	2	3
		Flow velocity(m/s)	4.01	2.67	3.21	2.14	2.67	1.78	2.29	1.52	2.00	1.34
		Judgement(≤3.0m/s)	Not available	Available	Not available	Available	Available	Available	Available	Available	Available	Available
	Schematic drawing											
	Total width (m)		20.40		23.40		18.50		20.50		22.50	
Discharge controllability			Low Discharge rate per gate opening is so small that operation of gate becomes complicated.		→		→		→		High Discharge rate per gate opening is so large that operation of gate becomes easy.	
Easiness of maintenance works			Low Inspection and maintenance items are larger.		→		→		→		High Inspection and maintenance items are smaller.	
Easiness of construction (*1)			Low Switching of cofferdam is required and construction period becomes longer.		→		→		→		High Switching of cofferdam is not required and construction period becomes shorter.	
Economy (*2)			Low The quantities of gate facilities and civil works are larger.		→		→		→		High The quantities of gate facilities and civil works are smaller.	
			Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia
Concrete volume of main body(m^3)			11,600	4,700	11,200	5,200	11,000	4,100	9,900	4,400	8,600	4,600
Number of foundation piles			520	220	500	230	500	190	450	200	390	210
Total weight of gate facilities(ton)			570	220	580	250	550	190	490	200	420	210
Cost for major civil works(Million USD)			6.9	2.9	6.7	3.1	6.6	2.5	5.9	2.6	5.2	2.8
Cost of gate facilities(Million USD)			13.1	4.9	12.2	5.3	11	3.7	9.5	3.8	8.1	4.1
Total cost (Million USD) (ratio)			20.0	7.8	18.9	8.4	17.6	6.2	15.4	6.4	13.3	6.9
			27.8 (1.38)		27.3 (1.35)		23.8 (1.18)		21.8 (1.08)		20.2 (1.00)	
Recommendation											Recommended plan by JICA survey team	

Note: *1: This item is the evaluation of Barh Yusef Regulator only. Regarding Ibrahimia Regulator, there is no wide difference.

*2: This is the comparison of the total cost.

Table 6-1.4 Number and width of vents for the large scale regulators (final results)

(a)Bahr Yusef Regulator (Design discharge = 227 m^3/s Maximum downstream water level= 45.82m)

Width of vent(m)		**5.00**	**6.00**	**8.00**	Remarks
Number of vents designed by Egyptian code		**5**	**4**	**3**	
Hydraulic check	Number of vents	**5**	**4**	**3**	
	Required Upstream WL. (m)	45.99 OK	46.00 OK	46.01 OK	≤Normal water level(=46.30m) (Inflow head loss coefficient=0.2)
Selected number of vent		**5**	**4**	**3**	Minimum number =3 vents
Total width including piers (m)		38.0	35.5	33.0	
Approx. Quantities	Concrete volume of main body(m^3)	8,200	7,500	6,600	
	Number of foundation piles	370	340	300	
	Bridge surface area(m^2)	380	355	330	RC bridge,Effective width=10m
	Total weight of gate facilities(ton)	432	392	353	Stoplogs (1set=2pairs)included
Cost	Major civil works(Million USD) (a)	5.2	4.7	4.2	Main body, foundation and bridge
	Gate facilities(Million USD) (b)	9.0	7.7	6.4	Manufacture and Installation,stoplogs included
	(a) + (b)	14.2	12.4	10.6	
	Ratio of cost	(1.15)	(1.00)	(0.85)	
Conclusion			**Selected**		

(b)Ibrahimia Regulator (Design discharge = 186 m^3/s Maximum downstream water level= 45.13m)

Width of vent(m)		**5.00**	**6.00**	**8.00**	Remarks
Number of vents designed by Egyptian code		**5**	**4**	**3**	
Hydraulic check	Number of vent	**5**	**4**	**3**	
	Required Upstream WL. (m)	45.22 OK	45.22 OK	45.22 OK	≤Normal water level(=46.30m) (Inflow head loss coefficient=0.2)
Selected number of vent		**5**	**4**	**3**	Minimum number =3 vents
Total width including piers (m)		38.0	35.5	33.0	
Approx. Quantities	Concrete volume of main body(m^3)	8,200	7,500	6,600	
	Number of foundation piles	370	340	300	
	Bridge surface area(m^2)	380	355	330	RC bridge,Effective width=10m
	Total weight of gate facilities(ton)	432	392	353	Stoplogs (1set=2pairs)included
Cost	Major civil works(Million USD) (a)	5.2	4.7	4.2	Main body, foundation and bridge
	Gate facilities(Million USD) (b)	9.0	7.7	6.4	Manufacture and Installation,stoplogs included
	(a) + (b)	14.2	12.4	10.6	
	Ratio of cost	(1.15)	(1.00)	(0.85)	
Conclusion			**Selected**		

Bahr Yusef + Ibrahimia (Million USD)	28.4	24.8	21.2	
(Ratio)	(1.15)	(1.00)	(0.85)	

6-2 Three small scale regulators

(1) Procedure of study

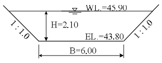
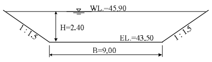
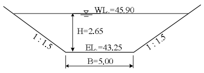
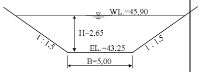
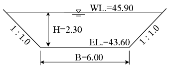
The small regulators are those in Badraman, Sahelyia, and Abo Gabal. Badraman and Abo Gabal regulators divert into two canals each. In these regulators, the results of reasonable combinations of vent width and numbers are shown in the ‘Result of study’ section below.

As for the Sahelyia and Abo Gabal regulators, the consideration of additional new hydraulic conditions was requested by the Egyptian side. The results are shown in the ‘Result of additional considerations’ section below.

1) Cross section and hydraulic conditions of downstream canals

Hydraulic parameters of connecting downstream canals such as flow area and velocity are obtained by uniform flow calculation based on the topographic survey result.

Table 6-2.1 Hydraulic conditions of downstream canals for the small scale regulators

Regulator Name		**New Sahelyia**	**New Badraman**		**New Abo Gabal**	
Canal Name		**Sahelyia**	**Diroutiah**	**Badraman**	**Irad Delgaw**	**Abo Gabal**
Design discharge	(m^3/s)	5.0	12.0	9.0	9.0	7.0
Water Level	(m)	45.90	45.90	45.90	45.90	45.90
Bed level	(m)	43.80	43.50	43.25	43.25	43.60
Water depth	(m)	2.10	2.40	2.65	2.65	2.30
Bed Width	(m)	6.00	9.00	5.00	5.00	6.00
Side slope 1:N		1.0	1.5	1.5	1.5	1.0
Flow area	(m^2)	17.01	30.24	23.78	23.78	19.09
Coefficient roughness		0.030	0.030	0.030	0.030	0.030
Canal bed slop		0.00005	0.00007	0.00007	0.00007	0.00007
Mean flow velocity	(m/s)	0.30	0.40	0.39	0.39	0.37
Design cross section						

2) Assumptions on width and number of vents

According to the textbook, *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrages*, the width of vents for small scale regulators constructed in branch canals is almost less than 3m. Therefore, the examined width was within 3m in a 50cm unit. Given the importance of distributing risk in the event that one of the gates fails to operate, as well as a discussion between the RGBS and the survey team at the 11th TAC meeting, two vents were proposed and a comparative study was carried out to examine the proposal.

3) Hydraulic evaluation

In addition to the flow capacity, the following requirements stipulated in Egyptian code must be met.

- Check 1 : Capacity of design discharge flow

  Calculated water level at the upstream of new regulators≤WL.46.30m

- Check 2 : The maximum allowable velocity (Vr) through vents

$2\ V_{DS} < Vr < 3\ V_{DS}$

where, Vr : velocity through vents (Vr =1.00-1.50 m/s)

V_{DS} : Velocity of channel downstream (m/s)

- Check 3 : Number of vents and total length of regulator between abutments

  B2= (0.6to1.0)x B1

  Where, B1:Channel bed width (m), B2:Width between abutments of regulator (m)
- Check 4 : The maximum allowable heading-up

$$h = \frac{V_{US}^2}{2gC^2}\left(\left(\frac{A_{US}}{A_r}\right)^2 - 1\right) \leq 10\ cm$$

or $$h = \alpha\beta \frac{V_{DS}^2}{2g}$$

Where, V_{US}: Velocity in channel without regulator (m/s)

A_{US}: Cross section area of flow without regulator (m^2)

Ar: Regulator vent area (m^2)

C:Factor depends on the vent width

α: Contraction ratio, β:Coefficient depending on a shape of pier

V_{DS}: Velocity of channel downstream (m/s)

g:Acceleration of gravity (=9.8m/s^2)

4) Comprehensive evaluation

A comprehensive evaluation of the combinations of the number and width of vents which meet the aforementioned hydraulic requirements was made to judge economy, discharge controllability, ease of maintenance, etc.

The costs of major civil works and gate facilities were roughly estimated as part of the economic evaluation.

(2) Result of study

A hydraulic examination and a comparison of rough cost estimates were carried out for the three following cases.

i) Case 1A: Width of vent is composed of 1.5m and 2.5m

ii) Case 1B: Width of vent is composed of 2.0m and 2.5m

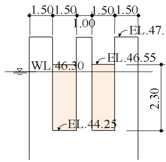
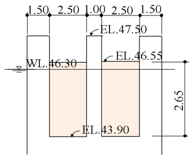
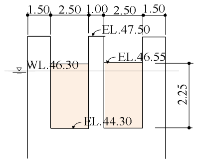
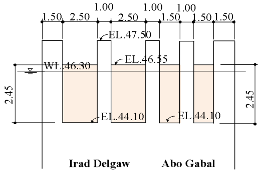
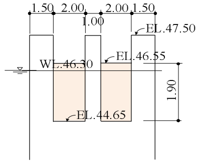
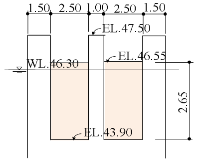
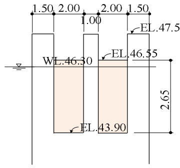
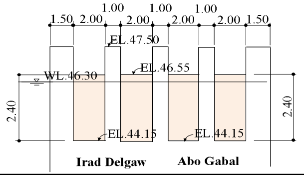
iii) Case 1C: Width of vent is 2.0m only

Table 6-2.2 summarizes the results for cases 1A, 1B, and 1C.

As there is no great difference in the construction costs in the three cases, case 1C was selected at the 12th TAC meeting, since it was the option where one stoplog was shared for all regulators during repair works.

Table 6-2.2 Comparison of width and number of vents for the small scale regulators (1/2)

(1/2)

Regulator Name			**New Sahelyia**	**New Badraman**		**New Abo Gabal**		**Rough cost ratio & Comments**
Canal Name			**Sahelyia**	**Diroutiah**	**Badraman**	**Irad Delgaw**	**Abo Gabal**	
Design discharge (m^3/s)			**5.0**	**12.0**	**9.0**	**9.0**	**7.0**	
Design cross section of regulators	**CASE1A: 2 different width (1.5m x 2.5m) Slide gate (underflow)**	Width and number of vents	**1.50m × 2Vents**	**2.50m × 2Vents**	**2.50m × 2Vents**	**2.50m × 2Vents**	**1.50m × 2Vents**	-Most economical plan -2types of stoplogs are required (1.5mx2.45m, 2.5mx2.65m)
		Gate height	Hgate=2.30m	Hgate=2.65m	Hgate=2.25m	Hgate=2.45m	Hgate=2.45m	
		Flow area	Ar=4.95m^2 (<5.61)	Ar=10.00m^2 (>9.98)	Ar=8.00m^2 (>7.83)	Ar=9.00m^2 (>7.83)	Ar=5.40m^2 (<6.30)	
		Velocity	Vr=1.01m/s (1.0<Vr<1.5)	Vr=1.20m/s (1.0<Vr<1.5)	Vr=1.13m/s (1.0<Vr<1.5)	Vr=1.00m/s (1.0<Vr<1.5)	Vr=1.30m/s (1.0<Vr<1.5)	
		Width ratio (B1: Canal B2:Regulator)	B2/B1=0.67 (0.6～1.0)	B2/B1=0.67 (0.6～1.0)	B2/B1=1.20 (0.6～1.0)	B2/B1=1.20 (0.6～1.0)	B2/B1=0.67 (0.6～1.0)	
		Heading up	h=9.6cm (<10cm)	h=9.9cm (<10cm)	h=9.0cm (<10cm)	h=6.8cm (<10cm)	h=15.5cm/ 0.6cm ※	
		Cross section of regulator						
		Concrete volume of main body(m^3)	772.2	669.5	639.2	1250.1		Cost ratio=1.00
		Bridge surface area(m^2)	-	100	100	-		
		Total gate leaf area(m2)	6.9	13.25	11.25	12.25	7.35	
		Civil works(Million USD)	0.28	0.31	0.30	0.46		
		Gate facilities(Million USD)	0.08	0.15	0.13	0.14	0.09	
		Stop logs (Million USD)	0.02					
		Total (Million USD)	1.97					
	CASE1B: 2 different width (2.0m x 2.5m) Slide gate (underflow)	Width and number of vents	**2.00m × 2Vents**	**2.50m × 2Vents**	**2.00m × 2Vents**	**2.00m × 2Vents**	**2.00m × 2Vents**	-Cost is almost same as CASE1A -2types of stoplogs are required (2.0mx2.65m, 2.5mx2.65m)
		Gate height	Hgate=1.90m	Hgate=2.65m	Hgate=2.65m	Hgate=2.40m	Hgate=2.40m	
		Flow area	Ar=5.00m^2 (<5.61)	Ar=10.00m^2 (>9.98)	Ar=8.00m^2 (>7.83)	Ar=7.00m^2 (<7.83)	Ar=7.00m^2 (>6.30)	
		Velocity	Vr=1.00m/s (1.0<Vr<1.5)	Vr=1.20m/s (1.0<Vr<1.5)	Vr=1.13m/s (1.0<Vr<1.5)	Vr=1.29m/s (1.0<Vr<1.5)	Vr=1.00m/s (1.0<Vr<1.5)	
		Width ratio (B1: Canal B2:Regulator)	B2/B1=0.83 (0.6～1.0)	B2/B1=0.67 (0.6～1.0)	B2/B1=1.00 (0.6～1.0)	B2/B1=1.00 (0.6～1.0)	B2/B1=0.83 (0.6～1.0)	
		Heading up	h=7.2cm (<10cm)	h=9.9cm (<10cm)	h=9.0cm (<10cm)	h=12.0cm/ 0.7cm ※	h=6.7cm (<10cm)	
		Cross section of regulator						
		Concrete volume of main body(m^3)	886.8	669.5	621.7	1256.0		Cost ratio=1.02
		Bridge surface area(m^2)	-	100	87.5	-		
		Total gate leaf area(m2)	7.6	13.25	10.6	9.6	9.6	
		Civil works(Million USD)	0.33	0.31	0.29	0.46		
		Gate facilities(Million USD)	0.09	0.15	0.12	0.11	0.11	
		Stop logs (Million USD)	0.02					
		Total (Million USD)	2.00					

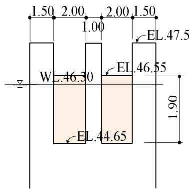
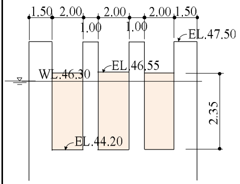
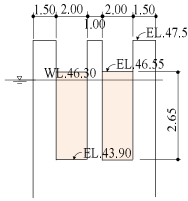
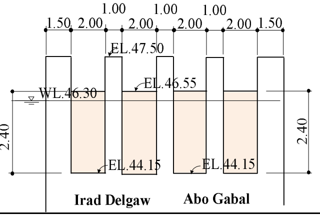
Note ; ( ) requirement by Egyptian code

※Heading up given by "$h=\alpha\beta V^2/2g$"

Exchange rate; $1=JPY121.93

Table 6-2.3 Comparison of width and number of vents for the small scale regulators (2/2)

(2/2)

Regulator Name			New Sahelyia	New Badraman		New Abo Gabal		Rough cost ratio & Comments
Canal Name			Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal	
Design discharge (m^3/s)			5.0	12.0	9.0	9.0	7.0	
Design cross section of regulators	CASE1C: Uniform width (2.0m) Slide gate (underflow)	Width and number of vents	**2.00m × 2Vents**	**2.00m × 3Vents**	**2.00m × 2Vents**	**2.00m × 2Vents**	**2.00m × 2Vents**	
		Gate height	Hgate=1.90m	Hgate=2.35m	Hgate=2.65m	Hgate=2.40m	Hgate=2.40m	
		Flow area	Ar=5.00m^2 (<5.61)	Ar=10.20m^2 (>9.98)	Ar=8.00m^2 (>7.83)	Ar=7.00m^2 (<7.83)	Ar=7.00m^2 (>6.30)	
		Velocity	Vr=1.00m/s (1.0<Vr<1.5)	Vr=1.18m/s (1.0<Vr<1.5)	Vr=1.13m/s (1.0<Vr<1.5)	Vr=1.29m/s (1.0<Vr<1.5)	Vr=1.00m/s (1.0<Vr<1.5)	
		Width ratio (B1: Canal B2:Regulator)	B2/B1=0.83 (0.6～1.0)	B2/B1=0.89 (0.6～1.0)	B2/B1=1.00 (0.6～1.0)	B2/B1=1.00 (0.6～1.0)	B2/B1=0.83 (0.6～1.0)	**Recommended plan**
		Heading up	h=7.2cm (<10cm)	h=9.5cm (<10cm)	h=9.0cm (<10cm)	h=12.0cm/ 0.7cm ※	h=6.7cm (<10cm)	
		Cross section of regulator						-Cost is almost same as CASE1A -Stoplog is only one type (2.0mx2.65m)
		Concrete volume of main body(m^3)	886.8	830.2	621.7	1256.0		
		Bridge surface area(m^2)	-	125.0	87.5	-		
		Total gate leaf area(m2)	7.6	14.1	10.6	9.6	9.6	
		Civil works(Million USD)	0.33	0.39	0.29	0.46		Cost ratio=1.05
		Gate facilities(Million USD)	0.09	0.16	0.12	0.11	0.11	
		Stop logs (Million USD)	0.01					
		Total (Million USD)	2.07					

Note ; ( ) requirement by Egyptian code

※Heading up given by "$h=\alpha\beta V^2/2g$"

Exchange rate; $1=JPY121.93

(3) Result of additional considerations

The new hydraulic conditions provided by the Design Working Group on the two small regulators (Sahelyia and Abo Gabal regulators) are:

a) To be a structure capable of taking minimum discharge from the hydraulic view,

b) To be at the same apron level as the existing Sahelyia and Abo Gabal regulators.

As a result of the hydraulic evaluation and compliance with Egyptian code, the reasonable combinations of vent width, numbers, and sill levels are shown in Table 6-2.5. These results were approved by the meeting held shortly after the 19th TAC meeting.

The applied design of small regulators is shown in Table 6-2.4.

Table 6-2.4 Vent width and numbers of the two small scale regulators

Regulator name	Sahelyia	Badraman		Abo Gabal	
Canal name	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal
Vent width	2.00m	2.00m	2.00m	2.00m	2.00m
Nos of vent	2 vents	3 vents	2 vents	2 vents	2 vents
Sill level	EL.43.00m	EL.44.20m	EL.43.90m	EL.43.60m	EL.43.60m

Table 6-2.5 Additional considerations on the two small scale regulators

Regulator Name					New Sahelyia								New Abo Gabal															
Canal Name					Sahelyia								Irad Delgaw								Abo Gabal							
Width and number of vents					2.00m × 2Vents				1.50m×2Vents				2.00m × 2Vents				1.50m × 2Vents				2.00m × 2Vents				1.50m × 2Vents			
					2Vents Open		1Vent Close		2Vents Open		1Vent Close		2Vents Open		1Vent Close		2Vents Open		1Vent Close		2Vents Open		1Vent Close		2Vents Open		1Vent Close	
Apron lebel				EL. (m)	43.00								43.60								43.60							
Max. design discharge			Max. design discharge (m^3/s)		5.0								9.0								7.0							
			U.S.W.L.	(m)	46.30								46.30								46.30							
			D.S.W.L.	(m)	45.90								45.90								45.90							
			Gate height	Hgate (m)	3.55								2.95								2.95							
	Regulator		Flow area	Ar (m^2)	11.60		5.80		8.70		4.35		9.20		4.60		6.90		3.45		9.20		4.60		6.90		3.45	
			Velocity	Vr (m/s)	0.43		0.86		0.57		1.15		0.98		1.96		1.30		2.61		0.76		1.52		1.01		2.03	
			Width	B2 (m)	5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50	
	Canal		Flow area	Ac (m^2)	16.56		16.56		16.56		16.56		23.40		23.40		23.40		23.40		19.09		19.09		19.09		19.09	
			Velocity	Vc (m/s)	0.30		0.30		0.30		0.30		0.39		0.39		0.39		0.39		0.37		0.37		0.37		0.37	
			Width	B1 (m)	4.50		4.50		4.50		4.50		3.30		3.30		3.30		3.30		6.00		6.00		6.00		6.00	
	Egyptian code	Check 1	2 < Vr/Vc < 3	Vr / Vc	1.42	NG	2.83	OK	1.89	NG	3.78	NG	2.50	OK	5.01	NG	3.34	NG	6.68	NG	2.06	OK	4.12	NG	2.74	OK	5.49	NG
			Vr =1.00~1.50m/s	Vr	0.43	NG	0.86	NG	0.57	NG	1.15	OK	0.98	NG	1.96	NG	1.30	OK	2.61	NG	0.76	NG	1.52	NG	1.01	OK	2.03	NG
		Check 2	0.6 < B2/B1< 1.0	B2 /B1	1.11	NG	0.44	NG	0.89	OK	0.33	NG	1.52	NG	0.61	OK	1.21	NG	0.45	NG	0.83	OK	0.33	NG	0.67	OK	0.25	NG
		Check 3	$h=Vc^2/(2gC^2)\times((Ac/Ar)^2-1)$ ≦ 10cm		0.73	OK	5.03	OK	1.84	OK	9.48	OK	6.33	OK	28.80	NG	12.16	NG	52.10	NG	3.43	OK	16.83	NG	6.90	OK	30.72	NG
			$h=\alpha\times\beta\times Vc^2/(2g)$ ≦ 10cm		0.18	OK	0.40	OK	0.29	OK	0.45	OK	0.61	OK	0.81	OK	0.71	OK	0.86	OK	0.47	OK	0.69	OK	0.58	OK	0.74	OK
Min. design discharge			Min. design discharge (m^3/s)		0.6								1.3								0.9							
			U.S.W.L.	(m)	44.30								44.30								44.30							
			D.S.W.L.	(m)	44.22								44.08								44.29							
	Regulator		Flow area	Ar (m^2)	4.88		2.44		3.66		1.83		1.92		0.96		1.44		0.72		2.76		1.38		2.07		1.04	
			Velocity	Vr (m/s)	0.12		0.25		0.16		0.33		0.68		1.35		0.90		1.81		0.33		0.65		0.43		0.87	
			Width	B2 (m)	5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50	
	Canal		Flow area	Ac (m^2)	3.76		3.76		3.76		3.76		5.98		5.98		5.98		5.98		4.63		4.63		4.63		4.63	
			Velocity	Vc (m/s)	0.16		0.16		0.16		0.16		0.24		0.24		0.24		0.24		0.19		0.19		0.19		0.19	
			Width	B1 (m)	4.50		4.50		4.50		4.50		3.30		3.30		3.30		3.30		6.00		6.00		6.00		6.00	
	Egyptian code	Check 1	2 < Vr/Vc < 3	Vr / Vc	0.75	NG	1.51	NG	1.01	NG	2.01	OK	2.84	OK	5.67	NG	3.78	NG	7.56	NG	1.68	NG	3.35	NG	2.24	OK	4.47	NG
			Vr =1.00~1.50m/s	Vr	0.12	NG	0.25	NG	0.16	NG	0.33	NG	0.68	NG	1.35	OK	0.90	NG	1.81	NG	0.33	NG	0.65	NG	0.43	NG	0.87	NG
		Check 2	0.6 < B2/B1< 1.0	B2 /B1	1.11	NG	0.44	NG	0.89	OK	0.33	NG	1.52	NG	0.61	OK	1.21	NG	0.45	NG	0.83	OK	0.33	NG	0.67	OK	0.25	NG
		Check 3	$h=Vc^2/(2gC^2)\times((Ac/Ar)^2-1)$ ≦ 10cm		-0.08	OK	0.28	OK	0.01	OK	0.65	OK	3.77	OK	16.36	NG	7.03	OK	29.42	NG	0.52	OK	2.94	OK	1.15	OK	5.45	OK
			$h=\alpha\times\beta\times Vc^2/(2g)$ ≦ 10cm		(0.05)	OK	0.06	OK	0.00	OK	0.09	OK	0.26	OK	0.32	OK	0.29	OK	0.33	OK	0.10	OK	0.18	OK	0.14	OK	0.19	OK
	Available water level (Non-uniform flow)			≦44.30m	44.22	OK	44.23	OK	44.23	OK	44.24	OK	44.10	OK	44.20	OK	44.12	OK	44.33	NG	44.30	OK	44.31	NG	44.30	OK	44.33	NG
【Japanese code】0.6≦Intake velocity (Vi)≦1.0				Vi (m/s)	0.38	NG	0.76	OK	0.51	NG	1.01	NG	0.83	OK	1.67	NG	1.11	NG	2.22	NG	0.65	OK	1.30	NG	0.86	OK	1.73	NG

7. Elevation of Main Structures

7-1 Sill elevation of apron

The elevation for the top of apron under the gate is determined by the location of the new regulators. The current bed elevation of the canal is set to avoid sediment problems, as there are no plans for the construction of a new canal.

The locations of the new regulators are grouped into two types: one for Abo Gabal and Sahelyia regulators, which are constructed upstream of the DGRs at a right angle against the flow direction (TYPE1), and another for Bahr Yusef, Badraman, and Ibrahimia regulators which are constructed downstream of the DGRs (TYPE2).

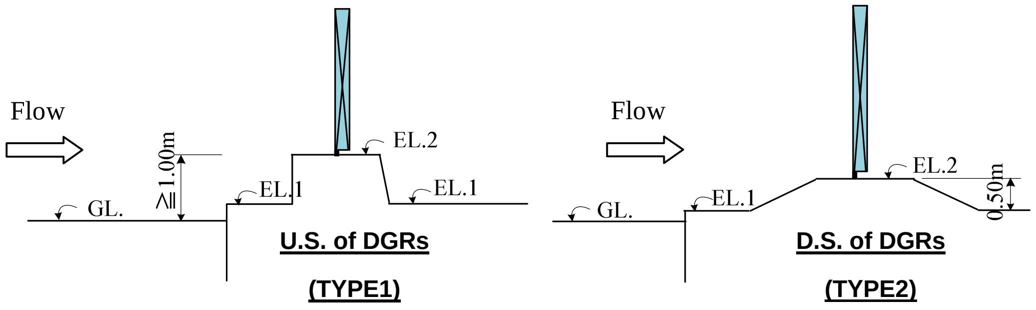
In response to strong requests from the Egyptian side, the sill level of the Abo Gabal and Sahelyia regulators should be of a particular height capable of taking water under the conditions of LLWL upstream with mini-discharge (refer to Chapter 6-2 (3)). The apron-apart from the sill parts-should be the same elevation as the existing one. In addition, the sill level should be 1.0m higher than the apron level. During the maintenance works for removing sedimentation, the elevation excavated should be less than the apron elevation (EL 1: refer to Figure 7-1.1)

The elevation of the latter type of regulators is set 0.5m higher than the current elevation of the upstream canal bed to account for unexpected sediments. Table 7-1.1 shows elevation of apron around gate sill.

Table 7-1.1 Elevation of apron around gate sill

Location Type	Regulator	Current canal bed GL.(m)	Elevation of the apron: EL.1 (m)[*1]	Elevation for the apron on the gate section: EL.2 (m)[*1]
U.S. of DGRs (TYPE1)	Abo Gabal	43.0±	42.75	43.60
	Sahelyia	44.0m±	41.55	43.00
D.S of DGRs (TYPE2)	Bahr Yusef	38.5～39.5	39.50	40.00
	Badraman	43.0±	43.40	43.90
	Diroutiah	43.5±	43.70	44.20
	Ibrahimia	39.5±	39.50	40.00

***1 : refer to Figure 7-1.1**



U.S. of DGRs (TYPE1)

D.S. of DGRs (TYPE2)

Figure 7-1.1 Schematic drawing for the elevation of apron around gate sill

7-2 Gate top elevation and height

The top elevation of the gate is designed as EL.46.55m (Upstream Design High Water Level 46.30m + Free Board 0.25m).

- Upstream Design High Water Level: US.H.W.L.= 46.30m
- Free Board: Fb = 0.25m

(Egyptian Code "Vol.3. Chap.5 Regulators and Gates")

- Top Elevation of the gate: EL.3=US.H.W.L.46.30m＋0.25m

= EL. 46.55m

The height of the gate is designed as the difference in elevation between the top of the gate and the apron on the gate section, as shown in Table 7-2.1.

Table 7-2.1 Gate height for each regulator

Regulator	Top elevation of the gate EL.3	Elevation of the apron on the gate section EL.2	Gate height H (m)	Remarks
Bahr Yusef	46.55m	40.00m	6.55m	Double leaf
Ibrahimia	46.55m	40.00m	6.65m	Double leaf
Sahelyia	46.55m	43.00m	3.55m	Single leaf
Diroutiah	46.55m	44.20m	2.35m	Single leaf
Badraman	46.55m	43.90m	2.65m	Single leaf
Abo Gabal	46.55m	43.60m	2.95m	Single leaf

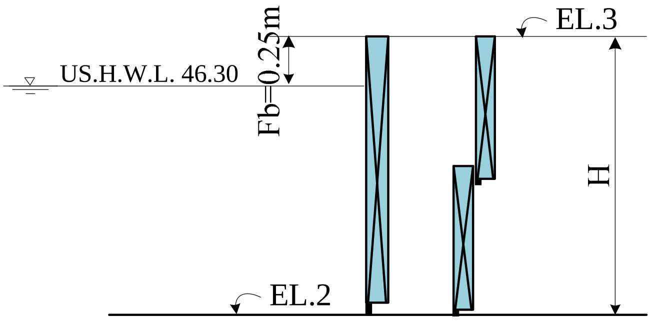


Figure 7-2.1 Schematic drawing for top elevation of the gate and its height

7-3 Bottom elevation of gate when fully opened

Bottom elevation of the fully open gate is designed as EL.47.50m (Upstream Unusual High Water Level 47.00m + Free board 0.50m).

・Upstream Unusual High Water Level: US.H.H.W.L.= 47.00m

・Free Board: Fb = 0.50m

(Egyptian Code “Vol.3. Chap.5 Regulators and Gates”)

・Bottom elevation of the fully open gate: EL.4 = US.H.H.W.L.47.00m＋0.50m = EL.47.50m

7-4 Elevation of downstream at the end of apron

As for the elevation at the end of the apron, the harmful effects of scoring should be considered to avoid damage to the apron and promote regulator longevity. Since the existing canal elevation at the downstream is higher than that at the design apron level, the long-term stability of the regulators and their safety from serious damage is ensured with flat apron design.

Accordingly, "EL 1" in Chapter 7-1" should be the downstream design apron level.

8. Design of Weir Body

8-1 Design of weir body

Since the foundation is composed of unconsolidated sand, silt, or clay, the regulator is of the 'floating' type. For this regulator type, the design of the length of the apron and the thickness of the regulator body complies with Egyptian Code "Vol.3. Chapter 5 Regulators and Gates" and *Part No.2 Design of Hydraulic Structures Spillways Regulators Barrage* as below.

(1) Length of downstream apron

Bligh's equation is applied to the length of the downstream apron, which is shown below.

$$Ls = 0.61 \times C \times \sqrt{}H$$

Where, Ls: Length of downstream apron (m)

C: Constant of Bligh equation

$\triangle H$: Maximum difference between upstream and downstream in water level (m)

(2) Creep length

In order to prevent piping, it is necessary to keep enough creep length along the foundation of the regulator. Required creep length is selected as the largest of the values calculated by Bligh's method and Lane's method

① Bligh's method

$$S' \geqq C \times \triangle H$$

Where, S': Creep length along the foundation of the regulator (m)

C: Constant of Bligh's equation

$\triangle H$: Maximum difference between upstream and downstream in water level (m)

② Lane's method

$$L' \geqq C' \times \triangle H$$

Where, L': Creep length along the foundation of the regulator (m)

C': Weighted Creep constant for Lane's method

$\triangle H$: Maximum difference between upstream and downstream in water level (m)

Table 8-1.1 Constant values for each method

Geological feature	C : Bligh	C' : Lane
Fine sand	15	7
Heavy clay	4	1.8

(3) Thickness of regulator body

The thickness of the middle and downstream apron is determined by the balance of uplift pressure under the apron.

$$t = 1.3 \times \frac{\triangle H - Hf}{\gamma\ - 1} - \frac{Hu \times t0}{S + t0}$$

Where, t: Required thickness of apron at the calculation point (m)

⊿H: Maximum difference between upstream and downstream in water level (m)

Hf: Head loss of the seepage water up to the calculation point (m)

γ : Specific gravity of the material for apron (kN/m^2)

1.3: Safety Factor

Hu: Height of the middle pier (m)

t0: Thickness of the middle pier (m)

S: Vent Width (m)

(4) Results

Figure 8-1.1 to 8-1.4 show the summary results of the hydraulic design to determine the dimensions of the apron and the regulator body. The dimensions of the apron of the new Sahelyia and Abo Gabal regulators are the same as those of the existing apron, as the new apron will be connected to the existing one.

Results of Hydraulic Design —Bahr-Yusef Reg.—

(3) Thickness of apron

Lost water head at Point A : $Hf_A = \Delta H \times L_A / \Sigma L = 6.80 \times 34.15/102.40 = 2.27m$

Lost water head at Point B : $Hf_B = \Delta H \times L_B / \Sigma L = 6.80 \times 39.65/102.40 = 2.63m$

Lost water head at Point C : $Hf_C = \Delta H \times L_C / \Sigma L = 6.80 \times 68.40/102.40 = 4.54m$

Lost water head at Point D : $Hf_D = \Delta H \times L_D / \Sigma L = 6.80 \times 89.40/102.40 = 5.94m$

a) At Point A

$t_A = 1.3 \times (\Delta H - Hf_A)/(\gamma - 1) - Hu \times t_0/(S+t_0)$

$= 1.3 \times (6.80-2.27)/(2.50-1) - 7.50 \times 2.50/(6.00+2.50) = \underline{1.72m}$

b) At Point B

$t_B = 1.3 \times (\Delta H - Hf_B)/(\gamma - 1) - Hu \times t_0/(S+t_0)$

$= 1.3 \times (6.80-2.63)/(2.50-1) - 7.00 \times 2.50/(6.00+2.50) = \underline{1.56m}$

c) At Point C

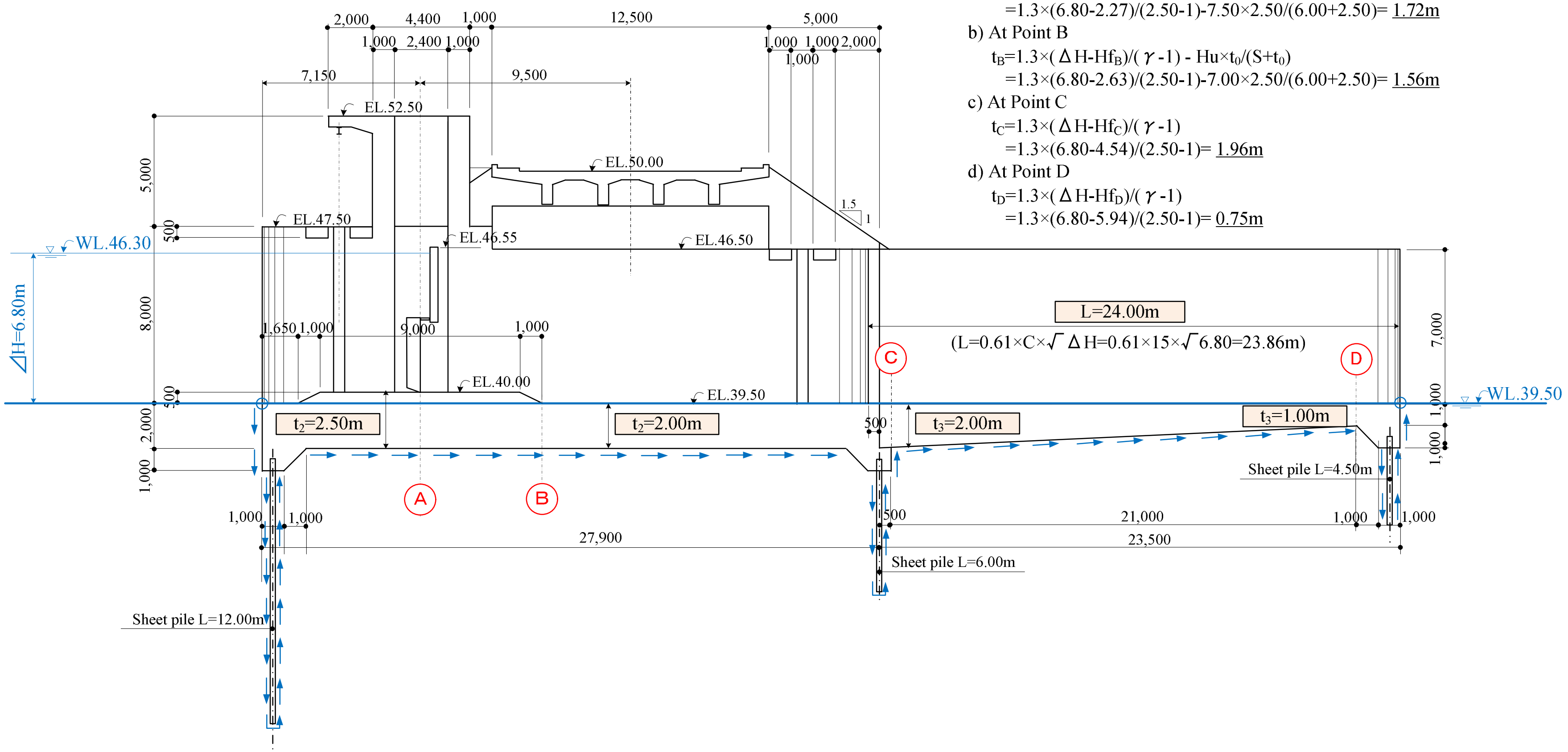
$t_C = 1.3 \times (\Delta H - Hf_C)/(\gamma - 1)$

$= 1.3 \times (6.80-4.54)/(2.50-1) = \underline{1.96m}$

d) At Point D

$t_D = 1.3 \times (\Delta H - Hf_D)/(\gamma - 1)$

$= 1.3 \times (6.80-5.94)/(2.50-1) = \underline{0.75m}$



(1) Design creep length

Horizontal creep length : $\Sigma H = 27.90+23.50 = 51.40m$

Vertical creep length : $\Sigma V = 3.00+11.5 \times 2+1.00+1.00$
$+5.50 \times 2+1.00+1.00+4.00 \times 2+2.00 = 51.00m$

Design creep length : $\Sigma L = \Sigma V + \Sigma H = 102.40m$

(2) Piping

a) Bligh method : $S' = C \times \Delta H = 15 \times 6.80 = 102.00m$
$\leqq S = \Sigma L = 102.40m$ (OK)

b) Lane method : $L' = C' \times \Delta H = 7 \times 6.80 = 47.60m$
$\leqq L = \Sigma V + 1/3 \Sigma H = 51.00 + 1/3 \times 51.40 = 68.13m$ (OK)

Figure 8-1.1 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Bahr Yusef regulator)

Results of Hydraulic Design —Ibrahimia Reg.—

(3) Thickness of apron

Lost water head at Point A : $Hf_A=\Delta H\times L_A/\Sigma L=6.80\times34.15/102.40=2.27m$

Lost water head at Point B : $Hf_B=\Delta H\times L_B/\Sigma L=6.80\times39.65/102.40=2.63m$

Lost water head at Point C : $Hf_C=\Delta H\times L_C/\Sigma L=6.80\times68.40/102.40=4.54m$

Lost water head at Point D : $Hf_D=\Delta H\times L_D/\Sigma L=6.80\times89.40/102.40=5.94m$

a) At Point A

$t_A=1.3\times(\Delta H-Hf_A)/(\gamma-1)-Hu\times t_0/(S+t_0)$

$=1.3\times(6.80-2.27)/(2.50-1)-7.50\times2.50/(6.00+2.50)=\underline{1.72m}$

b) At Point B

$t_B=1.3\times(\Delta H-Hf_B)/(\gamma-1)-Hu\times t_0/(S+t_0)$

$=1.3\times(6.80-2.63)/(2.50-1)-7.00\times2.50/(6.00+2.50)=\underline{1.56m}$

c) At Point C

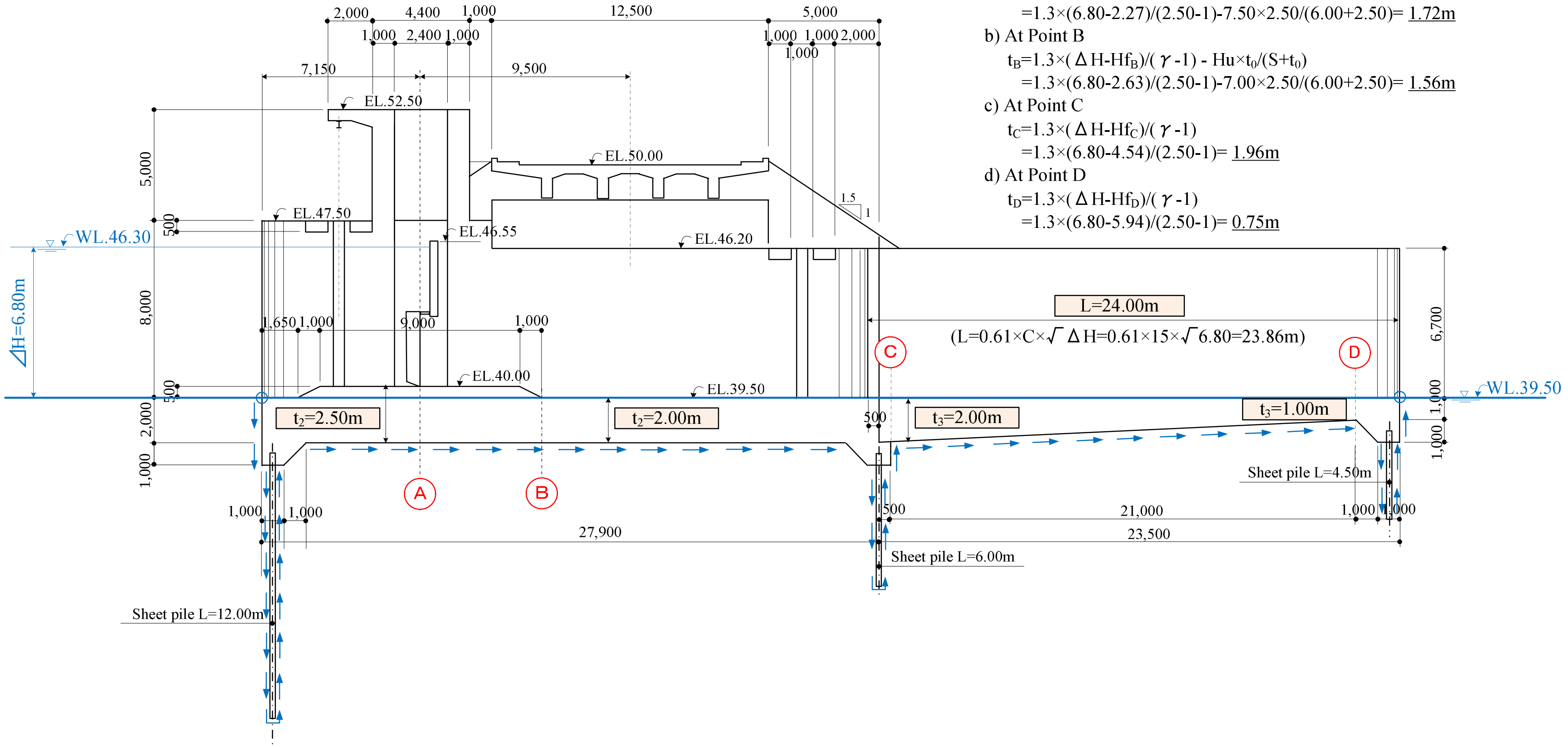
$t_C=1.3\times(\Delta H-Hf_C)/(\gamma-1)$

$=1.3\times(6.80-4.54)/(2.50-1)=\underline{1.96m}$

d) At Point D

$t_D=1.3\times(\Delta H-Hf_D)/(\gamma-1)$

$=1.3\times(6.80-5.94)/(2.50-1)=\underline{0.75m}$



(1) Design creep length

Horizontal creep length : $\Sigma H=27.90+23.50=51.40m$

Vertical creep length : $\Sigma V=3.00+11.5\times2+1.00+1.00$
$+5.50\times2+1.00+1.00+4.00\times2+2.00=51.00m$

Design creep length : $\Sigma L=\Sigma V+\Sigma H=102.40m$

(2) Piping

a) Bligh method : $S'=C\times\Delta H=15\times6.80=102.00m$

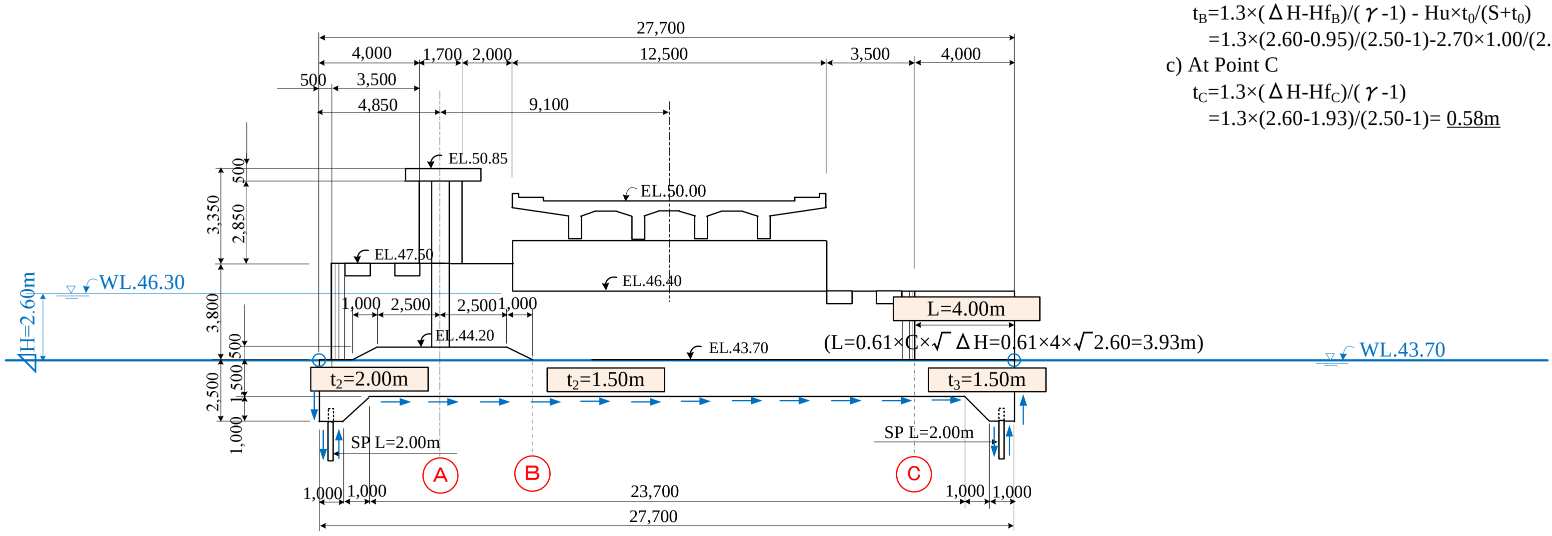
$\leqq S=\Sigma L=102.40m$ (OK)

b) Lane method : $L'=C'\times\Delta H=7\times6.80=47.60m$

$\leqq L=\Sigma V+1/3\Sigma H=51.00+1/3\times51.40=68.13m$ (OK)

Figure 8-1.2 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Ibrahimia regulator)

Results of Hydraulic Design　—Diroutiah Reg.—



(1) Design creep length

Horizontal creep length :$\Sigma H = 27.70\text{m}$

Vertical creep length :$\Sigma V = 2.50+1.5\times2+1.00+1.00+1.50\times2+2.50 = 13.00\text{m}$

Design creep length :$\Sigma L = \Sigma V + \Sigma H = 40.70\text{m}$

(2) Piping

a) Bligh method : $S' = C\times\Delta H = 4\times2.60 = 10.40\text{m}$

$\leqq S = \Sigma L = 40.70\text{m}$ (OK)

b) Lane method : $L' = C'\times\Delta H = 1.8\times2.60 = 4.68\text{m}$

$\leqq L = \Sigma V + 1/3\,\Sigma H = 13.00 + 1/3\times27.70 = 22.23\text{m}$ (OK)

(3) Thickness of apron

Lost water head at Point A : $Hf_A = \Delta H\times L_A / \Sigma L = 2.60\times11.35/40.70 = 0.73\text{m}$

Lost water head at Point B : $Hf_B = \Delta H\times L_B / \Sigma L = 2.60\times14.85/40.70 = 0.95\text{m}$

Lost water head at Point C : $Hf_C = \Delta H\times L_C / \Sigma L = 2.60\times30.20/40.70 = 1.93\text{m}$

a) At Point A

$t_A = 1.3\times(\Delta H - Hf_A)/(\gamma - 1) - Hu\times t_0/(S + t_0)$

$= 1.3\times(2.60-0.73)/(2.50-1) - 3.30\times1.00/(2.00+1.00) = \underline{0.52\text{m}}$

b) At Point B

$t_B = 1.3\times(\Delta H - Hf_B)/(\gamma - 1) - Hu\times t_0/(S + t_0)$

$= 1.3\times(2.60-0.95)/(2.50-1) - 2.70\times1.00/(2.00+1.00) = \underline{0.53\text{m}}$

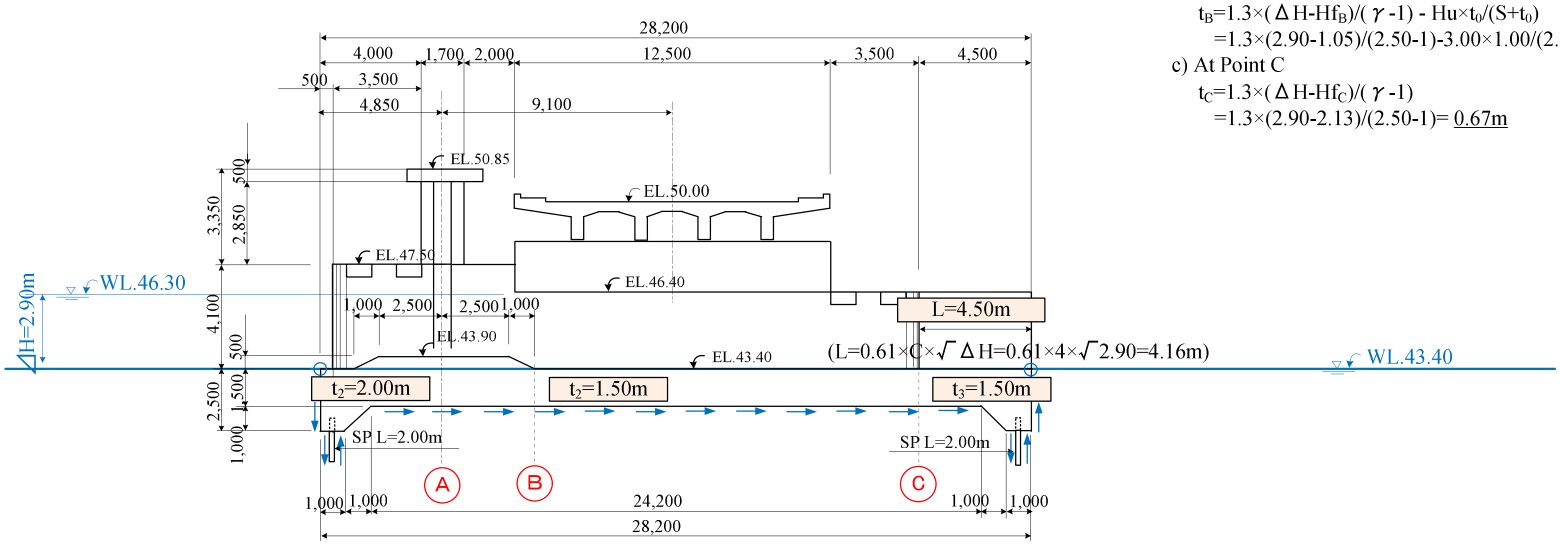
c) At Point C

$t_C = 1.3\times(\Delta H - Hf_C)/(\gamma - 1)$

$= 1.3\times(2.60-1.93)/(2.50-1) = \underline{0.58\text{m}}$

Figure 8-1.3 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Diroutiah regulator)

Results of Hydraulic Design —Badraman Reg.—



(3) Thickness of apron

Lost water head at Point A : $Hf_A=\Delta H \times L_A/\Sigma L=2.90\times11.35/41.20=0.80\text{m}$

Lost water head at Point B : $Hf_B=\Delta H \times L_B/\Sigma L=2.90\times14.85/41.20=1.05\text{m}$

Lost water head at Point C : $Hf_C=\Delta H \times L_C/\Sigma L=2.90\times30.20/41.20=2.13\text{m}$

a) At Point A

$t_A=1.3\times(\Delta H-Hf_A)/(\gamma-1) - Hu\times t_0/(S+t_0)$

$=1.3\times(2.90-0.80)/(2.50-1)-3.60\times1.00/(2.00+1.00)= \underline{0.62\text{m}}$

b) At Point B

$t_B=1.3\times(\Delta H-Hf_B)/(\gamma-1) - Hu\times t_0/(S+t_0)$

$=1.3\times(2.90-1.05)/(2.50-1)-3.00\times1.00/(2.00+1.00)= \underline{0.60\text{m}}$

c) At Point C

$t_C=1.3\times(\Delta H-Hf_C)/(\gamma-1)$

$=1.3\times(2.90-2.13)/(2.50-1)= \underline{0.67\text{m}}$

(1) Design creep length

Horizontal creep length : $\Sigma H=28.20\text{m}$

Vertical creep length : $\Sigma V=2.50+1.5\times2+1.00+1.00+1.50\times2+2.50=13.00\text{m}$

Design creep length : $\Sigma L=\Sigma V+\Sigma H=41.20\text{m}$

(2) Piping

a) Bligh method : $S'=C\times\Delta H=4\times2.90=11.60\text{m}$

$\leqq S=\Sigma L=41.20\text{m}$ (OK)

b) Lane method : $L'=C'\times\Delta H=1.8\times2.90=5.22\text{m}$

$\leqq L=\Sigma V+1/3\,\Sigma H=13.00+1/3\times28.20=22.40\text{m}$ (OK)

Figure 8-1.4 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Badraman regulator)

8-2 Design of downstream apron

The downstream apron should be designed for the protection of the bed in the large Bahr Yusef and Ibrahimia regulators, whose structures are separated into weir body and apron. The downstream aprons are 31.5m long at the bottom and are structured in a U-shape. Their shape is different from the weir body, with a middle pier on the bottom slab.

Although the Egyptian side requested a U-shaped structure, (a single body structure connected to two side walls and a bottom slab) an evaluation of structure and foundation types showed that the L-type structure of an L-type wall and an apron slab should be used. The foundation type selected should be of the pile foundation type in conformity with the regulators.

These decisions were approved by 22nd TAC, and the comparisons and evaluations are shown in Table 8-2.1.

Table 8-2.1 Comparison table of wall types at downstream apron (1/3)

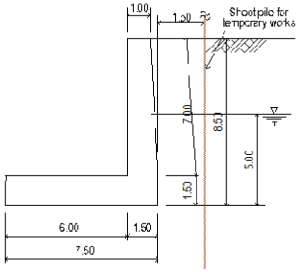
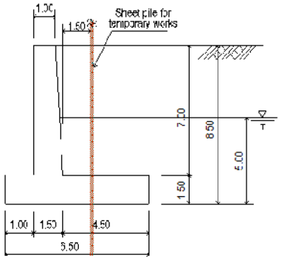
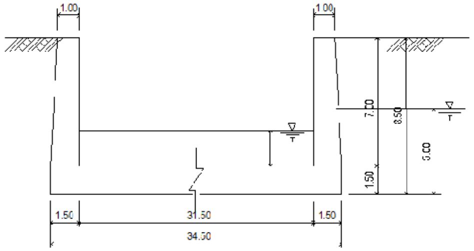
Type	L type wall	T type wall	U type (Raft foundation and one body)
Structure design		 Note: thickness of footing is 1.5m, same as the regulator apron. If it is over 2m, temporary double sheet pile will be unstable.	 Note: thickness of footing is 1.5m, same as regulator footing. If it is over 2m, temporary double sheet pie will be unstable.
Stability of raft foundation structure ・for land sliding ・for eccentricity	Safe stability is not secured because of substantial horizontal stress. 1) normal condition: Fs= 0.504 < 1.5 ········NG e=1.256 > 1.250 = B/6 ··NG 2) seismic condition: Fs= 0.442 < 1.15 ·······NG e= -0.688 < 2.500 = B/3 ··OK **(No good)**	Safe stability is secured as follows: 1) normal condition: Fs= 1.606 > 1.5 ········OK e=0.773 < 1.083 = B/6 ··OK 2) seismic condition: Fs= 1.653 > 1.15 ·······OK e= 0.647 < 2.167 = B/3···OK **(Good)**	Safe stability is secured as follows: 1) symmetry structural form 2) offset of horizontal stress. ⇒Stable OK **(Good)**
Stability of bearing capacity of raft foundation	The actual stress to the ground is larger than the allowable bearing capacity because of the large eccentricity, so it is **not used as the raft foundation.** Measurements of foundation type: 1) normal condition: q= 68.53 kN/m2 > range out···NG (6.85 tf/m2) 2) seismic condition: q= 82.84 kN/m2 > range out···NG (8.28tf/m2) **(No good)**	The actual stress to the ground is larger than the allowable bearing capacity because of the great eccentricity, so it is **not used as the raft foundation.** Measurements of foundation type: 1) normal condition: q= 215.20 kN/m2 > range out···NG (21.5tf/m2) 2) seismic condition: q= 239.49 kN/m2 > range out···NG (23.95tf/m2) **(No good)**	The actual stress to the ground at Bahr Yusef is larger than the allowable bearing capacity, but at Ibrahimia it is within allowable bearing capacity. 1) normal condition: q= 50.18 kN/m2 > 49.16 kN/m2··NG < 91.48 kN/m2··OK (5.02tf/m2 > 4.92tf/m2) (< 9.15tf/m2) *: upper value: Bahr Yusef, lower value: Ibrahimia **(Moderate)**

Table 8-2.2 Comparison table of wall types at downstream apron (2/3)

Type		L type wall	T type wall		U type (Raft foundation and one body)	
Structural stress Note) Available steel bar should be **less than φ25mm** in the comparison table for the marketability.		Following bar arrangement is applied. 1) Wall: φ22@200mm 2) Footing: φ25@200mm ⇒Structural stress safety →OK **(Good)**	Following bar arrangement is applied. 1) Wall: φ22@200mm 2) Footing: φ25@200mm ⇒Structural stress safety →OK **(Good)**		Following bar arrangement is applied. 1) Wall: φ22@200mm 2) Footing: φ25@100mm ⇒Structural stress without safety →NG Note) Long footing is affected by strong moment especially at the center of footing. **(No good)**	
Wall	B, H, d (mm)	1000, 1500, 1430	1000, 1500, 1430		1000, 1500, 1430	
	M (kN·m)	377.19 (37.72tf·m)	377.19 (37.72tf·m)		376.66 (37.67tf·m)	
	N (kN)	0.00	0.00		0.00	
	S (kN)	165.19 (16.52tf·m)	165.19 (16.52tf·m)		183.82 (18.38tf·m)	
	Bar-arrange	φ22@200mm	φ22@200mm		φ22@200mm	
	σc / σca (N/mm2)	2.05 < 9.50 ←OK (20.5kgf/cm2 < 95kgf/cm2)	2.05 < 9.50 ←OK (20.5kgf/cm2 < 95kgf/cm2)		2.15 < 9.50 ←OK (20.5kgf/cm2 < 95kgf/cm2)	
	σs / σsa (N/mm2)	144.64 < 200.0 ←OK (1446.4kgf/cm2 < 2000kgf/cm2)	144.64 < 200.0 ←OK (1446.4kgf/cm2 < 2000kgf/cm2)		144.85 < 200.0 ←OK (1448.5kgf/cm2 < 2000kgf/cm2)	
	τc / τca (N/mm2)	0.116 < 0.7 ←OK (1.16kgf/cm2 < 7.0kgf/cm2)	0.116 < 0.7 ←OK (1.16kgf/cm2 < 7.0kgf/cm2)		0.129 < 0.7 ←OK (1.29kgf/cm2 < 7.0kgf/cm2)	
Footing	B, H, d (mm)	1000, 1500, 1430	1000, 1500, 1430		1000, 1500, 1430	
	M (kN·m)	377.19 (37.72tf·m)	**(Front footing)** -92.65(9.27tf·m)	**(Back footing)** 377.19 (37.72tf·m)	**(Edge of footing)** 376.67(37.67tf·m)	**(Center of footing)** -6192.41(619.24tf·m)
	N (kN)	0.00	0.00	0.00	0.00	0.00
	S (kN)	205.68 (20.57tf·m)	181.61 (18.16tf·m)	183.69 (18.37tf·m)	796.257 (79.63tf·m)	0.00
	Bar-arrange	φ25@200mm **(Dia. comply with U type)**	φ25@200mm **(Dia. comply with U type)**	φ25@200mm **(Dia. comply with U type)**	φ25@**100mm**	φ25@**100mm**
	σc / σca (N/mm2)	1.93 < 9.50 ←OK (19.3kgf/cm2 < 95kgf/cm2)	0.47 < 9.50 ←OK (4.7kgf/cm2 <95kgf/cm2)	1.93 < 9.50 ←OK (19.3kgf/cm2 <95kgf/cm2)	2.15 < 9.50 ←OK (21.5kgf/cm2 <95kgf/cm2)	**24.07 > 9.50**←NG (240.1kgf/cm2 >95kgf/cm2)
	σs / σsa (N/mm2)	111.77 < 200.0 ←OK (1117.7kgf/cm2 < 2000kgf/cm2)	27.45 < 200.0 ←OK (274.5kgf/cm2 < 2000kgf/cm2)	111.77 < 200.0 ←OK (1117.7kgf/cm2 < 2000kgf/cm2)	144.85 < 200.0 ←OK (1448.5kgf/cm2 < 2000kgf/cm2)	**941.62 > 200.0**←NG (9416.2kgf/cm2 > 2000kgf/cm2)
	τc / τca (N/mm2)	0.144 < 0.7 ← OK (1.44kgf/cm2 < 7.0kgf/cm2)	0.127 < 0.7 ←OK (1.3kgf/cm2 < 7.0kgf/cm2)	0.129 < 0.805 ←OK (1.3kgf/cm2 < 8.05kgf/cm2)	0.557 < 0.7 ←OK (5.6kgf/cm2 < 7.0kgf/cm2)	—

Table 8-2.3 Comparison table of wall types at downstream apron (3/3)

Type	L type wall	T type wall	U type (Raft foundation and one body)
Impact on construction	No negative impact on the construction works, but (pile) foundation works are needed for stability. **(Good)**	The back footing causes adverse effects to the double sheet piles of the diversion works. Considering the necessary length of back footing, the diversion area is forced to become narrow and the flow velocity becomes high. **(No good)**	Due to the large steel bar volume, footing must be thicker, due to the long span footing. The deep digging required for the deep footing causes high stress to the sheet pile of the diversion works. The concrete needs careful casting to avoid temperature stress cracks if the footing is very thick. However, the thick footing causes excess weight to the allowable bearing capacity. **(No good)**
General evaluation and possibility of raft foundation	Raft foundation is not applied. Suitable measurements of the foundation shall be made. L-type wall is the most reasonable wall type for the Bahr Yusef and Ibrahimia regulators. **(Applied)**	Raft foundation is not applied. Even if the length of backward footing is secured by the required one, the diversion area in the construction stage cannot be secured at safe flow velocity. T-type wall is not the best type for the Bahr Yusef and Ibrahimia regulators.	Raft foundation is not applied in Bahr Yusef. Ibrahimia might be available for raft foundation from the viewpoint of bearing capacity, but large moment and stress act on the footing. To ensure regulator longevity, it should avoid this stressful structure. U-type is not the best type for the Bahr Yusef and Ibrahimia regulators.

Remarks: Buttress type cannot be applied under the condition of low bearing capacity. Buttress type is usually effective under the following conditions: 1) high stress acting on a vertical wall 10m or higher, 2) high stress acting on backward footing due to the heavy weight of the embankment.

9. Design of Canal Bed Protection

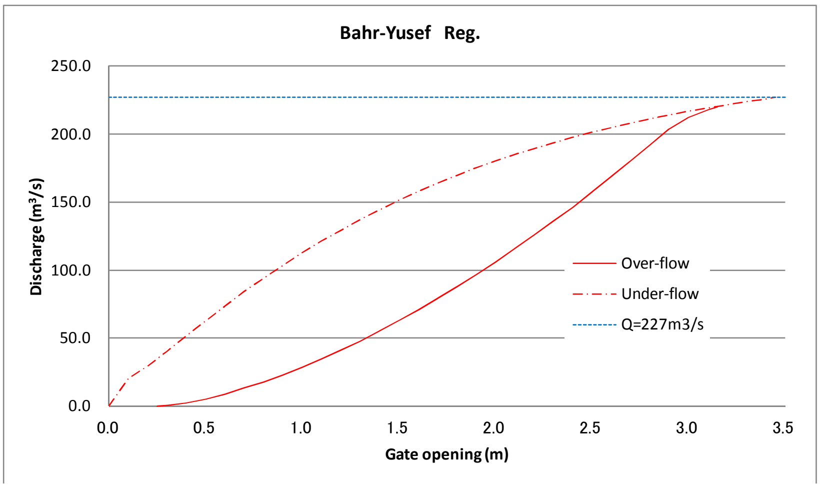
9-1 Basic design concept

The purpose of the bed protection works is to protect the dissipation and the local scouring downstream due to the high flow velocity. In the basic concept of design, the high flow velocity is gradually dissipated by the friction acting on the bed protection until it is the same velocity as that downstream of the canal at the end of the bed protection. This assumes that flowing beyond the limit of sediment movement has continuity of sediment transport, and equilibrium of the canal bed is preserved.

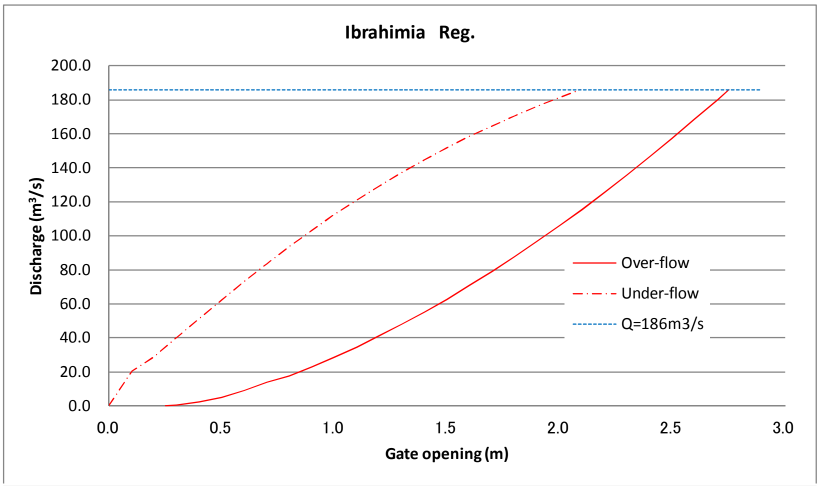
9-2 Length of canal bed protection

(1) Applicable gate operation for the new Bahr Yusef and Ibrahimia regulators

Underflow (submerged flow) gate operation is necessary for the new Bahr Yusef regulator when large discharge is required (refer to the upper chart of Figure 9-2.1). On the other hand, overflow gate operations can be applied to the new Ibrahimia regulator in any case (refer to the lower chart of Figure 9-2.1).



New Bahr Yusef regulator

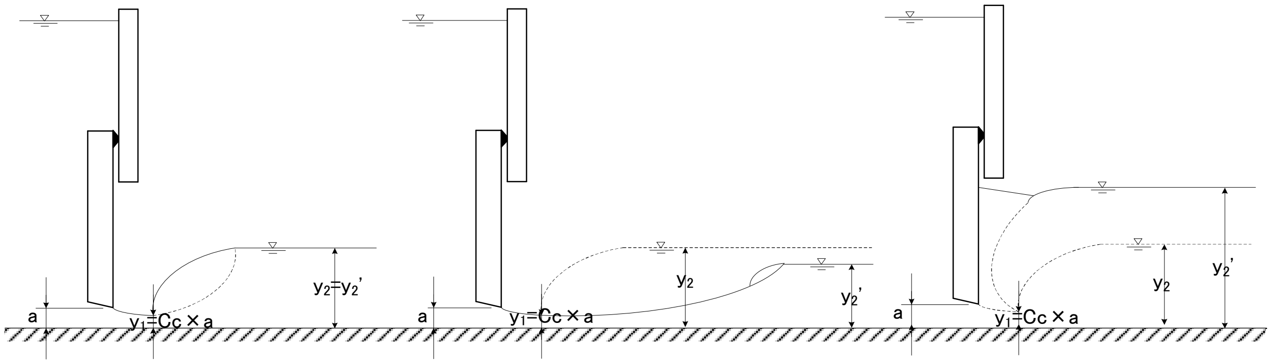


New Ibrahimia regulator

Figure 9-2.1 Relation between gate opening and discharge

(2) Type of hydraulic jump

The type of hydraulic jump which occurs just downstream of the gate is classified into three cases based on the relation between sequent depth (y2) and tailwater depth (y2') (refer to Figure 9-2.2).

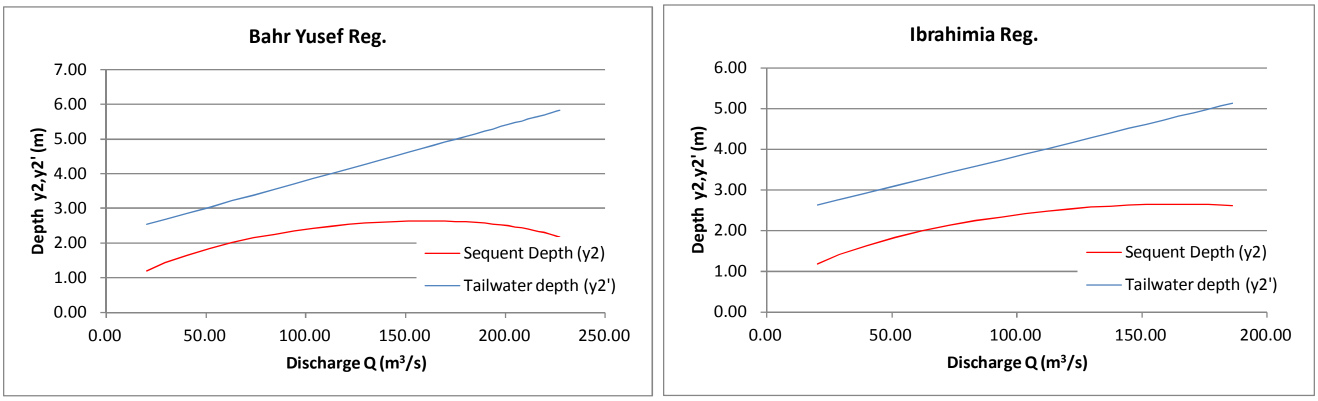


CASE 1 (y_2 = y_2')　　CASE 2 (y_2>y_2')　　CASE 3 (y_2<y_2')

Figure 9-2.2 Type of hydraulic jump

The study of the bed protection should consider the flow state in the case of underflow operation, assuming garbage flushing maintenance takes place.

The result of the study of the relation between sequent depth and tailwater depth at each discharge volume is shown in Figure 9-2.3. The tailwater depth (y2') is always larger than the sequent depth (y2) at any discharge volume, which is classified in case 3 of Figure 9-2.2.



New Bahr Yusef regulator　　New Ibrahimia regulator

Figure 9-2.3 Relation between sequent depth (y2) and tailwater depth (y2') at each discharge

The results indicate that flow state is classified as submerged flow, not exposed jet flow, or exposed hydraulic jump as in cases 1 and 2 in Figure 9-2.2.

(3) Determination of the length of bed protection

Judging from the abovementioned flow conditions just downstream of the gate, the energy for the hydraulic jump is found to be completely dissipated in the area of the downstream apron for both new regulators (and the flow state after the apron section is considered steady).

Therefore, the length of the bed protection is designed more as a connection canal, not as an energy dissipater.

Following numerous experiences in Japan, the length of the apron of a connection canal is recommended to be three to five times the design water depth (H). Thus, considering safety, the length is designed to be 30m (5 times H) from the downstream apron of both new Bahr Yusef and Ibrahimia regulators.

Table 9-2.1 Length of downstream bed protection (new Bahr Yusef and Ibrahimia regulators)

Regulator	Downstream water level DS.HWL	Elevation of downstream apron EL end	Design water depth H	Length of bed protection (3～5 H)	Applied
New Bahr Yusef regulator	45.82 m	39.50 m	6.32 m	18.96~31.60m	➡30.00m
New Ibrahimia regulator	45.13 m	39.50 m	5.63 m	16.89~28.15m	➡30.00m

(4) Determination of the length of the bed protection (New Badraman regulator)

As for the new Badraman regulator, the same method as that applied to the two large regulators is used. The new Badraman regulator (toward both Badraman and Ditoutiah canals) is designed to be 15m in length, as shown in Table 9-2-2.

Table 9-2.2 Length of downstream bed protection (new Badraman regulator)

Regulator	Downstream water level DS.HWL	Elevation of downstream apron EL end	Design water depth H	Length of bed protection (3～5 H)	Applied
New Badraman	45.90 m	43.40 m	2.50 m	7.50~12.50m	➡15.00m
New Ditoutiah	45.90 m	43.70 m	2.20 m	6.60~11.00m	➡15.00m

【Reference: Japanese design standard】

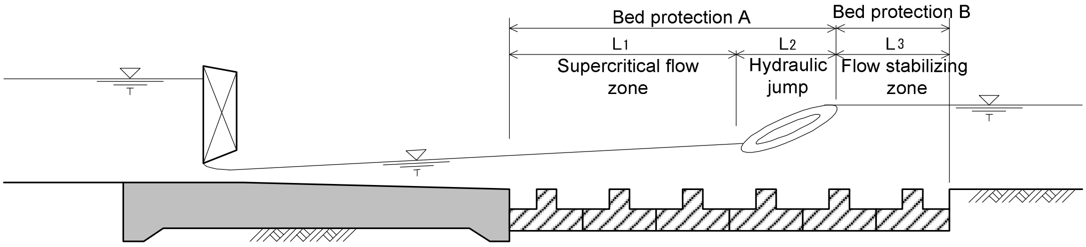


Figure 9-2.4 Design concept of bed protection in Japan

9-3 Stone size for the canal bed protection

(1) Applied formula

A large number of researchers in institutes have suggested various formulae to determine suitable riprap weight and size for certain flow states.

In this study, those riprap properties were calculated corresponding to the flow velocity using the following four formulae, which take into account the relatively gentle flow state.

- Isbash method (Isbash 1936)

$$V = C \times \left[2 \times g \times \frac{\gamma s - \gamma w}{\gamma w}\right]^{0.5} \times (D_{50})^{0.50}$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma_s}\right]^{1/3}$$

Where,

V : Average flow velocity (ft/s)

C : C=1.20

g : Accelerationof gravity ($g=32.2$ ft/s^2)

γ_s : Weight of riprap ($\gamma_s=137$ lb/ft^3)

γ_w : Weight of water ($\gamma_w=62.5$ lb/ft^3)

D_{50} : Average diameter of a riprap (ft)

W_{50} : Average weight of a riprap (lb)

- U.S. Geological Survey method (Blodgett 1981)

$$D_{50} = 0.01\ V^{2.44}$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma_s}\right]^{1/3}$$

Where,

V : Average flow velocity (ft/s)

γ_s : Weight of riprap ($\gamma_s=137$ lb/ft^3)

D_{50} : Average diameter of a riprap (ft)

W_{50} : Average weight of a riprap (lb)

- USBR 1936

$$D_{50} = (Vb / 3.88)^2$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma_s}\right]^{1/3}$$

Where,

Vb : Near bed velocity at 0.9d (m/s)

γ_s : Weight of riprap ($\gamma_s=2{,}200$ kg/m^3)

D_{50} : Average diameter of a riprap (m)

W_{50} : Average weight of a riprap (kg)

- Osama 1995

$$D_{50} = (Vb / 4.3)^2$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma_s}\right]^{1/3}$$

Where,

Vb	:	Near bed velocity at 0.9d (m/s)
γ_s	:	Weight of riprap (γ_s=2,200 kg/m^3)
D_{50}	:	Average diameter of a riprap (m)
W_{50}	:	Average weight of a riprap (kg)

(2) The flow velocity of formula to determine suitable riprap weight and size

In order to determine the average weight and diameter of riprap, the velocity for riprap design is set as 1.5 to 2.0 times the flow velocity (V), considering the temporary increase in velocity during gate maintenance and variations between calculated and actual flow velocities in each canal.

Table 9-3.1 Flow velocity to determine the suitable riprap weight and scale

	Discharge	Flow area	Flow velocity	Velocity for the riprap design	
	Qmax (m^3/s)	A (m^2)	V (m/s)	(1.5～2.0 V)	Applied
Bahr Yusef	227	151.68	1.50	2.25～3.00	➡2.50
Ibrahimia	186	135.12	1.38	2.07～2.76	➡2.50
Badraman	9	10.00	0.90	1.35～1.80	➡1.50
Diroutiah	12	13.20	0.91	1.37～1.82	➡1.50

(3) Determination of the average riprap weight and diameter

Tables 9-3.2 to 9-3.5 show the results of calculations for each flow velocity utilizing the above four formulae. There are some large differences among the riprap weights as determined by the recommended formula, but the riprap weights and sizes for the bed protection works on the downstream side of the regulators are as follows:

・Bahr Yusef, Ibrahimia	:	**D_{50} = 0.40 m**	**W_{50} = 60 kg**
・Badraman, Ditoutiah	:	**D_{50} = 0.20 m**	**W_{50} = 10 kg**

Table 9-3.2 Calculation result by Isbash method (Isbash 1936)

Va		C	γs	γw	D_{50}		W_{50}	
(m/s)	(ft/s)		(lb/ft^3)	(lb/ft^3)	(m)	(ft)	(kg)	(lb)
0.50	1.64	0.86	137	62.5	0.01	0.05	0.00	0.01
1.00	3.28	0.86	137	62.5	0.06	0.19	0.17	0.37
1.50	4.92	0.86	137	62.5	0.13	0.43	1.89	4.17
2.00	6.56	0.86	137	62.5	0.23	0.76	10.64	23.45
2.50	8.20	0.86	137	62.5	0.36	1.18	40.58	89.45
3.00	9.84	0.86	137	62.5	0.52	1.71	121.16	267.11

Table 9-3.3 Calculation result by U.S. Geological Survey method (Blodgett 1981)

Va		γs	D_{50}		W_{50}	
(m/s)	(ft/s)	(lb/ft^3)	(m)	(ft)	(kg)	(lb)
0.50	1.64	137	0.01	0.03	0.00	0.00
1.00	3.28	137	0.06	0.18	0.15	0.32
1.50	4.92	137	0.15	0.49	2.84	6.26
2.00	6.56	137	0.30	0.99	23.32	51.41
2.50	8.20	137	0.52	1.70	119.43	263.30
3.00	9.84	137	0.81	2.65	453.65	1000.14

Table 9-3.4 Calculation result by USBR 1936

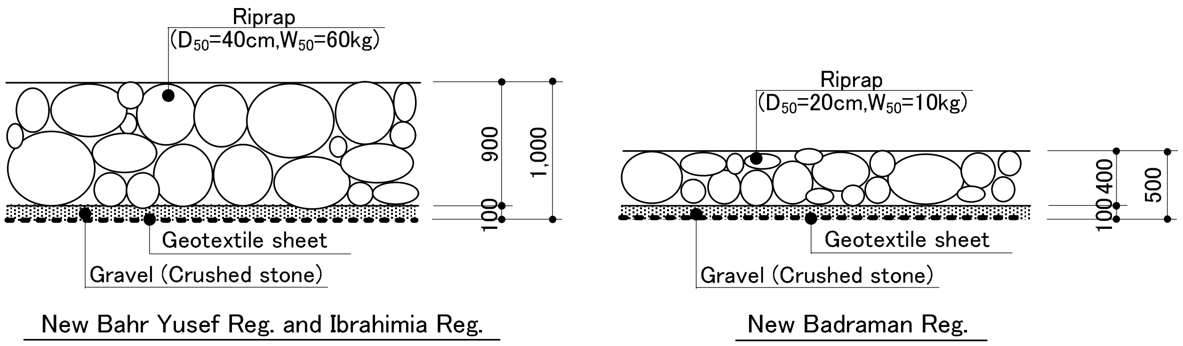
Vb (m/s)	γs (kg/m^3)	D_{50} (m)	W_{50} (kg)
0.50	2,200	0.02	0.00
1.00	2,200	0.07	0.25
1.50	2,200	0.15	2.88
2.00	2,200	0.27	16.20
2.50	2,200	0.42	61.79
3.00	2,200	0.60	184.50

Table 9-3.5 Calculation result by Osama 1995

Vb (m/s)	γs (kg/m^3)	D_{50} (m)	W_{50} (kg)
0.50	2,200	0.01	0.00
1.00	2,200	0.05	0.14
1.50	2,200	0.12	1.56
2.00	2,200	0.22	8.74
2.50	2,200	0.34	33.35
3.00	2,200	0.49	99.58

(4) Design of bed protection

The stone scale and design should be a combination of "Geotextile sheets + stones as filter (0.1~0.2m) + riprap stones (2~3 × D_{50})", which have been approved at the joint 22nd TAC meeting with MMG and DWG. The approved designs are as follows.



New Bahr Yusef Reg. and Ibrahimia Reg.

New Badraman Reg.

Figure 9-3.1Typical section of bed protection

【Reference: Calculations of Stone Gravel Size Distribution】

The compositions of bed protection materials and the purpose of installation are shown in Table 9-3.6.

Table 9-3.6 Compositions of bed materials and purposes of installation

Material	Purpose of Installation	Remarks
Riprap Stone	Installed to protect the dissipation and the local scouring downstream due to the high flow velocity.	Bahr Yusef and Ibrahimia Regulators: D_{50}=40 cm Badraman Regulator: D_{50}=20 cm
Gravel (Crushed stone)	Installed as the cushion material with rubble to prevent the damage of the geotextile sheets.	
Geotextile sheet	Installed to prevent the suction of the present bed materials and control the degradation of the streambed.	
Present streambed material	—	Fine sand D_{15}=0.14 mm, D_{50}=0.23 mm, and D_{85}=0.37 mm

The specifications of the stone materials used for the bed protection works are examined based on the "Standard Gravel Curve" as presented by HRI, Egypt.

The crushed stone installed under the riprap is intended to function as the cushion material. For that crushed stone, the hydraulic specifications are not required.

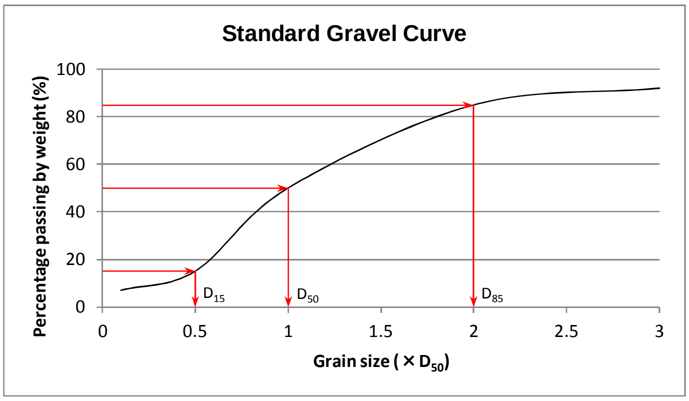


Figure 9-3.2 Standard gravel size distribution of riprap stone (Source: HRI)

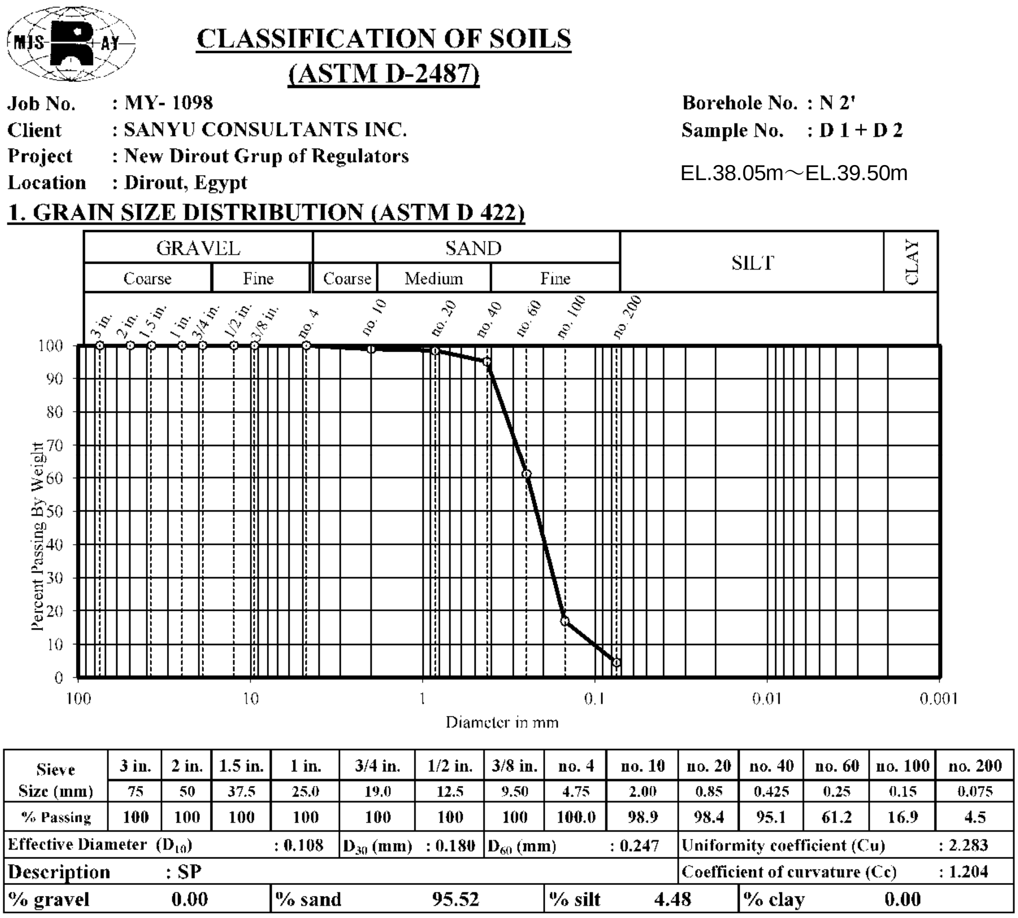
However, the crushed stone is required to have an effective grain size for piping to protect the suction from the riprap stones in order to keep long-term stability. Thus, the crushed stone size specifications should satisfy the following equation:

$$\frac{\text{15\% of grain size of filter material}}{\text{85\% of gravel size of the materials protected by filter}} < 5 \quad \cdots\cdots\cdots \quad \text{(Piping rule)}$$

Table 9-3.7 Grain size distribution for bed protection materials

	New Bahr Yusef Reg. New Ibrahimia Reg.			New Badraman Reg.		
	Riprap	Crushed stone	Remarks	Riprap	Crushed stone	Remarks
D_{15} (=0.5D_{50})	20 cm	1.25 cm	20/5.0=4 < 5 (OK)	10	1.25	10/5.0=2 < 5 (OK)
D_{50}	40 cm	2.5 cm		20	2.5	
D_{85} (=2.0D_{50})	80 cm	5.0 cm		80	5.0	

- Present bed materials under the downstream apron



CLASSIFICATION OF SOILS
(ASTM D-2487)

Job No. : MY- 1098
Client : SANYU CONSULTANTS INC.
Project : New Dirout Grup of Regulators
Location : Dirout, Egypt

Borehole No. : N 2'
Sample No. : D 1 + D 2
EL.38.05m～EL.39.50m

1. GRAIN SIZE DISTRIBUTION (ASTM D 422)

Sieve Size (mm)	3 in.	2 in.	1.5 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	no. 4	no. 10	no. 20	no. 40	no. 60	no. 100	no. 200
	75	50	37.5	25.0	19.0	12.5	9.50	4.75	2.00	0.85	0.425	0.25	0.15	0.075
% Passing	100	100	100	100	100	100	100	100.0	98.9	98.4	95.1	61.2	16.9	4.5

Effective Diameter (D_{10}) : 0.108
D_{30} (mm) : 0.180
D_{60} (mm) : 0.247
Uniformity coefficient (Cu) : 2.283
Description : SP
Coefficient of curvature (Cc) : 1.204
% gravel 0.00
% sand 95.52
% silt 4.48
% clay 0.00

Percent passing by weight	Grain size (mm)		Remarks
15%	D_{15}	0.139	
50%	D_{50}	0.225	
85%	D_{85}	0.373	

10. Design of Pier

10-1Height and thickness of pier

(1) Height of pier

The height of the pier is determined by the bottom elevation and the height of a fully opened gate (EL.4 and h respectively), height of free-board (Fb), and the thickness of the regulator top (t) shown in Table 10-1.1.

Elevation of the pier top EL.5 = the bottom elevation of fully opened gate (EL.4) + the height of fully opened gate(h) + Free board (Fb) + the thickness of the regulator top (t)

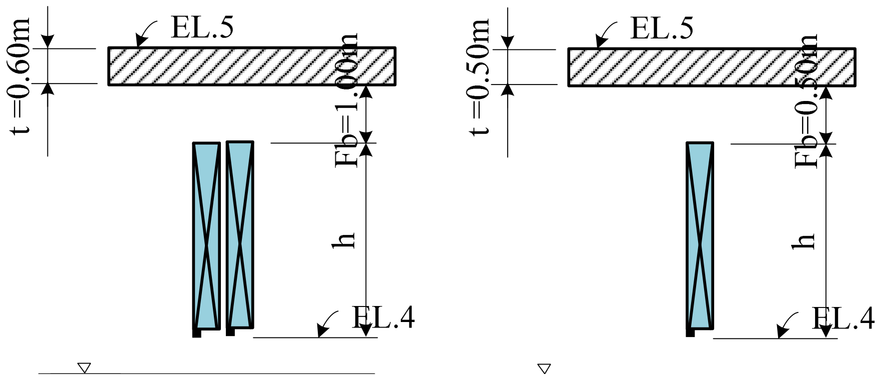
Where, the bottom elevation of fully opened gate (EL.4): refer to 7-3.

Height of fully opened gate (h): lower gate height for the double leaf gate

Free board (Fb): Room for the gate structure (such as spoiler and hook) and free space during reel-up, which is 1.0m for a large scale gate and 0.5m for a small scale gate

Table 10-1.1 Height of pier for each regulator

Regulator	Bottom elevation of the fully open gate: EL.4 (m)	Height of fully open gate: h (m)	Free board: Fb (m)	Thickness of top regulator: t (m)	Elevation of the pier top: EL.5 (m)
Bahr Yusef	47.50	3.40	1.00	0.60	52.50
Ibrahimia	47.50	3.40	1.00	0.60	52.50
Sahelyia	47.50	3.55	0.50	0.50	52.05
Diroutiah	47.50	2.35	0.50	0.50	50.85
Badraman	47.50	2.65	0.50	0.50	51.15
Abo Gabal	47.50	2.95	0.50	0.50	51.45



Large scale (double leaf) gate

Small scale (single leaf) gate

Figure 10-1.1 Schematic drawing of the elevation of the bottom of the fully opened gate (EL.4) and pier top (EL.5)

(2) Thickness of pier

The thickness of the pier should leave enough room for the groove, the transference of the load of the gate onto the pier body, and for ensuring structural stability.

Experiential regulations from the Egyptian Code “Vol.3. Chap.5 Regulators and Gates,” require 1/4 to 1/3 of the vent width. Moreover, another experiential formula is shown below from the textbook *Part No.2 Design of Hydraulic Structures Spillways Regulators Barrage*.

tp = (0,25～0.35)×S ≧ 1.00m

where, tp: Thickness of the pier (m) *Minimum pier thickness is 1.00m

S: Vent width (m)

Thickness of the piers for large scale regulators (Bahr Yusef and Ibrahimia) and small scale regulators (Sahelyia, Badraman, and Abo Gabal) is calculated as follows.

Large scale regulators S=6.00m: tp = (0.25～0.35) ×6.00 = 1.50m～2.10m

Small scale regulators S=2.00m: tp = (0.25～0.35) ×2.00 = 0.50m～0.70m ⇒ tp = 1.00m

Regarding the gate (double roller gate with hydraulic cylinder) for large scale regulators, the guide wall is not designed to reduce the height of piers. In this case, larger room (2.40m×0.85m) is required for the blockout.

Therefore, pier thickness for the large scale regulators is calculated as follows.

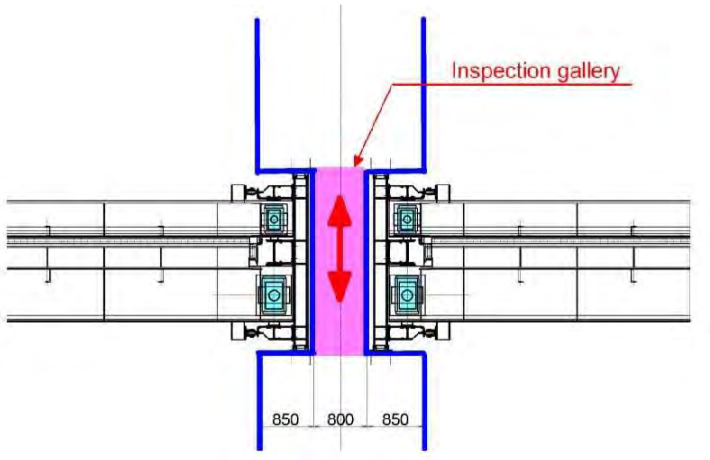


Figure 10-1.2 Schematic drawing for pier width

tp = 0.85m (blockout for the groove)×2＋0.80m（effective pier material width and gallery）

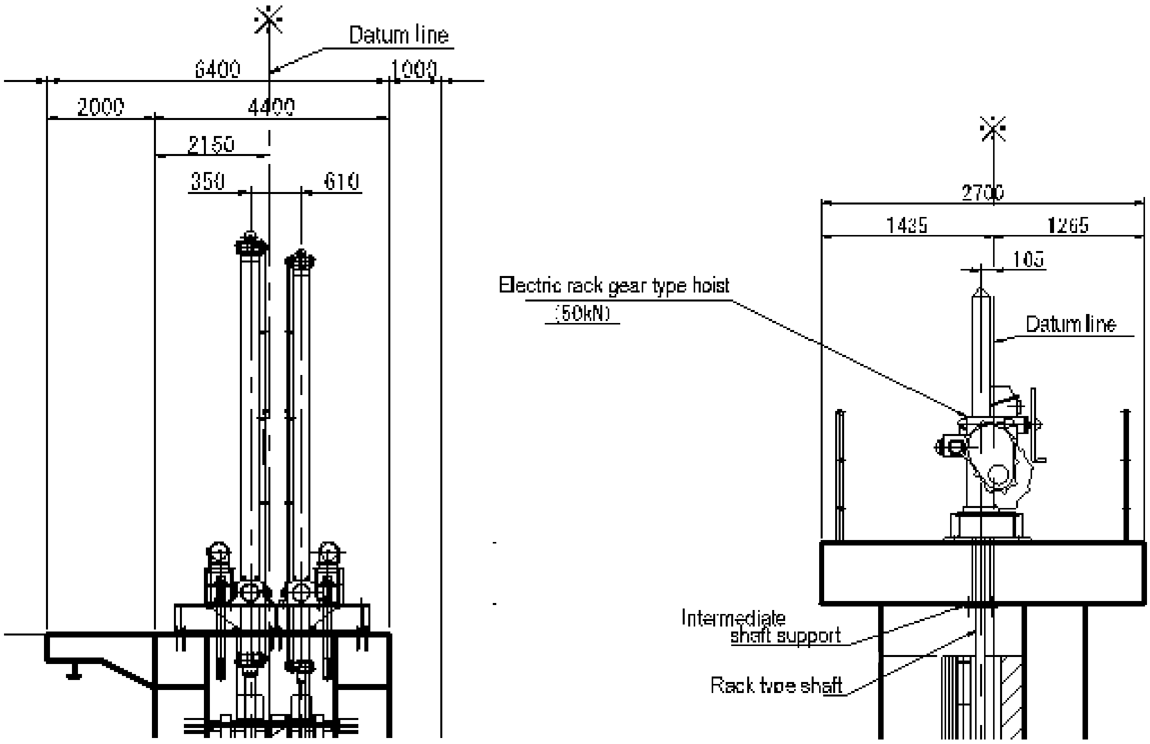
= 2.50m)

Thus, the thickness of the piers is 2.50m for large scale regulators and 1.00m for small scale regulators.

10-2 Design of the superstructure of pier

Operation space is designed on top of the piers, taking into account space for a rack which lifts/lowers gate, as well as space for conducting inspections. For large scale regulators (New Bahr Yusef and Ibrahimia), clearance for gate extraction was designed with the base frame of the hydraulic cylinder. In addition, a rail for the hoist crane was designed.

The superstructure of the piers (operation space) is shown in Figure 10-2.1.



Gate for large regulators (double leaf)

Gate for small regulators (single leaf)

Figure 10-2.1 Schematic drawing of the top of pier (operation space)