JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF SETTLEMENT AND REGIONAL DEVELOPMENT
THE REPUBLIC OF INDONESIA

THE DETAILED DESIGN OF FLOOD CONTROL, URBAN DRAINAGE AND WATER RESOURCES DEVELOPMENT IN SEMARANG IN THE REPUBLIC OF INDONESIA

FINAL REPORT

COMPONENT A:
WEST FLOODWAY / GARANG RIVER IMPROVEMENT

VOLUME III DESIGN CRITERIA

AUGUST 2000

CTI ENGINEERING INTERNATIONAL CO., LTD.
IN ASSOCIATION WITH
PACIFIC CONSULTANTS INTERNATIONAL
AND
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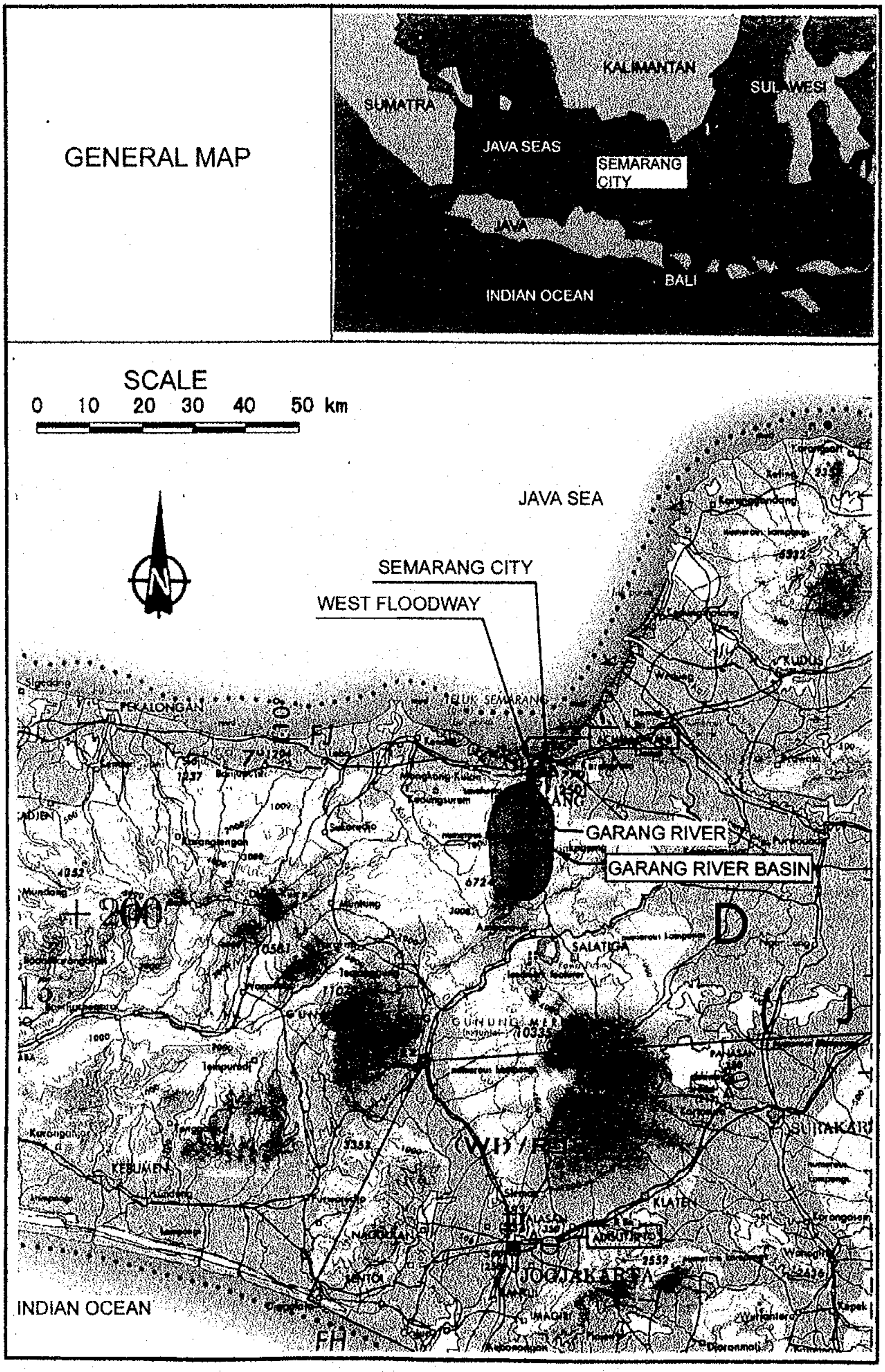
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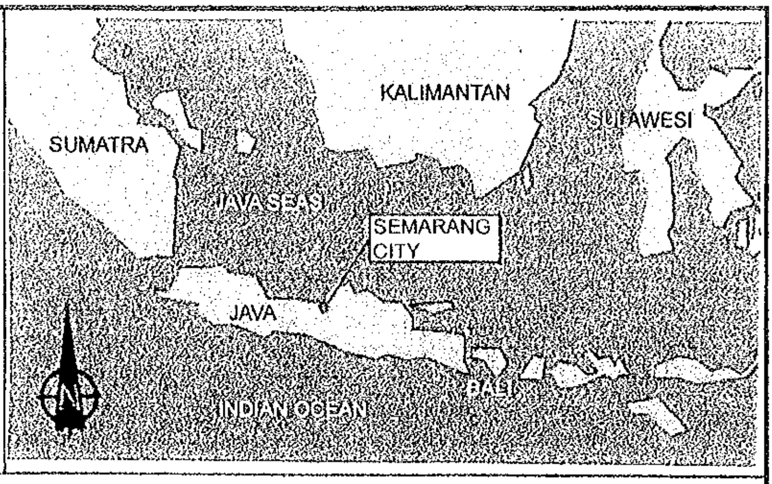
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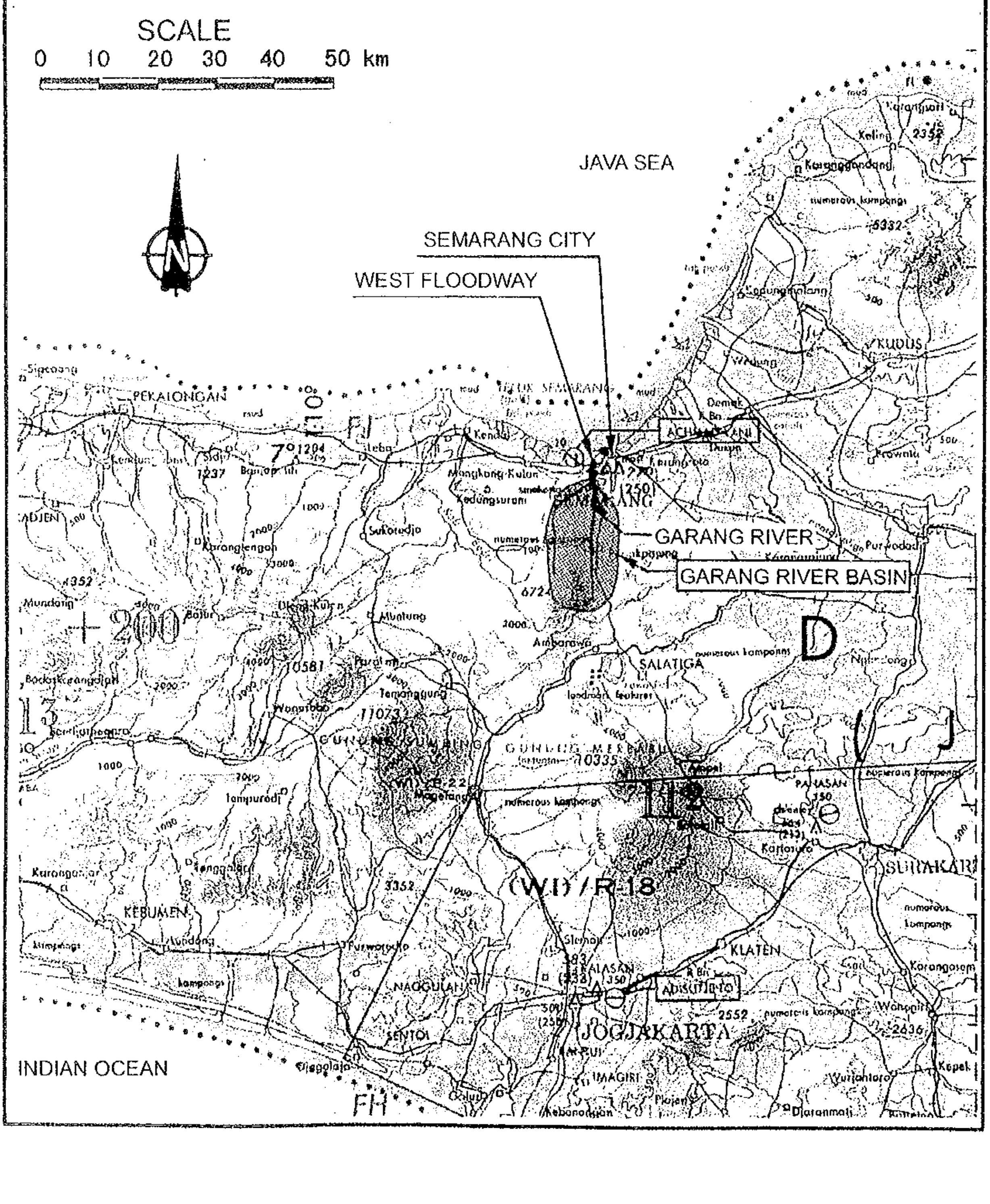
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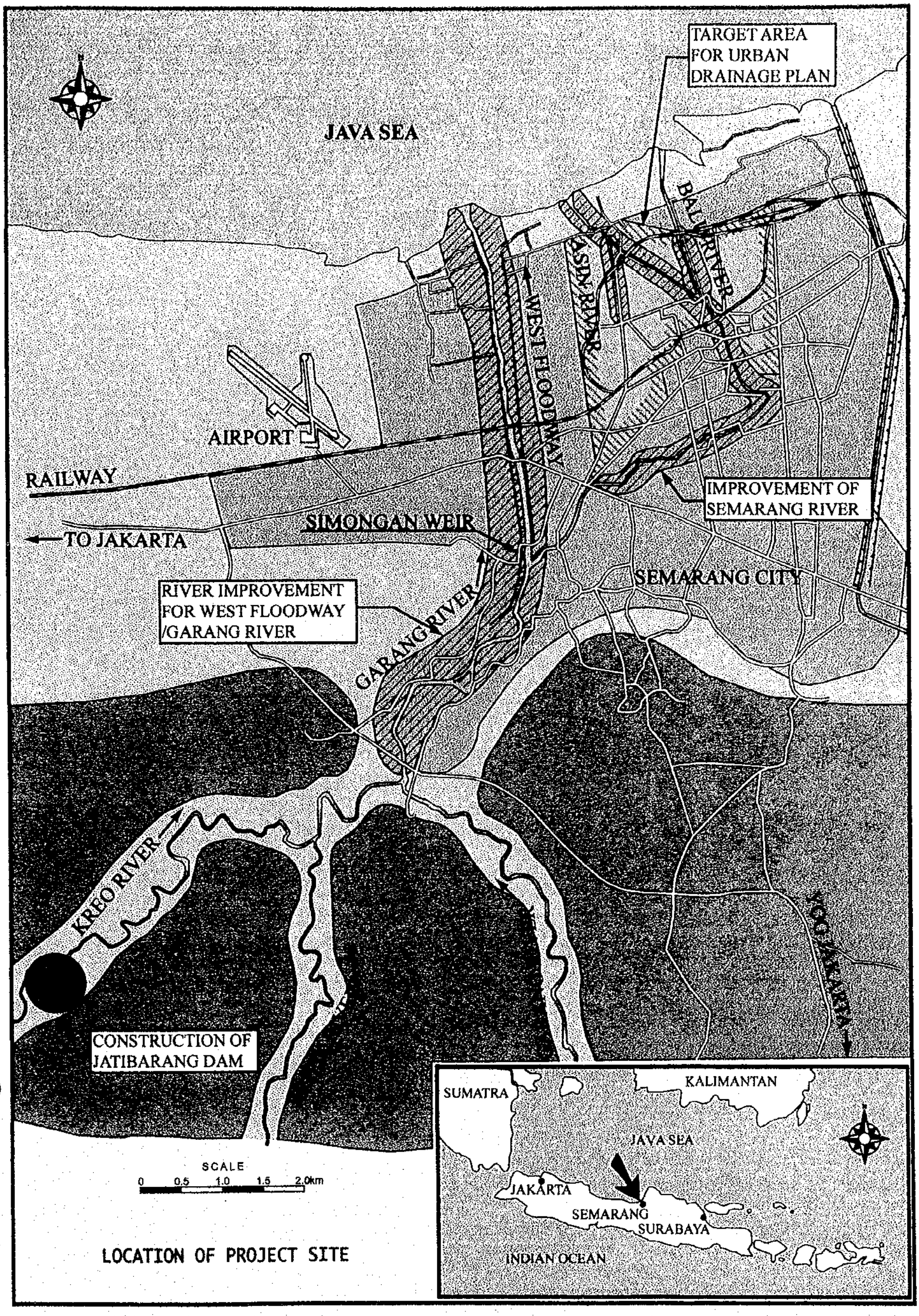

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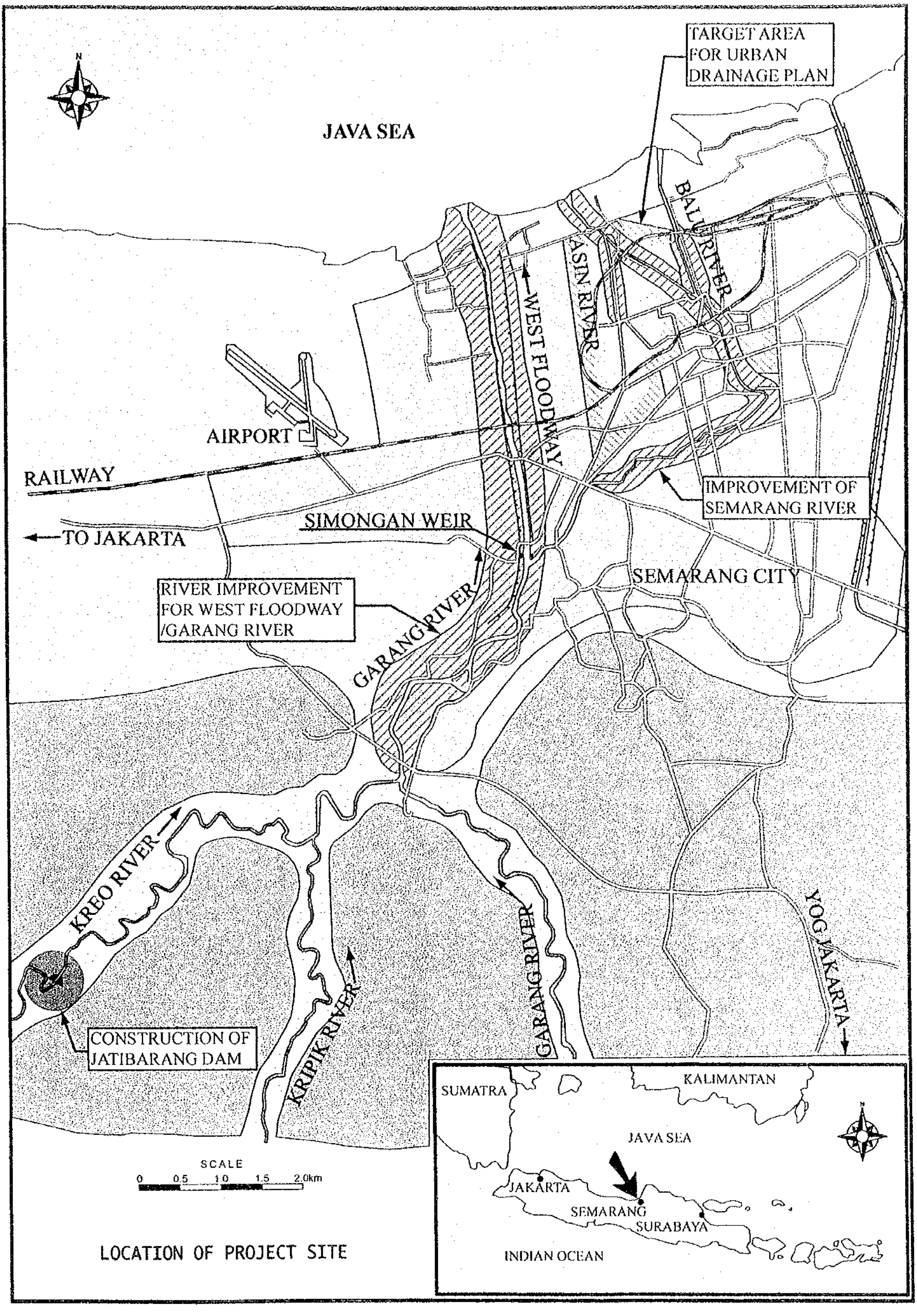

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TERMS AND ABBREVIATIONS

1. INDONESIAN GOVERNMENT AGENCIES AND ORGANIZATIONS

GOI	:	Government of Indonesia
BAPPENAS	:	Badan Perencanaan Pembangunan National (National Development Planning Board)
BAPPEDA	:	Badan Perencanaan Pembangunan Daerah (Provincial Development Planning Board)
BINAMARGA	:	Directorate General of Road and Bridge, Ministry of Public Works
BAPEDAL	:	Badan Pengendalian Dampak Lingkungan (Environmental Impact Assessement Board)
BPN	:	Badan Pertanahan Nasional (National Land Agency)
BPP	:	Balai Penyuluhan Pertanian (Agricultural Extension Center)
DPU	:	Departemen Pekerjaan Umum (Ministry of Public Works)
DGWRD	:	Directorate General of Water Resources Development, Ministry of Public Works
DGCK	:	Directorate General of Cipta Karya (Housing, Building and Urban Development, Ministry of Public Works)
DGRD	:	Directorate General of Research and Development, Ministry of Public Works)
DOR	:	Directorate of Rivers
DPUP	:	Dinas Pekerjaan Umum Propinsi (Provincial Public Works Services)
IHE	:	Institute of Hydraulic Engineering (Bandung)
PJKA	:	Perusahaan Jawatan Kereta Api (Railway Company, Old Name)
PERUMKA	:	Perusahaan Umum Kereta Api (Indonesian Railway Public Corporation, New Name)
PDAM	:	Perusahaan Daerah Air Minum (Water Works Company)
PMG	:	Pusat Meteorologi dan Geofisika (Center of Meteorology and Geographysics)
PLN	:	Perusahaan Listrik Negara (State Electricity Corporation)
P3SA	:	Proyek Pengembangan dan Penyelidikan Sumber-Sumber Air (Water Resources Development and Investigation Project)

2. JAPANESE GOVERNMENT / INTERNATIONAL ORGANIZATIONS

GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
MOC	:	Ministry of Construction, Japan
JEM	:	Japan Electric Machine Industry
ADB	:	Asian Development Bank

IBRD	:	International Bank for Reconstruction and Development (World Bank)
UNDP	:	United Nations Development Program
WMO	:	World Meteorological Organization
ASTM	:	American Society for Testing and Materials
ASME	:	American Society of Mechanical Engineer
USASI	:	United States of America Standards
IEC	:	International Electrotechnical Committee
NEMA	:	National Electrical Manufacturers Association

3. MEASUREMENT UNITS

(Length)

mm	:	millimeter(s)
cm	:	centimeter(s)
m	:	meter(s)
km	:	kilometer(s)

(Weight)

g, gr	:	gram(s)
kg	:	kilogram(s)
t, ton	:	tonnage (s)

(Area)

mm^2	:	square millimeter(s)
cm^2	:	square centimeter(s)
m^2	:	square meter(s)
km^2	:	square kilometer(s)
ha(has)	:	hectare(s)

(Time)

sec., s	:	second(s)
min	:	minute(s)
h (hrs)	:	hour(s)
d (dys)	:	day(s)
y, yr(yrs)	:	year(s)

(Volume)

cm^3	:	cubic centimeter(s)
m^3	:	cubic meter(s)

(Discharge)

l, ltr	:	liter(s)
EL., El.	:	Elevation

(Combined Units)

Speed/Velocity

cm/sec, cm/s	:	centimeter per second
m/sec, m/s	:	meter per second
km/hr, km/h	:	kilometer per hour

Stress

kgf/cm^2	:	kilogram per square centimeter
tf/m^2	:	ton per square meter
N/mm^2	:	newton per square millimeter
Mpa	:	mega pascal

Discharge

ltr/sec, l/s	:	liter per second
m^3/sec, m^3/s	:	cubic meter per second
m^3/yr, m^3/y	:	cubic meter per year

(Note : Other combined units may be constructed similarly as above)

Electricity

MW	:	megawatt	GW	:	gegawatt
MWh	:	megawatt hour	GWh	:	gegawatt hour
kV	:	kilovolt			

4. MONETARY TERMS

¥	:	Japanese Yen
US$	:	United States Dollar
Rp.	:	Indonesian Rupiah

5. INDONESIAN TERMS

JKT	:	Jakarta
Jawa	:	Java
Propinsi	:	Province
Kabupaten, Kab.	:	District (Regency)
Kotamadya, Kodya	:	Municipality
Kecamatan, Kec.	:	Sub-District
Desa	:	Village (Rural Area)
Kampung, Kp.	:	Village (Rural Area)
Kelurahan	:	Village (Urban Area)
Kali, Sungai	:	River
Gunung	:	Mountain
Rawa	:	Swamp
Danau	:	Lake
Laut	:	Sea
PT.	:	Incorporated or Limited
PPT	:	Panitia Pembebasan Tanah (Land Acquisition Committee)
KOMPUS	:	Komisi Pusat (Central Committee for Environmental Impact Assessment)
KA-ANDAL	:	Terms of Reference of Environmental Impact Statement
ANDAL	:	Environmental Impact Statement
RKL	:	Environmental Management Plan

RPL	:	Environmental Monitoring Plan
AMDAL	:	Environmental Impact Assessment
BPPM2	:	Semarang Port Bench Mark
SPB	:	Semarang Peil Baru (New Semarang Level)
TTG	:	Tanda Tinggi Geodesi (National Bench Mark)

6. OTHERS

JRATUNSELUNA PROJECT	:	Water Resources Development Projects for Jragung, Tuntang, Serang, Lusi and Juwana Rivers
SSUDP	:	Semarang and Surakarta Urban Development Program
IUIDP	:	Integrated Urban Infrastructures Development Program
SWL	:	Surcharge Water Level
DFWL	:	Design Flood Water Level
PMP	:	Probable Maximum Precipitation
PMF	:	Probable Maximum Flood
EIRR	:	Economic Internal Rate of Return
JIS	:	Japanese Industrial Standard
USASI	:	United States of America Standards
SWR	:	Shadow Wage Rate
CIF	:	Cost, Insurance and Freight
VAT	:	Value Added Tax.

CHAPTER 1 GENERAL

1.1 Introduction

The Structural Design Criteria are prepared to serve for the detailed design of structures subject to both the river improvement works of West Floodway/Garang River and the urban drainage system improvement in Semarang City. The criteria contain the adopted code/design standards, properties of structural materials to be used, applicable design parameters such as loads, allowable stress of materials, safety factors for stability analysis and structural details which are to be considered in designing.

In designing the objective structures, the Indonesian guidelines and local conditions in Semarang area are considered as much as possible. The minor engineering assumptions and judgment of design which are not mentioned in the criteria, will be considered and decided by each design engineer during the detailed design work.

1.1 Objective Structures

The Design Criteria will be applied to the detailed design of the following structures.

(1) West Floodway/Garang River Improvement

- New Simongan Weir consisting of flood diversion and sediment control gates, intake structures, protection works for river bank and riverbed, maintenance bridge and control/management office buildings,
- Earth dike and floodwall (concrete type and wet masonry type),
- Riparian structures such as revetment, groin and ground sill,
- Raising works for Railway Bridge and their related works,
- Waterfront facilities and
- Drainage outlet works.

(2) Urban Drainage System Improvement

- Pumping facilities consisting of inlet structures, drainage pumps, outlet structures, river bank and riverbed protection works, and operation/control house building,
- Water gate consisting of foundation structure, concrete pier, steel gate, side walls, operation deck and room, and maintenance bridge,
- Various types of revetment,

- Drainage outlets (box culvert and pipe),
- Concrete gravity type dike, and
- Roads and bridges.

1.2 Code and Standards

The design and computation are based on internationally accepted codes, standards as well as conformity with Indonesian codes, standards and practice.

The following codes and standards are principally used in establishing design conditions of each structures.

Indonesian Standards

- Standar Industi Indonesia (SII), 1986 (Indonesian Industrial Standard)
- Peraturan Beton Bertulang Indonesia PBBI 71-Ni-2, 1971 (Indonesian Guideline for Reinforced Concrete)
- Pembaebanan Rencana Rumah dan Gedung, SNI-1727-1989F (Building Design Load Code)
- Pedoman Perencanaan Pembebanan Jalam dan Jembatan, 1989 (Guideline for Highway and Bridge Design Loads, SNI-1725-1989)
- Peraturan Perencanaan Bangunan Baja Indonesa, 1984 (Indonesian Steel Structures Code)
- Peraturan Bangunan Nasional dan Pelengkap (Regulation of National Building and Finishes 1978)
- Pedoman Perencanaan Ketahanan Gempa Untuk Rumah dan Gedung (Guideline for Earthquake Resistant Building Design, SNI-1726-1989)
- Pedoman Perencanaan Tahan Gempa Untuk Jembatan Jalan Raya, 1986 (Guideline for Earthquake Resistant Highway Bridge Design)
- Flood Control Manual, Ministry of Public Works, Government of Indonesia.
- Standar Perencanaan Irigasi, Departemen Pekerjaan Umum, 1986 (Design Standards of Irrigation, Ministry of Public Works, Government of Indonesia).
- Peraturan Perencanaan Teknik Jembatan May 1992 BINAMARGA (BMS) (Bridge Design Code)
- Design Manual, December 1992 BINAMARGA

In addition, the following standards/specifications are used to supplement the design codes/standards mentioned above.

Japanese Standards

- Technical Standards for River and Sabo Works, River Association of Japan.
- Specifications for Design and Construction of Road Bridge, Japan Road Association.
- Design Specifications for River Gate, River Association of Japan.
- Specifications for Highway Bridges, Part-I Common Specifications, Part-II Concrete Bridges, Part-IV Substructures, Highway Association of Japan
- Japanese Industrial Standard (JIS), Japanese Standards Association.

CHAPTER 2 HYDRAULIC DESIGN CRITERIA

2.1 Calculation of Water Level of River Channel

(1) Uniform Flow Calculation

In principle, the design high water level profile is set based on the uniform flow calculation. This method is commonly applied for the river stretch of which water level is not affected by tide. As a uniform flow calculation method, the following Manning's Formula is used.

$$Q = \frac{1}{n} \times I^{1/2} \times R^{2/3} \times A$$

where;

Q : design discharge (m^3/s)
n : Manning's roughness coefficient
I : gradient of river bed
R : hydraulic radius (m)
A : flow area (m^2)

(2) Non Uniform Flow Calculation

For the river channel where water level is influenced by the downstream water level, non-uniform flow method is employed to compute the water surface profile. The calculation equation is presented as follows:

$$\{H_2 + \frac{D_2}{2g}\left(\frac{Q_2}{A_2}\right)^2\} - \{H_1 + \frac{D_1}{2g}\left(\frac{Q_1}{A_1}\right)^2\} = h_e$$

$$h_e = \frac{1}{2}\{\frac{N_1^2}{A_1^2}\frac{Q_1^2}{R_1^{4/3}} + \frac{N_2^2}{A_2^2}\frac{Q_2^2}{R_2^{4/3}}\} \times \Delta X$$

Using Iida's Formula, coefficients; D,N and R are expressed below.

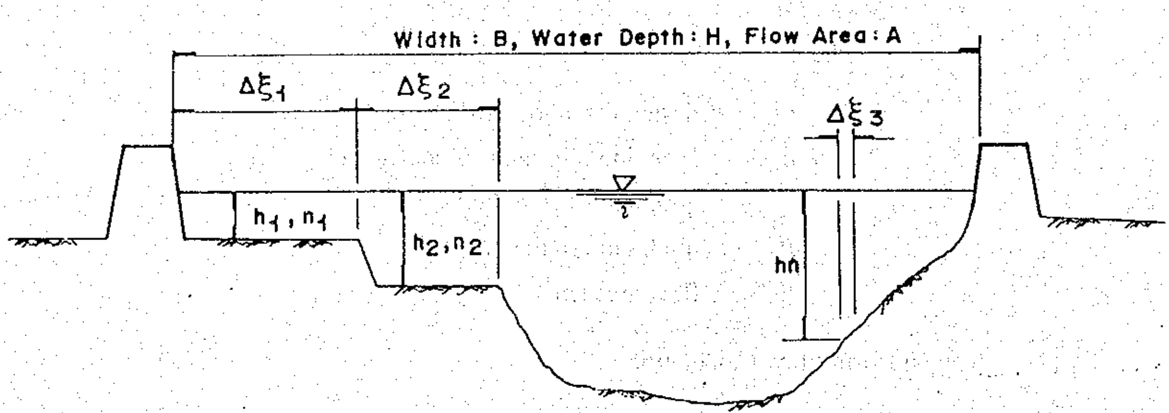
$$D = \alpha \cdot \frac{A^2 \int_0^B \frac{h^3}{n^3} d\xi}{\left(\int_0^B \frac{h^{5/3}}{n} d\xi\right)^3}, \quad N = \frac{\int_0^B h^{5/3} d\xi}{\int_0^B \frac{h^{5/3}}{n} d\xi}, \quad R = \left(\frac{1}{A}\int_0^B h^{5/3}\right)^{3/2}$$

where,

H : elevation of water level (m)
h_e : difference in water level between two sections
g : acceleration of gravity (9.8 m/s^2)

Q : discharge (m^3/s)
A : flow area (m^2)
ΔX : distance between two cross sections (m)
D : coefficient for correction
N : equivalent roughness coefficient for the whole cross sections
R : equivalent hydraulic depth for the whole cross sections
n : Manning's roughness coefficient for each cross section
α : energy coefficient (1.0)
B : river width subject to computation.

Suffix denotes the number of cross sections from downstream to upstream.



CHANNEL CROSS SECTION

(3) Rise in Water Level Due to Bridge Pier

Bridge pier can be an obstruction in the flow of river channel. Due to this, water level in the upstream channel of bridge pier will be raised. The amount of rise in water stage is estimated by the following D'Aubuisson's formula.

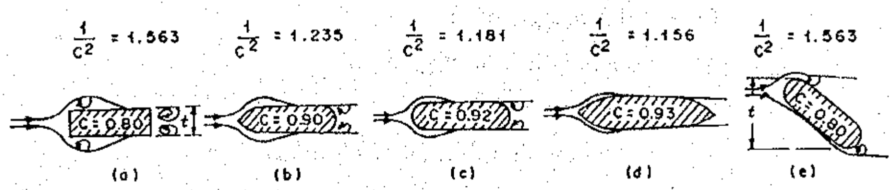
$$\Delta h = \frac{Q^2}{2 \cdot g}\left\{\frac{1}{C^2 \cdot b_2{}^2 \cdot (H_1 - \Delta h)^2} - \frac{1}{b_1{}^2 \cdot H_1{}^2}\right\}$$

where,

Δh : amount of water rise due to bridge pier (m)
Q : discharge (m^3/s)
C : coefficient determined by the cross sectional shape of pier
b_1 : width of channel in the upstream of pier (m)
b_2 : $b_2 = b_1 - \Sigma t$

t : width of one pier (m)
H_l : water depth of channel in the upstream of pier

Coefficient C is given as shown in the following figures, depending on the cross sectional shape of pier.



2.2 Discharge Calculation

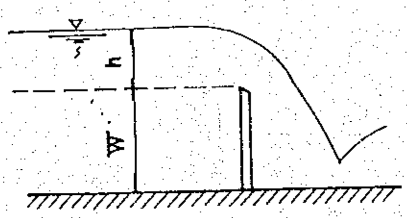
(1) Discharge Over Steel Roller Gate

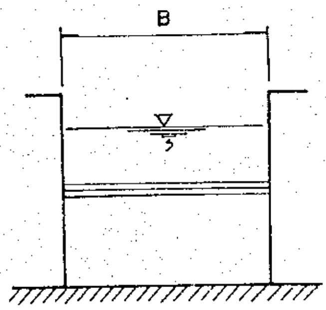
Discharge flowing over the steel roller gate is estimated by assuming that the shape of steel roller gate is equivalent to a sharp crested weir, and the formula shown below is used.

$$Q = C \cdot B \cdot H^{3/2}$$

Where,

Q : discharge (m^3/s)
C : discharge coefficient of sharp-crested weir (C=1.8～2.0)
B : effective width of gate (m)
H : overflow depth (m)





(2) Discharge Below Vertical Slide/Roller Gate

Discharge flowing under a steel slide/roller gate is estimated based on the following formulas.

$$Q = a \cdot b \cdot C \cdot \sqrt{2 \cdot g \cdot h1}$$

where,

- Q : discharge (m^3/s)
- a : opening height of gate (m)
- b : width of gate (m)
- g : acceleration of gravity (9.8 m/s^2)
- h1 : water depth in front of the gate (m)
- C : discharge coefficient obtained as shown below:

When flow under the gate is free efflux, C is given as follows:

$$C = C_c \cdot \sqrt{\left(1 - C_c \frac{a}{h1}\right) \div \left\{1 - \left(C_c \frac{a}{h1}\right)^2\right\}}$$

where, C_c : shrinkage factor (0.6)

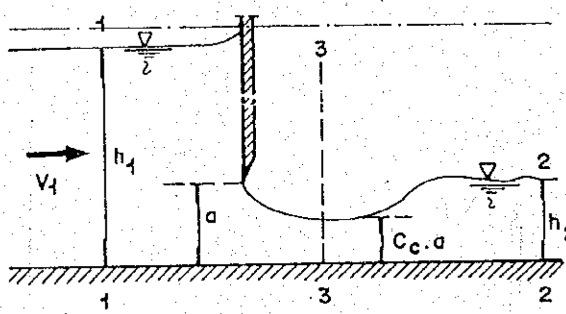
When submerged flow occurs, the following equations are used.

$$F(c) = A \cdot C^4 + B \cdot C^2 + D = 0$$

Where,

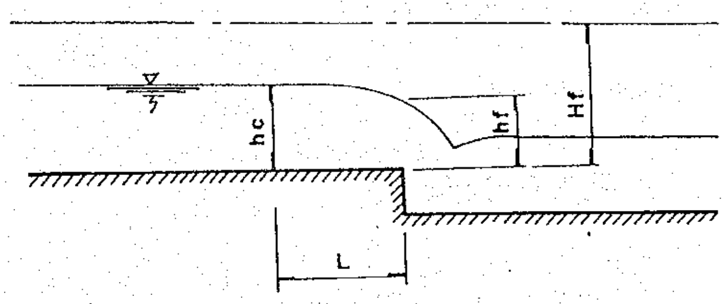
$$A = \left(\frac{a}{h1} - \frac{1}{C_c^2} \cdot \frac{h1}{a}\right)^2 \quad , \quad B = 2 \cdot \left(\frac{a}{h1} - \frac{1}{C_c^2} \cdot \frac{h1}{a}\right) \cdot \frac{h1}{a} - 4 \cdot \left(\frac{h1}{h2} - \frac{h1}{C_c \cdot a}\right)$$

$$D = \left(\frac{h1}{a}\right)^2 - \left(\frac{h2}{a}\right)^2$$



(3) Flow on Riverbed in the Step Form

When the lower end portion of river channel forms step like the following figure, the river flow changes its flow pattern from tranquil flow to critical flow and the step portion will play a role of weir. The discharge at this portion can be estimated by the following formula.

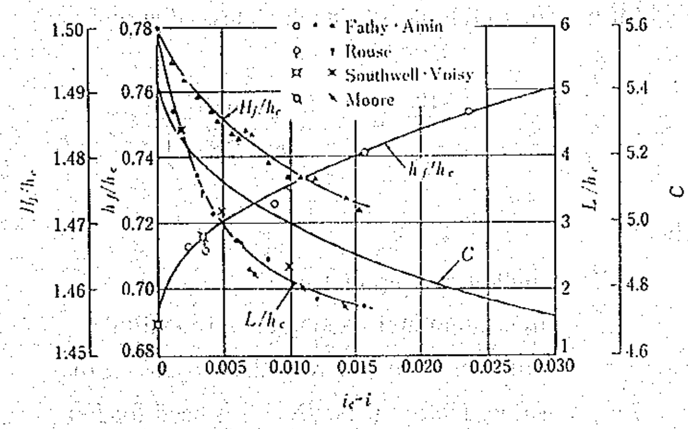


$$Q = C \cdot B \cdot h_f^{3/2}, \qquad C = \sqrt{g} \cdot (h_c / h_f)^{3/2}$$

where,

- Q : overflow volume (m^3/s)
- C : discharge coefficient ($m^{1/2}/s$)
- B : width of channel (m)
- h_c : critical depth (m)
- h_f : water depth at the step (m)
- L : distance between the step and point of critical depth (m)
- H_f : energy head at the step portion (m)

Figure below shows the relation among C, h_f / h_c, H_f / h_f, L / h_c.



2.3 Hydraulic Design of Weir and Ground Sill

(1) Length of Apron

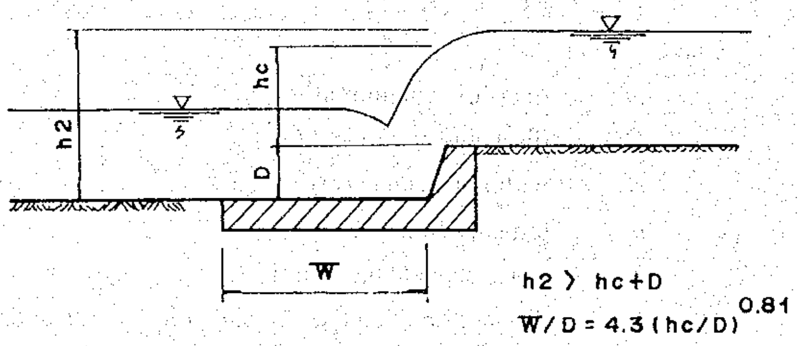
Riverbeds of the immediate upstream and downstream of hydraulic drop structure are subject to the direct impact of water and flowing stones. Therefore, those riverbeds shall be well protected by concrete aprons. The length of concrete apron is estimated by applying the following formula.

(RAND's formula)

$$W / D = 4.3 \cdot (h_c / D)^{0.81}$$

where,

W : length of apron (m)
D : difference in elevation (m)
h_c : critical depth (m)



(2) Thickness of Apron

Apron shall have enough thickness so that the stability against uplift can be fulfilled. The following formula is used to decide the thickness of apron.

$$t = Fs \cdot \frac{U_{pm} - h_2 \cdot W_0}{r_c - 1} \left\{ = Fs \cdot \frac{U_{pm} - h \cdot W_o}{r_c - 9.8} \right\}$$

where,

t : thickness of apron (m)
U_{pm} : maximum uplift acting on apron (tf/m^2)
r_c : unit weight of concrete (2.35 to 2.45 tf/m^3)
Fs : safety factor (generally 4/3 is used for Fs)

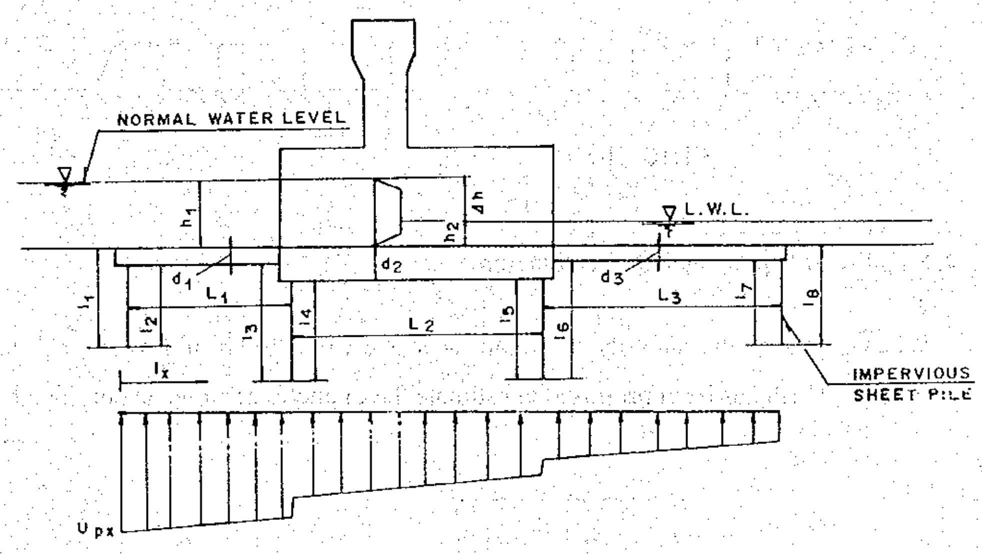
(3) Uplift Acting on Weir

When impervious sheet piles are driven into the pervious layer, uplift acting on the weir is calculated with the formula below.

$$U_{px} = (h_2 + \Delta h \cdot \frac{\sum l - l_x}{\sum l} + dl) \cdot W_0$$

where,

- U_{px} : uplift at any point on floor slab (tf/m^2)
- Δh : difference in water level (h_2-h_1) (m)
- lx : length of path of percolation from uppermost end (m)
- Σl : total length of path of percolation (m)
- W_0 : unit weight of water (tf/m^3)
- d : thickness of floor slab at any point (m)



2.4 Flowing Force and Riverbed Protection

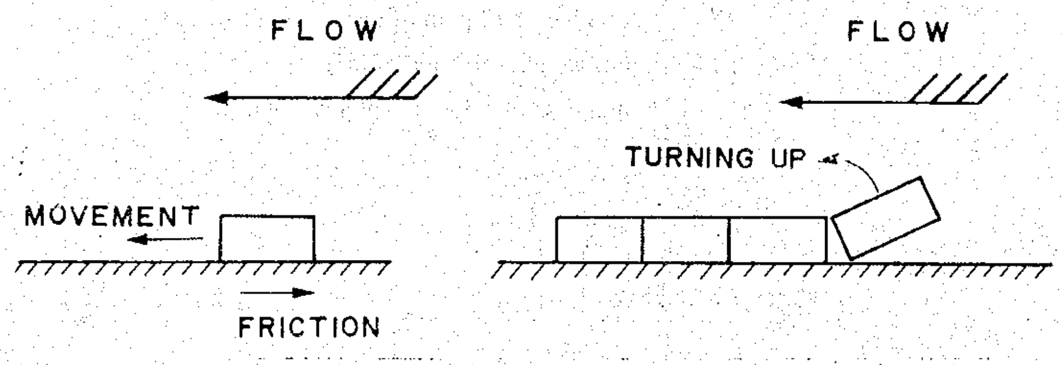
(1) Stability of Riverbed Protection against Flowing Force

Foot/riverbed protections are destroyed, if the acting flowing force exceeds the resisting force of protection works such as concrete block and gabion. The major patterns of destruction are sliding and over turning of blocks. To stabilize the foot/riverbed protection, finding the proper shape, weight and arrangement of blocks are important. The following formula is proposed to decide the shape and weight of concrete blocks.

$$W > \alpha \cdot \left(\frac{\rho_w}{\rho_b - \rho_w} \right)^3 \cdot \frac{\rho_b}{g^2} \cdot \left(\frac{V_d}{\beta} \right)^6$$

where,

W	: weight of concrete block (tf/m^3)
ρ_w	: density of water (1.0 t/m^3)
ρ_b	: density of concrete block (t/m^3)
V_d	: typical velocity of flow (m/s)
g	: acceleration of gravity (9.8 m/s^2)
α, β	: coefficient of concrete block (α=0.45～1.2, β=1.4～2.8)



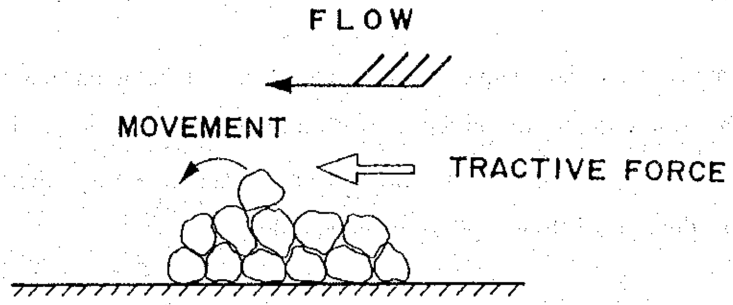
(2) Stability of Riprap against Tractive Force

When assessing the stability of riprap against tractive force of flow, the following formula which has been proposed to estimate the diameter of stone, is employed.

$$D_m = \frac{1}{E_1^2 \cdot 2 \cdot g \cdot \left[\frac{\rho_s}{\rho_w} - 1 \right]} \cdot V_0^2$$

where,

D_m	: average diameter of stone (m)
E_1	: coefficient of strength of flow disturbance (0.86～1.2)
ρ_s	: density of stone (t/m^3)
ρ_w	: density of water (1.0 t/m^3)
V_d	: typical velocity of flow (m/s)
g	: acceleration of gravity (9.8 m/s^2)



2.5 Conditions of Hydraulic Calculation

(1) Roughness Coefficient

For the uniform and non-uniform flow calculation, the following Manning's roughness coefficient are used based on the recommended figures in "Flood Control Manual".

Low Water Channel (excavated)	0.030
Low Water Channel (existing)	0.033
Flood Plain (excavated) *1	0.035
Flood Plain (existing)	0.040
Channel with Lining (narrow channel)	0.025

*1 The flood plain here is referred to the bottom portion of high water channel.

(2) Design Tidal Level at River Mouth

The design tidal levels at the river mouth are determined based on the tidal data observed at Semarang Harbor. Since the tidal data observed in the past have been affected by land subsidence in the low lying area, the most recent data of April 1997 to August 1997, which are considered less affected, are used for the tidal analysis.

Kind of Water Level	Elevation (TTG)
Highest High Water Level (HHWL)	EL. +0.45 m
Mean High Water Level (MHWL)	EL. +0.25 m
Mean Sea Level (MSL)	EL. -0.23 m
Mean Low Water Level (MLWL)	EL. -0..70 m
Lowest Low Water Level (LLWL)	EL. -0..90 m

For the non-uniform flow calculation in the event of flooding, the mean high water level of EL. +0.250 m is used as the starting water level at the river mouth.

(2) Super Critical Flow

Super critical flow arises at the channel of Simongan Weir, when the gates are totally opened. And the water depth of this flow will influence the water level of the upstream channel. So, assuming that the channel cross section is equivalent to the trapezoidal shape, the critical flow depth is given as follow.

$$h_c = \left(\frac{\alpha \cdot Q^2}{g} \right) \cdot \frac{(b + 2 \cdot m \cdot h_c)^{1/3}}{(b + m \cdot h_c)}$$

where,

h_c	: depth of super critical flow (m)
Q	: discharge (m^3/s)
α	: energy coefficient (=1.0)
b	: width of riverbed (m)
m	: side slope
g	: acceleration of gravity (9.8 m/s^2)