3.0 STORM DRAINAGE

3.1 GENERAL

Good drainage is vital to flat urban areas such as Lulu Island. It is essential that every storm sewer must be designed accurately minimizing conflicts with present and future drainage patterns and utilities.

Essentially, Lulu Island is dyked against floods from the river and storm surges. The primary conveyance systems are open canals or box culverts. Pump stations are generally located at the extremity of the north-south gravity conveyance canals.

Stormwater management is the planning, analysis and control of stormwater runoff in consideration of the opportunities and constraints that both the engineered and natural drainage systems have to offer. The objective is to maximize the practical level of service to development, while minimizing the risk to properties and public safety. The design of the stormwater management system shall incorporate techniques such as adequate conveyance capacities, appropriate lot drainage and other stormwater best management practises to mitigate the runoff impacts due to changes in land use.

A Stormwater Management Plan and Sediment Control Plan are required for all proposed developments within the City of Richmond.

3.1.1 Stormwater Management Plan

The stormwater management plan involves the planning and design required to alleviate the hydrological impacts of land development and/or land use changes. A Stormwater Management Plan describes the details of how drainage servicing will be provided to the proposed development, indicate how the development will impact existing drainage infrastructure downstream, and show how the proposed drainage system meets the City's design criteria set out herein.

A Stormwater Management Plan must be provided by all developments unless otherwise specified at the discretion of the General Manager.

The Plan must be provided in drawing format, as part of the engineering drawing submission, in accordance with the City's submission criteria. Where it is not practical to show all required background and analytical information on the drawing, the Plan may be accompanied by a written report.

The Stormwater Management Plan must include the following information:

- Drainage Catchment areas including existing and ultimate land uses
- The development area within the drainage catchment including all features such as roads, ditches, drainage control structures, storm sewers, culverts, and drainage facilities
- Hydrologic and hydraulic calculations summarized in table form and supporting parameters
- Flow routing
- Proposed minimum building elevations (MBE) and 10-year Hydraulic Grade line (HGL)
- Construction of sediment control plan
- Existing + Instream Applications + Proposed Development and OCP (Ultimate Development) flows and system capacities

3.1.2 Design Frequency

The drainage system comprises of storm sewers, culverts, channels and pump stations designed to collect and carry the peak runoff from storm events up to and including the 1:10 year return frequency.

The drainage system shall be designed to prevent flooding, property damage and minimize public inconvenience caused by the frequent storm events up to the return frequency.

3.1.3 Sediment Control and Sediment Control Plan

The proposed drainage system must be designed in such a way as to provide adequate control of sediments. This includes incorporating sediment catches at regular intervals along the primary box culvert, inspection chambers, catch basins and manholes for the purpose of sediment control. For manhole sump requirements refer to Section 3.14.

During the construction phases of the culvert system, temporary sediment catches must be constructed upstream of all discharge points into the City drainage system.

For all new developments a Sediment Control Plan must be submitted. The Sediment Control Plan should include the following information:

- Vicinity map showing location of site in relation to the surrounding area
- Site plan details. This should include existing vegetation, existing and proposed ground contours, existing and proposed drainage patterns, limits of clearing and grading, limits of cut and fill and locations of sediment control best management practices

- Identification of erosion and sediment control best management practices should include consideration for:
  a. Cover Practices – the first line of defence is to prevent erosion. Examples include limiting the impact of development through the use of such measures as buffer vegetation strips.
  b. Structural Practices – this includes sediment catches in the storm sewer system and where necessary other features such as sediment ponds and inlet protection measures.
  c. Construction Management Measures – good construction management is as important as physical practices for erosion and sediment control. Examples include staging construction activities to minimize exposed areas, gravel access pads to construction sites, construction vehicle wash facilities, vegetation strips, silt fences, covering of stockpiles, catch basin protection and cleaning of all storm sewer facilities before connection.

3.2 RUNOFF ANALYSIS

Storm drainage systems shall be designed to accommodate the post-development flows using the Rational Method or the Runoff Hydrograph Method.

<u>Rational Method</u>

- For developments where the total is 10 hectares or less

<u>Runoff Hydrograph Method</u>

- For developments where the total drainage catchment is greater than 10 hectares
- For the design of all storage facilities

<u>Catchment Area</u>

The catchment boundary shall be determined based on the following:

- The actual contours of the land and natural drainage flow patterns. The Consultant is responsible for obtaining true and accurate surface and invert elevations for the analysis, which may entail survey pickup.
- Existing drainage network and pump station locations
- Overall drainage plan established by the City through any Master Drainage Plans (MDP) or other area servicing plans established for the catchment in which the subject property is located

Minor changes in the catchment boundaries may be accepted, if approved by the General Manger. The Consultant is responsible for obtaining approval for the drainage catchment boundaries from the General Manager prior to the final design.

3.3 RATIONAL METHOD

The Rational Method calculates the peak flow using the formula:

$Q = RAIN$ Where: Q = Flow in m^3/s
R = Runoff Coefficient
A = drainage area in ha
I = Rainfall intensity in mm/hr
$N = 0.00278$

3.3.1 Runoff Coefficients

The runoff coefficients shall be based on the zoned land use defined in the adopted Zoning Bylaw of the City of Richmond. Future land use designations shall be defined by the City's Official Community Plan (OCP).

Table 3.1 Runoff Coefficients

Land Use Type	Coefficient (1:10 year)
Agricultural (cultivated)	0.10-0.25
Single Family Residential	0.70
Multi Family Residential	0.75
Commercial	0.90
Industrial	0.90
Institutional	0.80
Parks/Grasslands	0.25
Roofs or Pavement	0.95

3.3.2 Time of Concentration

The time of concentration is the time required for water to flow from the most remote point of the catchment area to the design node. For both urban and rural areas, the time of concentration consists of the following formula:

$T_c = T_i + T_t$

Where: T_c = time of concentration in minutes
T_i = inlet or overland flow time in minutes
T_t = travel time in conveyance channels in minutes

Inlet or Overland Flow Time (T_i)

a) Listed below are the minimum inlet times for urban areas:

Table 3.2 Minimum Inlet Times

Sub- Catchment Area (m^2)	Inlet time (Min)
< 2000	10
2000 - 4000	15

b) The inlet time for larger or rural areas shall be calculated using the following method:

$$T_i = \frac{3.26(1.1 - C)\, L^{0.5}}{S^{0.33}}$$

Where: T_i = inlet time in minutes,
C = runoff coefficient
L = travel distance in m,
maximum length = 300 m
S = slope of travel path (%)

Travel Time (T_t)

The travel time in conveyance channels can be estimated using the Modified Manning formula:

$$T_t = \frac{Ln}{60R^{0.667}S^{0.5}}$$

Where: T_t = travel time in minutes
L = Length of conveyance channel in m
n = Manning roughness
0.060 Natural channels
0.040 Excavated ditches
0.015 Concrete pipe
0.013 PVC pipe
R = Hydraulic radius (area/wetted perimeter) in m
S = slope in m/m

3.3.3 Rainfall Intensity

The rainfall intensity for the Rational Method formula shall be determined from a rainfall Intensity-Duration-Frequency (IDF) curve based on the calculated time of concentration.

Rainfall IDF curves (Figure 3.1 on page 3-16) were developed from the Vancouver Airport weather station and are to be applied in the City of Richmond.

3.3.4 Presentation of Rational Calculations

The Consultant will be required to tabulate the rational calculations on the "Storm Sewer Design- Rational Method" table (Table 3.3 on page 3-17) for submission along with the appropriate plans and other relevant information.

3.4 RUNOFF HYDROGRAPH METHOD

3.4.1 Selection of Modeling Program

For basins larger than 10 hectares, hydrologic programs shall be used for runoff analyses. Hydrologic programs shall also be used for the design of all stormwater detention facilities. Standard runoff simulations shall be modelled with a hydrodynamic modelling software such as DHI MOUSE. Other programs may be considered, if approved by the General Manager.

3.4.2 Catchment Parameters

The catchment parameters must reflect the existing land use, the type of soils, ground cover and typical antecedent moisture condition for the winter. Future land use designations shall be defined by the City's Official Community Plan.

Where information is not available, use the impervious fractions shown in Table 3.4 for analysis. In areas of existing development or where more detailed information is available, the Consultant shall verify that the values shown are representative of the true conditions.

Table 3.4 Common Impervious Fractions

Land Use	Total Impervious
Parks & Agricultural	0.25
Single Family Residential	0.80
Multi-Family Residential	0.85
Commercial	0.95
Industrial	0.95
Institutional	1.0

3.4.3 Storm Events

In order to determine the governing storm event, hydrographs must be generated at key locations of the drainage system for:

- 2-hour design storms (Figure 3.2 on page 3-18)
- 24-hour design storms (Figure 3.3 on page 3-19)

3.4.4 Presentation of Modeling Results

To document the design rationale used to develop the hydrologic model and to standardize the presentation of model results, the design reports shall include appropriate sections, which will indicate the following:

- Type and version of computer model used
- All parameters and specific simulation assumptions used
- Design storms used, to be clearly documented and plotted
- Peak flows and total runoff volumes
- Summary of peak flows and inflow/outflow hydrographs of storage facilities

The report documentation should include:

- A plan showing sub-catchment areas, catchment boundaries and the drainage system
- A plan identifying the specific land uses modeled for each development condition analysed
- The function layout and sizing of any flow control/diversion structure and the tabular/graphical plots of inflow and outflow hydrographs
- Tables summarizing the input and output values

3.5 HYDRAULICS

3.5.1 Pipe and Channel Capacity

The required capacity shall be calculated using the Manning Formula under free flow (non-surcharged) condition. The Manning formula is:

$$Q = \frac{A\ R^{0.667}\ S^{0.5}}{n}$$

Where: Q = flow capacity in m^3/s
A = cross sectional area in m^2
R = Hydraulic radius (area/wetted perimeter) in m
S = slope of hydraulic grade line in m/m
n = Manning roughness coefficient
0.060 Natural channels
0.040 Excavated ditches
0.015 Concrete pipe
0.013 PVC pipe

Alternately, the Consultant may a hydrodynamic modelling software such as DHI MOUSE use DHI MOUSE software to determine pipe or channel capacities. Other programs may be considered, if approved by the General Manger.

The Consultant must consider inlet and outlet control conditions when applicable.

3.5.2 Hydraulic Grade Line (HGL) & Minimum Building Elevation (MBE)

Every effort should be made to avoid surcharge of the existing and/or proposed drainage system. However, if this is unachievable due to site constraints, surcharging maybe allowed with approval of the General Manager. It shall be the Consultant's responsibility to prove no surcharging is unattainable.

The HGL for the governing design event shall be below the lower of a) the existing & future MBE and b) the road surface, as to not to cause flooding within the drainage catchment. The maximum HGL shall be plotted along the drainage system where the HGL surcharges above the crown of the pipe. It shall be the Consultant's responsibility to verify existing MBEs, which may entail survey pickup.

3.6 MINIMUM VELOCITY

The minimum velocity for conduits flowing full or half full shall be 0.60 m/s, where achievable.

Where drainage discharge enters an open channel provisions for energy dissipation shall be provided to prevent scour.

3.7 MINIMUM PIPE SIZES

- Storm Sewers — 600 mm diameter
- Culverts — 600 mm diameter, unless otherwise approved by the General Manager
- Lane drainage — 200 mm diameter

3.8 MINIMUM GRADES

The following minimum grades shall be used for designing of storm sewers.

- Box culvert 0.01%
- Earth canal (ditch) 0.03%
- Storm sewer (mains) 0.05%

It may be necessary to analyse the earth characteristics for ditches to prevent scouring even at minimum grades specified.

The Consultant shall design the drainage system to ensure that the upstream conveyance system can achieve minimum grades.

3.9 LOCATION

The location of the storm sewer main shall be in accordance with the City's standard utility location as shown on the "Typical Cross Section" drawings in Section 7.0. It may be necessary to vary from the standard cross-section because of the existing ditch or underground utilities. Any variation from the standard utility location must have the prior approval of the General Manager.

Where feasible, all new storm lines must interconnect at the high points to provide alternate routing of storm water in case of blockage and for added subsurface storage capacity.

3.10 SEPARATION

The elevations of all existing underground utilities crossing the proposed storm sewer shall be confirmed in the field and shall be shown on the plan and profile.

The minimum requirements for separation of storm sewer (including ditches) from watermain are as follows, unless otherwise indicated by Provincial Health Regulations.

The following separations are from edge to edge unless otherwise specified.

3.10.1 Horizontal Separation

- Private Utilities: 1.0 m
- Roadway lighting base & conduit and traffic communications conduit: 0.3 m
- Sanitary: 1.2 m between sewer pipes & 0.3 m between manholes
- Watermain: refer to Section 5.9.1

3.10.2 Vertical Separation

- Private Utilities: 0.3 m
- Roadway lighting and traffic communications conduit: 0.3 m
- Sanitary: 0.3 m
- Watermain: refer to Section 5.9.2

3.11 MINIMUM DEPTH OF COVER

Storm sewers shall be installed at a reasonable depth to:

- Service properties on both sides of the roadway
- Permit gravity service to all tributary lands
- Clear other underground utilities
- Prevent freezing
- Prevent damage from surface loading - The Consultant shall verify that the pipe material and bedding are suitable for the live and dead loads imposed on the pipe
- Minimum cover shall be 0.9 m unless otherwise approved by the General Manager

The maximum cover is 4.5 m, except under special circumstances and with approval of the General Manager.

3.12 PIPE JOINTS

All joints shall be gasketed and water tight.

3.13 CURVILINEAR SEWERS

Pipes are not to be laid on a curve unless approved by the General Manager.

3.14 MANHOLES

3.14.1 Location

- Every 100 m along a piped system
- Every change in grade
- Every change of pipe size
- Every change in alignment
- Every pipe intersection except for 100 mm - 200 mm service connections, service connections which are less than 1/2 the size of the mainline and catch basin connections, unless otherwise approved by the General Manager
- Every future pipe intersection
- End of every line

3.14.2 Hydraulic Details

When establishing inverts in a manhole, the following relationship should be maintained:

- For a junction of two or more pipes, where the larger pipe involved is 300 mm diameter or less, the spring lines shall be coincident
- For junction of two or more pipes, where at least one of the pipes is 375 mm diameter or more, the crowns shall be coincident provided that there is sufficient cover at the ultimate terminal

In built up areas where there is not sufficient cover available at the ultimate terminal, the design may be invert to invert with the hydraulic grade line shown on the profile.

3.14.3 Other Requirements

- A manhole may not be required, if approved by the General Manager, immediately at a tie-in point to a large diameter sewer or box culvert if there is an existing manhole on the large diameter sewer or box culvert within 50 m of the tie-in point. In this case a sump manhole may instead be placed on the proposed storm sewer main immediately upstream of the tie-in point.
- Generally manholes should be located outside the wheel path on the roadway
- Where ditches discharge into a storm sewer system, the initial manhole shall be of a sump type. All non-sump manholes shall be channelled and benched. A detail drawing shall be provided for manholes of special design.
- The last manhole before the storm outlet or connection into an existing or proposed box culvert shall have a 600 mm sediment sump
- Sump manholes are required at every second manhole on a straight run, every change in pipe direction and at all intersecting mainline sewers

3.15 CATCH BASINS (C.B.)

The maximum spacing shall be established to permit each C.B. to drain a maximum area of:

- 700 m^2 on road grades up to 1%
- 500 m^2 on road grades between 1% - 3%
- 350 m^2 on road grades greater than 3%

Catch basins are to be spaced to:

- Avoid interference with crosswalks
- Prevent overflows to driveways, sidewalk, boulevards and private properties
- Avoid low points within curb returns at intersections
- Upstream end of radius at intersections
- Low points (sags)
- Every 100 m (maximum) along roadways

The Consultant must ensure that sufficient inlet capacity is provided to adequately collect the runoff.

Generally 600 mm diameter reinforced concrete catch basins shall be used for roadway drainage except when installation is restricted by depth. Then special prefabricated pan catch basins shall be used.

Leads shall be 150 mm in diameter (minimum) and be 30 m in length (maximum).

<u>Double Catch Basins</u>

- Where maximum spacing is maintained and the maximum catch basin drainage area has been exceeded
- To be provided at all low points in road grade where the water will flood across private property
- Leads shall be 200 mm in diameter (minimum)
- Shall discharge into manholes, where possible
- Shall not be connected directly together but rather one basin will be wyed into the lead of the other

3.16 SERVICE CONNECTION/INSPECTION CHAMBERS

Every lot (existing or newly created) capable of being serviced, whether it is vacant or not, must be serviced by one connection, including an appropriate type of inspection chamber. Additional service connections and inspection chambers may be allowed with the approval of the General Manager.

Unless otherwise approved, connections are to serve gravity flow from the property.

3.16.1 Service Connections

Minimum Size & Grade

- 100 mm diameter for single family
- 150 mm diameter for all other uses, unless otherwise approved by the General Manager
- 0.5% from property line to main

Depth

- The elevation of the connection at the property line is to be above the existing and future HGL of the discharge point
- Tie-ins should be as high as possible, at or above spring line are preferable. If tying into a box culvert, and a spring line connection is not feasible, the tie-in invert should not be lower than 450 mm above invert of the box culvert to avoid blockage due to sediment accumulation at the bottom of the box culvert

Other Requirements

- Service connections are to be installed perpendicular to the main
- Service connections may be tied into manholes, if:
  - The connection is not oriented against the flow in the main
  - The manhole hydraulic requirements are achieved

3.16.2 Inspection Chambers (I.C.)

Type

- Type IA or Type II Inspection Chamber:
  - For all existing single family properties with or without drain tiles
  - For all new single family properties

- Type III Inspection Chamber:
  - For industrial, commercial and multi family residential properties
  - Or for properties of sufficient size which will require a larger connection

Manholes are required on service connections greater than 300 mm in diameter.

<u>Location & Depth</u>

- I.C.s must be situated on City property immediately downstream of the property line
- For existing houses, the homeowner may be consulted regarding the location of the I.C. prior to the installation. Chainage of the I.C. shall be shown on the plan
- Invert elevation of the I.C. shall be calculated so that the furthest point on the lot must be capable of being drained
- Offset of I.C., are required on the drawing if different from the Standard Detail Drawings

<u>Other Requirements</u>

- I.C.s should not be connected to a standard catch basin or catch basin lead
- Maximum distance between I.C.s, used for boulevard drainage, should not exceed 20 m, unless under special circumstances with approval of the General Manager
- Single connection shall be installed where I.C.s are located along the frontage of one property
- Double connection shall be installed where I.C.s are located on a lot line between two properties
- Drawings are to specify whether the Type II and Type III I.C.s are c/w frame & grate or frame & solid cover
- The minimum lead size is 150 mm in diameter. If the lead size is different from the Standard Detail Drawings, it shall be clearly marked on the drawing

3.17 LANE DRAINAGE

The lane drainage system shall be designed to convey lane runoff only. Service connections are not permitted to connect to lane drainage systems. The ultimate lane catchment areas should be used to calculate design flows and shall be shown on the drawings as well. The system hydraulic conditions should be checked to ensure that HGL would not cause flooding in the system.

3.18 INLET AND OUTLET STRUCTURE

Outlets for culverts and storm sewers, having discharge velocities greater than 1.0 m/s require riprap or an approved energy dissipating structure to control erosion.

A trash screen/safety grillage is required at the entrance to every permanent storm sewer.

3.19 RUNOFF QUALITY CONTROL TREATMENT FACILITIES

Runoff quality treatment should be taken into consideration. Treatment faculties may be included in the drainage system where necessary. Quality treatment facilities include, but are not limited to the following:

- Oil/grit separators
- Silt traps
- Retention storage facilities
- Grassed swales
- Constructed wetlands

Guidelines and specific requirements for runoff quality treatment faculties must meet current federal, provincial and regional regulations. The Consultant is responsible for obtaining approval from the General Manger prior to design.

FIGURE 3.1 SHORT DURATION RAINFALL INTENSITY-DURATION-FREQUENCY (IDF) CURVES
(Source: Atmospheric Environment Service - Environment Canada; Vancouver International Airport, 1961 to 1998)

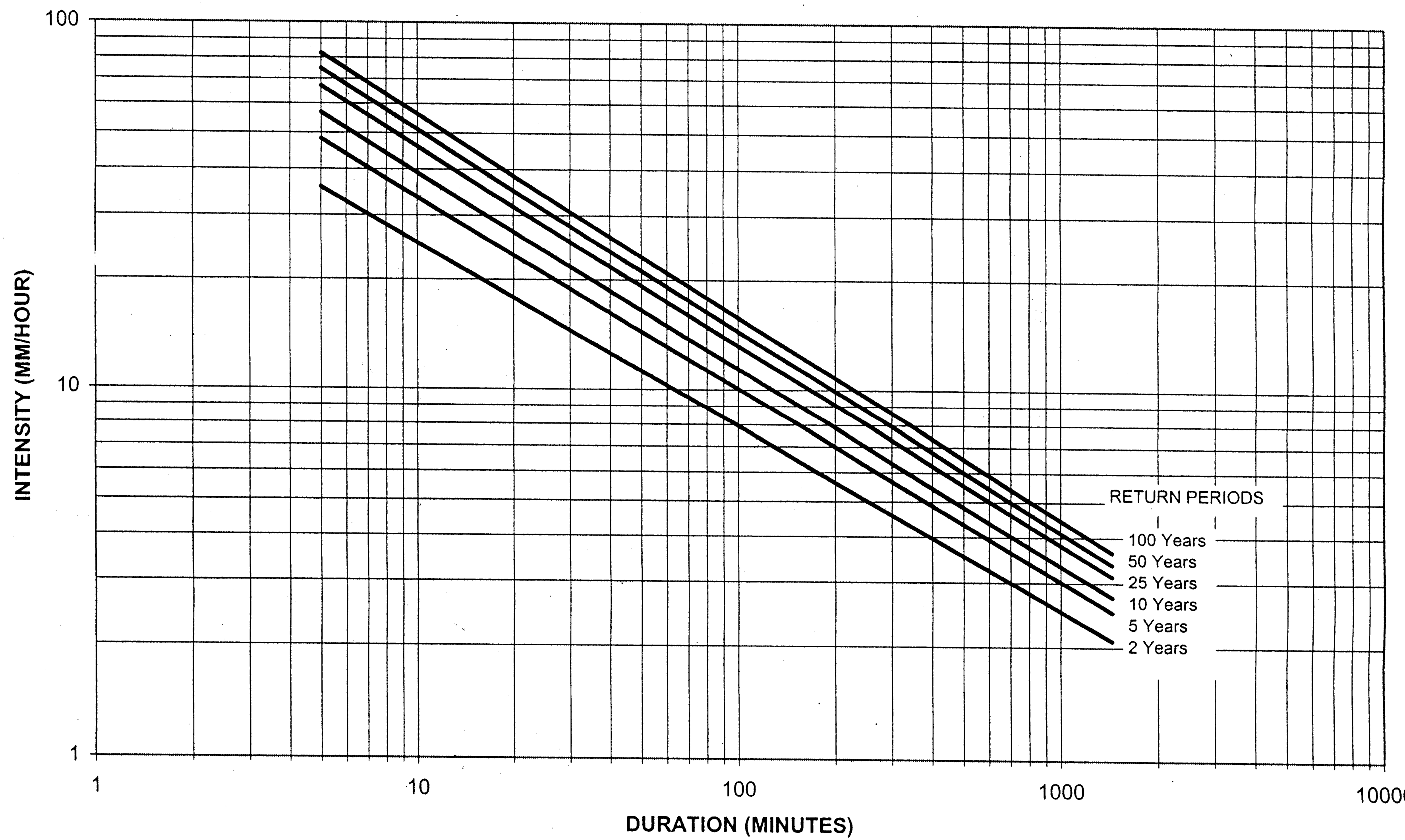

TABLE 3.3 STORM SEWER DESIGN - RATIONAL METHOD

Project Location ____________________ **Date:** ____________________

Reference No. ____________________ **Calculated by:** ____________________

Sheet ________ **of** ____________

LOCATION			CATCHMENT AREA		LAND USE & RUNOFF COEFFICIENT / AREA				FLOW TIME			RAINFALL	RUNOFF	SEWER DESIGN						ELEVATION						HYDRAULIC GRADE LINE			NOTES
			Increment Area																	Invert		Crown		Rim					
Road	From MH	To MH	No.	A (ha)	LAND USE	R	RA	Σ RA	Ti (min)	Tt (min)	Tc (min)	Intensity (mm/hr)	Design Flow (m^3/s)	Capacity (m^3/s)	Diameter (mm)	Slope (%)	n	Velocity (m/s)	Pipe Length (m)	From	To	From	To	From	To	HGL Slope (%)	Upper Elevation (m)	Lower Elevation (m)	

FIGURE 3.2 10-YEAR 2-HOUR "SITE LEVEL" STORM

Time (min)	Rainfall Intensity (mm/hour)
5	9.24
10	9.24
15	18.36
20	18.36
25	10.32
30	10.32
35	10.32
40	10.32
45	12.60
50	12.60
55	13.20
60	13.20
65	24.12
70	24.12
75	2.28
80	2.28
85	4.56
90	4.56
95	6.96
100	6.96
105	2.28
110	2.28
115	0.00
120	0.00

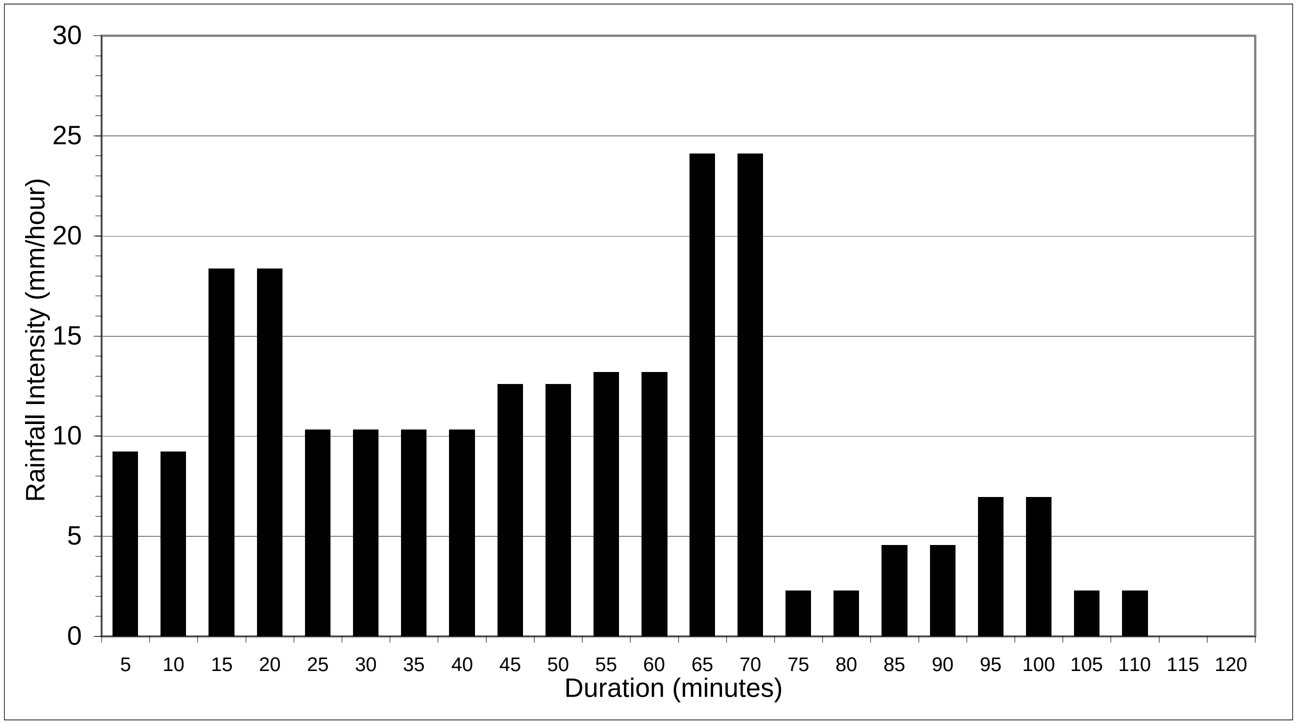

FIGURE 3.3 10-YEAR 24-HOUR "PLANNING LEVEL" STORM

Time (hours)	Rainfall Intensity (mm/hour)
1	1.81
2	1.89
3	1.99
4	2.11
5	2.25
6	2.43
7	2.67
8	3.01
9	3.54
10	6.70
11	6.70
12	6.70
13	6.70
14	3.24
15	2.82
16	2.54
17	2.34
18	2.18
19	2.05
20	1.94
21	1.85
22	1.77
23	1.74
24	1.70