

DID MANUAL



GOVERNMENT OF MALAYSIA DEPARTMENT OF IRRIGATION AND DRAINAGE

Volume 1 – Flood Management



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Foreword

The first edition of the Manual was published in 1960 and was actually based on the experiences and knowledge of DID engineers in planning, design, construction, operations and maintenance of large volume water management systems for irrigation, drainage, floods and river conservancy. The manual became invaluable references for both practising as well as officers newly posted to an unfamiliar engineering environment.

Over these years the role and experience of the DID has expanded beyond an agriculture-based environment to cover urbanisation needs but the principle role of being the country's leading expert in large volume water management remains. The challenges are also wider covering issues of environment and its sustainability. Recognising this, the Department decided that it is timely for the DID Manual be reviewed and updated. Continuing the spirit of our predecessors, this Manual is not only about the fundamentals of related engineering knowledge but also based on the concept of sharing experience and knowledge of practising engineers. This new version now includes the latest standards and practices, technologies, best engineering practices that are applicable and useful for the country.

This Manual consists of eleven separate volumes covering Flood Management; River Management; Coastal Management; Hydrology and Water Resources; Irrigation and Agricultural Drainage; Geotechnical, Site Investigation and Engineering Survey; Engineering Modelling; Mechanical and Electrical Services; Dam Safety, Inspections and Monitoring; Contract Administration; and Construction Management. Within each Volume is a wide range of related topics including topics on future concerns that should put on record our care for the future generations.

This DID Manual is developed through contributions from nearly 200 professionals from the Government as well as private sectors who are very experienced and experts in their respective fields. It has not been an easy exercise and the success in publishing this is the results of hard work and tenacity of all those involved. The Manual has been written to serve as a source of information and to provide guidance and reference pertaining to the latest information, knowledge and best practices for DID engineers and personnel. The Manual would enable new DID engineers and personnel to have a jump-start in carrying out their duties. This is one of the many initiatives undertaken by DID to improve its delivery system and to achieve the mission of the Department in providing an efficient and effective service. This Manual will also be useful reference for non-DID Engineers, other non-engineering professionals, Contractors, Consultants, the Academia, Developers and students involved and interested in water-related development and management. Just as it was before, this DID Manual is, in a way, a record of the history of engineering knowledge and development in the water and water resources engineering applications in Malaysia.

There are just too many to name and congratulate individually, all those involved in preparing this Manual. Most of them are my fellow professionals and well-respected within the profession. I wish to record my sincere thanks and appreciation to all of them and I am confident that their contributions will be truly appreciated by the readers for many years to come.



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List of Abbreviations

AAD	Annual Average Damages
ADP	Acoustic Doppler Profiler
AEP	Average Exceedence Probability
AMIP	Atmospheric Model Intercomparison Project
ARI	Average Recurrence Interval
BER	Beyond Economical Repair
BFE	Base Flood Elevation
BFI	Base Flow Index
CBD	Central Business District
CFMP	Catchment Flood Management Plan
CT	Current Transformers
CWP	Center for Watershed Protection
DBKL	Dewan Bandaraya Kuala Lumpur
DBMS	Data Base Management System
DDF	Depth-Duration-Frequency
DEM	Digital Elevation Model
DHS	Department of Homeland Security
DID	Department of Irrigation and Drainage
DOE	Department of Environment
DTM	Digital Terrain Mapping
EIA	Environmental Impact Assessment
ELV	Estimated Limiting Values
ESCP	Erosion and Sediment Control Plans
EQA	Environmental Quality Act
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FPL	Flood Planning Levels
FSR	Flood Studies Report
GWP	Global Water Partnership
GIS	Geographic Information Systems
HCI	Human-Computer Interface
HOST	Hydrology of Soil Types
HP	Hydrological Procedures
IDF	Intensity-Duration-Frequency
IHDTM	Institute of Hydrology Digital Terrain Model

IFM	Integrated Flood Management
IWRM	RELATION TO INTEGRATED WATER RESOURCES MANAGEMENT
IRBM	INTEGRATED RIVER BASIN MANAGEMENT
JPS	JABATAN PENGAIRAN DAN SALIRAN
LDP	Longest Drainage Path
LIDAR	Light Detection And Ranging
LUAS	Lembaga Urus Air Selangor
MCCB	Moulded Case Circuit Breakers
MCB	Miniature Circuit Breakers
MMC	Malaysian Mining Corporation Berhad
MMIS	Maintenance Management Information System
MNKT	National Council for Local Governments
MSMA	Manual Saliran Mesra Alam or Storm Water Management Manual
SL	Mainstream length
NFIP	National Flood Insurance Program
NVP	National Vision Policy
NPS	Non-Point Source
NRCS	National Resources Conservation Service
NWRC	National Water Resources Council
NMP	Ninth Malaysia Plan
OPP3	Third Outline Perspective Plan
PMF	Probable Maximum Flood
O&M	Operation and Maintenance
OS	Ordnance Survey
OSC	One Stop Center
OSD	On-Site Detention
POT	Peaks-Over-Threshold
PPM	Planned Preventive Maintenance
QAP	Quality Assurance Programme
QPF	Quantitative Precipitation Forecasts
QPE	Quantitative Precipitation Estimation
URBLOC	Urban Location Index
RFE	Regulatory Flood Elevation
SI	Site Investigation
SMP	Shoreline Management Plans
SOP	Standard Operating Procedures
SPR	Standard Percentage Runoff
SSR	Site Storage Requirement
STUDH	Sediment Transport in Unsteady, 2-Dimensional Flow, Horizontal Plane program
TC	Time of Concentration
TCG	Tidal Control Gate
WRAP	Winter Rain Acceptance Potential
WMO	World Meteorological Organization.
VT	Voltage Transformers

List of Glossary

Term	Definition
Annual Exceedance Probability (AEP):	Refers to the probability or risk of a natural event with a given size occurring or being exceeded in any given year. A 90% AEP event represents a high probability of flood occurring or being exceeded; meaning it would occur quite often and would be relatively small. On the other hand, a 1% AEP event has a low probability of occurrence or being exceeded; therefore it would be fairly rare but it would be relatively large.
Annual Exceedence Series:	The base value is selected so that the number of values in the series is equal to the number of years of the record.
Annual Maximum Flood:	The largest annual values of flood flow.
Asset:	Item owned, maintained or operated by DID that can be uniquely identified.
Astronomical Tide:	The variation in sea level caused by the gravitational effects of (principally) the moon and sun.
Average Annual Damage (AAD):	The total damage caused by all floods over a long time divided by the number of years in that period. (It is assumed that the population and development situation of interest does not change over the period of analysis).
Average Annual Flood:	The mean of the annual floods over a number of years.
Average Recurrence Interval (ARI):	The average elapsed time in years between floods of a given size occurring. For example a 1 year flood occurs on average once every year, therefore the ARI value would be relatively small. Contrast to that, a 100 year ARI flood (i.e. occurs on average once every one hundred years and fairly rare) would have a relatively large ARI value.
Baseflow:	The portion of a stream flow that is not due to storm runoff, and is supported by groundwater seepage into a channel.
Base Flood:	A flood with pre-selected probability-of-occurrence.
Basin:	Drainage area of a stream or a lake.
Bathymetry:	The configuration of the sea, estuary or river bed, as measured by depth contours.

Term	Definition
Berm:	A shelf that breaks the continuity of a slope; a linear embankment or dike.
Best Management Practice (BMP):	A structure or practice designed in stormwater management to prevent the discharge of one or more pollutants to the land surface thus minimising the chance of wash-off by stormwater. It can also be referred to a structure or practice to temporarily store or treat urban stormwater runoff to reduce flooding, remove pollutants, and provide other amenities (such as recreational, fishing spots, etc.).
Beyond Economic Repair:	Uneconomical to regain the proper level of reliability.
Bonding:	Public borrowing method whereby money is obtained to pay for an improvement, equipment, and/or associated services such as construction management, and repaid in future years, with repayment guaranteed by the full credit of the city issuing the bonds.
Breakdown Maintenance:	Corrective maintenance carried out on an item that has failed to meet a specified condition.
Brownfield Site:	A site for which new development is proposed that has been developed in the past. Brownfield sites often have particular problems, for example contaminated ground and polluted groundwater.
Bulkhead:	Vertical walls constructed from either plain or reinforced-concrete sheet piles, timber piles, or cribbing and are rigid forms of slope protection.
Bypass Flow:	Flow which eludes an inlet on grade and is carried to the next inlet downgrade in the street or channel.
Catchments:	The area of land draining to a specific location. It includes the catchments of tributaries as well as the main river.
Catchments Flood Management Plan:	High level plan for managing floods in river catchments.
Channel Design:	Channel are usually designed for subcritical, uniform flow and the chutes and some concrete channels are designed for supercritical flow.
Condition Appraisal:	Assess condition of equipment, system or facilities and recommend for upgrading or replacement.
Consequence:	The consequence of flooding is the impact of the flood including economic damages and social impacts.
Conveyance:	The ability of a watercourse or other flow path to carry (or convey) water.

Term	Definition
Corrective Maintenance:	The action performed to restore an item to a specified condition when it fail.
Critical Ordinary Watercourses:	Ordinary Watercourses which the Environment Agency and other operating authorities agree are critical because they have the potential to put at risk from flooding large numbers of people and property.
Design Storm:	A precipitation pattern defined for use in the design of a hydrologic system resulting rates of flow through the system.
Design Flow:	Corresponding to the design storm calculated using rainfall-runoff and flow routing procedures.
Design Flood:	Commonly called the standard project flood (SPF) and the SPF is estimated using rainfall-runoff modelling by applying the unit hydrograph method to the standard project storm (SPS), which is the greatest storm that may be reasonably expected. The 100-year flood has been adopted as the base for purposes of flood management measures. The 500-year flood is also employed to indicate additional areas of flood risk in the community.
Detention Pond:	Pond to store floodwater temporarily.
Discharge:	The rate of flow of water, as measured in terms of volume per unit time, for example cubic meters per second (m^3/s).
Dumped Riprap:	Graded stone (or broken concrete) placed on a prepared surface, usually with some type of filter layer between the stone and the supporting bank.
Effective Warning Time:	The time available for the evacuation of people and their goods and possessions before the onset of flooding.
Emergency Maintenance:	Corrective maintenance that should be initiated immediately upon detection for reason of health, safety and security.
Emergency Spillway	The channel of a pond-type BMP, designed to pass a storm event that exceeds the design capacity of the primary discharge structure.
Encroachment:	The advance or infringement of uses, plant growth, fill, excavation, building, permanent structures or developments into a floodplain which may impede or alter the flow capacity of a floodplain.
Evacuation:	Removal of people and property at risk following a warning.
Extreme value series:	The largest or smallest values occurring in each of the equally-long time intervals of the record.

Term	Definition
Flash flooding:	Sudden and unexpected flooding caused by local heavy rainfall or rainfall in another area.
Flood:	A body of water, rising, swelling and overflowing land not usually thus covered. Also, overflowing of the bank of a stream, lake or drainage system of water onto adjacent land as a result of storm, ice melt, tidal action and channel obstruction.
Floodbox:	A culvert through the bund with a flap gate at the outlet. Trash racks may be fitted at the inlet and/or the outlet.
Flood Control:	The use of techniques to change the physical characteristics of floods.
Flood Control Benefits:	<i>Direct:</i> Reduction in flood damage to land and property in terms of cost of restoration to pre-flood condition; <i>Indirect:</i> Higher grade use of land formerly flooded in terms of increased earnings, and reduced interruption of business, industry and commerce, traffic, communications and other activities both within and outside the area subject to flooding.
Flood Emergency:	A condition or situation caused by flooding that requires urgent action or assistance.
Flood Emergency Plan:	An agreed set of roles, responsibilities, functions, actions and management arrangements to deal with flood events.
Flood Forecasting:	Prediction of the characteristics of an imminent future flood.
Flood Frequency Analysis:	The analysis to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions. It is often presented graphically in probability paper as frequency curve. The accuracy of a computed curve can be improved when other information is available considering the nonhomogeneity and outliers.
Flood Hazard:	The impact of a flood on the safety of people, including the potential for loss of life and injury. The degree of hazard varies with the severity of flooding and is affected by flood behavior (extent, depth, velocity, duration, amount of warning and rate of rise of floodwaters), topography, population at risk and emergency management.
Flood Hazard Zone:	Any land area susceptible to flooding or flood related damage as designated on the floodplain management maps. Such flood hazard zones may include but not be limited to areas highly susceptible to erosion, stream meander sensitivity, moveable bed, scour, wave action, and subsidence.
Flood Insurance Study:	The official report provided by the insurance authorities that includes flood profiles and base flood elevations.

Term	Definition
Flood Management:	The organization of responses to flood problems.
Flood Management Plans:	A term used in this document to collectively describe Shoreline Management Plans, Catchments Flood Management Plans and Strategy Plans.
Flood Mitigation:	Involves managing the effects of flooding, rather than trying to prevent it altogether.
Floodplain:	Area susceptible to inundation by a base flood including areas where drainage is or may be restricted by man-made structures which have been or may be covered partially or wholly by flood water from the base flood.
Floodplain Acquisition:	Purchase and demolition by public authorities of properties in risk areas.
Floodplain Management Measures:	The full range of measures available to prevent or reduce flood hazard and disruption.
Floodplain Management Option:	A set of possible measures for the management of a particular area of the floodplain.
Floodplain Regulation:	Laws defining acceptable use of land in defined areas, thus controlling the extent and type of future development.
Flood Planning Level:	Flood planning levels are derived from a combination of flood events, an historic flood or floods of certain Average Exceedence Probability and a freeboard.
Flood Proofing:	Any combination of structural and non-structural additions, changes or adjustments to structures, made well before a flood event, which reduce or eliminate flood damage to real estate or improved property, water and sanitary facilities, structures and their contents.
Flood Protection:	Protection against the damaging effects of floods.
Flood Relocation:	Voluntary or compulsory movement of people and property out of risk areas.
Flood Recovery:	Flood recovery refers to clean-up, welfare, restoration of services and other forms of assistance provided by local authorities and voluntary organizations after a flood.
Flood Risk:	The chance of experiencing a flood, expressed in terms of the return period.
Flood Routing:	Determining the rise and fall of floodwater as it progresses downstream.

Term	Definition
Flood Stage:	The elevation of the water surface above which the stream is considered to be in flood.
Flood Storage Areas:	Those parts of the floodplain that is important for the temporary storage of floodwaters during the passage of a flood.
Flood Study:	A comprehensive technical investigation of flood behavior.
Floodway:	The channel of a watercourse and those portions of the adjoining floodplain which are reasonably required to carry and discharge the floodwaters of a selected probability-of-occurrence flood.
Floodway Fringe:	Area of a floodplain adjacent to the floodway where encroachment may be permitted.
Flood Warning:	Issuing the result of a forecast to the public or public authorities.
Flood Zoning:	Definition of areas, based on flood risk, within floodplain appropriate for different land uses.
Fluvial:	Relating to rivers.
Freeboard:	The height above a defined flood level typically used to provide a factor of safety in, for example, the setting of floor levels and embankment crest levels.
Frequency Distribution:	The probability distribution used in frequency analysis.
Greenfield Site:	A site for which new development is proposed that has not been developed in the past.
Hydraulic Jump:	A flow discontinuity, which occurs at an abrupt transition from subcritical to supercritical flow.
Hydraulics:	The study of water flow; in particular the evaluation of flow parameters such as stage and velocity in a river or stream.
Hydrograph:	A graph that shows for a particular location, the variation with time of discharge (discharge hydrograph) or water level (stage hydrograph) during the course of a flood.
Hydrology:	The study of the rainfall and runoff process and relates to the derivation of hydrographs for given floods, draughts and other water resources aspects.
Hydrologic Design Level:	The magnitude of the hydrologic event to be considered for the design of a structure or project.

Term	Definition
Hydrological Model:	Focussing on converting rainfall in runoff. Any subcatchment which is does not have river cross section can be represented with hydrologic model.
Indicative Flood Map:	Floodplain maps which cover the coastline, estuaries arid the larger rivers. These maps show the estimated flood limit with one in 100 chance of occurring in any year.
Infobanjir:	The name of the department regulating flood awareness and flood warning campaign (DID).
Inlet:	A form of connection between the surface of a ground and a drain or sewer for the admission of surface and stormwater runoff.
Insurance:	Purchase of guaranteed financial relief by means of a regular payment made before a flood.
Insurance Rate Map:	An official map on which insurance authorities has delineated both the special flood hazard areas and the risk premium zones applicable to the community.
Land Use Planning:	Control and supervision of land use in floodplain (zoning, regulation, acquisition, relocation).
Level of Protection:	The level of protection is based on hydrologic design level, which is return period or average recurrence interval.
Local Plan:	Statutory land use plan covering a local authority district, prepared by District Councils.
Log Book:	A record of functional parameters read and observation made during periodic check.
Loop Curve:	Relationship between Flow and water level at any particular river cross section which show some differences during rising and recession of flood water normally occur at mild slope river affected by constriction.
Main River:	Rivers for which the DID has control powers for maintenance, improvement and construction of new works.
Management:	Entire process of planning, regulating and intervention for reducing disasters, as well as the response and recovery measures.
Mitigation:	Action taken to reduce the effects of a disaster on a nation or community.

Term	Definition
Non-structural Measures:	The measures which alter the exposure of life and property to flooding utilizing preventive approach.
Orifice:	An opening with closed perimeter usually sharp-edged and of regular form in a plate, wall, or partition through which water may flow. Generally used for the purpose of measurement or flow control.
Outlet:	Point of water disposal of a stream, river, lake, tidewater or artificial drain.
Overflow Rate:	Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.
Overtopping:	To flow over the limits of a containment or conveyance element.
Partial Duration Series:	A series of data which are selected so that their magnitude is greater than a predefined base value.
Peak Discharge:	The maximum discharge occurring during a flood event past a given point on a river system.
Planned Preventive Maintenance (PPM):	Periodic maintenance on equipment, system or facilities to minimize risk of failure and to ensure continued proper operation.
Platform Level:	Platform level for flood protection is associated with Flood Planning Level (FPL).
Policy:	Established uniform approach.
Preparedness:	Measures which enable governments, communities and individuals to respond rapidly to disaster situations to cope with it effectively.
Prevention:	Measures for impeding a disaster event, or preventing it from having harmful effects on people, their property and settlements.
Probability:	The probability of flooding is the chance of a flood occurring, and may be expressed as the chance of a particular flood occurring in any one-year (for example, the flood with a 1 in 200 chance of occurring in any year).

Term	Definition
Probable Maximum Flood:	Corresponding to and derived from a probable maximum precipitation and developed for the design of runoff control structures especially related to flood control dam. It is the greatest flood to be expected assuming complete coincidence of all factors that would produce the heaviest rainfall and maximum flood.
Probable Maximum Precipitation:	Is the estimated limiting value of precipitation and defined as the analytically estimated greatest depth of precipitation for a given duration that is physically possible and reasonably characteristic over a particular geographical region at a certain time of year. The World Meteorological Organization defined as a quantity of precipitation that is close to the physical upper limit for a given duration over a particular basin, has return period of as long as 500,000,000 years, corresponding approximately a frequency factor of 15.
Rating Curve:	Relationship between Flow and water level at any particular river cross section.
Reconstruction:	The actions taken to reestablish a community after a period of rehabilitation subsequent to a disaster.
Rehabilitation:	The interventions taken after a disaster with a view to restoring a stricken community to its normal living conditions.
Relief measures:	Actions taken immediately following the occurrence of a disaster.
Residual flood risk:	The remaining level of flood risk that a community is exposed to after floodplain management measures to reduce risk have been implemented.
Response:	Measures directed towards saving life and protecting property and to dealing with the immediate danger and other effects caused by the disaster.
Retention:	The holding of runoff in a basin without release except through means of evaporation, infiltration or emergency bypass.
Return Period:	Defined as the average recurrence interval between events equaling or exceeding a specified magnitude.
Revetment:	A revetment is a facing, such as of stone or concrete, used to add support to an embankment.
Risk:	The expected loss due to a particular hazard.
River Basin Development:	The orderly marshalling of land use and water resources of a river basin for multiple purposes to promote human welfare and economic sustainability.

Term	Definition
River Bund:	Embankment of natural or artificial slope or wall usually earthen parallel the course of a river to prevent flooding.
River Cross-section:	The shape of a river that is perpendicular to the flow which is describe by chainage and elevation.
Runoff:	The amount of rainfall that drains into the surface drainage network to become stream flow.
Routine Corrective Maintenance:	Corrective maintenance carried out on items that remain in service until the commencement of repairs.
Routine Inspection:	Task of periodic close observation and assessment on equipment, system or facilities.
SCADA:	System that performs <u>S</u> upervisory <u>C</u> ontrol <u>A</u> nd <u>D</u> ata <u>A</u> cquisition, typically used to perform data collection and control at the supervisory level.
Shoreline Management Plan:	High level plan for managing floods and coastal erosion in coastal cells, or relatively self contained lengths of coastline.
Source Measures:	A series of mitigation measures undertaken as close as possible to the origin of surface runoff or pollution in urban environment.
Spillway:	A passage (such as a paved apron or channel) for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.
Stage:	Equivalent to "water level". Both are measured relative to a specified datum.
Stage Hydrograph:	A graph which shows how the water level at a particular location changes with time during a flood. The stage hydrograph must be referenced to a particular datum.
Stakeholder:	Individual or organization who are directly affected by a particular phenomena or activity, for example flood management. Stakeholders in flood management include those affected by flooding and those involved in flood mitigation.
Stormwater:	Water resulting from runoff from a storm event. During a rainfall event some water remains on the surface or is held in the soil or underground aquifer as groundwater, a portion of the water is used directly by plants and the remainder flows over the surface. This overland flow is called stormwater. It usually moves as overland (sheet) flow or channel (concentrated) flow.

Term	Definition
Stormwater Management:	The process of controlling the quality and quantity of stormwater to protect the downstream environment.
Strategy Plan:	Flood management plans for sub-divisions of river catchments or coastal cells, which identify appropriate schemes to implement the policies set out in CFMPs and ISMPs respectively.
Structural Measures:	The measures which alter the physical characteristics of the floods utilizing curative approach.
Structure Plan:	Statutory land use plan covering a State, and prepared by JPBD.
Vulnerability:	Difficulty to cope with stress. Also, potential loss of people and goods from a damaging phenomenon.
Watercourse:	A river, stream or ditch (but not public sewer).

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CHAPTER 1 INTRODUCTION

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1 INTRODUCTION

1.1 OBJECTIVES OF THE MANUAL

This Volume of the DID Manual focuses on topics related to the Flood Management function of the Department of Irrigation and Drainage Malaysia (DID). It covers the broad spectrum of the technical and non-technical aspects of flood management as practised in the country. This includes the engineering aspects of planning and design and the principles of flood management as a whole.

This manual also serves as a reference for flood management practices in the country. In some ways, it is also a record of the history of flood management practices in Malaysia.

1.2 TARGET USERS

This manual serves as a reference for DID engineers and staffs involved in the planning and design of flood management systems as well as those managing the DID offices in the States and Districts.

It is also useful for consultants, contractors as well as managers and planners in the public and private sectors as well as all those involved or interested in various aspects of the flood management and practices in the country.

1.3 CHARACTERISTICS OF THE MANUAL

This Manual is designed to reflect the philosophy of flood management and practices of the DID at this point of time. These may change over time but many of the fundamentals could, as shown by history, remain. Also, records of experiences in the past are useful to understand the gradual development of flood management approaches up to now and into the future.

Each chapter in this Volume is designed to be as complete as possible in its subject matter. Where necessary, cross-references are provided for certain related subjects such as those pertaining to hydrology and rivers (Volume 2: River Engineering) and coastal estuary (Volume 3: Coastal Management).

This manual provides the principles, technologies and management techniques in flood management practices. It blends the basic concepts of flood management with theories and practice as experienced by DID. It also provides worked examples and case studies from Malaysia and abroad. A special chapter on issues of future concern is also included especially on the impacts of climate change.

1.4 CONTENTS OF THE MANUAL

This Manual covers topics related to flood management as listed in the Table of Contents. It is divided into 13 chapters. Chapter 1 is an introduction the Manual. Chapter 2 gives an overview of the local flood scenarios covering the nature of flood, its trends in Malaysia, types of floods and their impacts. A history of floods in the country is also presented. This is followed by Chapter 3 providing an introduction to the Integrated Flood Management (IFM) approach and its relationship with the Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM).

Chapter 4 discusses the legislative and institutional aspects of flood management in Malaysia. Chapter 5 is on the data and information requirements for planning, design and management of floods whilst Chapter 6 describes the guidelines on flood mitigation engineering options.

Chapter 7 elaborates on the options of flood mitigation structural measures such as water level regulating structures (barrages, tidal gates), dams, river improvements/diversions, and flood and stormwater quality control structures (detention/retention ponds).

Non-structural measures are discussed in Chapter 8. These include flood plain management, flood mapping, flood proofing, flood forecasting and response, flood damage and flood insurance. Other measures such as public education and awareness in flood management are also discussed. Chapter 9 touches on river morphology and characteristics that are important considerations for the planning, design and maintenance of flood mitigation works.

Chapter 10 deals with the design criteria for flood mitigation. Chapter 11 specifically addresses the flood mitigation modelling and discusses the procedure setting up numerical models. Chapter 12 outlines the operation and maintenance (O&M) aspects of flood management covering best management practices for flood control, mitigation works, preventive and corrective maintenance.

Chapter 13, the final chapter, concludes the Manual with future concerns on flood management particularly on the impacts of climate change on flood management in Malaysia.

CHAPTER 2 FLOODS IN MALAYSIA

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2 FLOODS IN MALAYSIA

2.1 INTRODUCTION

"Sekali bah, sekali pasir berubah"

This is an old Malay adage with the connotation that a disruptive event more often than not brings about a change for the good of the people. Literally it translates as "each time it floods, the soil changes". This saying has a number of implications on the traditions and lives of people living in Malaysia. It implies acceptance that flood is not just a natural event but a frequent one and reference to it has naturally evolved as part the language and culture. It is an acceptance that flood is a part of life and to the risks of living in the flood plains. It also reflects on the benefits of floods more than the negative impacts. Also well repeated and relevant Malay adage is "*Kecil-kecil menjadi kawan, bila besar menjadi lawar*". This carries the meaning that when an event is small and manageable it is tolerable and even useful and beneficial but threatening when it gets bigger and out of control. Literally translated it is "A friend when small, an enemy when bigger". Although some refer this to fire, many also refer this adage to floods as well. Again it is the society's acceptance of floods as a natural event and has its benefits when manageable. However this adage is also a cautionary advice to be prepared for bigger and unmanageable event. Another adage is "*Kalau takut dilambung ombak, jangan berumah di tepi pantai*". Its translation is "If you fear being tossed by the sea, don't live by the sea side". This is an advice and recognition of risks particularly with respect to choice of places to stay and earn a living.

It is interesting that these age old words of wisdom and advice is still relevant to the principles of flood management in Malaysia. Also important is that these adages have positive connotations rather than negative and shows acceptance of flood, tolerance and the need to be prepared for eventualities.

Flood is a common occurrence in Malaysia because of the geographical characteristic of the country that brings an abundance of rains during the monsoon seasons and also due convection rains during the hot but humid periods. There are 189 river systems in the country (89 in Peninsular Malaysia; 78 in Sabah and 22 in Sarawak) all flowing directly to the sea. Of these, 85 are prone to frequent flooding.

Living in such an environment inevitably led to adaptation by the population in terms of lifestyles and flood risks management. A common example is that in the old days, houses are built on stilts in flood prone areas. Crop planting seasons were judiciously decided so as to be in time with the rains but avoiding the expected period of floods. The degree of tolerance to floods was perhaps higher in the old days when agriculture was the main occupation and the affected population was not as large as it is now.

As the country's economy transformed into industrialization, the population grew and urbanization expanded rapidly in the plains. Floods then developed into a national issue. Although a common occurrence, flood became an issue when it threatens lives and properties and severely disrupts social and economic activities. At times a flood event is classified as a disaster when it occurs unexpectedly or covers large areas and affecting a high number of the population and properties.

2.2 TYPES AND NATURE OF FLOOD

There are no formal categorizations of floods in Malaysia but is often broadly categorised as monsoonal, flash or tidal floods. In addition, floods are also described based on its location, characteristics, the cause, the timing as to when it occurs and its duration.

2.2.1 River Floods

River flooding is a natural process and part of the hydrological cycle of rainfall, surface and groundwater flow and storage (Madani et al, 2007). Floods occur whenever the capacity of the natural or man-made drainage system is unable to cope with the volume of water generated by rainfall. Floods vary considerably in size and duration. With prolonged rain falling over wide areas, the resultant surface waters flow into a network of ditches, streams and tributaries. The volume increases as it flows downstream and combines with flows from other channels. At the points where the flow is beyond the capacity that can be contained in the river channel, water overflows the river banks and consequently floods the adjacent flood plain.

2.2.2 Regional Floods

Regional floods are also river floods but the events cover a wide area or region. This is typical in large river basins such as that of the Kelantan River, Terengganu River and Pahang River. In large flood plains with extensive river system, flooding can occur over a considerable period after the rainfall stops as it takes time for the large volumes of water to drain out of the catchment. In some cases floods occur in dry weather conditions (no rains) on the downstream section of the river catchment. This is due to heavy rains on the hilly upper catchment away from the points of the flood event and location. River floods in Malaysia usually occur during the monsoon seasons. This is especially so in the East Coast of Peninsular Malaysia during the North-East Monsoon months between October and March every year.

2.2.3 Localised Floods

These are those occurring in small pockets of low-lying areas and often sensitive to small amount of rains. Being low-lying, natural drainage is difficult. Although some floods last only for a few hours, there are also areas that remain flooded for up to a month or more and well after the floods in the surrounding areas have receded. In this case, the flood water removal is mostly dependent on evaporation. One such area is in Buloh Kasap, Segamat, Johor and led to the colloquial term *Banjir Termenong*, literally, to "just sit, wait and ponder" whilst the flood takes its time to subside.

2.2.4 Coastal Floods

Coastal floods are those that occur on the coastal plains. There are two basic mechanisms. One is the tidal effects causing sea water to flow inland and spill over the low lying areas. The problem is exacerbated when high volume of river flows from inland and meets the tide as it moves inland. More so when the level of the river flow is lower than the tide level. River flow into the sea is also impeded when there are coastal wave surges. Another form of severe coastal flood that is still fresh in memory is the tsunami of December 2004 that affected the coasts of Langkawi Island, parts of Penang Island and the Kedah coast at Kuala Muda.

2.2.5 Urban Floods

Urban floods are those in built-up areas such as in cities, townships, commercial and residential areas. Urban floods affect more people and properties per unit area compared to those in agriculture and rural areas. Also the impact on traffic and services extends well beyond the physical location of the flood occurrence itself. The characteristics of urban flood can be more damaging and life threatening with roads becoming swift flowing channels, basements flooded and uncovered drains and bridges and crossings camouflaged by the flood waters.

2.2.6 Rural and Agriculture Floods

These are floods in rural settlements (villages) and agriculture production areas. In addition to threats on lives and properties, the concern is the impact of prolonged submergence on crop yields and production.

2.2.7 Flash Floods

A flood that rises and falls rapidly with little or no advance warning is called flash flood. Flash floods usually result from intense rainfall over a relatively small area. Flooding is usually due to intense local storms. This mostly happen in urban settings. The flood depths can be relatively shallow (100 mm or so) but there are cases of some being up to 2 metres depth but lasting less than 1 hour. In most cases the impact is not as severe as larger floods but, in urban areas, very disruptive to the daily routine of urbanites. As such these floods are also often termed as "nuisance floods".

2.3 CAUSES OF FLOOD

2.3.1 Natural causes of floods

The Monsoon winds greatly influence Malaysia's weather and therefore floods. The north-east monsoon (October-March) especially carries moisture as it blows across the South China Sea and results in long duration, intermittent rains as it hits the land mass. The east coast of Peninsular Malaysia is therefore very vulnerable to floods during this period. In December 2006 and January 2007, the State of Johor suffered a large scale flood event that affected most of the State. This was due to the high intensity long duration rains during that period.

The floods could be severe when heavy rainfall coincides with high tide and wave surges that impede river flow into the sea. Flood flow into the sea could also be impeded by sand bar formation across river mouths. This is another phenomenon common in the east coast areas.

Siltation of river beds is another natural phenomenon. Sediments carried by rivers from the hilly areas are gradually deposited on the slow moving meandering sections of the river in the flat plains on the coastal belt. This reduces the river carrying capacity and therefore easily overflows its banks during flood flows.

Short-bursts convective rains occur mostly during the dry months between the south-west monsoon and the north east monsoon seasons. Cities such as Kuala Lumpur are susceptible to this phenomenon and flash floods are often results of this.

Other natural causes of floods are landslides and river bank slips that block river flows. Mudflows in rivers also reduce the water carrying capacity of rivers.

In all cases however, it is the topography of an area that determines the susceptibility of that area to floods. A low-lying "bowl-shaped" topography will naturally be flooded when rains occur especially if the levels are lower than the nearest river.

2.3.2 Human Induced Floods

Land use changes without due consideration for drainage needs is perhaps the main human induced floods in the country. The Klang Valley flood issue is a good example. Urbanization here in the 60s and into the new millennium progressed very rapidly.

This resulted in more hard surface cover and therefore higher surface runoff during rains. However, the rate of the drainage infrastructure development to cater for this increased runoff lagged far behind urbanization progress. In some cases, there were no specific considerations for future flood flow requirements at all.

This consequently resulted in floods especially the Kuala Lumpur Floods of 1971 and 2004. The more serious implication is that it costs more now, economically and socially, to resolve flood issues in the already compact city.

The process of development itself can be the cause of floods. At this land clearing stage, erodible soils are carried by the surface flow into the rivers during rains. These are gradually deposited on river beds, reducing the river flow carrying capacity and hence the easily overtopped the river banks during high flows.

Other human induced floods are due to poor designs such as constrictions at bridges and culverts. Bridge piers or multi-culvert wall situated in the middle of rivers reduces flow efficiency and sometimes trap debris and solid wastes that in turn impede flow. There are also many cases of old bridges that were appropriately designed and constructed then but could no more cater for the increased runoff.

Floods can also occur as a result of operational requirements of structures and also due to structural failures. For example, water has to be released rapidly when the reservoir level reaches the maximum design level and this could cause floods in the downstream areas. A similar situation occurred during the Johor Flood of 2007 when water from the Bekok Dam had to be released for dam safety reasons. Flood bund breaches and structure abutment erosion are not uncommon incidences resulting in floods. In 1883, the dam upstream of Kuala Kubu town in Selangor collapsed and destroyed the town and many lives were lost. A new town, Kuala Kubu Bharu, was built and the old site is now known as Ampang Pecah (Collapsed Dam).

2.4 IMPACTS OF FLOOD

Nowadays the general perception seems to be that floods only have negative impacts. This should not be the case. Floods, being a natural phenomenon, are necessary for sustaining and even enriching and rejuvenating certain sector of biodiversity in the flood plains. It replenishes the lands with nutrient rich soils and therefore good for agriculture and natural vegetation. Certain floods clear debris as well as remove sediments from the flooded area. Flood also recharges ground water storage. In the past, in areas that are frequently flooded and the public has come to expect the annual return of the event as in Kota Bharu, Kelantan, flood is taken positively and seen as an occasion for enjoying a water festival and without significant interruptions to daily lives.

The negative impacts of floods are more prominent in highly populated and developed areas. Floods threaten lives, disrupt social and economic activities and destroy properties. Flood event causes distress and recovery can be costly both to individuals and the Government. In some areas, this has even deterred new investments in the flood prone area.

Irrespective of the positive and negative impacts of floods, there are other implications (adjustments) on the society living in flood prone areas that differ from countries that do not have the same level of flood occurrence. In Malaysia, since flood is a common event, there are specific needs for problem solving, preparedness and recovery. Floods require the Government to allocate special budget for its management covering mitigation works, forecasting and warning services, maintenance, relief and recovery works, repairs and other incidental expenditure. This is the same for individuals and the community. The affected people too will need to spend time and money on flood related issues before, during and after the event.

2.5 SCENARIO OF FLOODS IN MALAYSIA

2.5.1 Trend of Floods

Studies by Roseli, M (1999) concluded that, in Malaysia, converting land use from agriculture to urban area could increase the runoff rate two-fold.

A good example of increasing runoff trend with respect to development is shown in Figure 2.1 for the mean annual flood analysis for Sungai Klang river at Sulaiman bridge. This is the graph of cumulative mass of annual maximum discharge is plotted against the year from 1910 to 2000. An analysis of the graph shows that for over 70 years (1910 to 1980s) the mean annual flood flow at this point of the river is about 148 m³/s. This flow however, increased tremendously (three times more) 440 m³/s from the year 1988 onwards. This increase coincided with the period of economic boom in Malaysia and the tremendous urban development in the catchment above this point of the river.

This is the general trend of all urban areas in the country.

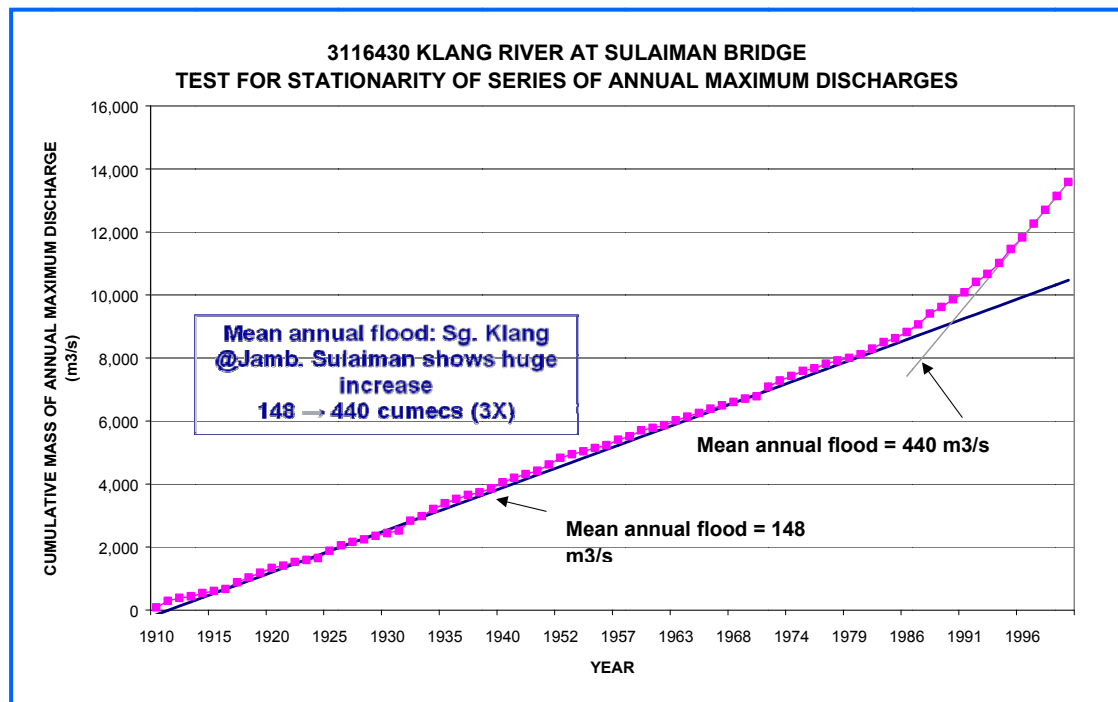


Figure 2.1 Mean annual flood analysis for Sungai Klang at Sulaiman bridge, Kuala Lumpur (Fuad, 2006)

2.5.2 Major Flood Events

Amongst all the natural disasters experienced in Malaysia, flooding by far is the most significant in terms of frequency, aerial extent, population affected as well as damage, not to mention the considerable socio-economic impact this has caused. Over 29,720 km² or 9% of the country is flood-prone (refer to APPENDIX 2.A), home to some 4.915 million people or 21% of the population. Flood damage is estimated at about RM915 million a year with an additional RM1.83 billion as losses due to consequential economic drag effects.

The well recorded major flood events in Malaysia are that of 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2001, 2003, 2004, 2006 and 2007. The 1926 floods, nicknamed "*Bah Merah*" (the Red Floods) due to the reddish colour of the sediment laden floodwaters, is believed by some to be the country's worst ever floods.

The January 1971 Kuala Lumpur flood (and in many other states) is significant for flood management approach in the country. It led to the Government's formal recognition that addressing urban flood issues require a concerted and systematic approach and the DID was selected to be the lead Government Department responsible. Another was the formation of the National Disaster and Relief Committee under the National Security Council. This committee is headed by the Deputy Prime Minister. Its Secretariat is the National Security Department of the Prime Minister's Department. A special commission on flood was also formed. This is the Flood Control Commission chaired by the Minister of NRE Ministry. The DID is the secretariat for this commission.

On 26 December 1996, the tropical storm Greg brought devastating floods and debris flow to Pampang River and Liawan River, near Keningau Town, Sabah, taking a toll of more than 200 lives and caused extensive property and structural damages. In October 2003, the southern part of Kedah and Penang experienced severe floods with return period (Annual Recurrence Interval, ARI) exceeding 200 years. More than 30,000 victims were evacuated and 4 lives were lost. Kedah was again hit by floods in mid-December 2005 and 20,000 people were evacuated. Perlis was also affected at the same time and 5 lives were lost.

In the second week of December 2004, the states of Kelantan and Terengganu were severely hit. The rainfalls recorded exceeded 400 mm in just over 5 days, the worse recorded ever in Kota Bharu and Tanah Merah, surpassing the 1926 'Bah Merah' flood level in Kota Bharu town by more than 0.5 m. The low lying areas in Terengganu were also badly affected. It could have been worse if not for the Kenyir Dam saving much of Kuala Terengganu by holding back over 700 million m³ of water, equivalent to 560 mm of rain continuously falling over the dam's entire catchments. For the state of Pahang, the situation was not much different. Severe floods were reported in Sungai Lembing and Kuantan. Flood damages amounted to more than RM30 million for the three states, with Kelantan suffering the most. The flood evacuees then were 10,500 in Kelantan, 4,050 in Terengganu and 2,550 in Pahang.

One of the worst flood events in recent years occurred in quick succession in the state of Johor in December 2006 and January 2007. Throughout the week starting from 18 December 2006 a series of floods occurred in Malacca, Pahang and Negeri Sembilan with Johor as the worst hit area. In Johor, major towns and cities suffering from the floods included Batu Pahat, Johor Bahru, Kluang, Kota Tinggi, Mersing, Muar, Pontian and Segamat have been flooded. The December 2006 flood was attributed to Typhoon Utor that hit the Philippines and Vietnam a few days earlier and that it was the reason for floods in Singapore and Indonesia too.

Besides the continuous, widespread and very intense rainfall, some of the main reasons for the widespread flooding in the Johor State are low lying areas, land subsidence (peat swamp areas), inadequate drainage capacity and high spring tide. The second flood in January 2007 (also referred to as the second wave flood) was worse than the first (that of December 2006). This was because of antecedent conditions due the first flood where the ground was already saturated and river flows were still high from the receding first flood in December 2006. This second wave left Johor almost paralyzed when all 8 districts were submerged by the flood. The worst affected areas then were Batu Pahat and Kluang. Most of the victims were without treated water and electricity supplies for many days. It was reported that incidences of water-borne diseases increased during that period. Muar was affected by floods lasting more than a month until January 2007. Many surrounding areas of Muar such as Pagoh, Lenga, Kundang Ulu, Bukit Gambir and Sawah Ring were seriously flooded from 19 December 2006 to early January 2007. Some of these were flooded up to 3 m depth.

About 22,933 people were evacuated to relief centers (The Star, 25 December, 2006). Treated water supply was unavailable to Muar residents for five consecutive days. The December 2006 and January 2007 floods in Johor State came as a surprise to many in terms of magnitude, extent and the huge resultant damages. The preliminary estimate of public facility damages alone amounted to more than RM 1.5 billion. Both waves of flood disaster were considered as the costliest flood in Malaysian history.

A rare but devastating flood event occurred on 26 December 2004. This was due to a tsunami tidal wave generated by a 9.0 earthquake on the Richter Scale at the epicenter in the Indian Ocean near Bandar Aceh in Sumatra, Indonesia. This tsunami wave intrusion into the coastal areas took 72 lives in Kedah and Penang.

2.5.3 Estimates of flood damages of significant flood events

Major recorded flood events in Malaysia started as early as 1926 and continued into 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2001, 2004, 2006 right through 2007. The past flood events on selected floods in Malaysia and its official flood loss estimates are shown in Table 2.1 and 2.2.

Table 2.1 Flood Events on Selected Floods in Malaysia for last 10 years

Flood Event (Year)	Place	Damage (RM million)	Deaths	Persons Evacuated
1997	Kedah, Terengganu	NA	5	5,321
1999	Kedah, Pulau Pinang, Perak Utara	NA	1	15,500
2000	Terengganu, Kelantan	7.1	NA	NA
2001	Pahang, Johor	NA	15	13,195
2002	Kuala Lumpur	NA	NA	NA
2003	Kuala Lumpur, Pulau Pinang, Kedah	NA	5	31,046
2004	Kelantan, Terengganu, Pahang	NA	17	17,080
2005	Kedah, Perlis, Kelantan, Terengganu	240.1	14	99,405
2006	Johor, Negeri Sembilan, Melaka	NA	15	107,000
2007	Pahang, Kelantan, Johor, Kedah (Dec.)	316.1	22	36,143
2007	Kuala Lumpur (June)	NA	NA	NA

Table 2.2 Official Flood Loss Estimates for Selected Floods event in Malaysia

Flood Event (Year)	(Place)	Damage (RM million at 1993 prices)	Deaths	Persons Evacuated
1967	Kelantan R. Basin	199.3	38	320,000
1967	Perak R. Basin	154.5	0	280,000
1967	Terengganu R. Basin	40.2	17	78,000
1971	Pahang R. Basin	93.1	24	153,000
1971	Kuala Lumpur	84.7	24	NA
1979	Peninsular Malaysia	NA	7	23,898
1982	Peninsular Malaysia	NA	8	9,893
1983	Peninsular Malaysia	NA	14	60,807
1984	Batu Pahat R. Basin	20.3	0	8,400
1986	Peninsular Malaysia	NA	0	40,698
1988	Peninsular Malaysia	NA	37	100,755
1988	Kelantan R. Basin	33.0	19	36,800
1988	Sabah	NA	1	NA
1991	Peninsular Malaysia	NA	11	NA
1992	Peninsular Malaysia	NA	12	NA
1993	Peninsular Malaysia	NA ^a	22	17,000
1995	Peninsular Malaysia	NA	0	14,900
1996	Sabah (June)	NA	1	9,000
1996	Sabah (December)	130.0 ^b	200 ^c	15,000

NA = not available

^a In the state of Kelantan, a total of 200 schools were closed during the 1993 flood resulting in 113,000 students missing school for a total of between six to 11 days.

^b The Sabah government estimated that damage to roads, bridges, schools, power lines, government offices and other public utilities would need at least RM 130 million to restore (*The Star*, 1 January 1997). If private properties, industries, businesses, corps, livestock, shipping vessels and other privately owned assets were taken into account, the damage figures would have been at least many million Ringgits higher. More than 4,552 houses were destroyed during this event.

^c Another 104 people were still missing nearly a week after the event.

2.6 FLOOD MANAGEMENT IN MALAYSIA

2.6.1 The Department of Irrigation and Drainage Malaysia (DID)

The DID is the lead Government agency responsible for flood management in Malaysia. Formed in 1932, its function then was to manage floods in agriculture areas through river conservancy. It also constructs and manages bunds and tidal gates in the coastal areas to protect the adjacent paddy areas. Following the big floods of 1971, flood mitigation for both urban and rural areas was added to its list of functions. This is in recognition of it being the only organization in the country with the expertise and experience in large volume water management. Under this function, the DID plans and implements flood mitigation projects around the country, advises Local Authorities, provide flood forecasting services and warnings and is the official custodian of the nation's hydrological data.

The DID was under the Ministry of Agriculture since its inception to January 2004 when it was transferred to the newly formed Ministry of Natural Resources. However its flood mitigation function for both urban and rural areas remains.

2.6.2 Flood Management Approaches

The flood management approach for urban floods in the early days can be said to be more on an *ad-hoc* basis. Prior to the formation of the DID, the Public Works Department was often directed to solve urban flood problems. In the rural areas, DID was the main department approached for such works. This is more of an incidental responsibility then because it was primarily responsible to protect paddy production areas. Being predominantly an agriculture-based economy then and paddy areas being in the flood plains, this was the convenient arrangement. Even then there were no rural flood protection projects *per se*. Flood protection works were more in the form of river conservancy and river training works as well as coastal bunds and tidal gates defending the adjacent paddy areas from seawater attacks and salinity.

The turning point was the 1971 floods when flood mitigation was added to DID's function. The Hydrology Division was also formalised and subsequently developed into the National custodian for hydrological data. It also provides flood forecasting and warning services. Prior to this, hydrological data collection were more for improved planning and design of irrigation and agriculture drainage system.

Upon taking this new responsibility, the DID focused on the urgent need to provide immediate flood relief works as well as to implement major flood mitigation projects to "catch-up" with the continuous and intense urban development. This required more structural measures than non-structural ones. This approach continued well into the 1990s and successfully mitigated floods in many areas. Mitigation is not alleviation and this is well recognised by the flood managers in the country. The success of the flood mitigation works inevitably led the public into a false sense of security or high expectations that floods have been eliminated. Thus rainfall and flood events beyond the design limits often caused intense public reaction.

The rate of urbanization far exceeded that of flood mitigation works. More and more agriculture lands are converted into urban use. In this circumstance, flood continues to be a national issue. Even from the beginning of the flood mitigation program in the 1970s it was recognised that structural measure is not the complete solution for floods but it was the urgent need then. Nonetheless many new rules, regulations and guidelines as regard to land use changes and new development requirements have been introduced since. New non-structural measures were introduced and the most significant being that required under the *Manual Saliran Mesra Alam* (User Friendly Drainage Manual - the Urban Stormwater Planning Manual). Compliance to this manual is now a mandatory requirement for all new urban development projects since 2001.

Since the new millennium, the DID has adopted the Integrated River Basin Development and the Integrated Flood Management approaches for its flood management programs. These will provide a balanced approach between structural and non-structural measures as well as higher levels of public participation.

2.6.3 Flood Relief Machinery and Organization

Following the disastrous flood of 1971, which affected many areas in Malaysia, the Government has established the Natural Disaster Relief Committee in 1972 with the task of coordinating flood relief operations at national, state and district levels with a view to prevent loss of human lives and to reduce flood damage. The coordination of relief operations is the responsibility of the Natural Disaster Relief Committee which is headed by the Deputy Prime Minister of Malaysia in the National Security Council of the Prime Minister's Department.

The committee members consist of various Cabinet Ministers such as the Minister of Finance, the Minister of Social Welfare, the Minister of Natural Resources and Environment, the Minister of Science, Technology and Innovation, senior government officials such as of the Government's Chief Secretary, the Army General, and related government agencies/departments such as DID, MMD, MACRES, Social Welfare Department, Police Department and Fire and Rescue Department.

The organisation of flood relief and operation is based on the Operation Procedure No. 29 published by the National Security Council. Beside that DID has published Circular No. 2/2003 – "Guidelines for Management of Flood Disasters during the Monsoon Season and Flash Floods" which is to coordinate the preparation of flood operations at federal, state and district levels.

2.6.4 Flood Forecasting and Warning System

Flood forecasting and warning system constitutes an effective and economical means to reduce loss of lives, trauma of disaster and property damage. Since 1971, DID has been designated with the task of providing flood forecasting and warning services to the public. Available records showed that flood warning services were first provided for the flood event of 1925 when floods occurred along the Kinta River in Perak and Klang River in Selangor and Bernam River in Selangor/Perak boundary. It is also known that the flood warning system based on river levels of the Kelantan River at Bradley Steps, Kuala Krai has been used to warn the people of Kota Bharu downstream since early 1900's. The police provided rainfall and water level readings and transmitted the information via VHF sets to the Flood Warning and Relief Committee in Kota Bharu.

After the floods of 1971, the flood warning systems of major rivers subjected to severe flooding were reviewed. The major deficiencies identified were inadequacy of rainfall and water level station networks to provide timely and reliable real-time data. Based on this review and its recommendations, telemetric stations, both rainfall and water level, were established at strategic locations to enable the transmission of real-time data to flood operation centres. The review also highlighted the need for more accurate flood forecasting techniques to replace the empirical river stage correlation technique, and recommended the use of mathematical models, which would take into account the rainfall and catchment characteristics as well as river system configurations.

To date, DID has established about 335 telemetric rain-gauges and 208 telemetric water level stations in the vicinity of 40 river basins for real time flood monitoring. At these stations, three critical flood levels are designated, namely Alert, Warning and Danger. In addition, 400 river observation points are provided with manual flood gauges and more than 250 siren stations has been established.

At this moment, the real time information of rainfall and river water level is published on-line via the *Info-Banjir* webpage and could be directly accessed by Government officials and the public. In addition, *short messages system* (SMS/text) is also provided to alert relevant officers of Government agencies such as Police, Army, Malaysia Meteorological Department (MMD), JPAM, DID, and National Security Division (BKN) at Prime Minister's Department.

2.6.5 (a) Structural Measures (Flood Management Options)

After the disastrous flood of 1971, besides the establishment of the Natural Disaster Relief Committee in 1972, the Government has also established the Permanent Flood Control Commission in December 1971 to implement flood control measures with a view to reduce flood occurrence and to minimize flood damage. This commission is presently chaired by the Minister of Natural Resources and Environment (previously chaired by the Minister of Agriculture) with DID as the secretariat.

2.6.6 (b) Non-Structural Measures (Flood Management Option)

In the past, local government and developers relied upon engineering solutions to move stormwater as quickly as possible into concrete channels toward discharge locations. As a result, the overload of stormwater entering waterways created significant flood damages. Today, the current emphasis of peak discharge control at source, a new Urban Stormwater Management Manual (MSMA) has been published by DID in 2000 which has superseded the Urban Drainage Planning and Design Procedure No.1 (1975). In January 2001, was approved by the Cabinet to be implemented and complied by all local authorities, public and private development projects as well.

The Urban Stormwater Management Manual procedure provides control at-source measures and recommendations on flood control by means of detention and retention, infiltration and purification process, including erosion and sedimentation controls. The quality and quantity of the runoff from developing areas can be maintained to be the same as pre-development condition.

In order to achieve the MSMA guideline objective, DID has implemented the following:

- i. Review previous drainage master plans using the new Urban Stormwater Management approach.
- ii. Upgrade old drainage systems in stages.
- iii. Network cooperation and support from other government agencies such as Local Authorities, Town and Country Planning Department, Forestry Department, Malaysia Highway Authority, Public Works Department, Department of Environment, CIDB, etc.
- iv. Organize training courses for engineers with the Institution of Engineers, Malaysia (IEM) for enhancing the practising engineers' expertise.
- v. Impose Erosion and Sedimentation Control Plan as mandatory approval for earth works development plan.

To date, some public development projects have implemented MSMA approach. At the Federal Government Administrative Center, Putrajaya, it has been applied by incorporating the lake and wetlands as storage and purifier of stormwater. In addition, there are some private housing projects utilising this new approach too.

2.7 FLOOD CONTROL USING STORM WATER MANAGEMENT MANUAL (MSMA)

In the year 2000, the DID formulated an entirely new approach to flood control by reducing peak discharge potential at source. This is the Storm Water Management Manual (MSMA) that specifies the control at source concept. By using rainfall harvesting, swales and detention/retention ponds for instance, it is possible to control and minimise the surface runoff (stormwater) at development sites from going direct into the waterways. The reduced and controlled volume reaching the waterway will thus cause less impact to the already swollen river. By following the procedures in the Manual, approach will effectively reduce the frequency and severity of floods in the urban areas and downstream of the project sites.

To comply with MSMA, the DID has come up with a 'Submission Checklist for Stormwater Management in Malaysia'. This set of checklist is to assist developers, contractors and consultants on the proper use of MSMA and to ensure better compliance to the measures in the Manual (DID, 2008d).

This policy will establish uniform technical standards while consolidating the regulatory requirements of several authorities. The policy addresses both water quality (pollutants) and water quantity (flood control) by establishing the level of required controls which can be achieved through the use of site planning, non-structural measures, and Best Management Practices (BMPs). BMPs reduce or prevent pollutants from reaching water bodies and control the quantity or runoff from a site. MSMA are designed to meet the stormwater management requirements under various regulatory programs.

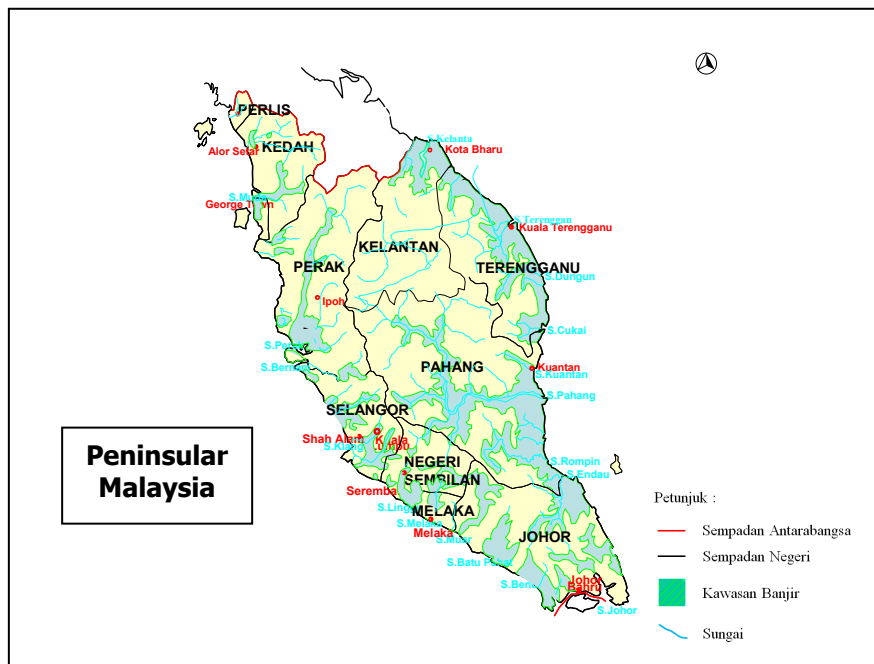
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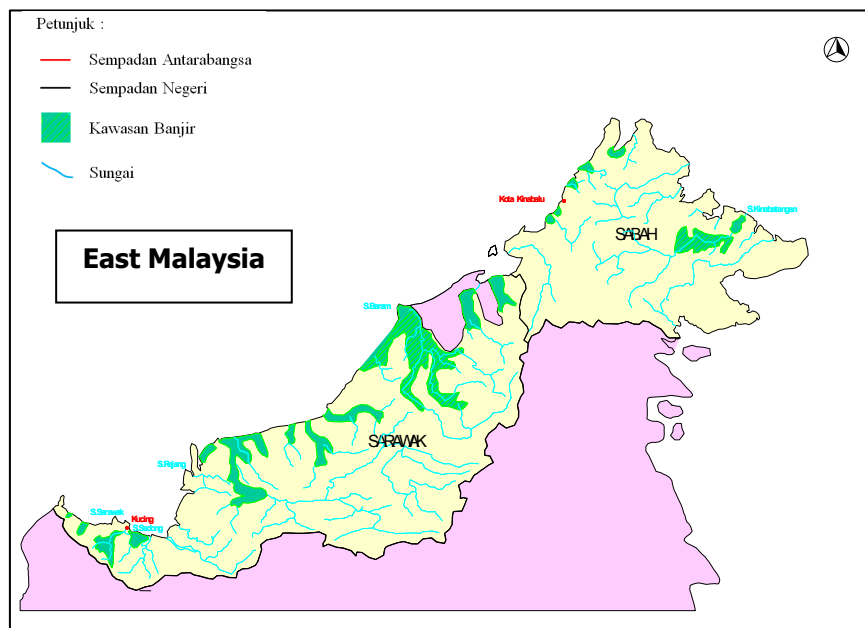
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APPENDIX 2.A FLOOD PRONE AREA IN MALAYSIA

Flood
in
Malaysia



Prone Area
Peninsular
(DID)



APPENDIX 2.B PHOTOS OF FLOOD EVENTS IN MALAYSIA



Photo 1: In front of Selangor State Headquarters Kuala Lumpur, 1926



Photo 2: In Kota Bharu town, Government Kelantan, 1967



Photo 3: In Kuala Lumpur, 1971



Photo 4: In Shah Alam, Selangor, 1995



Photo 5: In Kota Bharu, Kelantan, 2004



Photo 6: Floods in the east coast of Peninsular Malaysia, 2004, 2005 & 2006

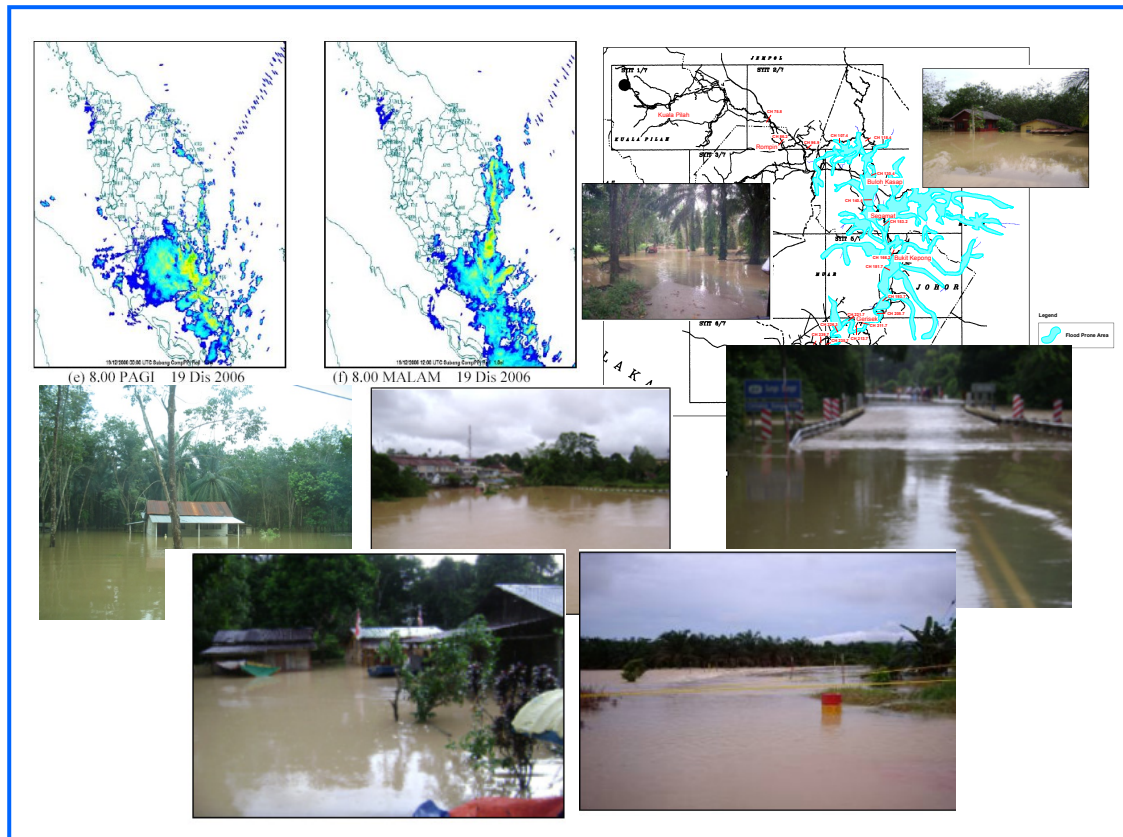


Photo 7: Floods in Johor, December 2006 and Jan 2007

CHAPTER 3 INTEGRATED FLOOD MANAGEMENT (IFM)

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3 INTEGRATED FLOOD MANAGEMENT (IFM)

3.1 INTRODUCTION

Over the past 40 years since 1971, flood management efforts in Malaysia focused primarily on trying to “catch-up” on rapid urbanization. This required installation of structural works in the form of improved and intensive flood mitigation systems. Flood warning systems were installed at critical areas prone to floods more as a temporary measure until physical improvement works are completed in that area. For larger catchments with characteristics that allow for time to forecast and warn the public of floods, flood forecasting and warning systems were provided. “Retro-fitting” flood mitigation systems in developed areas are challenging both socially and economically. This is because available corridors for river improvement and flood channel installation are limited due to encroachment by development. The problems are exacerbated by illegal settlements, attracted to the cities because of employment opportunities, located along the river banks and within the river reserves. This resulted in more people vulnerable to floods. Over time, public reaction to recurring floods became more unforgiving due to the misconception that the flood mitigation projects should have solved all the flood problems.

Physical works alone are thus inadequate and realising this and, since the 1980s, the DID developed new strategies for a broader approach for flood management. This included development coordination with all agencies directly and indirectly responsible for land development and custodians of Laws that can mitigate floods. Forward planning of river and drainage requirements were made in the form of masterplans, development plan monitoring at the State levels and producing appropriate guidelines for public and private developers. There were public awareness campaigns and programs to instil the love of rivers. In the year 2000, a milestone in flood management strategy was the introduction and adoption of the environmentally friendly drainage development requirements imposed on all developers. The major condition for approval is that all the estimated excess flow resulting from each development shall be contained before release into the main drainage systems. Investments were also increased for flood forecasting and warning system for a wider spectrum of the public and not just for those directly vulnerable. For Kuala Lumpur, these services can now be disseminated by the short messaging service (sms/text) via mobile telephones. Another interesting development related to flood management by DID is the urban rainwater harvesting system for buildings and small communities. The DID has also initiated programs to develop flood hazard and flood risk maps. Even the preference for structural measures has shifted considerably from hard to softer (and natural) finishes with beautification and environmental considerations.

All the above are progressions from a more structural approach towards a balanced approach that includes more emphasis on non-structural aspects flood management. This is the more integrated approach to flood management in Malaysia. The DID is now initiating efforts to formalise this approach into a more structured and systematic total flood management for the country. This is the Integrated Flood Management approach.

Integrated Flood Management is the process of promoting an integrated approach to flood management incorporated into the Integrated Water Resources Management (IWRM) aimed at maximising benefits from the use of floodplains without compromising on sustainability of the vital ecosystems.

Technically speaking, flood risk is the probability a given flood equals or exceeds its magnitude in any year for a defined area, the basis for flood protection design standard. However there are forever uncertainties attached to a flood event due to changes in climate, which presents a challenge to the designer. The needs for the establishment of IFM are recognized as follows (GWP and WMO, 2004c):

- A river basin is dynamic over time and space. There are a series of interactions between water, soil/sediment and pollutants/nutrients;
- Population growth and economic activities exert pressure on the natural system;
- Increased economic activities in floodplains increase vulnerability to flooding;
- High level of investment in floodplains, and the lack of alternative land means that abandoning flood-prone areas cannot be a viable option for flood damage reduction;
- Changes in land use across the basin affect runoff and the probability of a flood of a given magnitude;
- Changes in the intensity and duration of rainfall patterns as a result of climate change could increase flash floods and seasonal floods;
- The likelihood that existing flood protection measures could fail and how such situations should be managed need to be considered;
- Riverine aquatic ecosystems provide many benefits such as clean drinking water, food, flood mitigation and recreational opportunities; and
- A trade-off between competing interests in a river basin is required to determine the magnitude and variability of the flow regime needed within a basin to maximise the benefits to society and maintain a healthy riverine ecosystem.

Thus IFM should improve the functions of a river basin in its entirety including flood mitigation. While floods have benefits, they can never be fully controlled (GWP and WMO, 2004c). This approach should maximise the use of the floodplains for long-term.

3.2 RELATION TO INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) AND INTEGRATED RIVER BASIN MANAGEMENT (IRBM)

IWRM is defined by the Global Water Partnership (GWP) as “a process which promotes the coordinated management and development of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems”. This definition is based on the recognition that a single intervention has implications for the system as a whole. More positively, integrating management means multiple benefits may be achieved from a single intervention. In other words, IFM promotes an integrated rather than fragmented approach to flood management by integrating land and water resources development in the entire river basin. Figure 3.1 shows the integration of the different types of management.

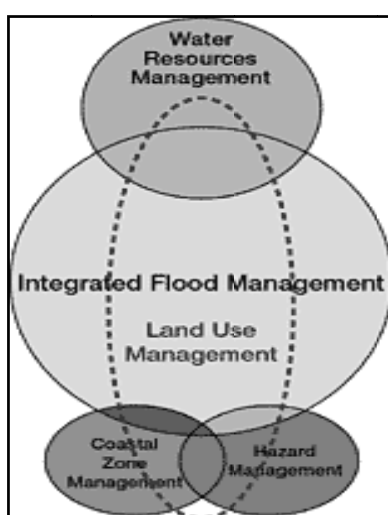


Figure 3.1 Integrated Flood Management Model (GWP and WMO, 2004d)

For flood management to be infused into IWRM, river basins should be considered as an integrated system where socio-economic activities, land-use patterns, hydro-morphological processes, etc., are constituent parts of the system. A consistent approach need therefore be applied to all forms of possible intervention. For example, the entire hydrological cycle should be considered in the system, not just differentiating floods from droughts when planning for water resources development.

IFM is therefore geared into the integration of measures to contain floods. This calls for linkages between relevant sectors, of which cooperation and co-ordination has no institutional or disciplinary boundary limits. The present mandate of many institutions only covers part of the river basin but seldom extend beyond the basin boundary. At the core of integration is effective communication possible only in the pursuit of common interest between the institutions. Emphasis should be to adopt flexible strategies on flood-prone regional basis (characterised by various physical, social, cultural and economic aspects), and to evaluate the different options available with their respective advantages and disadvantages.

A participatory and transparent approach would include a representative range of stakeholders in the decision making process, which is one key component of IFM. The degree of public participation can differ from region to region and stakeholder involvement should not necessarily result in a consensus. Therefore, a sound methodology to manage conflicts towards common resolution goals needs to be developed. One major challenge in this respect would be to develop a consensus on the question of funding for the overall activities when flood management is one of the main objectives. This could be established through dialogue among the stakeholders, particularly where such practices are not commonplace.

The basis of IWRM is that different uses of water are interdependent. IWRM means that all different uses of water resources are considered together. IWRM is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives.

Integrated River Basin Management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems. IRBM rests on the principle that naturally functioning river basin ecosystems, including accompanying wetland and groundwater systems, are the source of freshwater. Therefore, management of the river basins must include maintaining the ecosystem to function as a paramount goal. River basins are dynamic over space and time, and any single management intervention has implications on the system as a whole. The seven key elements to a successful IRBM initiative are:

- A long-term vision for the river basin, agreed to by all the major stakeholders;
- Integration of policies, decisions and costs across sectorial interests such as industry, agriculture, urban development, navigation, fisheries management and conservation, including through poverty reduction strategies;
- Strategic decision-making at the river basin scale, which guides actions at sub-basin or local levels;
- Effective timing, taking advantage of the opportunities as they arise while working within a strategic framework;
- Active participation by all relevant stakeholders in well-informed and transparent planning and decision-making;
- Adequate investment by governments, the private sector, and civil society organisations in capacity for river basin planning and participation processes; and
- A solid foundation of knowledge of the river basin and the natural and socio-economic forces that influence it.

3.3 FLOOD CONTROL VERSUS FLOOD MANAGEMENT

Flood Control has given way to the recognition that our ability to stop floods is finite. While floods cannot always be prevented, their threats to public safety, water supply, and the economy can be minimised by balancing traditional flood control with contingency planning.

Flood Management focused on managing floodwaters rather than managing flood risks (Madani, et al, 2007). It is financially and physically impossible to provide complete protection from flooding because engineered system such as bunds and dams that can prevent frequent small flood events and providing some level of protection can also lead to a false sense of security if communities do not know or appreciate the limitations of that protection.

Unplanned development can result in high risk for managing floods now and in the future, potentially increasing flood damages and management costs. Many of the infrastructures in flood management (bunds and dams) are designed to reduce or control peak flows. However, any flood control system will have some residual risk that is, the flood risk beyond that can be controlled by management. Since flood control capabilities are limited, sound flood management practices aim to effectively allocate resources to reduce economic and safety risks.

Flood risks are complex and changing. Flood management policies can be more effective if they account for interdependencies of the entire system as well as changes in land-use, climate and infrastructure (Madani, et al, 2007). Reducing flooding in one place can increase flooding elsewhere. A mix of structural and non-structural actions can be an effective and efficient approach to flood management. Flood damages are a function of both flood infrastructure and land-use. Both are important for understanding of how to focus flood protection efforts.

Unlike traditional methods of flood control, the goal of flood management is to minimise loss of life and net damages through both structural and non-structural actions. Structural approaches focus on flood control infrastructures to keep floodwaters away from people (e.g. dams, debris basins, bunds, weirs, canals and bypass). Non-structural approaches apply management methods (such as floodplain management, education, evacuation and emergency response) to minimize the damage potential of floods.

Flood risks change with technology, climate, settlement patterns and hydrology. Changing climate conditions and population growth will increase flood risks. New technology can, to a certain extent, decrease flood risks by improving management and infrastructure. For example, dam and reservoir upgrades and improved dam and reservoir operations and weather forecasting can reduce peak flows by allowing reservoir operators to make early releases and therefore absorb more of the peak flow in the dam. However, even with early releases, there are limits to the capacity of reservoirs to reduce floods.

With new technologies and infrastructure maintenance and upgrades, well planned development and floodplain management can reduce growing flood risks by minimising increases in peak flows due to runoff from new development, increasing the effectiveness of new and existing flood protection infrastructure, and putting fewer new homes and businesses in high risk areas (Madani, et al, 2007).

3.3.1 Framework of Flood Management Strategies

The basic framework of flood management strategies is shown in Table 3.1 (MLIT, 2007).

The need to implement IFM therefore depends on clear objective policies supported with appropriate legislation, regulations and economic instrument. Institutional structures with appropriate linkages as well as community-based institutions are a must as well. Transparent information management and exchange among all the stakeholders and scientific communities should be carried out for a clear understanding for all parties.

Table 3.1 Flood Management Strategies Framework

Strategies		Measures	Details of Measures	Administrative Organisation
Prevention of Inundation		Control of flooding (maintenance of facilities for flood control)	Widening of rivers and adjustment of river flows using dams and retarding basins.	River management (national and state governments)
		Safe ways of living	Restrictions and guidance on land usage (urbanization control areas, hazard maps)	River management. Local authorities.
		Inhibiting increases in flooding water	Development permits. Permits for rain water infiltration prevention activities.	State governments
Disaster limiting activities in cases of flooding (emergency responses)	Responsive action for emergencies	Flood prevention activities	Repairs of emergency facilities and provision of precise information. Responsive action to deal with scouring damage and leaking bunds.	River management. Flood prevention teams.
		Evacuation and rescue	Evacuation, rescue and provision of relief for residents	Local authorities. Organization of national and state governments, defence forces, etc.
	Responses implemented during normal periods	Guidance and instructions to residents	Dissemination of information regarding evacuation assembly points and evacuation routes. Dissemination of information regarding flood danger.	Local authorities. River management.
		Formulation of disaster prevention plans	Systemisation of various implementations with assumption of flooding. Allocation of roles and clarification of responsibilities.	National and regional public organizations. Designated organizations, etc.
		Sustaining appropriate functions of facilities	Management with consideration for changes in river beds. Maintenance of evacuation assembly points.	River management. State and local governments.

3.4 COMPONENTS OF INTEGRATED FLOOD MANAGEMENT

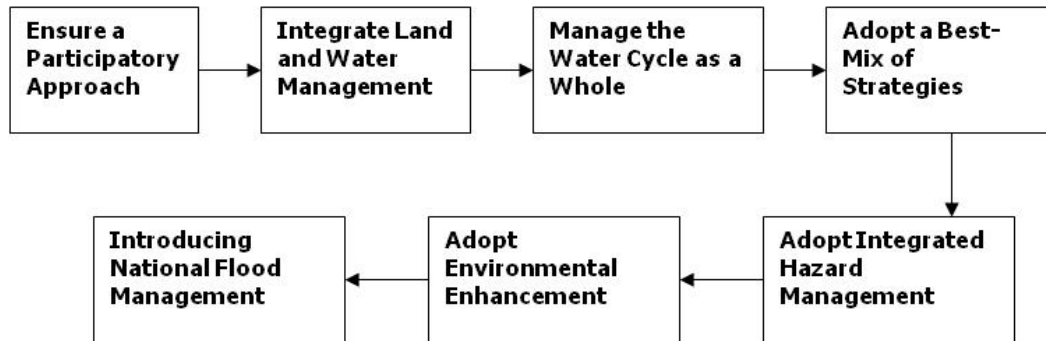


Figure 3.2 Schematic Diagram of Components of Integrated Flood Management

3.4.1 Ensure a Participatory Approach

IFM should be based on a participatory approach involving users, planners and policy-makers at all levels and should be open, transparent, inclusive and communicative. Decentralization of decision-making is necessary, with full public consultation and involvement of stakeholders in planning and implementation. Gender, religious and cultural differences must be taken into consideration. An appropriate combination of both the "bottom-up" and "top-down" approaches needs to be adopted. Coordination at the highest level to promote coordination and cooperation across functional and administrative boundaries needs to be ensured (GWP and WMO, 2004c).

3.4.2 Integrate Land and Water Management

Land use planning and water management must be combined in one synthesized plan, through coordination of land and water management authorities to achieve consistency in planning. The three main elements of river basin management (water quantity, water quality, and the processes of erosion and deposition) should be linked in planning (GWP and WMO, 2004c). Effects of land use changes on the various elements of the hydrological cycle need to be taken into consideration.

3.4.3 Manage the Water Cycle as a Whole

Flood management plans must be intertwined with drought management through the effective use of floodwater and/or by maximising the "positive" aspects of floods and the need to manage all floods, not just some. For example, how to manage floods greater than the design standard needs to be addressed and so are the need to seek multi-beneficial solutions that serve several different purposes simultaneously (GWP and WMO, 2004c).

3.4.4 Adopt a Best-Mix of Strategies

Flood management strategies should involve a combination of complementary options. A layered strategy, appropriate to given socio-economic and geo-climatic conditions and adaptable to changing conditions, should be adopted. An appropriate combination of structural and non-structural measures must be evaluated, adopted and implemented, recognizing the merits and demerits of both types of measures (GWP and WMO, 2004c).

3.4.5 Adopt Integrated Hazard Management Approaches

Flood management should be integrated into a wider risk management system of 'all hazard' emergency planning and management. Experts from all sectors, involving different disciplines, should be involved in the implementation of disaster management plans. Consistency in approaches to natural hazard management in all relevant national or local plans should be ensured. Early warnings and forecasts, that are key inputs for the reduction of the social and economic impact of all natural hazards, including floods, should be strengthened (GWP and WMO, 2004c).

3.4.6 Adopt Environmental Enhancement

Drainage of the floodplains is a relatively recent phenomenon (EA, 2003). Many of the natural floodplain woodland have been lost due to occupancy, agriculture and other form of land development. Floodplain acts as storage and conveyance of water and sediment during high river flow. It is also home to many flora, fauna and habitats including wildlife. The wetland of the floodplains requires protection.

Rivers also including those in the lowland have been physically modified, usually straightened or deepened, with channels often disconnected from their floodplain. Apart from wet grassland, there are habitats that depend on periodic inundation of the floodplain. Raising water level in the rivers can be regarded as a form of environment enhancement to nature taking into account the requirement of flora, fauna and the habitats in the area.

Changes in land-use in floodplains to allow more frequent flooding and or reduced drainage would potentially provide a range of public and private benefits including flood defence for urban areas, biodiversity enhancement, improved water quality, groundwater recharge and new business opportunities linked to wetland crops or sustainable outdoor leisure and tourism. Stable natural environments do offer some physical features that work for flood mitigation. These include good temporary storage characteristics and providing room for floods to move within natural boundaries.

3.4.7 Introducing National Flood Management Policy

There is a need to produce National Flood Management Policy. The overall aim of this policy is to reduce the risks to people, properties and natural environment from flooding by investing in measures that are technically, economically and environmentally sound and sustainable. It should be noted, however, that most floodplain habitats do not require protection from flooding and indeed benefit from seasonally higher water levels (EA, 2003). Such sites require water level management that allows nature conservation interests to be maintained. This explains the need to design river flood mitigation by not only considerations of the river systems but also the floodplains that could provide an extra conveyance as well as storage area. Also as important considerations to reduce flooding is the ability to attenuate peak outflow as compared to the peak inflow and not merely to design river works to convey water as quickly as possible downstream.

3.5 THE ROLE OF CATCHMENT FLOOD MANAGEMENT PLANS

There is a need to prepare an overall catchment flood management plan (CFMP) for Malaysia and for each of the catchments susceptible to flooding. CFMPs are a tool for assessing the sensitivity of the catchments to flood risks as a result of different scenarios, including development, land use change and climate change (EA, 2003), and additionally, different policy options for flood risks management including storage strategies, need of local protection works, and where appropriate, considering large scale changes in land use or alternative development locations. Identifying environmental impact and enhancement opportunities will be an integral part of this process.

CFMPs will create a much wider picture of needs and viable approaches to flood management for the whole of Malaysia that will help assess potential impacts and possibly drive relevant policy changes at the national level. CFMPs should also influence development policy by clearly identifying effective long-term flood management. Measures within the catchment and steering development away from areas that compromise these should be undertaken.

3.6 SOME ASPECTS OF RIVER FLOOD MANAGEMENT

In river management for flood alleviation, flood can be considered as disasters and to some extent benefits if it can be controlled in the floodplains and within certain river riparian zone, and with rationalizing the flood control systems. In protecting life and property from floods called for Integrated Flood Management (IFM) which integrates land and water within the contexts of Integrated Water Resources Management (IWRM). Basically it is the management of floodplains.

Flood management works in Japan for instance adopt IWRM and MSMA by focusing on storage, retarding basin and using the river channel itself as water storage with wide floodplains and considering the benefits of it to the public at large with walkway, soft landscaping works, golf range, overhead restaurant, training ground for baseball, even storage pond in the floodplains with club house and tennis courts. The floodplains are also used as an open space for people to gather in case of big fire and earthquakes.

Figure 3.3 shows a section of the natural river comprising of the main river channel which is also known as the central channel and the floodplains.

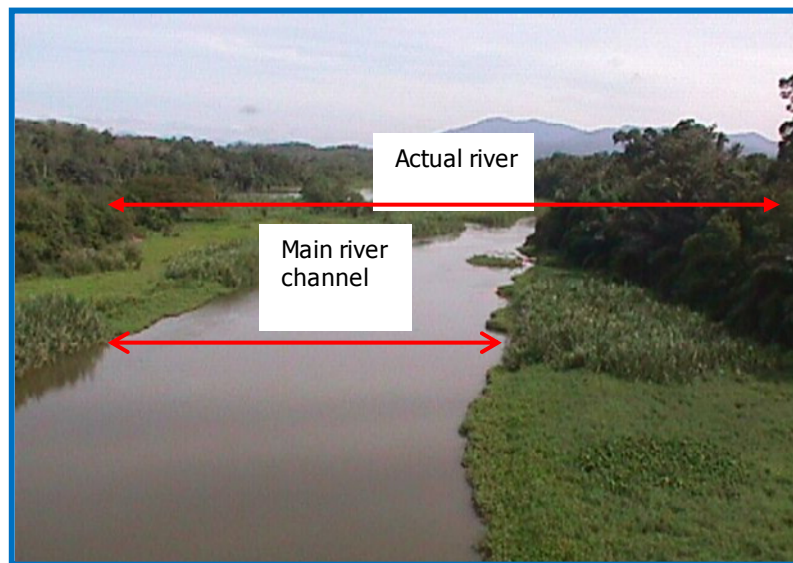


Figure 3.3 Example of Natural River

Examples of an actual river section with reserve are shown in Figure 3.4. Figure 3.5 shows also a river section with reserve and river corridor for not only flood management but also water resources enhancement, conservation and rehabilitation of river biodiversity.

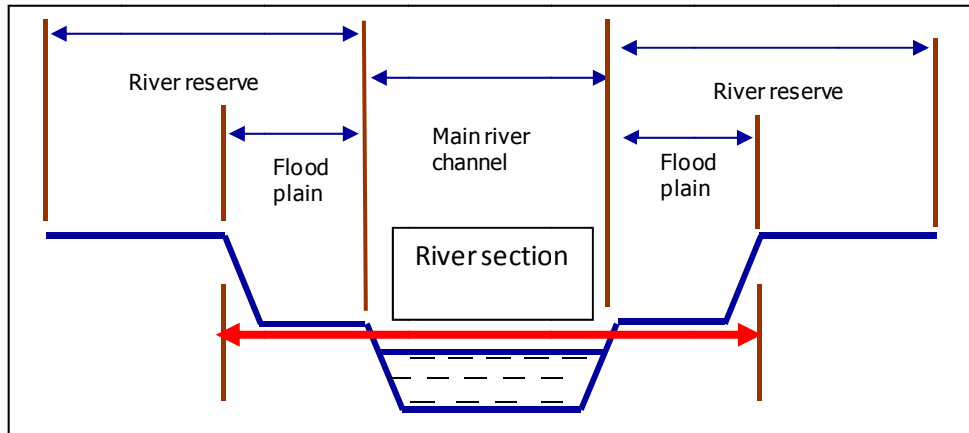


Figure 3.4 River Reserve (Prerequisite Requirement for Flood Mitigation/Management)

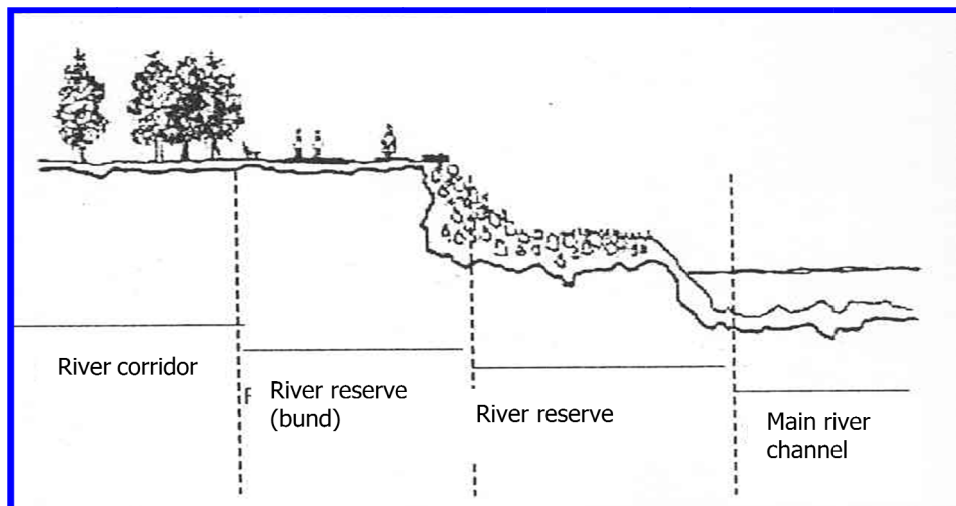


Figure 3.5 River Bank Cross-section

Examples of how in Japan, floodplains are used to contain floodwater and for public utility are shown in Figures 3.6(a) & (b), Figure 3.7 and Figure 3.8.

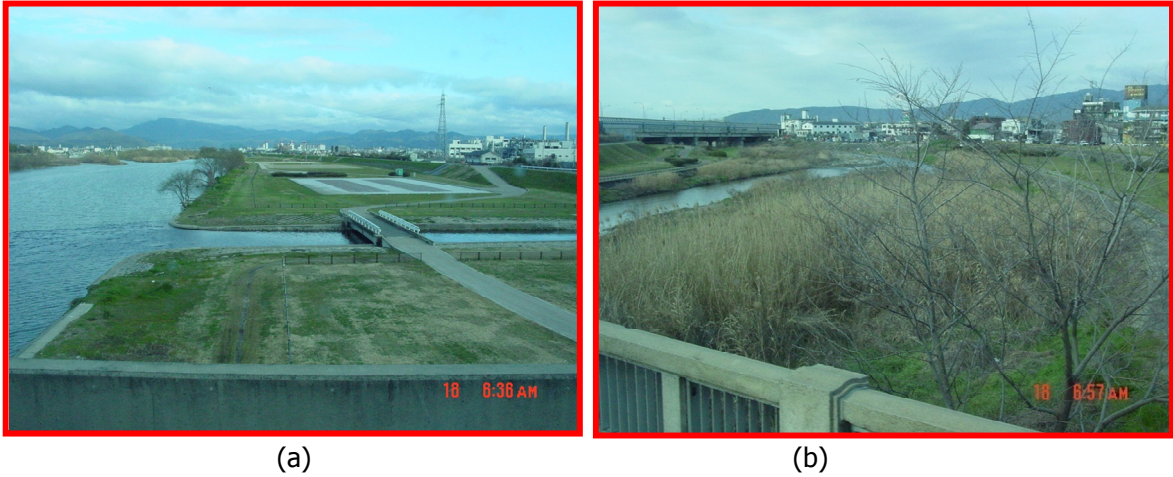


Figure 3.6 River with Wide Floodplain in Japan



Figure 3.7 Floodplain with Public Utility in Japan

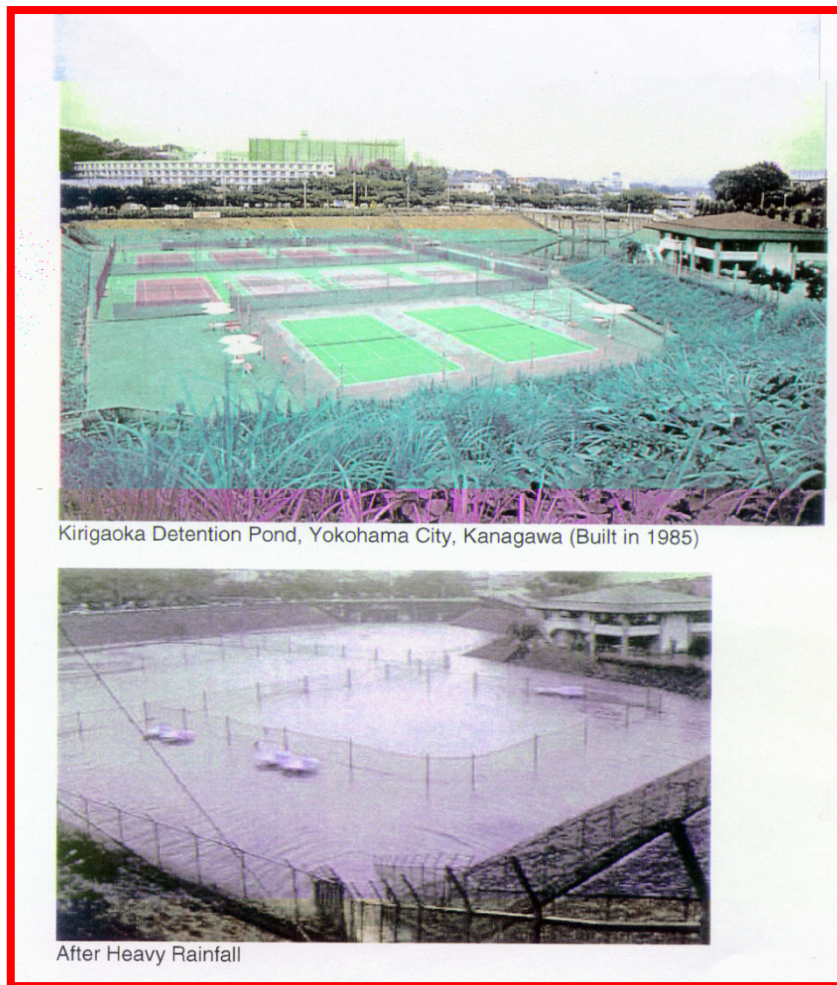


Figure 3.8 Floodplain Use As Club House and Detention Pond During Flood, in Yokohama City, Japan

In United Kingdom there are flood mitigation projects where the river itself is being turned into large storage areas with gated structure facilities (river with detention pond) to solve flooding problems downstream. Trees are planted in the floodplains as a means of water storage during high flows, as a way of adding oxygen and keeping the surrounding area cool. This has also been recommended in MSMA, 2000.

However, planting of trees for flood mitigation projects can also hinder encroachment of development in the river system.

Mechanism of removing solid waste/debris especially during high river flow away from the river channel can also help to reduce flooding downstream.

Rivers should be designed for environmental flow. This is important for flora and fauna as well as the stability of river banks. There are rivers for example in United Kingdom and Japan where the water levels in the central channel (i.e. the main river channel) are kept high all the time. The public should be educated to understand the importance of rivers to our society and how they can contribute to a 'clean, living, and vibrant' river.

Turning rivers and streams into concrete channels to cater for the design flood discharge is not a good approach. In flood mitigation works, the objective is the attenuation of the hydrograph/discharge. The better when more attenuation between the inflow peak discharge and the outflow peak discharge. The concrete-lined will increase the peak outflow discharge during heavy storm. Although it will discharge flood water faster when the rain ceases, it cannot attenuate flow much better than natural channel (see Chapter 11 for the typical natural waterway and composite waterway).

The concrete channel will not be able to be recharge with water during low flows effectively. Moreover, the Manning's resistance coefficient 'n' used in the design can change drastically just after one year in operation due to wear and tear. The channel capacity can also reduce between 15% and 20% (from experience of concrete irrigation channel in Tg. Karang, Selangor) due to the sediment-laden water. The Manning's 'n' is not static. It varies with depth. At high flow (during flood) the margin of difference between concrete channel and earth channel is small compared to low flow conditions.

The use of Manning's 'n' has often been misinterpreted (see Chapter 11 for further explanation), in particular when flow spills over the riverbank into the floodplain (as the normal case during flooding) because in the subject of momentum transfer and transition zone in the floodplain may be significant as 'dead storage'.

River sections should not be designed just to cater for the design return period and a certain rainfall hyetograph for calibration purposes, as we normally do. It should incorporate the climate change such as by taking into consideration of multi-burst rainfall patterns and magnitudes. The history of the multi-burst storms causing floods need be studied. The first storm event though very heavy compared to the rest may not cause any flood to occur. While the effect of the subsequent storms though not heavy as the previous ones, could be catastrophic to the flood events. Experience and research show that peak monsoon may start to occur at the 4th day of the multiple storm events (Roseli, M., 1999).

There is need to consider how the riparian zones (floodplains and river corridor) may be used to reduce floods, or study how forest can function like a retarding basin, or how storage dams can be meaningfully used to retard flows as has been practiced in Japan.

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CHAPTER 4 LEGISLATION AND INSTITUTION

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4 LEGISLATION AND INSTITUTION

4.1 INTRODUCTION

Interestingly, although flood is a frequent event in Malaysia, there is no law specifically to address it and the related issues. However there are many other laws, rules and regulations that are in force and these can be applied directly and indirectly to address flood issues.

The custodian of these laws is not that of one Government department only but designated to many different departments, each with its own responsibilities and functions. Managing floods therefore requires good inter-agency coordination and cooperation. This is not often easy but the Federal and State administrative culture, traditions and practices have evolved such that there is respect and understanding on the need to approach flood problems in an integrated manner.

The DID is the lead Government Department for flood management in the country. It plans and manages flood control systems at the Federal and State levels. Beyond these functions, the integrated flood management approach is achieved through the involvement of all relevant agencies through various administrative mechanisms that allow for consultations and arrangements to address related issues. This facilitates the DID in implementing the Integrated River Basin Management approach within which is the Integrated Flood Management approach.

4.2 CONSTITUTION OF MALAYSIA

The 9th Schedule of the Constitution of Malaysia stipulates the rights/powers/responsibilities of the Federal Government and State Government, contained respectively in the First List (List I) and Second List (List II). The Third List (List III or Concurrent List) however provides for shared responsibility between the Federal Government and State Government that includes flood mitigation (Item 8) under sub-head, *Drainage and Irrigation*.

Item 11 (First List) states the following: *Federal works and power, including (a) Public works for Federal purposes and (b) Water supplies, rivers and canals, except those wholly within one State or regulated by an agreement between all the States concerned; production, distributions by supply of water power.* This is clearly an indication of the Federal Government's responsibility not only to finance public works (taken to include flood mitigation) but also to provide control over water uses such as those required for hydroelectricity.

For control of siltation problems affecting the environment such as reducing river capacity, the Constitution stipulates that preventive measures fall under the State jurisdiction while curing measures fall under the commonly shared responsibility (Concurrent List). Item 6 (Second List) states the following: *State works and water, that is to say – (c) Subject to the Federal List, water (including water supplies, rivers and canals); control of silt; riparian rights.* Similarly for rehabilitation activities, Item 9 (Concurrent List) provides for the *rehabilitation of mining land or land which has suffered soil erosion.* These infer that major rehabilitation works should be carried out by the Federal DID while maintenance by the State/District DID.

The Constitution also stipulates that the State Government should regulate control over siltation problems. Current practice requires all land development projects be scrutinized by DID (State/District) prior to approval by the Local Authority. To speed up submission, One Stop Centre (OSC) (with Secretariat at the Town and Country Planning Department) has been set up at the Local Authority to receive development submissions (including all the Ministries). DID will ensure drainage/silt control is adequately provided in the proposal by the developer. Pertinent documents to be included in the submission are Drainage Layout Plan and Erosion and Sediment Control Plan (ESCP).

Item 9 (Concurrent List) stipulates the Federal Government and State Government are jointly responsible for undertaking rehabilitation works on land with soil erosion problems. Although the Constitution does not define the term “environment” in any of the lists, the Constitution has in fact provided for environmental considerations on sectorial basis (e.g. agriculture) which should be resolved jointly by the Federal Government and State Government. Thus, the State Government has the power to regulate activities that could cause soil or land erosion (Item 6 of State List). On the contrary, the Federal Government may impose conditional requirements to those causing such erosion (Item 9 of Concurrent List), for example, by imposing surcharge for failure to rectify the problem arising thereon.

4.2.1 Federal Legislation

Except for the EQA 1974, all Federal legislations may be adopted by the States in their Enactments if the States so wish, but would need prior endorsement by the State Assembly, except for the EQA 1974, which is applicable to every State without exception. The custodian of the EQA 1974 is the Department of Environment (DOE).

Many of the Acts, briefly described below, came into existence following the mandate of the Ministerial Function Act 1969. The State Government however may use their discretion whether or not to amend the Acts to suit their needs in formulating their own Enactments.

a) National Land Code, 1965

Constitutionally, land is a State matter. The Federal Government through the National Land Council exercises responsibility to ensure the States comply with the Land Code with uniformity in the administration of land matter. Flood mitigation is provided in the Code; for example, water bodies (rivers, drains, or ponds) must be provided with reserves, which should be demarcated in the proposal. If need be, such reserves must be acquired through land acquisition process. The Code also provides for regulation of land occupation by giving license to operate for such activities as river mining. Such permits would require the approval of the Local Authority usually upon technical advice of the DID.

The National Land Code also provides regulations for land conservation such as limiting developments on erosion prone terrains (e.g. unstable hill slopes) to ensure not only the safety of the occupants but also to minimize soil erosion that could pollute rivers and streams or constrict flows in channels leading to the receiving water bodies, thus causing floods that could otherwise be retarded if not avoided.

b) The Water Act, 1920 (Revised 1989)

Several States (namely Negeri Sembilan, Pahang, Perak, Selangor, Malacca, Penang and Federal Territory) have adopted the Water Act, 1920 as the basis for establishing their own water related Enactments. This came about as early as 1999. The State of Selangor is the first State to have gone beyond the Enactment boundary by establishing a water authority called the Selangor Waters Management Authority (LUAS). The Water Act has provisions for river conservancy and flood mitigation such as imposing licensing requirements for water abstraction, effluent discharge, felling of trees and building of structures.

c) The Drainage Works Act, 1954

This Act is applicable throughout the Peninsular Malaysia by way of gazetting designated agricultural drainage schemes. DID has long applied this Act to curb flood problems by constructing, operating and maintaining their drainage and irrigation systems including water related structures. The rates collected are used for maintenance of the systems.

d) The Local Government Act, 1976

This Act provides for the rights of the State Government to administer the Local Government within their area of jurisdiction. Flood mitigation is provided by imposing and collecting the drainage contribution, which is used for maintenance of the drainage facilities (for example, widening/deepening/cleaning of drains). In some States (e.g. Terengganu and Selangor), the DID collects the drainage contribution on behalf of the State Governments.

e) The Street, Drainage and Building Act, 1974

The Act applies throughout the Peninsular Malaysia, requiring the drainage layout of a proposed project be designed and submitted by the Professional Engineer for approval by the Local Authority. The DID is normally consulted to review the proposed project drainage plan prior to approval. The Act also provides for earthworks control which is normally incorporated into Earthworks Bylaws and Uniform Building By-laws (Subsets of the Act) by the Local Authority.

f) Town, Country and Planning Act, 1976

Mitigation of floods is provided in the Act by preventive control. For example, developers are required to demarcate areas for water storage, detention ponds, water bodies or wetlands in their development proposals. Similar conditions apply to the Local Structural Plan or the National Physical Plan. These demarcated areas are meant to maintain the environmental integrity of the developments, thus requiring stringent environmental control during construction as well as during operation.

g) Environmental Quality Act, 1974

The EQA Act applies throughout the nation and is enforced by the DOE. Flood mitigation is addressed in the Act by the requirement that EIA reports shall be submitted prior to project approval. The Local Authority will ensure flood mitigation is adequately provided in the development proposal with appropriate advice from the DID. For environmentally sensitive areas, the DOE is in the process of preparing related guidelines. When ready, the guidelines can be used by the DID for checking on flood control requirements in development project proposals.

h) The Land Conservation Act, 1960

The Act requires that all hilly areas of specific height and terrain conditions be gazetted. Cultivators, for instance, need to apply for permit prior to carrying out any farming activity. Land Office on the advice of DID may impose conditions for silt control on the farms. Alternatively the DID may impose further measures when the farmers lodge application for the renewal of their yearly licenses.

4.2.2 State Legislation

Various States have already enacted various legislations to administer water related issues in their States. Provisions in the Enactments may differ from State to State. For example, the Selangor State has formed their water authority, the Selangor Waters Management Authority (or LUAS) in 1999. LUAS has provisions for flood mitigation as conditional to approval of their projects throughout Selangor as follows:

Clause 41 (3) (h) states "In the exercise of the powers conferred by subsection (1), the Authority may take such measures as it thinks fit and in consultation with the relevant public authority, the mitigation and control of flooding."

Clause 68 (under Flood Defence) states “The Authority may in consultation with the relevant public authority, prescribe such measures as it deems fit for the control and management of floods”.

For the State of Kedah, the formation of the State’s water authority (LUAK) is underway and the enactment on which this is based on is the State of Kedah Water Resources Enactment, 2007.

For Sabah, flood mitigation has been provided in the following Enactments:

- Land Ordinance, 1930;
- Water Resources Enactment, 1998;
- Local Government Ordinance, 1961;
- Town & Country Planning Ordinance, 1950; and
- Conservation of the Environment Enactment, 1996.

For Sarawak, flood mitigation has coverage in the following Enactments:

- Natural Resources & Environment Ordinance, 1958;
- Local Authorities Ordinance, 1996;
- Land Code, 1958; and
- Water Ordinance, 1994.

These Enactments/Ordinances exist to serve the State Government for control of the resources and developments within their States. Generally, it is the DID that will endorse any flood mitigation proposed in the development project.

4.2.3 Local Government Legislation

Earthworks By-laws is one that is related to flood control. It is enforced by the Local Authority. The by-laws may differ in contents from State to State unless reference is made on some common base, for example, a particular Act formulated by the Federal Government. The contents related to flood mitigation in the By-laws are entirely adaptations from the Street, Drainage and Building Act, 1974. The By-laws may be used for checking on the submission of development proposals and sediment regulation compliance during construction of the project by the Local Authority.

As for the development outside the Local Authority’s jurisdiction zone, the developer will need to seek approval from the relevant departments/agencies.

4.3 FEDERAL/STATES/DISTRICT/LOCAL AUTHORITIES

The DID since inception, has played prominent roles in the planning and development of irrigation and drainage systems including flood mitigation in the country. This is based on the mandate provided in the Ministerial Function Act 1969 empowering the Minister of Natural Resources and Environment to lead and formulate the national flood mitigation programs. As is presently practised flood mitigation works should include riverbank landscaping, which serves dual functions, for beautification as well as soil stabilization. Presently, the DID has almost 10,000 personnel (Federal and State staff) located throughout the country and of this total, about 500 are engineers.

The DID’s scope of works for flood mitigation as mandated in the Ministerial Function Act 1969 for the Minister of Natural Resources and Environment covers the following:

- Providing advice to Local Authority on drainage plans submitted by developers
- Carrying out technical studies (e.g. Drainage Masterplan, Flood Mitigation Plan and IRBM Plan)
- Implementing flood mitigation, drainage works, irrigation works and river conservancy;
- Carrying out O&M for river infrastructures;

- Collecting hydrological data, monitoring and information dissemination on floods;
- Preparing guidelines for rivers, drainage system and hydraulic structures; and
- Conducting campaigns to improve public awareness for waterways (rivers and drains).

Following the disastrous flood of 1971, the Government formed the Natural Disaster Relief Committee in 1972 to coordinate flood relief operations at the national, state and district levels. The Committee is headed by the Deputy Prime Minister with Secretariat at the National Security Division of the Prime Minister's Office. The committee comprises various Cabinet Ministers (Finance; Social Welfare, Natural Resources and Environment; Science, Technology and Innovation; Information) and senior Government officials (Chief Secretary, Army, DID, MMD, MACRES, Social Welfare Department, Police Department and Fire and Rescue Department).

The Government also formed the Permanent Flood Control Commission in December 1971. The Commission is now chaired by the Minister of Natural Resources and Environment with DID as its Secretariat.

DID has also published a new urban drainage manual in 2000 called the Urban Stormwater Management Manual (MSMA) that replaced DID's Urban Drainage Planning and Design Procedure No.1 (1975) effective January 2001. The Manual addresses runoff control for both quantity and quality from source. Flood management is encouraged by use of detention/retention ponds and on-site detention (OSD). The Manual also contemplates on non-point source (NPS) pollutions that originate from feed-lots, agriculture lands, oil palms plantations and highway runoff. Water quality control is accomplished by directing runoff into gross pollutant traps, sedimentation ponds or swales. During construction of a project, sediment and erosion control (therefore a flood mitigation effort) is ensured by regulation requiring "Erosion and Sediment Control Plans (ESCP)" to be submitted by the developer prior to project approval.

4.3.1 Federal Level

DID is responsible for giving advice on the distribution of water, of which rivers are the main sources, to ensure there is enough for industrial sectors, domestic use, and the environment. Water resources management in the country is overseen by the National Water Resources Council (NWRC). The Council was formed after the 1997-1998 water crisis. The Council ensures water is properly managed according to the principles agreed among the States. The Council is chaired by the Prime Minister and members comprise all State Chiefs Minister. The DID is Secretariat for the Council.

The formation of the Ministry of Natural Resources and Environment in 2004 signifies the Federal Government's effort for integration in the water management. Now the DID has four major divisions directly involved in various aspects of flood management.

4.3.1.1 Flood Mitigation Division

This is the Division dealing with flood issues. The Division's foremost task is to produce a comprehensive master plan for resolving the national flood problems using structural and non-structural measures including flood defence (e.g. flood risk and flood hazard maps).

4.3.1.2 Urban Drainage Division

This Division focuses on urban drainage issue and provides advisory services on the use of the MSMA guidelines. It is also involved in implementing retrofitting out-of-date urban drainage systems that will incorporate new design standards and philosophy.

4.3.1.3 River and Coastal Divisions

River Division - The Division is to plan and implement river management programs, namely, river conservation and rehabilitation. It also implements public awareness and education campaign on flood management including public participation in river water quality monitoring. The Division collects and stores river data and monitor river reserve gazette. This Division will also undertake IRBM studies for some 189 river basins in the country.

Coastal Division - The Division is to plan and implement coastal management programs, namely erosion control, river mouth improvement and beach restoration based on the concept of Integrated Shoreline Management Plan (ISMP). On the recommendation of the National Coastal Erosion Study in 1986 (*Kajian Hakisan Pantai Kebangsaan Tahun 1986*), the Technical Coastal Engineering Centre was formed in DID whose duty is to implement the coastal erosion control programs throughout the country. A National Coastal Erosion Committee (*Jawatankuasa Hakisan Pantai Negara*) was formed and is responsible to review and approve development plans along the coastal zone.

4.3.1.4 Hydrology and Water Resources Division

The Division collects and disseminates hydrological data, in particular rainfall records, river water levels, river flows, water quality and water resources assessment. Such data are to be used by other Divisions or consultants for the design of flood mitigation structures. The Division also conducts flood warning and forecasting exercises for major rivers and towns.

4.3.2 State Level

Each State Government has its own DID offices with engineers seconded from the Federal DID establishment. The functions of the State DID are similar to that of the Federal DID. The major difference from the Federal is that the State DID is more an operational organization. It implements and manages both Federal and State funded projects. It also provides the State Government with advice on water resources matters.

4.3.3 District Level

Within each State are the District DID offices. These are front-liners and directly involved with the Local Authority and the public.

4.3.4 DID Project Office Level

These are project-specific offices for Federally funded large scale projects. The staffs are deployed from the Federal DID. Coordination with the State Government is through the State DID office. Upon completion, the projects are commissioned and handed over to the State DID for operations and maintenance.

4.3.5 One Stop Centre (OSC)

The One-Stop Agency (OSA) initiated the 1980's is to expedite the approval of land development applications. Since such approval also involves Federal agencies, the OSA concept was changed into that of One-Stop Centre (OSC) that began in 2007 in Peninsular Malaysia.

At the State and Local Council levels, the OSC team normally comprises officers from all the relevant departments involved in the approval process. DID is one of those. Where necessary, the DID representative may obtain technical support from the Federal DID.

The Ministry of Housing and Local Government has made amendments to the SDBA (ACT 133), allowing the Professionals (Engineers and Architects) to participate in the development process by taking full responsibility for the safety of physical works and functionality of the mitigation measures installed on site. This responsibility carries on until the issuance of CFO (Certificate of Fitness for Occupancy). Clause in Section 70A of SDBA specifies that earthwork plans (including ESCP) should be submitted to the OSC for approval and that the maintenance of earthworks extenuating facilities should be performed regularly. Additionally, section 71 emphasizes that in the event of failure of the earthworks retaining facility due to mud flow or landslide, hefty fines could be imposed to the responsible party (developer, contractor, designer and the submitting person).

4.4 OTHER RELEVANT AGENCIES

4.4.1 Local Authorities (Local Governments)

With respect to flood mitigation, Local Authority functions as follows:

- Approves applications on drainage plans from developers;
- Inspects construction works by developers on components (including drainage system) to be taken over by Local Authority;
- Approves licensing of commercial and trade activities;
- Regulates earthworks during construction to avoid excessive erosion and sedimentation;
- Regulates construction works and other activities to ensure general cleanliness and prevent threat to health;
- Implements environment awareness programs and environment improvement projects;
- Regulates solid waste management carried out by service providers (e.g. Alam Flora) and collection & disposal of solid waste for areas not covered by the service providers;
- Maintains urban drainage facilities (tertiary drains);
- Develops and maintains riparian areas; and
- Collects property assessment taxes.

All together there are one hundred and one (101) Local Authorities in the Peninsular Malaysia comprising five (5) City Councils, twenty three (23) Town Councils and sixty nine (69) District Councils. Other local authorities are specially created to suit the national needs (e.g. Perbadanan Putrajaya for Federal Territory of Putrajaya, Lembaga Kemajuan Johor Tenggara (KEJORA) and Lembaga Kemajuan Terengganu Tengah (KETENGAH).

The recently established Perbadanan Putrajaya has initiated new development plans to upgrade Putrajaya to be a modern Administrative Capital of Malaysia. The introduction of Putrajaya lakes and wetlands has brought about the development of local expertise and experience in the particular expertise not previously available in the country.

All the City and Town Councils usually employ engineers for their technical departments. However, most of the District Councils do not employ engineers, although certain councils have little choice except to resort to merely sub-professionals (technical assistants or technicians) rather than engineers.

The Government has also launched regional development packages (e.g. ECER, IRDA) to enhance the economic growth and equitable wealth distribution within the country.

4.4.2 The Ministry of Housing and Local Government

The functions of the Ministry are as follows:

- Planning and implementing policies and programs in line with the national development policy;
- Coordinating the provision of adequate housing for all citizens especially those of lower income group;
- Ensuring that local governments are provided with adequate resources to establish communities that are modern and attractive;
- Providing efficient and effective enforcement and control services for the safety of lives and properties; and
- Strengthening and implementing planning systems for the physical, economic, and environmental aspects of towns and country based on the Town and Country Planning Act.

4.4.3 Department of Local Government

The functions of the department are as follows:

- Planning physical development programs for local governments;
- Planning and implementing federal government grants to Local Authorities;
- Assisting Local Authorities in property assessment, preparation of accounts and strengthen financial performance;
- Providing advisory services to state governments/Local Authorities on local government matters;
- Implementing policies on establishment, standardization, spatial expansion, reforms and amendments to laws and regulations;
- Acting as secretariat to National Council for Local Governments (MNKT) and scheduled meetings;
- Planning, coordinating and supervising the implementation of projects for development, drainage, roads, solid waste management for Local Authorities;
- Reviewing relevant laws on technical aspects to produce proposal for amendment to revise existing provisions;
- Preparing policies and guidelines relating to safety and stability of buildings and the environmental framework (including environmental impact assessment/EIA);
- Planning and managing studies and research relating to construction industries and their impact to the environment;
- Acting as expert referral on safety and stability of buildings and existing environmental framework or those altered due to development;
- Planning cleanliness and beautification program for Local Authorities;
- Coordinating the ICT development for Local Authorities; and
- Planning the development of new villages and infrastructure and socio-economic facilities.

4.4.4 Department of Town and Country Planning (TCPD)

AS with most Departments, the TCPD are represented Federal, State and local levels.

a) Federal Level

TCPD at the federal level translates national policies into town planning strategies, establishes systems and methodologies for town planning, and assists government agencies in their planning process.

The departmental duties include:

- Encouraging a comprehensive, effective and efficient planning system through planning laws, methodologies, studies, standards and procedures;
- Translating national socio-economic policies into physical and spatial forms according to the land use formulas and policies, and settlement programs;
- Providing management services to ensure efficiency in planning;
- Providing training and human resource planning for town planning services;
- Assisting government agencies in the preparation of Development Plans;
- Preparing, updating and publishing statistics, bulletins and methods relevant to town and country planning; and
- Providing country planning services to the Ministry of Rural Development and Department of Aboriginal Affairs, particularly on growth centres to be developed as competitive settlements, and in the preparation of settlement plans.

b) State Level

At the state level, TCPD plays an advisory role to the State Government in town planning as follows:

- Acting as the main advisor to the state government on all planning aspects, including land use and development;
- Advising the state governments on land use control and building policies;
- Advising the local authorities on land use control and building policies;
- Determining the general use and zoning of land, and assists in the preparation of town plans;
- Conducting relevant studies and research on land use and development; and
- Functioning as the Secretary for the State Planning Committee formed under the TCP Act 1976 (Act 172).

c) Local Level

At the local level, TCPD gives assistance in the development projects by monitoring land use requirements are met within the municipal boundary. The departmental duties include:

- Planning, coordinating and controlling the use and development of land and buildings in the Local Authority area; and
- Carrying out, assisting and promoting the collection, updating and production of statistics, bulletins, monographs and other publications relevant to town and country planning and its methodology.

4.4.5 Department of Environment (DOE)

DOE is a Federal Department and has branch offices in every State and in some Districts within the State. The duties of the DOE include:

- Licensing, monitoring and controlling IWK and the bigger industries on discharge of sewage and industrial effluent;
- Licensing, monitoring and controlling activities relating to scheduled waste management;
- Controlling EIA for prescribed activities;
- Providing technical assistance, prepare regulations and guidelines;
- Water quality data collection (privatized to ASMA since 1995);
- Conducting studies to improve river water quality (conducted by River Section); and
- Carrying out environment awareness programs.

4.4.6 Integrated River Basin Management Authorities

River Basin Organizations for Integrated River Basin Management is still limited in Malaysia. So far the Selangor State is the only state that has established an RBO type of organization through the enactment of the Selangor Waters Management Authority (LUAS).

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- [3] Constitution of Malaysia. Percetakan Nasional Malaysia Berhad.
- [4] Department of Irrigation and Drainage Malaysia, 2007. *Preparation of National Strategic Stormwater Management Plan. Final Report.*
- [5] Laws of Malaysia, 2006. The Commissioner of Law Revision, Malaysia under the authority of The Revision of Laws Act 1968 collaboration with Percetakan Nasional Malaysia Berhad.

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APPENDIX 4.A LIST OF LAWS

Table 4.1 List of Laws

No.	Name	Owner	Regulator	Relevant Clause	Impact
1	Constitution	Malaysia	Parliament	<ul style="list-style-type: none"> Federal List, Item 11 - <i>Federal works and power, including (a) Public works for federal purposes and (b) Water supplies, rivers and canals, except those wholly within one State or regulated by an agreement between all the States concerned; production, distributions by supply of water power.</i> Concurrent List, Item 8 - <i>Drainage and irrigation.</i> Concurrent list, Item 9 - <i>Rehabilitation of mining land and land which has suffered soil erosion.</i> State List, Item 6 - <i>State works and water, that is to say (c) Subject to the Federal List, water (including water supplies, rivers and canals); control of silt; riparian rights.</i> 	<ul style="list-style-type: none"> Federal funding to reduce flood events and flood damages. Funding shared by Federal and State Governments. Only covers water bodies in gazetted drainage and irrigation areas for both development and maintenance programs. Federal and State collectively review various laws to contain erosion problems caused by land opening. Less sedimentation shall flow into water bodies; thus, less flood and mud flood events, and damages. State Government gives permits and enforces compliances to land opening operators (developers, miners, farmers and etc), water extraction operators, sets, gazettes river reserve and river maintenance i.e. desilting works

Table 4.1 List of Laws (continued)

No.	Name	Owner	Regulator	Relevant Clause	Impact
2	National Land Code, 1965 (Act 56)	Federal Government	State Government Director of Lands and Mines (PTG)	<ul style="list-style-type: none"> Section 13 defines water bodies covered by this Code. Section 62 allows river reserve to be gazetted. 	<ul style="list-style-type: none"> Covers natural and artificial water bodies inclusive of all natural rivers, brooks, streams, canals and drains. 50 meter left and right of river banks shall be declared as rivers (gazette).
3	Water Act, 1920 (Act 418)	Federal Government		<ul style="list-style-type: none"> Section 2 defines rivers Section 4 compulsory restoration of river banks Section 5 prohibits any acts along rivers Section 7 prohibits any water diversion works Section 14 restricts construction of structures Section 15: Penalties and sanctions for prosecution for Section 4, 5 and 7 	<ul style="list-style-type: none"> Covers natural water bodies inclusive of its tributaries. Also covers canals if gazetted. Any works create interference on the river banks shall restore back to its pre-disturbed state. Applicants must have permit to do any acts i.e. fell any tree, obstruct or interfere or build structures applicants must get permit to extract or build structures for water diversion purposes Prohibits construction of walls and buildings within 50 feet from both banks or flood channels Section 4 – fines RM500. Continue offence – RM10 per day Section 5 or 7 – fines RM1000

Table 4.1 List of Laws (continued)

No.	Name	Owner	Regulator	Relevant Clause	Impact
4	Drainage Works Act, 1954 (Act 354)	Federal Government	State Government • Department of Irrigation and Drainage (DID)	<ul style="list-style-type: none"> Section 2 defines drainage area and drainage works Section 3: Declaration of drainage area Section 4: Appointment of Drainage Board Section 7: Imposition of drainage rate Section 11: Interference on drainage works Section 12: Illegal drain construction Section 13: Illegal use of vehicles and boats Section 18: Power to compound 	<ul style="list-style-type: none"> Demarcation of drainage area through a declaration Notification through a gazette DID as secretariat Notification through a gazette for annual rate Section 11 – fines RM500; jail 6 months or both. Offence through 14 days written notice Section 12 – fines RM500; jail 6 months or both Section 13(6) – fines RM200; jail 3 months or both Section 18 – compound RM75
5	Local Government Act, 1976 (Act 171)	Federal Government	State Government • Local Authority	<ul style="list-style-type: none"> Section 69: Committing nuisance in streams Section 70: Pollution of streams with trade refuse Section 132: Drainage rate 	<ul style="list-style-type: none"> Section 69 – fines RM2, 000; jail 1 year or both. Continue offence RM500 per day Section 70 – fines RM5, 000; jail 2 years or both. Continue offence RM500 per day Mitigation works required to cater extra discharge from new developments shall be taken care through drainage contributions
6	Street, Drainage and Building Act, 1974 (Act 133)	Federal Government	State Government • Local Authority	<ul style="list-style-type: none"> Section 70A: Earthworks Section 70A(17) may formulate bylaw i.e. Earthwork By-Laws for submission of Earthwork Plans Section 71: Penalty for failure of earthworks (enforcement) 	<ul style="list-style-type: none"> Submission of Drainage Layout Plans and ESC Plans. Section 70A (9) – fines RM50, 000; jail 5 years. Continue offence RM 500 per day Section 70A (17) (d) – fines RM2, 000. Continue offence RM100 per day Section 71 – fines RM500,000; jail 10 years or both

Table 4.1 List of Laws (continued)

No.	Name	Owner	Regulator	Relevant Clause	Impact
7	Town, Country and Planning Act, 1976 (Act 172)	Federal Government	<ul style="list-style-type: none"> State Government Local Authority 	<ul style="list-style-type: none"> Section 18: Land usage Section 19 prohibits development without planning permission Section 20 prohibits development contrary to planning permission Section 25: Revocation and modification of planning permission and approval of building plans Section 26: Offences to unauthorized developments for Section 18 Section 27(6): Enforcement for Section 19 Section 27(9): Enforcement for Section 19 Section 28(6): Enforcement for Section 20 Section 28(9): Enforcement for Section 20 Section 29(4): Enforcement for Section 25 Section 29(6): Enforcement for Section 25 Section 30: Requisition notice 	<ul style="list-style-type: none"> Any development should conform to local Plan Exception for Local Authorities Project proponents must follow planning permission Local Authority has the right to revoke and modify approved planning permissions Section 18 – fines RM500; jail 2 years or both. Continue offence – fines RM5000 per day Section 19 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day Section 19 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day Section 20 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day Section 20 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day Section 20 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day Section 20 – fines RM100, 000; jail 6 months or both. Continue offence – fines RM5000 per day

Table 4.1 List of Laws (continued)

No.	Name	Owner	Regulator	Relevant Clause	Impact
8	Environmental Quality Act, 1974 (Act 127)	Federal Government	Federal Government • Department of Environment (DOE)	<ul style="list-style-type: none"> • Section 16: Guilty of license holder • Section 18: Guilty of prescribed premises • Section 25 restricts pollution on inland waters • Section 31: Power to instruct repair • Section 33: Power to prohibit or control licensed persons from discharging • Section 34A: EIA Report • Section 34B prohibits against depositing scheduled waste • Section 45: Compound 	<ul style="list-style-type: none"> • Section 16(2) – fines RM25, 000; jail 2 years or both. Continue offence RM1000 • Section 18(3) – fines RM50, 000; jail 2 years or both. Continue offence RM1000 • Section 25(3) – fines RM100, 000; jail 5 years or both. Continue offence RM1000 • Section 31(3) – RM25,000; jail 2 years or both • Section 33(2) – fines RM50, 000; jail 5 years or both. Continue offence RM1000 • Section 34A – fines RM100, 000; jail 5 years or both. Continue offence RM1000 • Section 34B – fines RM500,000; jail 5 years or both • Section 45 – compounds not exceeding RM2000
9	Land Conservation Act, 1960 (Act 385)	Federal Government	State Government • PTG • Land Office	<ul style="list-style-type: none"> • Section 3: declaration of hill lands • Section 5 prohibits farming of short term crop without permit • Section 18: Penalty • Section 19: Maintenance work 	<ul style="list-style-type: none"> • Notification through a gazette • Allows control through annual permit. DID can impose ESCP for short term crop activities • Fines RM5,000; jail 6 months • Land Office specifies types of mitigation works should be complied by land owners to rectify problems through advice of DID

APPENDIX 4B LIST OF AGENCIES

Table 4.2 List of Agencies

No.	Agency	Function
1	Ministry of Natural Resources and Environment (NRE)	<ul style="list-style-type: none"> • Secretariat for National Water Resources Council • Secretariat for National Land Council • Secretariat for National Forestry Council • Secretariat for Cabinet Committee for Highlands and Islands Development • Conduct study for National Water Resources Policy
2	DID	<ul style="list-style-type: none"> • Secretariat for Permanent Flood Control Commission • Flood mitigation study, design and mitigation works • Urban drainage study, design and local flooding mitigation works • IRBM study • Rivers/river mouths, regional ponds and main drains maintenance • Flood levees/bunds maintenance • Flood pumps maintenance • Flood barrages maintenance • Flood dams maintenance • Permanent Technical Advisor for flood mitigation, rivers, urban drainage, water extraction and sand mining works at Federal, State and Local Governments • Technical Advisor for One Stop Centre (OSC) i.e. Drainage Layout Plans and ESC Plans • Hydrology data collection, monitoring and information dissemination on floods • Prepare guidelines for rivers and drainage system • Implement campaign to improve public awareness on rivers, floods and etc
3	Local Authorities	<ul style="list-style-type: none"> • Urban drainage works for tertiary drains • Maintenance of tertiary drains including rubbish collection • Permits for tertiary drains diversions and conversions • Approvals for Drainage Layout Plans and ESC Plans • Enforcement for construction works
4	TCPD	<ul style="list-style-type: none"> • Secretariat for National Physical Council • Secretariat for State Planning Committee • Secretariat for One Stop Centre • Advisor for State Governments and local Authorities on planning, land use control and building policies • Conduct studies for Local and Structure Plans • Conduct research on land use and development
5	DOE	<ul style="list-style-type: none"> • Give license, monitor and control of IWK and the bigger industries on discharge of sewage and industrial effluent • Give permits, monitoring and controlling activities relating to scheduled waste management • Secretariat for EIA on 26 numbers of prescribed activities • Providing technical assistance, prepare regulations and guidelines • Water quality data collection (privatized to ASMA since 1995); • Conducting studies to improve river water quality (conducted by River Division until recently merged with Marine Division to become Water Division)

Table 4.2 List of Agencies (continued)

No.	Agency	Function
6	LUAS/River Authorities	<ul style="list-style-type: none"> • Initiate work on: <ul style="list-style-type: none"> ○ Planning – preparation of ICM/IRBM Plans ○ Implement the ICM Plan as approved by the Authority ○ Prepare regulations and guidelines to establish uniform/common standards and practices among agencies ○ Prepare map to delineate responsibilities between LA and SWMA/DID over urban drainage ○ Cooperative agreement with related agencies to establish a framework for partnership ○ Integrated MIS and DSS facilities to disseminate data to related agencies for integrated management especially on O&M ○ The establishment of the statutory Catchment Management Committee to determine policies, programs and action plans related to the implementation of the ICMP. • Impose and control implementation of EIA for non-prescribed activities • Regulate in-stream resource alteration activities (other than water abstraction) • Provide comment/advice to TCPD in preparation of structure and local plans especially on flood mitigation measures, river reserves, corridors and flood plains and retention of forests. • Provide advice and assistance to the District and Land Offices on matters pertaining to land development planning approval, land alienation, amalgamation, subdivision and land use conversion

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CHAPTER 5 DATA COLLECTION

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5 DATA COLLECTION

5.1 INTRODUCTION

Data and information collection is one of the most important activities in every aspect of planning, design and management of flood mitigation system. It is the basis of all decisions made. Data collection is the process of collecting, verifying and selecting information for analyses and used subsequently in various steps of decision making. The quality of data itself must be checked for accuracy, validity and authenticity. Some data and information require them to be obtained from authorised or institutionally recognised sources. For example, the accepted source of data and information on rainfall in Malaysia is only from the Hydrology and Water Resources Division of the Department of Irrigation and Drainage and the Malaysian Meteorological Services Department.

5.2 THE NEED FOR DATA

Data are collected for a purpose. This purpose must be carefully defined to ensure relevance, necessity and adequacy of data. Flood management data for analysis is summarized in Table 5.1.

Table 5.1 Data and Analysis

Type of Data	Purpose (Type of Analysis)
a) Hydrological Data - Rainfall - Streamflow / Discharge - River stage	- Hydrology analysis, IDF curve, hydrological modelling and hydraulic modelling. - Hydrology analysis (hydrograph), rating curve, hydrological modelling and hydraulic modelling. - Hydraulic analysis, rating curve, flood map and hydraulic modelling.
b) Hydraulic Data - Sediment data - Tidal data	- Hydraulic analysis and hydraulic modelling. - Hydraulic analysis and hydraulic modelling.
c) River Characteristics - Cross-section and Longitudinal Section - River Geometry - River Structure	- Hydraulic analysis, hydraulic modelling and detailed design. - Hydraulic modelling. - Hydraulic analysis, flood map, detailed design and hydraulic model.
d) Maps & Plans - Topographic maps - Structural plan & drainage layout - Local development plan - Master development plan - Landuse map (existing & future) - Soil map - Geology map - Contour map - Site survey plan - Cadastral plan/ Sheet	- Hydrology analysis, hydraulic analysis and flood map. - Hydraulic analysis and flood map. - Hydraulic analysis, flood map and detailed design. - Flood map, detailed design and hydraulic analysis. - Hydrology analysis, hydraulic analysis, flood map and hydrological modelling. - Hydrology analysis, sedimentation and erosion analysis. - Detailed design. - Flood map and hydraulic modelling, hydrology analysis - Hydraulic analysis, flood map, hydraulic modelling and detailed design. - Hydraulic analysis and flood map, detail design
e) River Section & Corridor Survey - River section - Corridor survey	- Hydraulic analysis and hydraulic modelling. - Hydraulic analysis and flood map.
f) Satellites & Images - Images (Aerial photograph) - Digital Earth Model (DEM) & Digital Terrain Model (DTM) - Satellite imagery (Earth Mapping)	- Flood map. - Hydraulic analysis and flood map. - Flood map.
g) Vulnerability Data - Socio-economy data - Physical Data	- Flood damage assessment and ERP. - Flood damage assessment.
h) Data for Previous Flood Events & Related Studies - Flood prone area - Flood level - Extend of flooding - Flood depth - Flood damage - Flood history - Documented report - Oral/communication/interview	- Built-up platform level and flood map. - Hydraulic analysis, flood map and hydraulic modelling. - Hydraulic analysis and flood map. - Hydraulic analysis and flood map. - Hydraulic analysis and flood map. - Hydraulic analysis and flood map. - Hydrology analysis, hydraulic analysis, flood map, flood damage assessment and detailed design. - Hydrology analysis, hydraulic analysis, flood map, ERP and flood damage assessment.
i) Flood Properties	- Flood risk and detailed design.
j) Soil Investigation	- Detailed design.
k) Catchments Characteristics	- Hydrology analysis, hydraulic analysis, hydrological modelling and hydraulic modelling.
l) Data for Operation and Maintenance	- As Built Plan - Standard Operation and Maintenance Procedure

Hydrological analysis is one of the basic steps in flood system planning and design. It is to determine the frequency and magnitude of floods affecting a particular area (development project, watershed, river system). Computer modelling can predict flood impacts due to changes in rainfall, runoff, land use and obstruction to flow. Physical modelling is used if necessary to complement computer models or if mathematical equations are deemed inadequate for the purpose. Rainfall-runoff models can estimate runoff discharge and can be compared with empirical formulae to ensure flood hydrographs (flow over time) can be used for design of the mitigating measures.

Hydraulic analysis involves determining flow, water level, and velocity in rivers due to obstruction to flow, and unmanaged land use and runoff under normal conditions and during flood events.

5.3 HYDROLOGICAL DATA

Hydrological data are records of natural phenomena (rainfall, stream flow and discharge). The data are used for design of flood mitigating measures, flood forecasting, hydrological modelling, real-time monitoring and flood risk mapping. Hydrological data take years to be established as reliable database.

5.3.1 Rainfall Data

Rainfall data can be acquired from the DID rainfall stations network managed by the Hydrology and Water Resources Division, DID [<http://www.water.gov.my>] and Malaysia Meteorological Department, MMD [<http://www.kjc.gov.my>].

Rainfall data can be measured by the minute, hourly, daily, monthly or yearly basis. Continuous rainfall is best recorded on daily basis. One approach to check rainfall records from rain gauges is by using homogeneity double mass curve analysis.

Rainfall data are used for the analysis of design storm and model calibration. Area reduction for data collection will provide realistic rainfall volume. Rainfall data are also used as input to rainfall-runoff models to estimate flow hydrographs in hydrodynamic modelling.

Figure 5.1 and Figure 5.2 illustrate respectively the daily and monthly rainfall distributions at the DID Johor Bahru Station No 1437116. Table 5.2 and Figure 5.3 show the average and maximum monthly rainfalls at the Kemaman DID Station (January 1970 till December 2000).

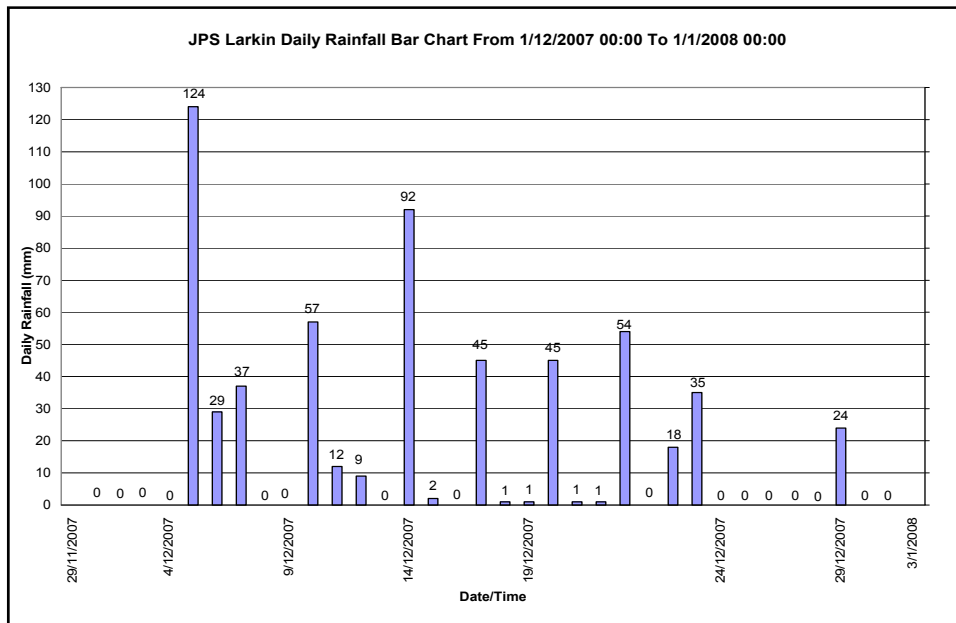


Figure 5.1 Daily Rainfall Distribution at Johor Bahru (Johor Bahru DID Station # 1437116)

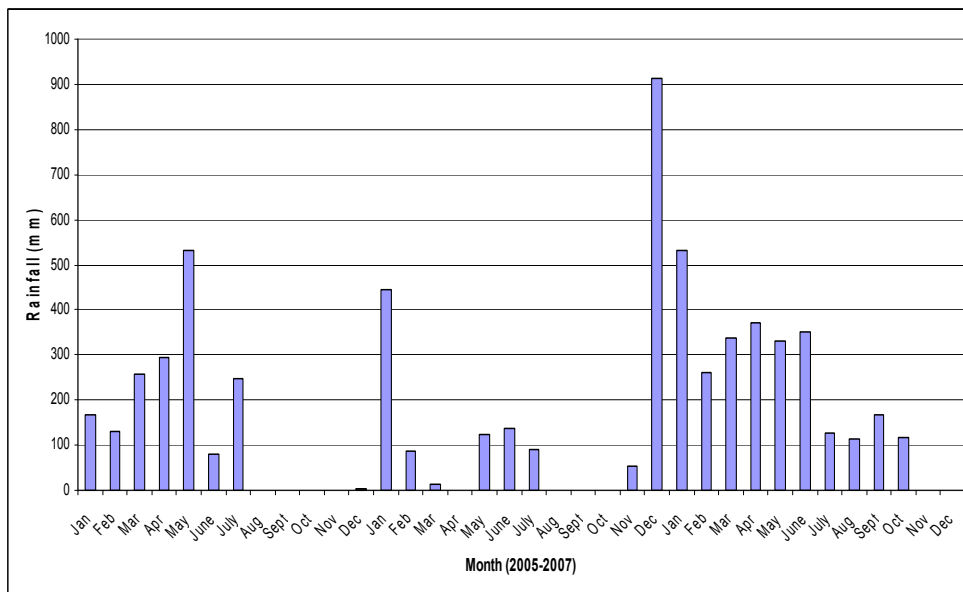


Figure 5.2 Monthly Rainfall Distributions at the Johor Bahru DID Station

Table 5.2 Monthly Rainfalls at Kemaman DID Station # 4234109

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	0	0	0	0	0	0	145	132	200	391	308	865
1971	572	211	306	11	102	143	108	219	175	339	0	891
1972	50	64	56	0	29	53	0	64	0	66	244	0
1973	0	62	0	0	0	65	145	106	153	128	0	0
1974	0	0	0	222	90	490	210	509	118	391	503	472
1975	929	291	72	304	337	178	154	48	186	254	889	544
1976	20	4	39	65	196	123	170	128	345	0	0	0
1977	0	0	0	0	0	0	0	0	269	0	0	343
1978	155	75	58	6	75	408	124	131	267	352	356	241
1979	135	78	33	0	93	139	148	218	153	248	631	256
1980	192	46	100	132	177	154	152	143	116	254	227	622
1981	62	147	87	247	186	24	174	58	246	138	459	388
1982	43	7	118	207	152	184	135	300	41	162	150	689
1983	116	25	39	1	138	84	55	125	160	212	312	2339
1984	414	384	135	229	0	00	82	133	242	230	308	1090
1985	82	299	380	154	237	147	165	41	250	159	188	544
1986	100	2	84	52	67	128	114	93	132	0	0	0
1987	0	4	90	105	66	186	141	30	381	60	201	903
1988	78	151	315	166	144	187	255	116	0	181	1318	188
1989	220	37	282	115	268	204	56	232	0	0	480	250
1990	321	80	76	209	139	119	115	165	267	162	544	210
1991	606	3	0	154	52	177	83	183	215	94	1089	1246
1992	0	20	54	27	57	112	129	356	2	0	595	911
1993	436	89	305	132	128	127	128	289	166	252	717	484
1994	134	48	454	24	0	0	29	225	282	77	1326	0
1995	0	0	0	107	139	180	164	83	293	146	0	556
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	218	69	140	81	206	113	51	278	0
1998	24	4	105	6	188	216	329	174	0	301	317	836
1999	212	338	95	188	0	0	99	183	212	245	196	125
2000	0	239	0	235	165	132	35	217	141	410	650	267
mean	233.4	108.3	149.2	132.6	137.3	164.0	133.0	169.2	197.1	212.1	511.9	635.8
max	929	384	454	304	337	490	329	509	381	410	1326	2339



Note: Longterm of no rainfall could be due faulty rainfall

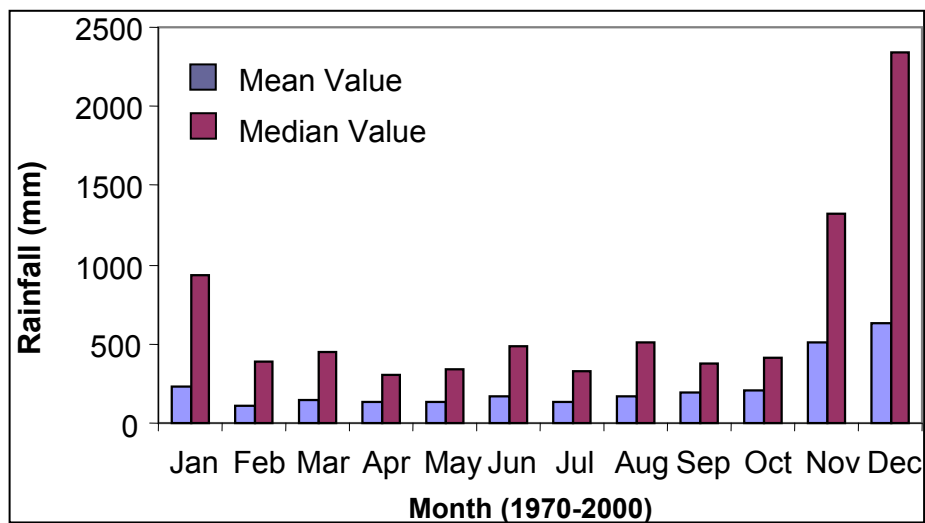


Figure 5.3 Average and Maximum Monthly Rainfalls at Kemaman DID Station # 4234109

Design storm (rainfall intensity) is a function of rainfall duration and frequency. These parameters are used to produce IDF curve. The design storm is then converted to a discharge. These are prerequisites to rainfall-runoff modelling. The IDF curve can be used to estimate the frequency of an observed rainfall during a future flood event.

Methods for developing IDF curves are given in MSMA (2000). The development procedure requires data series, distribution identification, estimation of distribution parameters, selection of distribution and quartile estimation of chosen ARIs.

5.3.2 River Stage and Discharge

5.3.2.1 River Stage

The hydrology, hydraulic analyses and design generally require water level observations at regular intervals (hourly, daily, monthly or annually) at selected sections of the river system.

Rating curve for a river is a plot of river discharge against water level (stage) produced from curve fitting. The curve is useful to obtain river discharge values for a particular observed (measured) water level. Such curves are derived assuming steady, uniform flows in the river. [This topic is discussed further in Chapter 4 (Volume 4 - Hydrology and Water Resources)].

Figure 5.4 shows a typical river stage vs. time and Figure 5.5 shows water levels along a cross-section of a river at Ladang Victoria, Sg. Muda.

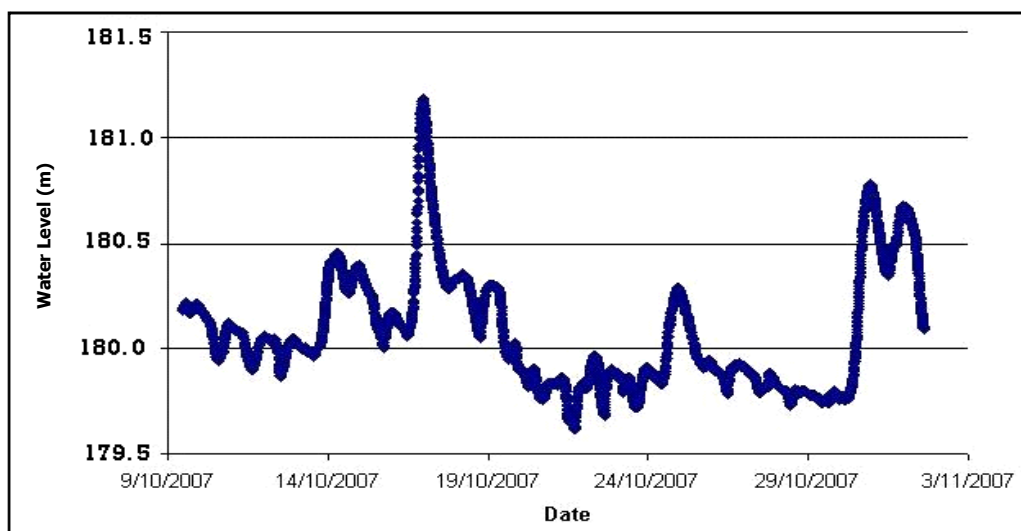


Figure 5.4 Typical River Stage

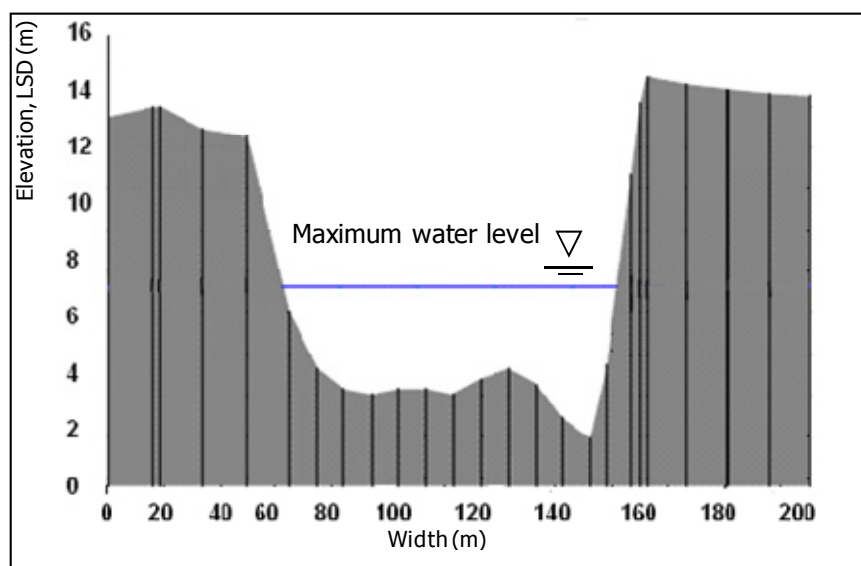


Figure 5.5 Water Levels at selected cross-section of a River in Ladang Victoria, Sg. Muda, 2006

5.3.2.2 Discharge

Discharge data is used for flood analysis, modelling, and model calibration. A particular rainfall-runoff relationship will produce a particular hydrograph pattern for a given drainage area. Hydrograph represents flow variation over time. Figure 5.6 shows a typical hydrograph of runoff. The area under the curve, discharge \times time, equals volume.

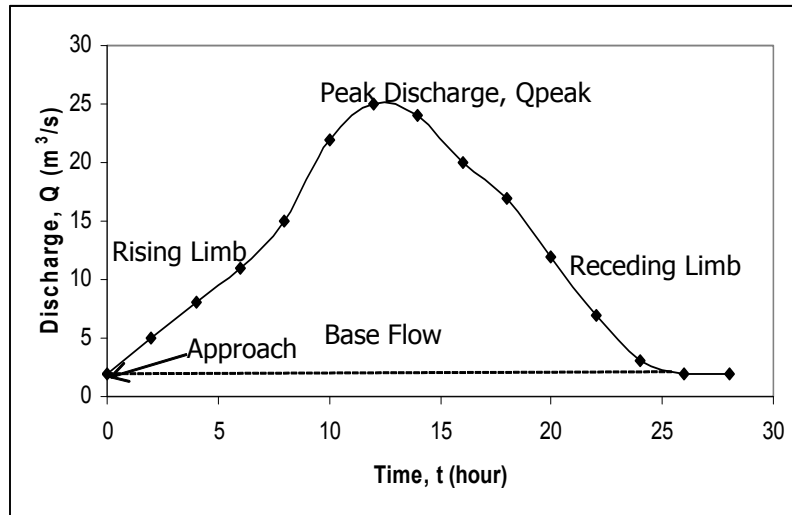


Figure 5.6 Typical Hydrograph

Flood peak data for flood mitigation design are derived from the annual maximum flow series and peaks-over-threshold (POT) series obtained from several stations. Flood peaks are also published as flows. Flood events records give hourly rainfall and river flow data for a specific flood. River flow data may be obtained from DID.

Flood hydrograph gives estimate of flood flow as input to the hydraulic model used. Predicted (simulated) data (e.g. water level) obtained from the model are checked against observed (measured) data.

5.3.3 Data for Previous Floods & Related Studies

5.3.3.1 Flood Prone Area

Flood prone area is the area bordering a stream that is likely to be covered by flood waters at a given flood stage. The Johor Flood Maps (December 2006 Floods and January 2007 Floods) in Appendix 5.A is an example of a flood map. This map shows the extent flood-prone areas. Such map can also be prepared if the river profile, riverbank elevation vs. water depth during floods and during absence of floods, and the maximum bankfull depths are known. On a broader perspective, the flood prone areas all over Malaysia are shown in Appendix 2.A. Figure 5.7 shows the flood prone area at Iskandar Development Region (IDR), Johor, while Table 5.3 shows the flood affected area at Sg. Skudai on December 19, 2006.

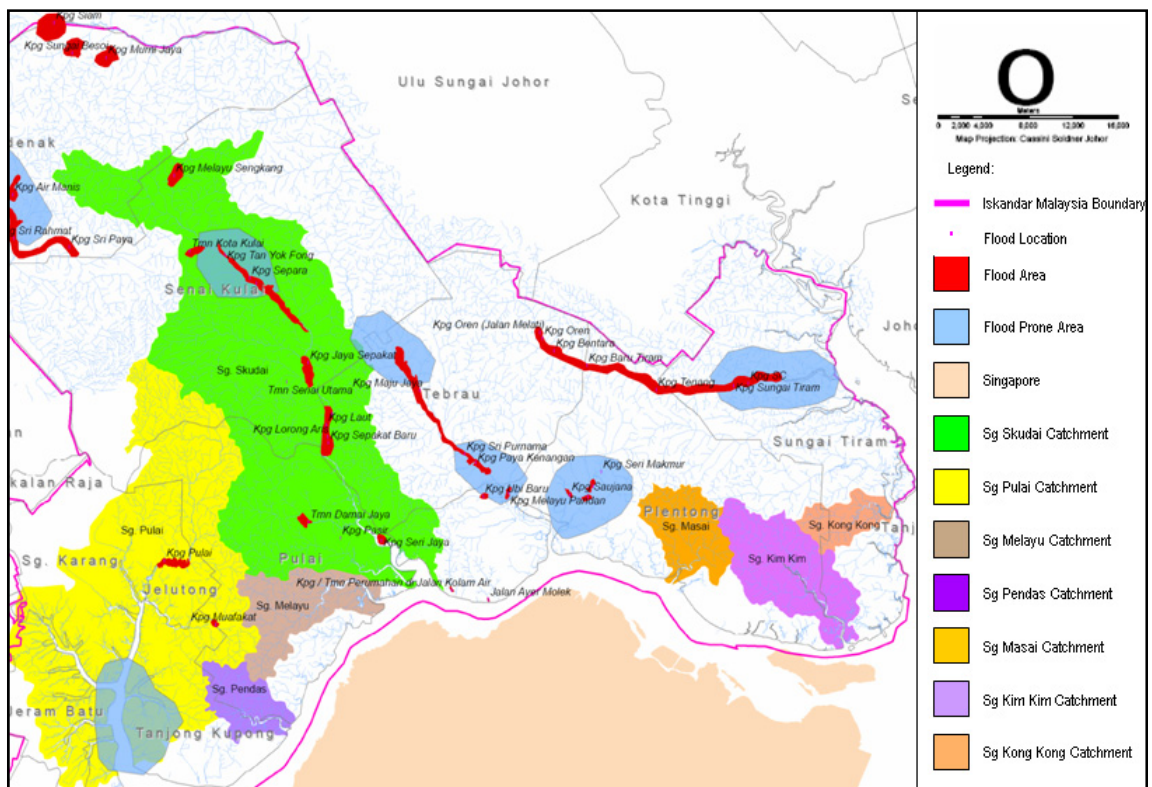


Figure 5.7 Flood Prone Areas at Iskandar Development Region, Johor

Table 5.3 Flood Affected Area at Sg. Skudai, Johor (Dec. 19, 2006 Floods)

Area/Kampung	Estimated Area (km ²)	Maximum Flood Recorded (m)	Flooding Duration (day)	Possible Causes
Kg. Pasir, Senai	1.00	1.00	2.00	Flood plain, overflow Skudai river
Kg. Laut and Skudai Parade, Skudai	2.00	2.00	5.00	Flood plain, overflowed Skudai river
Kg. Jaya Sepakat, Senai	1.00	1.00	1.00	Flood plain, overflowed Skudai river
Kg. Jaya Sepakat Baru, Skudai	1.00	1.00	1.00	Flood plain, overflowed Skudai river
Kg. Baru Senai, Senai	1.00	2.00	2.00	River valley, outburst of Sg Senai
Taman Mewah	1.00	1.00	1.00	Clogged drain
Kg. Separa and Kg. Pertanian	2.00	2.00	2.00	Flood plain, river overflow
Kg. Baru Sengkang	1.00	0.75	1.00	Flood plain area
Taman Aman, Senai	0.25	1.50	1.00	Undersized and constricted outflow

5.3.3.2 Flood Damage

Flood damage (cost) can be tangible (quantifiable, like damage to roads and dwellings) or intangible (not quantifiable, like damage to environment (water quality, aquatic life), or psychological stress, illness). Flood damage must be assessed immediately after flood event.

Flood damage can also be classified as actual or potential. Actual damage is assessed by valuation of property lost or repaired. Potential damage is maximum damage a particular flood (say a 100-year flood) could cause. [Please refer to Chapter 8 for more details.]

5.3.3.3 Flood History

Information about historical floods can be obtained from past gauging records. Important data are flood depths and the exact dates (month/year) of heavy rainfall. Gauging records are likely obtainable from DID but information may be also be obtained from Local Authorities. One useful data is visual evidence of floods such as flood marks on tree trunks or walls of dwellings.

Historical floods help in understanding more about the flood behaviour, for benchmarking and for calibration or verification of the flood models to develop. [More detailed flood history is given in Chapter 2 (sub-topic 2.5).]

5.3.3.4 Documented Report

Documented past study/project reports (in hard or soft copy) or manuals (e.g. MSMA) must be retrievable for use in research or current development projects.

5.4 RIVER SECTION AND FLOODPLAIN FEATURES

5.4.1 River Section Survey

Selected river channel sections, their locations, geometry profiles, physical characteristics, and obstructions to flow are the data needed to be surveyed as input to the hydrological/hydraulic modelling. Acoustic Doppler Profiler (ADP) can be used to determine the river hydrographics. The Digital Terrain Mapping (DTM) is used to develop the area topography. Structural details that need to be noted during the survey are as follows:

- Types of structure (fences, sheds, or man-made structure)
- Outfalls, culverts and tidal gates
- Bund and bank protections
- Plantations, small-holdings and agriculture plots
- Jungle, scrub, bushes and other natural vegetation.


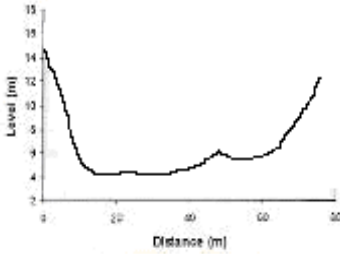

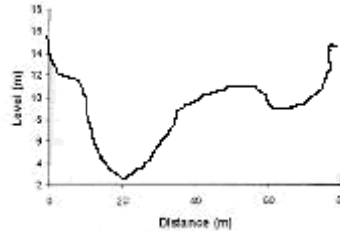
Selecting the proper river cross-section is to ensure the river features or properties are representative for use in modelling. The cross-section survey should furnish data such as changes in slope, meanders, constriction, bifurcation, islands and roughness variation in the river. Channel geometry and changes in the floodplain can be studied using various methods (Table 5.4).

Table 5.4 Different Methods for Studying Channel Geometry and Changes in Floodplain

Method	Functions
Walk-Through survey (Convection method)	<ul style="list-style-type: none"> • Observing and gathering information up close, which is not possible using other survey methods
Aerial photographs/Satellite images	<ul style="list-style-type: none"> • Provide the bird's eye view of the river sections and its surroundings. Effective for observing and keeping track of changes in the floodplain
Topographic Maps	<ul style="list-style-type: none"> • Provide elevations of the river corridor and floodplain
Light Detection And Ranging (LiDAR)	<ul style="list-style-type: none"> • Remote sensing technology effective for measuring elevations of floodplain and channel geometry

The survey information is used to produce a graphical representation of the river cross-section and floodplain at a particular section along the channel. Each cross-section should show the size and geometry of the channel, shape of the floodplain, and changes in elevation of the ground. This information is used in the hydraulic studies. Longitudinal river sections can also be produced. [More detailed engineering survey can be referred to Volume 6 of the Manual (Geotechnical Manual - Site Investigation and Engineering Survey).] Examples of typical river cross-sections are shown in Table 5.5 below.

Table 5.5 Survey of Cross Sections at Sg Muda, Kedah, (2006)

Present Condition	Cross Section	Width (m)	Chainage (m)
		70	1934
		116	2441

The survey above has some inherent limitations. It neither depicts the true ground features nor includes details of the existing structures on the river (e.g. bridges, drains and weirs) and in the river reserve. All it has is levels along the cross-sections. Such limited information can be used in the hydraulic model to predict at best only the preliminary water surface profile along the river, say, for flood mitigation alternatives.

Generally for a natural river, survey of cross-sections may cover 100 m to 500 m intervals. If an eco-sounder is used in between the surveyed intervals, the intervals may be increased to 500 m to 1000 m. For a concrete channel, two or three intervals would be sufficient because of uniformity in the channel shape. However, for a channel with highly variable cross-sections, more number of longitudinal intervals (also transverse intervals) would be required. For the transverse (cross-section) to determine the levels in a riverbed, a 5 m interval is common for a cross-section 50 m to 100 m wide, as illustrated in Figure 5.8.

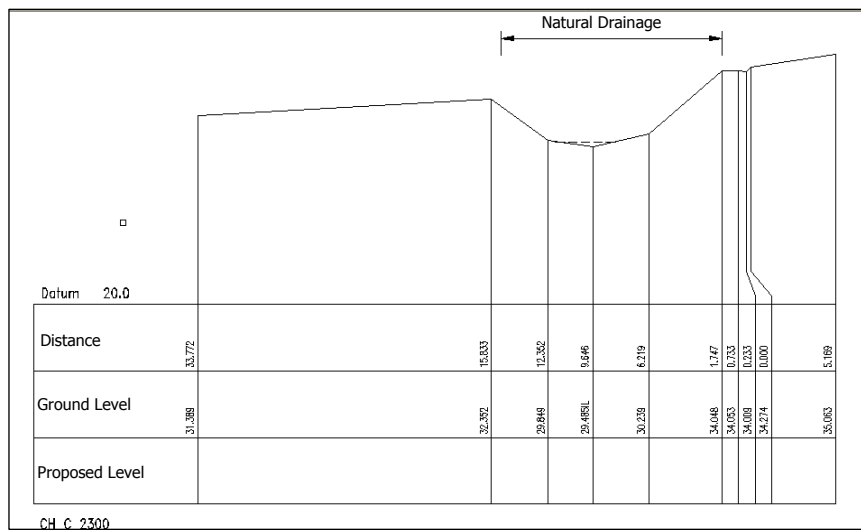


Figure 5.8 An Example of Kulai River Survey Cross-section, 2006

5.4.2 LiDAR Survey

LiDAR (Light Detection and Ranging) is a relatively new surveying method of capturing ground features using laser technology. A significant advantage of this technique is a high accuracy of ground elevation data that can be very useful in applications such as hydraulic or hydrologic modelling. LiDAR height data can be incorporated into GIS after which a Digital Elevation Model (DEM) can be established. With DEM, many other information can be generated such as the determination of river catchment, flow direction and accumulation, slope and volume calculation. In addition, a more effective visualization of the topography in relation to other features can be established by draping the required features onto the 3D perspective view that can be generated using the LiDAR height data.

Apart from height data, LiDAR also provides feature data. This is certainly advantageous because of the very current information. This is of particularly important when the landuse and river alignment data is required for the analysis.

Limiting the corridor width for the survey is necessary to control the cost of this data collection. The width of the corridor is subject to the minimal requirement for any related section of the study, for example the extent of flood spreading from the river. The application and operation of LiDAR technology is summarised in Table 5.6.

Table 5.6 Information About LiDAR Technology

Technology	How It Works	Applications	Limitations
Light Detection And Ranging (LiDAR)	<p>a) After hitting the tree-canopy the laser beam finds a hole between the foliage and reaches the ground.</p> <p>b) The returns are registered and a dataset is created instantly. Most often used are the first and last returns.</p> <p>c) The first will show the highest features such as the tree canopy, buildings etc.</p> <p>d) The last return is ground level. This data set will provide valuable accurate data on the surface of the earth.</p>	<ul style="list-style-type: none"> • LiDAR data can be seamlessly integrated with other data sets, including orthophotos, multispectral, hyperspectral and panchromatic imagery. • LiDAR is combined with Geographic Information System (GIS) data and other surveying information to generate complex geomorphic-structure mapping products, building renderings, advanced three dimensional modelling/earthworks and many more high quality mapping products. 	<ul style="list-style-type: none"> • LiDAR cannot be collected through clouds or dense haze/smoke; however, the data are collected at relatively low altitudes, often below cloud level, and can also be collected during the night when cloudy conditions are less pervasive. • LiDAR has difficulty mapping earth surfaces with dense vegetation. Pulse returns can scatter and reflect within vegetation causing variation in elevations, thus limiting the penetration and return from "true" earth surfaces. • Accuracies are limited by the inherent errors from the onboard GPS, and the inertial measurement unit (IMU). The GPS records the aircraft position on x, y, z coordinates, while the IMU corrects errors in coordinate measurements caused by pitch and roll from the aircraft. • LiDAR (being an Infrared measurement) is applicable only up to the water surface but not in the water.

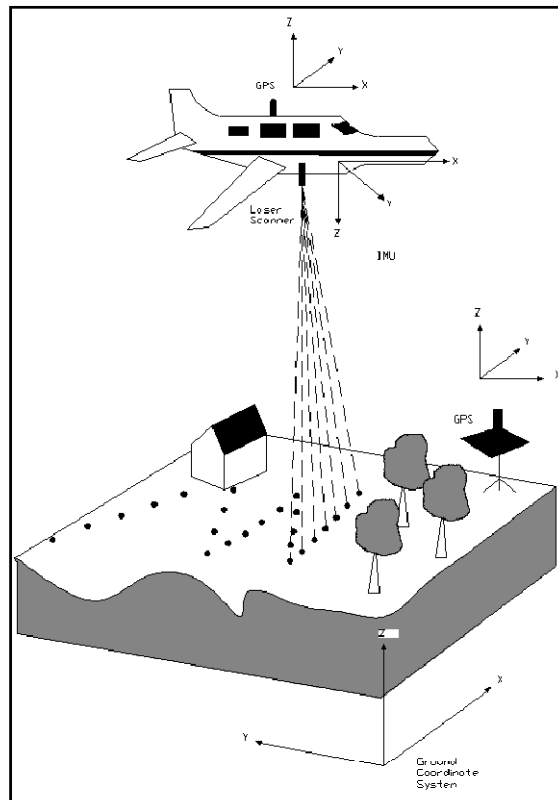


Figure 5.9 How Light Detection and Ranging Works

More detailed explanations about LiDAR survey can be referred to Volume 6 of the Manual (Geotechnical Manual - Site Investigation and Engineering Survey). Figure 5.9 shows how LiDAR and ranging theory works.

LiDAR offers several advantages over traditional methods for data collection. It is accurate, quick, can be cost-effective and can successfully define intermediate surfaces (treetops (canopy) or power lines) LiDAR also allows for the real-time accumulation of tens of thousands of points per second, which can be immediately made available for DEM generation or topographic mapping.

The following specifications are generally quoted for LiDAR accuracy:

- LiDAR accuracy is derived from statistical sampling of the LiDAR data. This is generally quoted as 1 sigma (meaning 68% of the data will fall within this limit) or 2 sigma (95%) and so on;
- Accuracy specifications are generally taken across the entire scan width of a system despite the fact that accuracy will decrease with increasing scan angle; it is common to see the quoted accuracy being the average of the error at minimum and maximum scan angles;
- Accuracy is generally taken in the Global Positioning System (GPS) reference frame so the effects of geo-id modelling are ignored;
- Accuracy analysis is generally taken by comparing with known ground control points but details of how this is done are generally not included; and
- Accuracy analysis tends to focus on vertical accuracy (Z) and details on how planimetric accuracy (X-Y) is verified are vague.

LiDAR accuracy is generally given in the vertical direction as horizontal accuracy is indirectly controlled by vertical accuracy. This is because the obtaining horizontal accuracy is not easy due to the difficulty in locating Ground Control Points (GCPs) corresponding to the LiDAR coordinates. The vertical accuracy is determined by comparing the Z coordinates of the data with the true elevations of a reference (which is generally a flat surface). The LiDAR accuracy can also be stated as RMSE or 1.96 RMSEz. This is called fundamental vertical accuracy when the RMSE is determined for a flat, non-obtrusive and good reflecting surface. The accuracy should also be quoted for other types of surfaces, which in this case is called "supplemental and consolidated vertical accuracies".

In general, the airborne survey and mapping requirement should comprise the following deliverables:

- Digital Surface Model (DSM) of point cloud with vertical accuracy of 0.15 m;
- Digital Terrain Model (DTM) with vertical accuracy of 0.15 m on clear ground;
- Contours at 1m interval in coordinated-registered format as generated from LiDAR survey;
- Land cover map derived from LiDAR Quickbird image for the project area;
- Generating river cross section profiles at every 1000m interval (extended up to 25 m either side of the river banks);
- Generating river longitudinal profile;
- Building vectorization at 50 m set-up; and
- Mosaic image with topographical in hardcopy (A1) size at 1:5000 scale.

5.5 SOIL INVESTIGATION

Soil investigation (SI) is required primarily:

- a) To determine the thickness and lateral extent of the soil strata (soil profiles);
- b) To obtain representative soil samples for identification and classification (soil parameters);
- c) To determine the groundwater table levels;
- d) To study suitability of the site for flood mitigation structures;
- e) To determine difficulties that might be encountered when applying some specific construction method; and
- f) To enable a safe, practical and economical design.

There are various methods for conducting SI work:

- Trial pits;
- Shafts and headings,
- Percussion boring;
- Wash boring;
- Mechanical and hand augers; and
- Geophysical methods (Seismic refraction method, Electrical resistivity method).

Soil samples can be categorized as disturbed samples and undisturbed samples.

Various types of samplers are available such as:

- Open drive samplers;
- Thin-walled samplers;
- Split-barrel samplers;
- Stationary piston samplers;
- Continuous samplers; and
- Compressed air samplers.

5.5.1 Planning of the Subsurface Investigation

Planning of the subsurface investigation involves four steps:

a) Desk Study

Desk study includes review of the following information:

- Geological Maps and Memoirs
 - Reviewing geological maps with understanding of the associated depositional processes can enable a preliminary assessment of ground conditions to be made.
- Topographic Map
 - Using topographic map to examine the terrains and other site conditions and to determine access to site (this should be counter-checked with site reconnaissance results)
- Aerial Photographs
 - Using aerial photographs to indicate geomorphology features, land use, problem areas and layout arrangements especially for highways and hill-site developments.
- Site Histories and Details of Adjacent Development
 - Knowledge of site history (land use before the current development, tunnels, and underground services) should be available before planning the field tests.
 - Information of adjacent developments (types of structures, foundation systems) is required for design and to prevent the proposed project affecting the serviceability of the adjacent structures.
 - If the subsoil information of adjacent site is available, it will help the design engineer to optimize the SI works required for the project.
- Requirements of the Proposed Structures or Foundations
 - For a proper and cost effective SI, the design engineer should have sufficient information on the requirements of the completed structures and their tolerance of differential movements.

b) Site Reconnaissance

Site reconnaissance should ensure the following:

- Site reconnaissance should confirm information obtained from desk study and field study. This includes examining adjacent and nearby development for telltale signs of problems and as part of the pre-dilapidation survey.
- Site reconnaissance should allow the design engineer to compare the surface features and topography of the site with data and information obtained from the desk study.
- Checking of the presence of exposed services and cut and fill areas.
- Locating and studying the outcrops to identify previous slips or collapse that will act as an indicator of stability of the site.
- Studying the vegetation that give tell tale signs of localized very soft areas where additional subsurface investigation should be carried out.

c) Extent of Subsurface Investigation

The extent of subsurface investigation depends on:

- Available subsurface information
- Geological formation and features
- Variability of subsoil and groundwater
- Proposed structures and platforms
- Adjacent properties and their conditions

Parameters to consider in subsurface investigation are described in Table 5.7.

Table 5.7 Parameters to Consider During the Extent of SI

Item	Task	Description
1	Number/Spacing (Minimum Requirements)	<ul style="list-style-type: none"> • There are no hard and fast rules but generally 10m to 30m spacing is enough for structures. • The spacing can be increased for alluvial subsoil with more consistent layers (as interpreted from preliminary SI or where geophysical a survey is used to interpolate or identify problem areas. • At bridges generally one borehole at every pier or abutment.
2	Structures	<ul style="list-style-type: none"> • Up to soil depth where the pressure induced by structure has little or no influence.
3	Depth	<ul style="list-style-type: none"> • In fill area, up to a depth with SPT'N', 50 • In cut Area, up to a depth exceeding potential slip surface or when hard material is encountered. • For deep foundation in soft clay, up to a depth with SPT'N', 50 for at least 7 times consecutively and at least one borehole coring into rock. • In limestone area, continuous coring into solid rock for 10m is required to detect cavities. • In an actual field work depth of boreholes is usually deeper because the foundation system is yet to be decided and the cost of going deeper is not significant as compared to cost of mobilization.
4	Geophysical Survey	<ul style="list-style-type: none"> • Geophysical survey should be used for large area and to determine the general bedrock profile and characteristics.

d) Selection of Types of Field Tests and Sampling Methods

Selection of the types of field tests and sampling methods should be based on the information gathered from the desk study and site reconnaissance. The commonly used field testing methods in subsurface investigation are:

- Light Dynamic Penetrometer (JKR or Mackintosh Probes)
- Borehole with Standard Penetration Tests (SPT), collection of disturbed and undisturbed soil samples and rock coring
- Rock Coring
- Piezocone (CPTU)
- Pressuremeter

For more in-depth understanding of the various methods of SI and sampling, the reader may refer to books on the subject (e.g. *Soil Mechanics, 6th Edition* by R. F. Craig, *Soils and Foundation* by Cheng Liu and Jack B. Evett).

SI results are normally summarized or presented in the form of borehole logs (Figure 5.10) and these include date of investigation, location, name of client, ground level and details of equipment.

The detailed explanation about SI methods can be referred to Chapter 5, Volume 6: "Geotechnical Manual, Site Investigation and Engineering Survey". Table 5.8 show the guidelines for boring layout.

Table 5.8 Guidelines for Boring Layout

Area of Investigation	Recommended Boring Layout
Bridge Foundations	<ul style="list-style-type: none"> • For piers or abutments over 30m wide, provide a minimum of two borings. • For piers or abutments less than 30m wide, provide a minimum of one boring. • Additional borings should be provided in areas of erratic subsurface conditions.
Retaining Walls	<ul style="list-style-type: none"> • A minimum of one boring should be performed for each retaining wall. • For retaining walls more than 30m length, the spacing between borings should be no greater than 60m. • Additional borings inboard and outboard of the wall line to define conditions at the toe of the wall and in the zone behind the wall to estimate lateral loads and anchorage capacities should be considered.
Roadways	<ul style="list-style-type: none"> • The spacing of borings along the roadway alignment generally should not exceed 60m. • The spacing and location of the borings should be selected considering the geologic complexity and soil/rock strata continuity within the project area, with the objective of defining the vertical and horizontal boundaries of district soil and rock units within the project limits.
Cuts	<ul style="list-style-type: none"> • A minimum of one boring should be performed for each cut slope. • For cuts more than 60m in length, the spacing between borings along the length of the cut should generally be between 60m and 120m. • At critical locations and high cuts, provide a minimum of three borings in the transverse direction to define the existing geological conditions for stability analyses. • For an active slide, place at least one boring upslope of the sliding area.
Embankments	<ul style="list-style-type: none"> • Use criteria presented above for Cuts.
Culverts	<ul style="list-style-type: none"> • A minimum of one boring at each major culvert. • Additional borings should be provided for long culverts on in areas of erratic subsurface conditions.

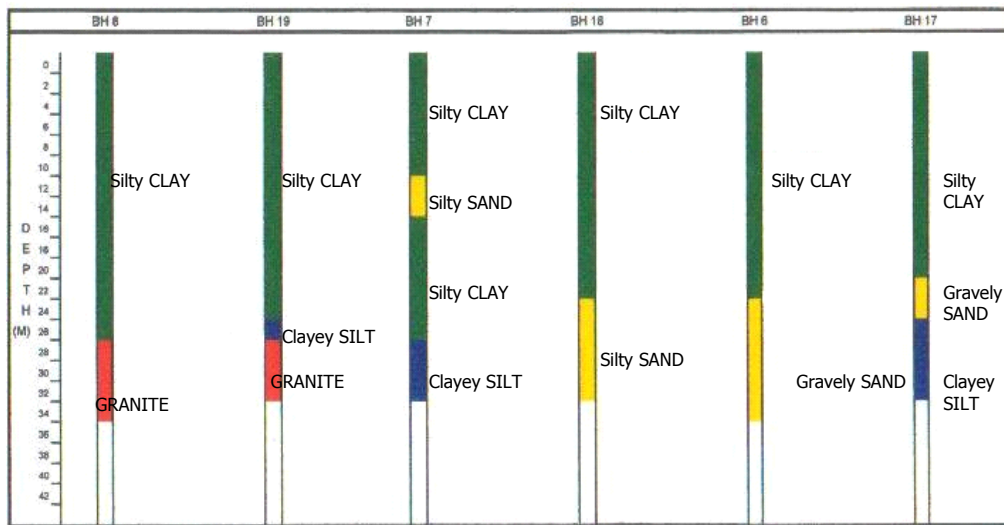


Figure 5.10 Borehole Log Examples

5.6 MAPS AND PLANS

The following typical map layers are required namely, boundaries (catchment; sub-catchments), river alignment, land parcels, landuse, geology, soil, topography, location of major flood events and flood prone areas. Data sources needed for the hydraulic simulations are given in Table 5.9. Table 5.10 briefly describes common practical ways for preparing flood maps, which involves drawing map layers using points, lines or polygons configurations. Points are used for presenting river crossings, bridges, or culverts. Lines represent river networks, roads, and contours, etc. Polygons represent land parcels, catchment boundaries, and landuse, etc.

Table 5.9 Information Needed to Carry Out the Hydraulic Simulation

Type of Map	Description	Example of Map
Local Structure Plan	Covers information for planning, which should be accessible to planners such as: <ul style="list-style-type: none"> • Land use maps • Flood management policies for sections of the floodplain • Map layers (flood risk areas - also available from Indicative Flood Maps; future flood risk areas; information on existing flood defences; outline of location/extent of proposed flood management measures; other information related to floodplain developments (conservation, recreation, etc) • Map Layers (floodplain function- flood conveyance, flood storage, etc). 	
Development Master Plan	Useful tool for developers and planners to reach consensus and agreement about the way an area is developed.	
Topography (digital)	Contour of infrastructures.	Figure 5.11
Land Use (Existing and Future)	Flood behaviour and magnitude (depending on land use and human activities). Of importance are land changes from pervious state to impervious state (e.g. development of a satellite township on secondary forested area). Flood risk map (FRM) must be updated frequently based on changing land use to ensure reliability of the map.	Figure 5.12
Soil Type	Showing distribution of soil types and/or soil properties (soil pH, textures, organic matter, depths of horizons etc.).	Figure 5.13
Geologic Maps	Usually superimposed over a topographic map with the addition of a colour mask with letter symbols to represent the kind of geologic unit such as bedrock.	Figure 5.14
Cadastral Plan/Certified Plan	Record of areas and values of land and of landholders that originally was compiled for purposes of taxation.	Figure 5.15
Contour Plan	A drawing which represents existing and/or proposed surface contours of a field or other designated area.	Figure 5.16

Table 5.10 Various Practices for Preparing Flood Maps

Practices	Description	Map Content	Application
Basic information for flood hazards maps	The proper use and application of flood hazard maps into planning processes and awareness campaigns require the consideration of some very basic information on the map	<ul style="list-style-type: none"> Title of the map: making clear reference to the map content such as flood parameter(i.e. flood extent, depth, flow velocity, past event) and probability consideration (i.e. defining more precisely what mean low, medium and high probability of occurrence) Location of the map as part of the catchments or country site (and/or telephone number) If necessary: a disclaimer, including remarks on the quality of information can be added 	-
Flood extent map/flood plain map	The most widely distributed instrument	<ul style="list-style-type: none"> The potential flood extent for or a small range of flood event frequencies has to be presented as a surface covering the topography. For reference roads, railways, houses, property boundaries and the permanent water bodies from which the floods may originate may be included. In addition, the protecting effect of defence works and areas designated for flood storage may be included 	<ul style="list-style-type: none"> Serves as a basic product to establish danger maps and risk maps Land use planning City and village planning Rural planning Risk management Awareness building
Flood depth map	The values of water level (depth) can be derived from flow models (2D and 1D) for river flooding, from statistical analyses or from observations. Normally in rivers numerical models have to be used and for lakes and sea statistical methods can be used. There is a wide range of applications of such maps.	<ul style="list-style-type: none"> The flood depth map provides information about the water in a particular location for a given recurrence interval/probability of flood Depending on the local conditions the water depth is given in centimetres or meters 	<ul style="list-style-type: none"> Serve as a basic product to establish danger and flood damage maps City and village planning Risk management/ Evacuation.
Flow velocity and flood propagation map	Flow velocity information is much more difficult to get than water depth information. Normally reasonable flow velocity information can be derived only from 2D-flow models and in some cases also from 1D-flow models.	<ul style="list-style-type: none"> The flood hazard in a particular location is represented by the velocity of the flowing water (or sediment in case of debris flow) or by the velocity of the flood propagation The flow velocities can be shown as vectors, the length of the vector representing the velocity. Also, return period should be provided. The velocity can be retrieved for various recurrence intervals (50, 100 years and an extreme event) 	<ul style="list-style-type: none"> Flow velocity: planning of flood defence measures or any structure within the flood area. Flood propagation: Planning tool for emergency response. Evacuation schemes, implementation of temporal flood protection measures. The information requires a well-functioning early warning and alert system.

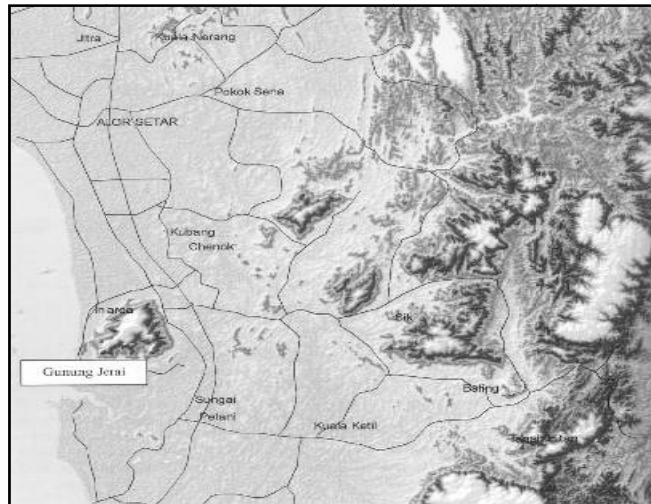


Figure 5.11 Topographic Map for the Sg. Muda Area, Kedah

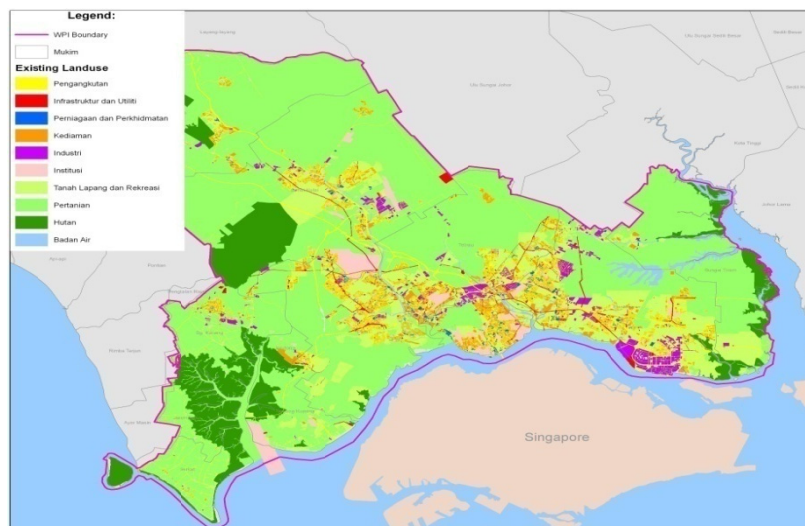


Figure 5.12 Existing Land Use Plan for Iskandar Malaysia, Johor

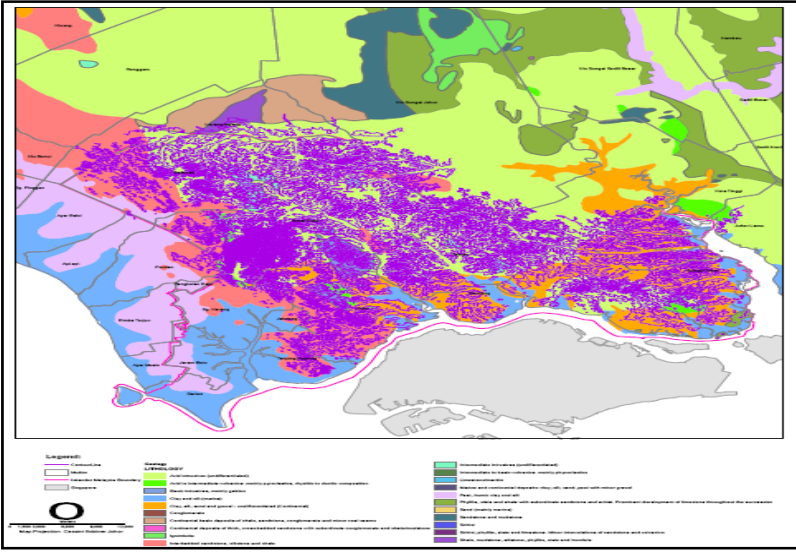


Figure 5.13 Soil Map Plan for Iskandar Malaysia, Johor

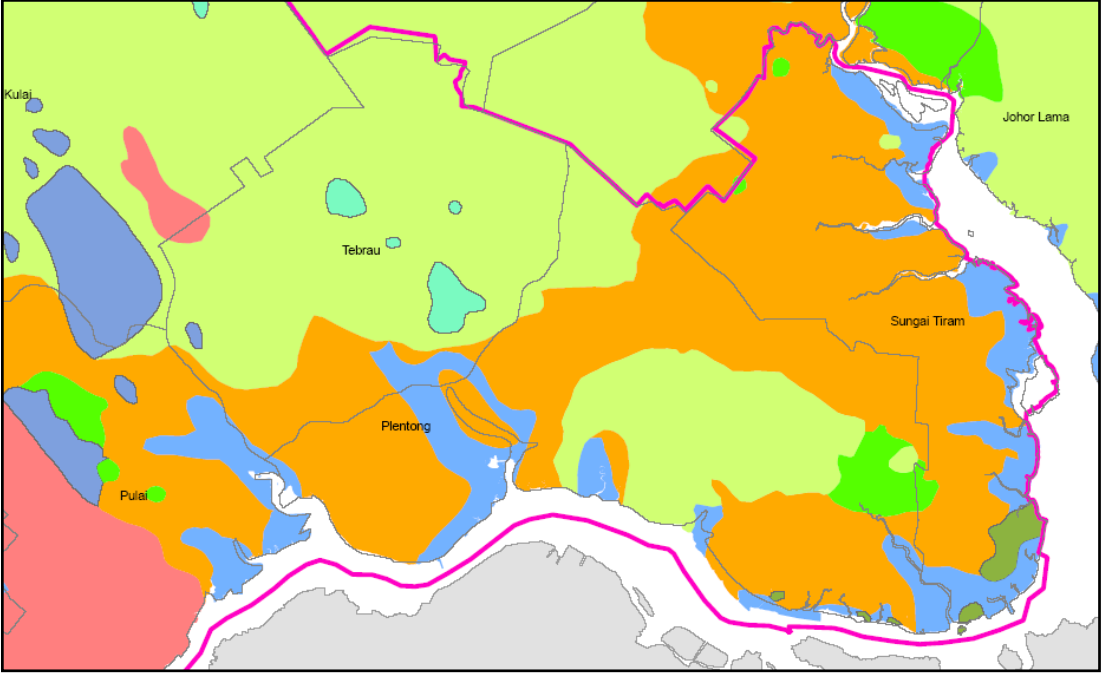


Figure 5.14 Geology Map for a Part of Iskandar Malaysia, Johor

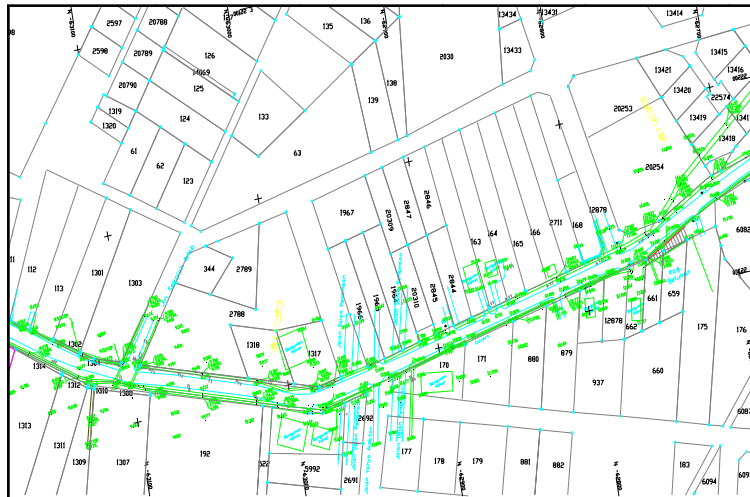


Figure 5.15 Cadastral Sheet for Sungai Segget, Johor

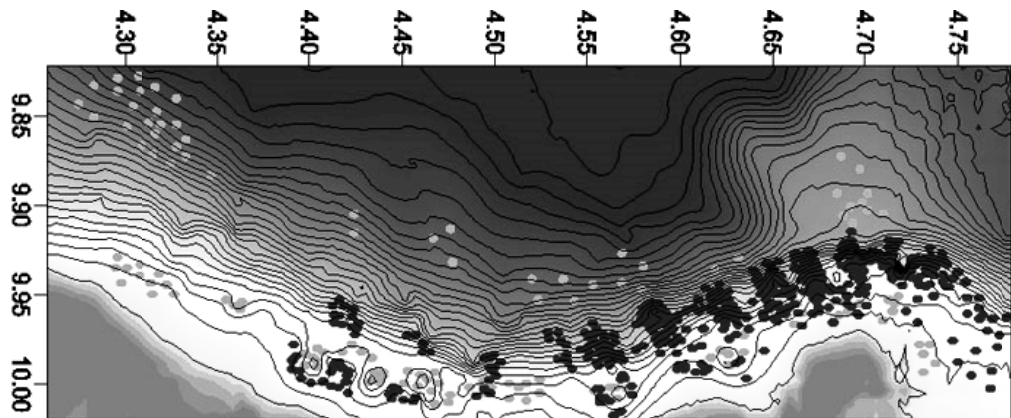


Figure 5.16 Contour Map for a Development at Teluk Intan, Perak

5.7 SATELLITES AND IMAGES

Radar data is more widely used as they give spatially oriented rainfall data as opposed to point rainfall data from the rain gauge stations. Nevertheless, radar data are presently used to complement the hydrological data due to their low accuracy.

Images may be taken from airplane or satellites, respectively called aerial photographs and satellite images. This will allow detailed observation of the variables over inaccessible terrains otherwise amenable only to point sampling. Studying these images promotes better understanding of the nature and actual characteristics of the study area. Different forms of images for standard digital products and fusion products are given in Table 5.11, Table 5.12 and Table 5.13. Applying these products can assist in producing the topographical images.

Table 5.11 Standard Digital Products (Geo-coded) by the Malaysian Centre for Remote Sensing, (MACRES, 2005)

NO.	DATA TYPE	PRODUCT DESCRIPTION
1.	Landsat-5 TM & Landsat-7 ETM+ (15m - 30 resolution)	Full Scene (185km x 185km area) Quarter Scene (93km x 93km area) Sub-Scene (15km x 15km area)
2.	SPOT 1, 2, 4 Pan (10 m resolution -B&W)	Full Scene (60km x 60km area)
3.	SPOT 1, 2, 4 XS (20 m resolution -colour)	Sub-Scene (5km x 5km area)
4.	SPOT-5 (A or B) Pan (5 m resolution -B&W)	Full Scene (60km x 60km area)
5.	SPOT-5 (THR) Supermode Pan (2.5 m resolution -B&W)	Sub-Scene (5km x 5km area)
6.	SPOT-5 (J) XS (10 m resolution -colour)	Full Scene (60km x 60km area) Sub-Scene (10km x 10km area)
7.	Radarsat Fine Mode (9 m resolution) Standard Mode (25 m resolution) Wide Mode (23 - 25 m resolution) Extended High Mode (25 m resolution) Extended Low Mode (25 m resolution)	Full Scene
8.	Radarsat Scan SAR Narrow Mode (50 m resolution) Wide Mode (50 m resolution)	
9.	Ikonos (1 m resolution-colour)	Pan-Sharpener (sq. km)
10.	QuickBird (0.67 m resolution-colour)	

Note:

- (i) Quarter scene is $\frac{1}{4}$ of the full scene
- (ii) Sub-scene is a minimum order
- (iii) B&W: Black and White

Table 5.12 MACRES Fusion Product (MACRES, 2005)

MACRES Fusion Product			
NO.	DATA TYPE	PRODUCT DESCRIPTION	AREA SIZE
1.	Landsat-7 ETM+	15m resolution Option: Natural or False Colour (3 bands)	Full Scene & Quarter Scene Full Scene & Quarter
2.	SPOT 1, 2,	10 m resolution (All bands)	
3.	SPOT 1, 2, 4	10 m resolution Natural Colour(3 bands)	
4.	SPOT 5	5 m resolution (All bands)	
5.	SPOT 5	5 m resolution Natural Colour(3 bands)	
6.	SPOT 5 Supermode Colour	2.5 m resolution (All bands)	
7.	SPOT 5 Supermode Colour	2.5 m resolution Natural Colour (3 bands)	

Table 5.13 MACRES Fusion Product with the Scale and Paper Size (MACRES, 2005)

NO.	DATA	PAPER SIZE/SCALE
1.	Landsat	20" x 24 " (1:50,000,1:100,000) 30" x 40" (1:50,000,1:100,000,1:250,000)
2.	SPOT	20" x 24 " (1:10,000,1:25,000,1:100,000) 30" x 40" (1:10,000,1:25,000,1:50,000,1:100,000)
3.	IKONOS	20" x 24 " (1:5,000,1:10,000) 30" x 40" (1:5,000,1:10,000,1:25,000)
4.	QuickBird	20" x 24 " (1:3,500,1:5,000,1:10,000) 30" x 40" (1:3,000,1:5,000,1:10,000,1:25,000)

Images such as aerial photographs (Figure 5.17) and satellite (Remote Sensing) imageries (Figure 5.18) are another form of representing geospatial information. This is effective for feature recognition and planning and performing tasks such as fieldwork exercises.

Ordinary image cannot be fitted with other datasets without geo-reference. This task requires selection of ground control points (GCPs) common to the features that are easily recognized on the image. Coordinate transformation is then performed based on these selected GCPs.

Remote sensing image requires processing such as image enhancement, feature classification, ground-truthing and raster-to-vector conversion. Another process is spatial resolution to provide information for the intended analysis for which the highest resolution (up to 0.6 m) can be obtained from the Quickbird satellite sensor.

These images are used for various purposes (river corridor survey, catchment characteristics survey, or hydraulic structure location survey). Satellite image of any place in the world is acquirable using Google Earth, MIRAVI, or UNOSAT for free (Figure 5.19).



Figure 5.17 Aerial Photograph for Kota Kinabalu, Sabah



Figure 5.18 Satellite Image for Kelantan and Terengganu Boundary

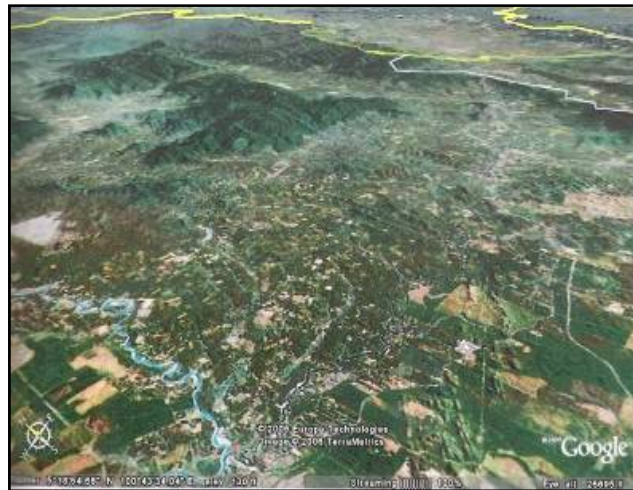


Figure 5.19 Google Earth Mapping for Kuala Ketil and Baling, Kedah Watershed Area

5.8 CATCHMENT CHARACTERISTICS

The nature of catchment characteristics will determine shape of the catchment hydrographs. Existing catchment surveys need to be collated, or if not available, conducted for delineating major hydrological features. Soil/geological characteristics will determine the effective runoff while topographic features determine baseline characteristics of the contributing sub-catchments, which in turn will assist with gauge siting or modelling. Then a simple relationship may be developed, say, between rainfall at limited number of sites and the total area of precipitation for which the aerial/satellite photography is most valuable. Aerial survey using LiDAR technology is currently available and is usually coupled with Digital Terrain Mapping (DTM) (Figure 5.20). Using this technique, the data can be correlated to land use, catchment roughness, flood plain area and flood damages.

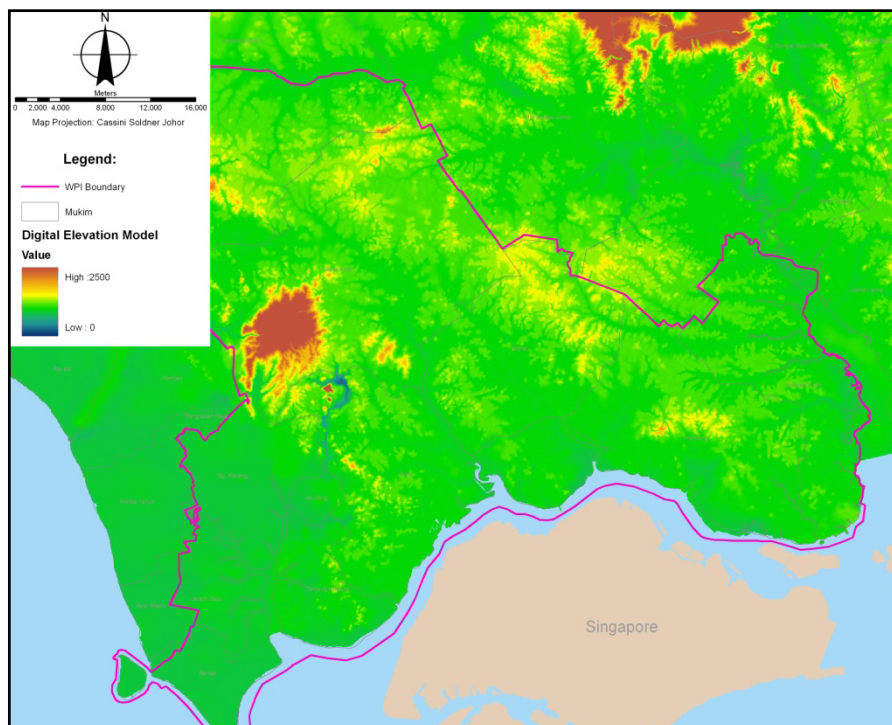


Figure 5.20 Digital Elevations Mapping for Iskandar Development Region, Malaysia, Johor

Catchment characteristics include the following:

- Catchment area
- Catchment shape
- Time of concentration
- Longest drainage path
- Mean altitude
- River lengths and networks
- Catchment steepness
- Dominant aspects of catchment slopes
- Number of reservoirs and lakes
- Average annual rainfall
- Annual maximum rainfall
- Standard percentage runoff from catchment
- Baseflow measurement
- Proportion of catchment wet time
- Urbanization/extent of flood/location/pollutant concentration
- IDF parameters
- Land cover and land use

5.8.1 Catchment Description

a) The Need for Catchment Descriptors

It is useful to quantify the physical and climatological properties of a catchment so that flood peak data may be transferred and applied to hydrologically similar catchments.

b) Catchment Characteristics from Maps

Methods for obtaining morphometric variables (e.g. mainstreams length) from Ordinance Survey (OS) maps are available. Figure 5.21 and Figure 5.22 show the catchment areas for Sg. Muda, Kedah and Sg. Skudai, Johor, respectively.



Figure 5.21 Example of Sg. Muda River Basin, Kedah

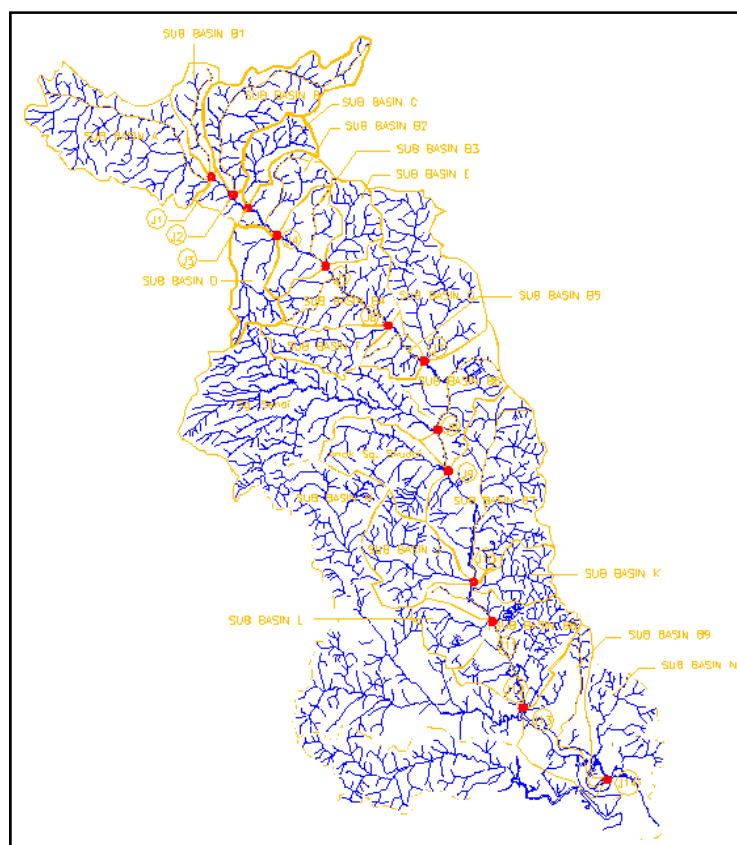


Figure 5.22 Example of Sg. Skudai River Basin, Johor

c) Catchment Descriptors from Digital Spatial Data

Digitized river data, taken from maps (of scale 1:50000), are used to position river valleys. Table 5.14 shows an estimated length of the Skudai river catchment area.

Table 5.14 Sg. Skudai River Catchment System Components

River System	Total Length (Km)	Catchment Area (Km ²)	General Characteristics of Landuse
Sungai Skudai (main)	46	325	Settlement areas along the river banks, heavy industrial areas within 1-2 km inland, plantation and rural at the hill sloping areas
Sungai Sengkang (Tributaries)	12	15	Mainly agricultural and rural
Sungai Senai (Tributaries)	15	32	Forested areas at the upstream and urbanizing and residential areas at the downstream end
Sungai Melana (Tributaries)	20	42	Mainly residential areas and business centres

d) Selection of Catchment Descriptors

- i. *Drainage Networks* - Catchment drainage is taken from 1:25000 scale maps; rivers/streams from 1:50000 maps; stream networks from 1:25000 maps.
- ii. *Flood Attenuation*.
- iii. *Soils*.
- iv. *Urban Land Cover* - fractions of urban land cover are derived manually by evaluating the extent of flesh-coloured areas using the 1:50000 scale maps.

e) Provision of Catchment Descriptors

- i) *Descriptor of Gauged Catchments*
- ii) *Descriptors for Ungauged Catchments* - Values are provided for catchments of 0.5 km² or more, on a 50 m grid.

5.9 RIVER CHARACTERISTICS

Hydraulic analysis will determine flood profile in a river including its floodplain. Data required for the purpose are as follows.

5.9.1 Cross-Section and Longitudinal Section

Data of selected river cross-sections should give representative river properties for subsequent use in modelling. Cross-sections should show changes in slope, meanders, constriction, bifurcation, islands and riverbed roughness.

Cross-sections should have suitable intervals along the channel reach. Other data include channel conveyance capacity (flow area times channel slope).

The extent of floodplain provides additional flow capacity for over-flooded channels. Contours from topographical maps, spot levels from survey of major rivers including riverbank levels from river cross-sections survey are used to estimate cross-sections of the floodplain.

Knowledge of downstream boundary conditions (tidal fluctuations, flood level at drainage outfall, culverts, and bridges, etc) is also required. If the level at the downstream end of the channel reach is high due to high tide or a constricted culvert, the backwater effect will raise the flood level upstream. How far upstream the backwater effect is felt would depend on the channel slope and the magnitude of flood discharge.

5.9.2 River Geometry

Geometry data are required for the existing cross-sections between the river mouth and upstream of the river system. The data include lateral distance and elevations obtained from field surveys. Typical river reserve and riverbank cross-sections are shown in Figure 3.3 and Figure 3.4 (Chapter 3). Figure 5.23 shows some cross-sections of a river.

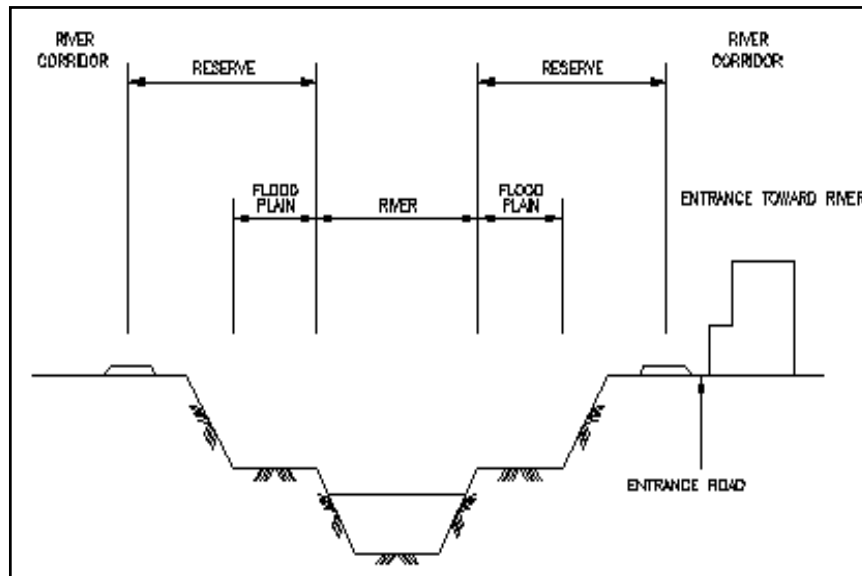


Figure 5.23 Geometry of a River Cross-Section









5.9.3 River Structures

Structures on/crossing/by the river (dams, ponds, bridges, weirs, barrages, gates, bypasses, bunds and roads) can have significant impacts on flood behaviour. These man-made structures will affect flood patterns such as increasing the backwater effect or constricting flood flows. Flood mitigation structures (dams or bypasses) may reduce flood levels at certain locations but may increase risks of flooding in other locations. Therefore, these structures must be noted and their impacts studied. Table 5.15 shows some of the hydraulic infrastructures associated with a flood mitigation study.

Data required for river structures include:

- Weir constrictions (sill level of weir, width of stilling basin, number of gates, and size of gates)
- Dimensions of opening under bridges
- Cross-section of river at bridge crossings
- Bedrock outcrops

Table 5.15 Hydraulics Infrastructure Intersections at Sg. Skudai and its Tributaries

No	Location	Structure Type	Picture	Comment
1	Sengkang at the upper reach of the river system.	Culvert across the road		Functioning well
2	Taman Kulai Baru	Lined Channel		Structure is undersized for a mostly paved catchment
3	Opposite Railway Station	Culvert		Poor maintenance showing stucked garbage underneath
4	Taman Indahpura, Kulai	Detention pond		Capacity seems adequate and well functioning
5	Kampung Pertanian	DID Water Level Monitoring Station		Important device for real-time flood warning system
6	Senai Town	Culvert across the road		Improper maintenance causing constriction to flow and backflow
7	PUB at the middle reach of Sg. Skudai	Weir		Functioning well but operation should be coordinated with Sg. Skudai flood conditions
8	Kampung Laut,	Rubbish Trap		Functioning well

5.10 HYDRAULIC DATA

Hydraulic data include sediment and tide data.

5.10.1 Sediment Data

During flooding, soil erosion can occur upstream and sedimentation at the downstream section causing the landscape to change. Sediment data are used to calculate riverbed and riverbank mobility and sediment transport (suspended load and bed load). Sediment data are as follows:

- Sediment particle size (Figure 5.24 and Figure 5.25);
- Specific weight of particle;
- Velocity of water;
- Kinematic viscosity of water; and
- Channel geometry data.

The data above are used to develop flow/sediment rating curves. Sediment may come from riverbed load, suspended load or wash load, of which bed load sediment can change most easily over a sandy riverbed. Riverbed material data (particle size distribution and specific gravity) can be plotted as S-curves for downstream/upstream cross-sections. Table 5.16 shows an example of a riverbed or riverbank sampling program.

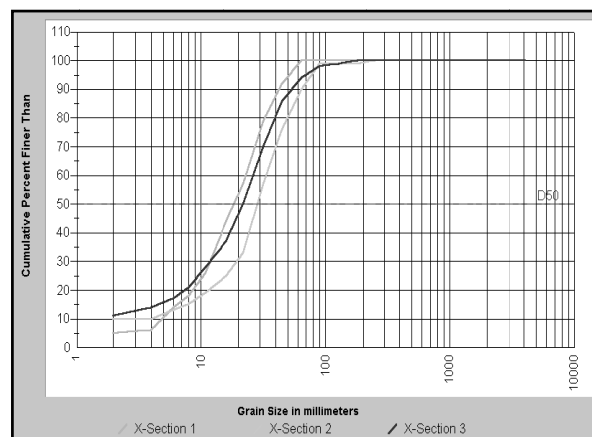


Figure 5.24 Grain Size Distribution Graph

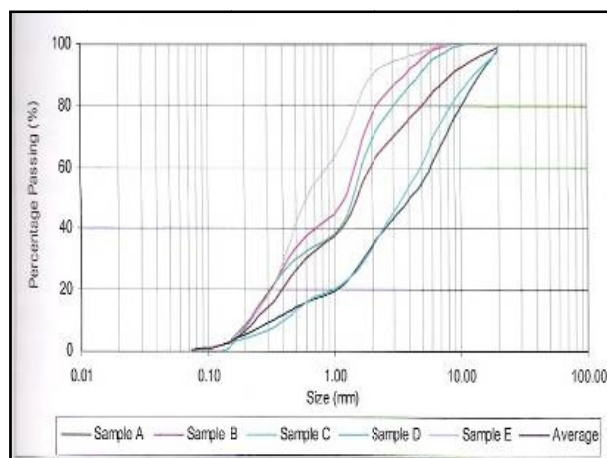


Figure 5.25 Sediment Distribution Curves

Table 5.16 Example of River Bed and Bank Sampling Programme

Site No.	Chainage No.	Name of Location	Total Sample	No. of Samples		
				Bank Material (Left)	Bed Material	Bank Material (Right)
M1	CH 0.20	River Mouth	5	1	3	1
M2	CH 1.40	Site 1	7	1	4	2
M3	CH 4.86	Bridge	8	1	5	2
M4	CH 12.64	Site 2	7	1	4	2

5.10.2 Tide Data

Tide records at river mouth are used to define time variation of storage at a downstream cross-section. Tide data are used as input to the modelling processes. Flood mapping along a river subject to tidal influences requires good estimation of tides. At present, the agencies responsible for publishing tide data are the Survey and Mapping Department (SMP), the Royal Malaysian Navy (RMN), and Port Authorities. Combined with hydrodynamic analysis, tide data can generate good flood levels along a river for mapping purposes. Data based on the Admiralty Chart Datum (ACD) must be standardized to the Land Survey Datum (LSD).

A hydraulic study requires estimation of the probable extreme tide levels at a given location. The RMN Tide Tables furnish times and heights of the predicted high tides for each day of the year together with other calculated data. Other data include the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) that are useful to the coastal ports (MSMA, 2000). HAT and LAT data are defined respectively as the highest and lowest levels that could occur under average meteorological and astronomical conditions. Meteorological effects (e.g. storm surge) may cause actual extreme tide levels to be higher or lower than the HAT/LAT levels.

Predicted tide levels take into account the astronomical effects and are based upon average meteorological conditions and consequently the actual tide levels may differ significantly from the predicted levels. The combined effect of surge would require examination and analysis of the local records and possibly collection of additional data (MSMA, 2001). In dealing with historical records, relations between local datum planes are often poorly defined and the history of many gauges is poorly documented. Thus the possibility of undocumented changes in the datum or in the location of a gauge should be considered. Tide data must be adjusted to the same datum as the datum used for the terrestrial tide levels.

Typical observed tide levels (1995 – 2006) for the Johor Bahru and Kukup stations are summarized in Table 5.17 and Table 5.18 respectively. Water levels for JB range from 1.859 m to 2.259 m while the range is 2.057 m to 2.247 m for Kukup (based on LSD). All levels are referred to the zero elevation of tide gauge at the tidal station. These levels may be benchmarked to the Survey Department requirements. The tide situations must be studied for modelling exercise to assess the adequacy of outfall capacity taking into account outfall siltation problems that may contribute to flooding especially in the low lying coastal areas. Figure 5.26 shows a tide profile at Pulau Kukup, Johor.

Table 5.17 Observed Tide Levels at Johor Bahru (1995 – 2006)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
BM No J 0416	6.079	6.079	6.079	6.072	6.079	6.079	6.079	6.079	6.079	6.079	6.079	6.079
Extreme High Water (EHW)	4.68	4.63	4.63	4.68	4.91	4.51	4.59	4.63	4.61	4.69	4.51	4.68
Mean High Water Springs (MHWS)	4.24	4.22	4.19	4.21	4.24	4.22	4.21	4.16	4.17	4.17	4.1	4.15
Mean High Water Neaps (MHWN)	3.46	3.46	3.42	3.47	3.44	3.48	3.5	3.45	3.46	3.45	3.43	3.44
Mean Sea Level (MSL)	2.841	2.842	2.841	2.842	2.845	2.847	2.849	2.851	2.853	2.852	2.851	2.852
DTGSM	2.657	2.657	2.657	2.657	2.651	2.651	2.651	2.657	2.657	2.657	2.657	2.657
Mean Low Water Neaps (MLWN)	2.27	2.26	2.23	2.28	2.28	2.28	2.34	2.34	2.35	2.3	2.27	2.3
Mean Low Water Springs (MLWS)	1.61	1.57	1.53	1.52	1.59	1.59	1.57	1.58	1.59	1.59	1.53	1.6
Datum Level	1.108	1.12	1.125	1.104	1.108	1.077	1.063	1.056	1.031	1.149	0.996	1.031
Extreme Low Water (ELW)	0.76	0.74	0.9	0.86	0.71	0.68	0.78	0.81	0.68	0.6	0.61	0.62
Zero of Tide Gauge	0	0	0	0	0	0	0	0	0	0	0	0

(Source: JUPEM, 2006)

Table 5.18 Observed Tide Levels at Kukup (1995 – 2006)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
BM No J 1323	6.884	6.884	6.884	6.884	6.884	6.884	6.884	6.884	6.884	6.884	6.884	6.884
Extreme High Water (EHW)	6.12	5.96	6	5.93	6	5.97	6.03	5.98	6	6.04	6	6.08
Mean High Water Springs (MHWS)	5.39	5.36	5.31	5.35	5.39	5.36	5.37	5.34	5.33	5.32	5.32	5.35
Mean High Water Neaps (MHWN)	4.54	4.59	4.47	4.56	4.57	4.58	4.56	4.49	4.49	4.48	4.44	4.45
Mean Sea Level (MSL)	3.99	3.992	3.987	3.988	3.992	3.996	3.999	3.998	3.998	3.999	3.998	3.999
DTGSM	3.873	3.873	3.873	3.873	3.873	3.868	3.868	3.873	3.873	3.873	3.873	3.873
Mean Low Water Neaps (MLWN)	3.37	3.4	3.28	3.37	3.42	3.44	3.45	3.38	3.4	3.39	3.4	3.41
Mean Low Water Springs (MLWS)	2.73	2.73	2.65	2.7	2.77	2.76	2.75	2.71	2.71	2.74	2.72	2.74
Datum Level	2.44	2.35	2.24	2.36	2.41	2.44	2.47	2.35	2.38	2.4	2.34	2.38
Extreme Low Water (ELW)	2.166	2.185	2.169	2.171	2.169	2.16	2.155	2.122	2.116	2.116	2.118	2.108
Zero of Tide Gauge	0	0	0	0	0	0	0	0	0	0	0	0

(Source: JUPEM, 2006)

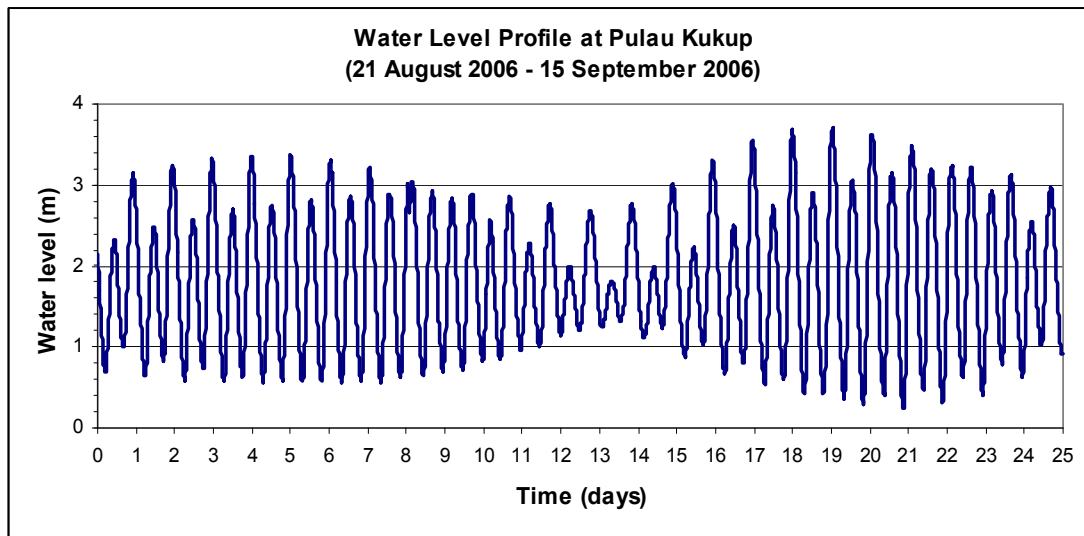


Figure 5.26 Tide Level Profiles at Pulau Kukup, Johor, (Royal Malaysian Navy, 2006)

5.11 DATA FOR OPERATION AND MAINTENANCE

5.11.1 As Built Drawings (ABDs)

Upon completion of the flood mitigation works, all ABDs shall be properly kept by the office responsible for the operations both in hardcopies and softcopies. ABDs could comprise the following drawings:

- Survey drawings;
- Structural drawings;
- Infrastructure drawings;
- Mechanical/electrical drawings;
- Installation and equipment drawings;
- Reference materials;
- Suppliers hand-over documents and reference materials; and
- Operating instruction and maintenance manual.

For reference/documentation purposes, all ABDs shall be compiled, catalogued and filed. Use of modular computerised information system for digital format storage is recommended.

5.11.2 Standard Operating Procedure (SOP)

A consistent and periodic maintenance program is the best way to ensure flood control structures will continue to perform. The mitigation structures should be routinely inspected. Any problems observed must be immediately repaired. Repair work for detention/retention ponds can be for the embankment, emergency spillway, inlet and outlet structure, removal of sediment and control of algal growth, insects and odours.

SOP should be included in the non-routine inspection. SOP is a set of instructions for operational features without loss of their effectiveness. SOP may cover standard maintenance, annual inspection, semi-annual inspection, annual maintenance and maintenance (normally 3-6 months). SOP can be effective for performance/organisational improvements. SOP promotes good quality to the operating systems.

5.12 SOCIO-ECONOMY DATA

A socio-economic impact assessment is used to examine how floods will change life of the residents of a community. The following are indicators to measure the potential socio-economic impacts of flood areas:

- i. Number of people in flood risk areas for a range of flood events;
- ii. Number of people requiring evacuation or other assistance;
- iii. Number and type of properties at risk of flooding for a range of flooding events;
- iv. Average depths of flooding and flood damages for a range of flood events;
- v. Number of people evacuated from their homes, and period of evacuation;
- vi. Cost of the emergency response and clean-up; and
- vii. Number of people affected.

Flood data that need processing include:

- Likely rate or speed of surface runoff;
- Flood prone area with degree of flooding;
- Likely flood duration;
- Economic/social/environmental consequences of flooding on occupancy of site;
- Extent/depth of previous or predicted floods.

Socio-economic impacts of a flood on a community may actually begin on the day the flood event occurs. Changes in the social structure and interactions among the community members may result once the damage to the community is felt and made known. In addition, real, measurable and often significant effects on the human environment can take place as soon as there are changes in the social or economic conditions. Conducting a socio-economy impact assessment is very important for several factors as listed in Table 5.19.

Table 5.19 Socio-Economic Factors and Application

No.	Socio-Economic Factor/Indicators	Applications
1	Outline the Environmental Quality Management Plan (EQMP)	Alert the community (residents and local officials) of the impact and magnitude of the flood on community's social and economic well-being.
2	Address the perception and awareness of relevant inhabitants, local residents and other affected parties	Help communities to avoid creating inequities among community groups and encourage the positive impacts.
3	Commercial, industrial activities and the extend of losses	Provides estimates of expected changes in demographics, housing, public services and even the aesthetic quality of the community resulted after the disaster.
4	Cost-benefit analysis of the flood disaster	Provides an opportunity for diverse community values to be integrated into decision-making process.
5	Current and future development and land value	Provides a foundation for assessing the cumulative impacts of development on a community's social and economic resources.

5.12.1 Guideline for Conducting Socio-Economy Assessment

a) Defining the Scope Socio-Economic Impact Assessment

Well planned socio-economic assessment saves time and money. The scope must be refined based on community priorities. This can be evaluated from residents or community leaders. Survey and interview is excellent for identifying priority in the community's social/economic goals. Community members (civic group representatives, religious leaders, citizen action groups) may guide the assessment for a single proposed development. This provides a foundation for designing and conducting future assessments provided the survey is representative of the diverse community values, concerns, and interests.

b) Identifying and Evaluating Development Impacts

Impacts need to be assessed quantitatively and qualitatively. Measuring community perceptions about flood is important just as estimating loss of jobs due to floods.

Estimating quantitative changes in the socio-economic characteristics of the community and measuring community perceptions about a flood are outlined below. Each section describes the types of useful information, available resources and questions to facilitate data collection.

i. Quantitative Changes

Floods can cause changes in community characteristics (demographics, housing, public services, markets, employment and income and aesthetic quality).

ii. Community Perceptions

The socio-economic impact assessment is for assessing changes in a community's social well-being after a flood event. These social changes are more difficult to quantify than changes in the social environment because the assessment relies on the perceptions of current and new residents about how a flood may affect their quality of life. This helps local officials, planners, developers and the public to identify and address the potential conflicts of interest accompanying the development. In addition to the quality of life issues, it is important to assess flood influence on the neighbourhood cohesion or cultural differences among the community.

5.13 DATA REQUIREMENT FOR EMERGENCY RESPONSE PLANNING

Emergency Response Plan (ERP) is an essential component in flood management. It provides an organized structure for actions in the event of a flood emergency.

Emergency in the ERP context is defined as an incidence with potential to cause injury or loss of life, and damage to property and the surrounding environment.

This section outlines the requirements for preparing an ERP for the operational phase of a proposed project. This is not intended to provide details of how to handle potential emergency situations but to highlight the salient areas of concern. Once the proposed project commences operation the ERP can be used as a template for the development of a more detailed site-specific plan.

There are (USEPA, 2002) eight core elements of an effective ERP, namely:

- System Specific Information;
- CWS Roles and Responsibilities;
- Communication Procedure (Who, What, and When);
- Personnel Safety;
- Identification of Alternate Water Sources;
- Replacement Equipment and Chemical Supplies;
- Property Protection; and
- Water Sampling and Monitoring.

5.14 DATA COLLECTION RESPONSIBILITIES

Data of river flows, water levels and flooded areas are routinely collected by DID with the help of the local authorities. Data of flood hazard (emergency planning, socio-economy) and floodplain management should be under the responsibility of the local authorities and municipalities as they are the closest to the development sites. Assistance from the emergency services as well as the affected local communities should be made available as and when needed. Table 5.20 shows data obtainable from the local authorities.

Table 5.20 Data Available From Government Agencies

No	Department	Responsibilities
1	Department of Irrigation and Drainage (DID)	Main departments for planning, preparing and disseminating flood hazard map such as hydrology data (river flow, water level, and rainfall), hydraulic data and annual flood report.
2	Department of Agriculture (MOA)	Providing soil map.
3	Malaysian Remote Sensing Agency (Remote Sensing Malaysia)	Providing the satellite images due to flood forecasting and warning activities.
4	Department of Survey and Mapping, Malaysia (DSM)	To provide topographical, cadastral, thematic and utility maps for the purposes of planning, management and development of flood hazard map.
5	Malaysian Meteorological Department (MMD)	Providing weather forecast information due to flood forecasting and warning activities such as tidal charts, survey of land data and contour map.

5.15 DATA MANAGEMENT

Data management is a broad field of management responsibility. It is essentially a process of data handling as a resource in an organization.

Hydrologic and hydraulics study is geospatially related. Location of the hydrological and other supporting features must be captured and stored for an efficient data management. Use of Geographical Information System (GIS) will support this requirement as it offers management and analysis tools for digital application throughout the study processes. This is advantageous in terms of data handling flexibility as well as savings in processing time.

The following tasks are commonly accomplished for major GIS applications:

- Database design and development;
- Data manipulation and analysis;
- Data retrieval and display; and
- Data update.

5.15.1 Database Design

Database is the first step for GIS related work. This involves designing and configuring various map layers and layer attributes required for future query and analysis. Input from other sources is part of the design to fulfil this requirement.

5.15.2 Recognition of Map Layers

GIS application needs a geospatial database, which is a repository of feature layers to support information retrieval and other analyses. These maps are structured to accommodate certain attributes required for future query and analysis, for instance, in situations where the river should contain basic information (river name, tributary and length). Other attributes may be added from time to time depending on the requirements.

5.15.3 Structuring the Feature and Attribute Codes

All map layers need to be established and are stored in the GIS database, accompanied by feature/attribute codes as specified in the MS1759 guidelines in which the method for encoding the geospatial data provides description of the features and their attributes for the exchange of digital geographic information. The purpose of the feature is to facilitate sharing and exchanging data producers and users.

5.15.4 Database Development

Geospatial database determines whether or not a GIS application is successful. Major tasks involve data entry, error cleaning and coordinate registration. Since map data may come from a number of sources in a number of forms, certain procedures have to be followed accordingly.

5.15.5 Paper Map Conversion

Prior to mapping digital technology, the geospatial information is stored and portrayed on hard copy maps. It is fortunate most data are available in digital formats. However, those which are not, have to undergo a conversion process called map digitizing. Digitizing using digitizers was common in the early days of GIS application. Nowadays the more convenient way is by scanning the map document and doing a head-up digitizing.

a) Entering Existing Digital Data

Digital datasets obtained from agencies are included in the database by going through checking and conversion procedures. Some of these are in non-topological forms that need error checks prior to the topologization process.

b) Integrating Satellite Image Data

For tasks such as field works, initial documents needed include topographic maps, road maps or satellite images. Images are also available from Google Earth which are stored in the World Geodetic System 84 (WGS84). This requires conversion. It must also be registered for permission to use the information.

c) Integrating GPS Data

Use of Global Positioning System (GPS) is now very common. Field checking and data updating using GPS are very handy and quick. The GPS data are stored in the WGS84 coordinate system and need to be converted as well as further differential corrections to get more accurate results of the feature positions. Height data as captured by GPS have to be corrected since they are referenced to Ellipsoid instead of Mean Sea Level (MSL) or GeoId.

5.15.6 Data Manipulation and Analysis

With a database established, further manipulations are needed to generate new datasets. This requires a feature-clipping process. Other tasks include:

- height data manipulation
- delineation of catchment and sub-catchment boundaries
- measurement of length and area

a) Manipulating Height Data

Height data is one of the most important parameters in the hydrologic or hydraulic modelling. Existing JUPEM's topographic maps, as made available to the general public, are produced with 20 m contour intervals. However, manipulation of the original spot height data (captured by JUPEM) could produce more accurate contour lines. This can be made available if requested but needs further processing including format conversion since the data obtained are in the ASCII format. The spot heights are converted into Triangulated Irregular Network (TIN) which is then used to produce a 1 m contour map with a slope map.

b) Delineating Catchment Boundaries

With GIS package, an automatic generation of the catchment area (including sub-catchments) can be accomplished but this requires two datasets namely height and river/drainage alignments.

c) Feature Clipping

Certain features may need to be clipped to fall within a boundary of interest. An example is landuse information that has to be extracted for each river catchment.

d) Calculation of Area

Area of a certain polygonal feature may be required for certain analyses. With GIS, this measurement can be obtained using geo-referenced source maps. In cases where the satellite images or aerial photographs are available (and geo-referenced), the boundary of a certain feature (such as existing detention ponds) can be delineated directly on screen and the required area computed.

e) Producing Maps For Ground Survey

In certain situations, detailed information on the lengths of centreline and boundaries of rivers are required. Since the existing river dataset is in the form of mixed lines (certain portion as single line while others as double line), a new map has to be produced to represent, say, the river centreline. Only after geo-referencing can those length measurements be produced and tabulated from a survey onto maps.

5.15.7 Data Retrieval and Display

Retrieving and displaying the information from the GIS database is the main activity in GIS application. Since GIS stores both the spatial and attribute information, queries can be made either graphically or by attributes. The display could be in the form of selected features, a list of attributes (describing the feature characteristics) or charts.

a) Displaying Graphic Information

A GIS stores and manipulates spatial and attribute data. With the map layers properly stored in the database, various queries can be made. The spatial/graphical information can be displayed by specifying a certain attribute attached to it. More complex queries can also be made by imposing adequate conditions for example to show only the industrial areas within the catchment of a study area.

b) Displaying Attribute Information

Apart from query facility to show graphical information, GIS also offers another form of query that can show the characteristics or attributes of a particular feature.

c) Producing Charts

The GIS can also generate a generalized or summarized form of information as required for certain analyses. For instance, it can calculate and generate figures of the proportion (or percentage) of certain type of landuse or certain type of soil within a certain catchment area.

d) Producing Maps

Most of the GIS output is published in the form of maps. A proper map should not just contain features meaningful to the map user but also presented in a format that can be easily read and interpreted by the user. The GIS can also produce such quality that follows standard cartographic design. This allows for choice of colours, text (label) and symbols, scale, orientation and margin information.

With GIS, maps can be designed to fit a certain size of printing paper. Some maps are suitable for A3-size paper (say for a report) while others may only require A1, A0 or A00 paper size (e.g. for a wall display). The map output can be exported into a print-ready format such as Adobe's PDF so that they can be easily printed or reproduced.

5.15.8 Data Management Operations and Maintenance

a) Commitment

To sustain the database, there should be need for a long-term commitment for data management application. Adequate personnel should be available not only for routine operation, but also to modify the system as the need arises. Failures to provide such support will likely result in a gradual loss of system capabilities, which may ultimately contribute to system collapse.

b) Archives

The database should be backed up regularly. The system should always be prepared for major hardware or software failures and data loss. Procedures should be made as simple as possible to ensure that backups are regularly made.

As the database evolves with time and technology changes over time, data archiving should allow retrieval of the historical data stored in the earlier structure or design. Archiving of data should be done using a non-volatile media (e.g. CD-ROM) or a system independent of the data format.

c) Design Re-evaluation

As a result of established feedback mechanisms and to ensure the data management system meets its objectives (i.e. complying with the needs of clients), periodic evaluations should be undertaken and representatives of the system user should be present.

Design evaluation is recommended to ensure the system takes advantage of recent technological developments. Special attention should be given to establish procedures for upgrading archived data so that data in the old format are not lost and will continue to be accessible.

5.15.9 Asset Information

Asset Information is a brief summary of the information contained in the Asset Management Plan. The integrity of asset information is paramount for improving the relevance and reliability of asset management and asset financial reporting and asset strategic planning of any organization. The effectiveness of an asset management database system depends on its ability to allow operators to quickly and easily store, recall, sort, analyse and evaluate different types of information about assets. The Geographic Information Systems (GIS) can be used as a front-end function to aid in the spatial identification of assets or groups of assets in the asset register. These are usually used in conjunction with CAD systems. The benefits are mapping representation of the assets, rapid downloading of field data, quick identification of assets by area (polygon) and planning for operation and maintenance. The Global Positioning Systems (GPS) can be used in conjunction with Geographical Information System to provide instant location information. The benefits are improved management data for operation & maintenance operations, monitoring of emergency response operations and for fleet management.

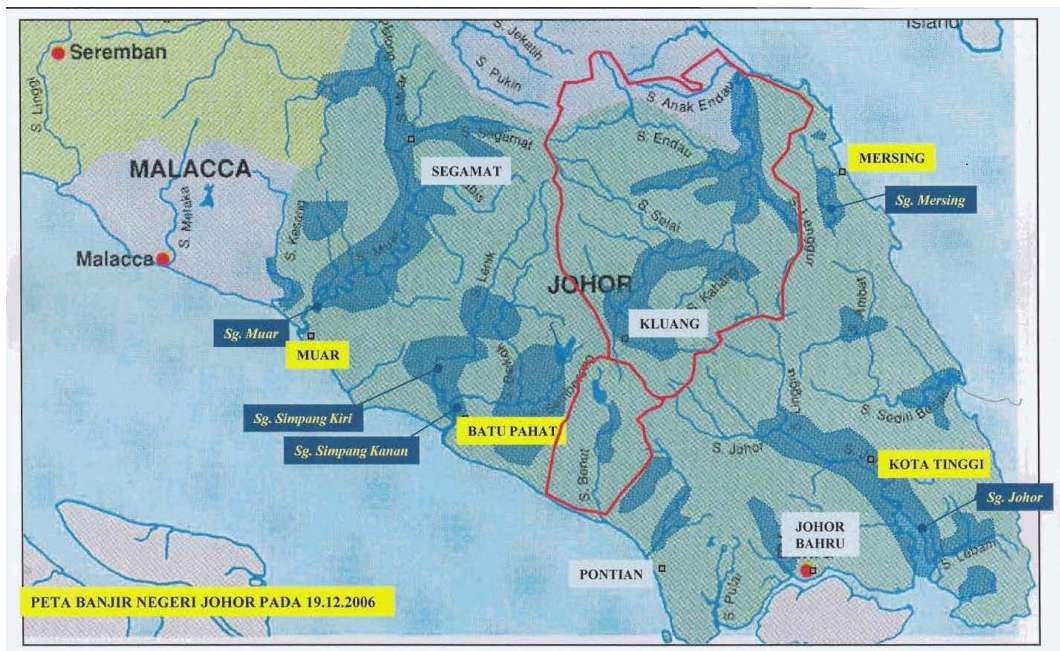
The Central Asset Inventory (CAI) is a vital component of the underlying solution for the asset information strategy. Essentially, CAI is a database which provides a means of linking between records held in different systems and thereby enables separate systems to operate in conjunction with each other. To do this, it provides the means by which records in different databases can be joined together. This enables the various attributes to be collected from different sources, giving a single master set of data for each asset. Thus it allows for the continued use of individual systems with their own databases without the need a massive (large storage) single database.

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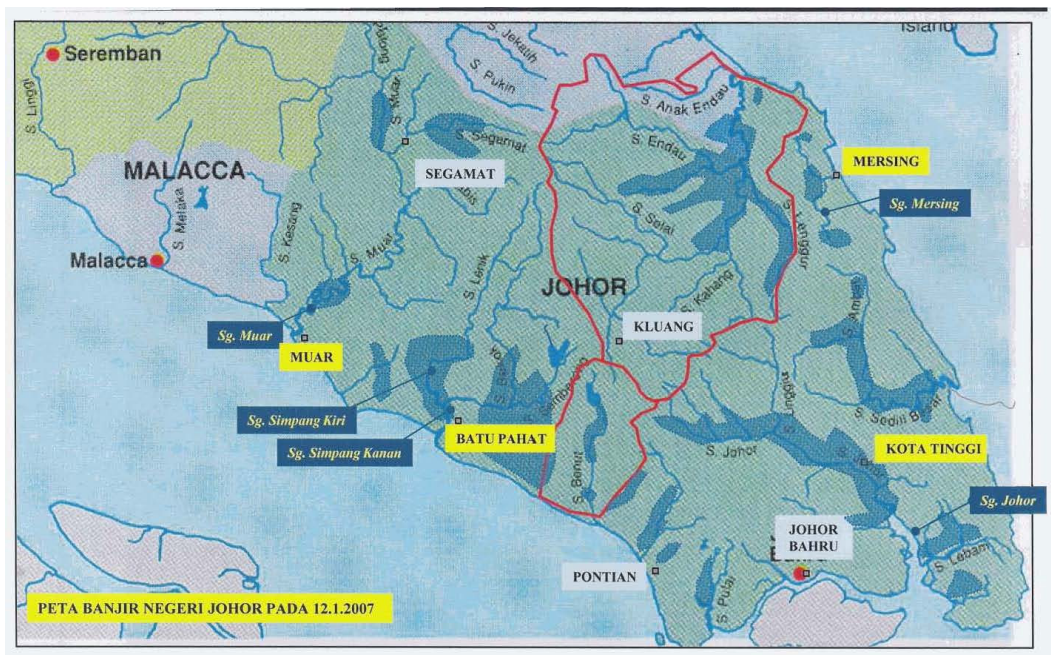
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APPENDIX 5.A FLOOD MAP OF JOHOR



Flood Map Derived from the December 2006 Floods in the State of Johor



Flood Map for January 2007 in the State of Johor

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CHAPTER 6 FLOOD MITIGATION GUIDELINES

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6 FLOOD MITIGATION GUIDELINES

6.1 PLANNING FOR FLOOD MITIGATION

Planning for flood mitigation should cover the entire river basin while promoting the coordinated development and management of actions regarding water, land and related resources. Priority should be given to the integrated water management rather than management of flood alone. Experience has shown that effective flood prevention and protection has to be taken up to the entire river basin.

The fundamental process of planning for flood mitigation shall address the two key elements and can be summarized as illustrated in Figure 6.1.

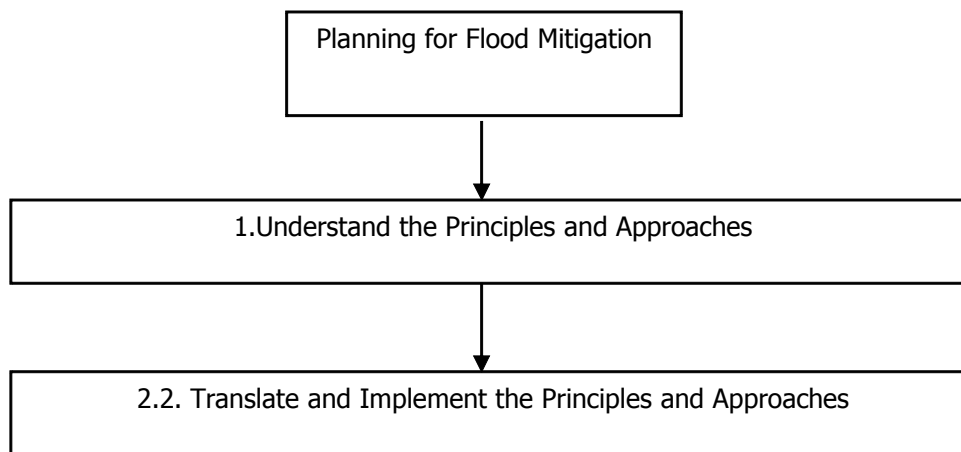


Figure 6.1 Flow Chart for the Planning for Flood Mitigation

The subject of understanding the principles of and approaches to flood mitigation is addressed in detail in Appendix 6(A) while that of translating and implementing the principles and approaches is given in Appendix 6(B).

6.2 LEVEL OF PROTECTION

Level of protection for a flood mitigation project is represented by the project's design criterion of the return period or average recurrence interval (ARI). Some hydrologic models may assume a 25-yr rainfall would actually cause a 25-yr flood magnitude. Although unlikely in reality, the assumption is reasonable because rainfall itself, being dynamic in behaviour, is taken as an average expectation. In actuality, a 25-yr flood will not occur if a 25-yr rainfall occurs on a dry watershed. Similarly, a 50-yr flood could occur from a 25-yr rainfall if the watershed was already saturated before the rains. For modelling purposes, it is often assumed that a T-yr rainfall on a watershed that exists in a T-yr hydrologic condition would produce a T-yr flood.

Design of a large hydraulic structure or project is based on an estimated limiting value (ELV), which is implicitly the probable maximum precipitation (PMP). PMP, as defined by the World Meteorological Organization (1983), is a quantity of precipitation close to the physical upper limit for a given duration over a particular basin. Worldwide records indicate that PMP can have a return period as long as 500,000,000 years. This return period actually varies geographically. An arbitrary return period of 10,000 yr may be assigned by designers to PMP or PMF (the probable maximum flood) but in reality this has no physical basis (Mays, 2001).

In terms of potential failure, structures are classified as major, intermediate, or minor. As an example from the National Academy of Sciences (1983), a small dam has 1500 m³ to 30,500 m³ of storage (equivalent to 7.6 m to 12.2 m high); an intermediate dam from 30,500 m³ to 1,524,000 m³ of storage (12.2 m to 30.5 m high) and a large dam with storage exceeding 1,524,000 m³ (30.5 m high).

Typically, the capacity of a channel may exceed about once every 2 years. This level of protection may be indicated by delineation of the floodplain (based on the extent of alluvial soils) having a return period of approximately 10 years.

It is proposed that for a 100-year return period, the floodplain should be defined for all open channels in the drainage system and the 100-year return period discharge should be computed for the existing watershed conditions using appropriate hydrologic methods, depending on the availability of data.

For larger streams, adequate historical stream gauge data may be available and the 100-year discharge can be computed using the Extreme-Gumble distribution. For other channels in areas where adequate stream gauge data are not available, the 100-year return period discharge can be computed using a detailed hydrologic model of the watershed.

Typically, a 100-year rainfall with a balanced triangular distribution is normally assumed in modelling. For smaller channels, a storm of 24-hour duration is used. For larger channels, a duration greater than or equal to the time to peak is preferred.

Computed water surface elevations cross-checked with topographic maps are used to delineate the 100-year return period floodplain, assuming a level water surface across the channel.

River bunds and flood walls are used to confine river water within the river, thus preventing the floodwater from spillage into the floodplain. The bunds or walls normally run parallel with the river, affording a 100 percent protection until overtopping occurs after which the structures provide no more flood protection.

The levels of protection for rural and urban landuse are summarized in Table 6.1.

Table 6.1 Summary of the Level of Protection

Landuse	Platform Level	Consideration
Rural	25- 50 yr	Primarily focus on the protection of human health and safety, and valuable goods and property, agricultural property, mass deposition, landslide, rising groundwater table, water and soil solution.
Urban	100 yr	Primarily focus on the protection of human health and safety, and valuable goods and property, high density of population, high value of property, national level issue, environmental pollution, sewage network, landslide, water and soil pollution

Example 6.1: Example Calculation on Level of Protection

Note:

Level of protection is related to hydrologic design level. Rainfall and flow records are required to determine the hydrologic design level. Modelling often assumes a T-yr rainfall on a watershed that exists in a T-yr hydrologic condition will produce a T-yr flood (McCuen, 2004). In reality, a similar rainfall amount can generate different flood magnitudes in the same watershed under dry or saturated conditions. Rainfall in an already saturated watershed will generate extremely higher flood magnitudes than when it is dry.

Problem:

Batu Pahat experienced extreme flood events in December 2006 and January 2007. The mean and standard deviations for the annual daily maximum rainfall data recorded at Ladang Yong Peng up to year 2007 have been calculated to be 10.2 cm and 6.05 cm respectively. Determine the design storm that could allow for a level of protection for a 100-year storm using the frequency factor method and the annual maximum rainfall data provided. Use the Extreme Value Type I distribution.

Solution:

$$K_T = \frac{\sqrt{6}}{n} \left(0.5772 + \ln \ln \frac{T}{T-1} \right)$$

$$= \frac{\sqrt{6}}{n} \left(0.5772 + \ln \ln \frac{100}{100-1} \right)$$

$$= 3.138 \{ \}$$

T = Return Period (ARI), K_T = Frequency Factor

$$x_T = \bar{x} + K_T S$$

$$x_{100} = 10.2 + 3.138(6.05)$$

$$x_{100} = 29.18 \text{ cm}$$

The 100-yr design storm of 29.2 cm or 292 mm may thus generate a 100-yr flood.

6.2.1 Introduction to Flood Frequency Methodology

The flood frequency methods described in this section and the following section are adapted from the Flood Estimation Handbook (Robson and Reed, 1999) published by the Institute of Hydrology, Wallingford, United Kingdom.

This section introduces the statistical flood frequency methodology for single site analysis while describing flood frequency concepts. For single site analysis, only the flood data from the subject site are used. There are two types of flood data: the annual maximum series and the peaks-over-threshold (POT) series. Both the annual maximum and POT series are usually analysed in terms of water year.

The annual maximum series consists of the largest observed flow in each water year. These data do not indicate whether several major floods have occurred in a water year; only the single largest flow is recorded. However annual maximum series sometimes includes values that arise from poorly

defined peaks of flow. This occurs when a catchment has not experienced any floods in a water year. Such occurrences are typical of highly permeable catchments and may require special treatment.

A POT series consists of all distinct peak flows that are greater than a selected threshold flow. Usually the abstraction threshold is set so that the series contains an average of four or more peaks per year. Independent rules to determine when peaks can be considered distinct, must be carefully applied. The resulting POT series is irregular; in some years there may be many floods, and in other years, no floods at all.

POT data provide a more complete picture of the flood regime than the annual maximum but are also more difficult to abstract and therefore not always available. The method employing the annual maximum series is acceptable but the method using the POT data is preferred when available.

The POT abstraction threshold is ideally set low so that there is flexibility for future analyses. A low threshold would allow a large number of peaks to be included such as small, medium-sized, and large floods. For analytical purposes, the threshold level may be raised above the abstraction threshold; peak flows smaller than this level, are then ignored. Varying the threshold will allow different aspects of the data to be emphasized.

6.2.2 Estimating Annual Maximum Flood

The catchment flood data are used to estimate the flood index. The recommended index flood is the median annual maximum flood, referred to as QMED. This is the flood that is exceeded in exactly half of all years.

QMED estimates can be obtained from either the POT series or the annual maximum series. In general, the POT data give better QMED estimates, especially for shorter record lengths. Using POT data is equivalent to collecting the annual maximum data for one to two years. If QMED estimate is based on a record shorter than 14 years, then an adjustment for climatic variation is recommended.

Calculation of the median annual maximum flood using the annual maximum data is straightforward. The median is the middle-ranking value of a series of numbers. To find the median, the series is sorted into the size of decreasing order, so that Q_i is the i^{th} largest annual maximum flood. If the total record length is n , then QMED is estimated as follows.

$$QMED = Q_{\frac{n+1}{2}} \text{ for } n \text{ odd and } QMED = \frac{1}{2} Q_{\frac{n}{2}} + Q_{\frac{n}{2}+1} \quad (6.1)$$

The POT data are a series of flood data that are bigger than the selected threshold. If a low threshold is used, the POT series contains numerous floods, some of which are of moderate or small size. Using a high threshold leaves just a few large events in the POT series. In the QMED estimation, the main interest is in the rarer floods, so a high threshold is most useful. In other circumstances, for example when studying flood seasonality, a lower threshold is more appropriate.

The POT and the annual maximum data are closely linked. Provided the POT threshold is low enough, the annual maximum will be the maximum of the POT events in a year. Because POT records contain more floods than the annual maximum records, a better estimate of QMED can often be obtained from the POT data. The benefit of using POT data is greater when record lengths are shorter than 14 years.

6.2.3 Flood Frequency Analysis

A fundamental component of flood frequency analysis is to fit a flood frequency distribution to either a site or pooled data. One common approach is to use the distribution fitting moments, maximum likelihood estimation or the L-moments methods. The L-moments method is preferred for flood frequency estimation because of its robust properties in the presence of unusually small or large values (outliers).

Flood frequency analysis for estimating design flood discharge may be referred to Volume 4 (Chapter 5) of the DID Hydrology and Water Resources Manual (2008). Regional frequency analysis is available in Volume 4 (Chapter 2) of the same Manual based on the Probable Maximum Precipitation (PMP) method.

The method of moments requires fitting a distribution to match the distribution mean, variance, etc., with the sample mean, variance, etc. The method is best suited to symmetric distributions. It can give poor results when data are strongly skewed because sample estimates of skewness become unreliable. Since strong skewness is a feature of many flood series, the L-moments method is preferred to the conventional moment methods in flood frequency analysis. The maximum likelihood method provides flexibility to estimation but can require either solution of complex equations or use of numerical optimization schemes. It is not uncommon for numerical problems to arise during the search for a maximum, thus preventing a solution from being found. The L-moments approach has been shown to be comparable to if not out-perform the maximum likelihood method for flood estimation in small to medium sized samples.

The L-moments method is similar to the method of moments but is based on L-moments rather than conventional moments. The method is developed based on probability weighted moments, which is computationally convenient. The method is presented in detail elsewhere (Hosking and Wallis, 1997).

The L-moments method is based on the linear combination of data. Note that the L in the L-moments method gives emphasis on linearity. Just as the mean, variance and skewness are defined in terms of the moments, the L-mean, L-scale, and L-skewness are defined in terms of the L-moments.

The first L-moment is identical to the usual mean. It is a measure of location, sometimes referred to as the L-mean. The second L-moment is a measure of the spread or dispersion of data, sometimes referred to as the L-scale. It is based on the differences between observations in a sample. The third L-moment is a measure of symmetry of the data.

Flood peak behaviour is best described using a continuous distribution, one that can take any value within a range (possibly infinite). A continuous distribution is usually defined in terms of either the probability density function or the cumulative distribution function. When selecting distribution, it is best to choose the one with the fewest parameters that gives an adequate fit.

Because of the record lengths that are typically available, two or three parameter distributions are most commonly used for flood frequency estimation. Four and five parameter distributions are rarely used directly as flood frequency curves, but they have other important uses. Table 6.2 illustrates various types of the distribution methods for describing flood frequency.

Table 6.2 Distributions Used for Describing Flood Frequency

2-parameter:	Gumbel	(G)
	Logistic	(L)
	Log-Normal	(LN2)
3-parameter:	Generalised Extreme value	(GEV)
	Generalised Logistic	(GL)
	Pearson Type 3	(PE3)
	Log-Normal	(LN3)
	Generalised Pareto	(GP)
4-parameter	Kappa	
5-parameter	Wakeby	

The annual maximum and the POT series are examples of extreme value series, which is the extreme of the entire flow series. It is appropriate to describe the series using standard distributions such as the normal distribution that provides insufficient chance of a large event occurring.

Many other distributions are available to describe such series. These tend to be characterized by an appreciable chance of a very large value occurring. Such distributions will be loosely referred to here as extreme value distributions.

6.2.4 Adjusting for Urbanisation

Urbanisation has a marked effect on the hydrological regime of a catchment. It tends to accelerate and magnify flood response and change the seasonality of flooding. Adjustments made to the urban development will enable estimation of flood frequency for urbanized catchments.

The term "adjustments" is used because urban development is viewed as causing modifications to the behaviour of the catchment in its rural state. It describes the net effect of urbanization if a typical degree of flood alleviation that has taken place for an urbanized catchment is obtained by applying an adjustment to the rural pooled growth curve.

Urbanisation affects flooding in a variety of ways and may cause the following:

- a) Faster runoff because of improved drainage;
- b) Increased runoff because surfaces are less permeable;
- c) Reduced sensitivity to antecedent catchment wetness, because urban surfaces wet-up quickly; and
- d) Changes in the flood water or drainage patterns.

These changes mean that urbanized catchments generally show increased flooding for most rainfall events relative to their rural counterparts. Urban effects tend to be particularly pronounced in response to short-duration rainfall events, typical of convective storms and the resulting implications to the urban catchments may be as follows:

- a) Altered flood regime, with greater tendency all-year round; and
- b) Increase in flood frequency.

For the most extreme (long return period) rainfall events, the impact of urbanization on flood response is likely to be small. Under such conditions, a catchment becomes fully saturated, with almost all water moving rapidly to the river by surface and near-surface routes, during which times, the catchment can be expected to behave much as it would in its original rural state.

A highly permeable catchment tends to be most affected by urbanization. This is because the soil properties can drastically alter from being permeable to impermeable in urban surfaces.

Approaches to flood mitigation in urbanized areas include:

- a) Small-scale mitigation works that are an integral part of urbanization, e.g. soakaways, combined sewers, tanks in storm-water sewers;
- b) Medium-scale storage-based mitigation works designed to reduce flood flows, e.g. balancing ponds;
- c) Flood defence works that are non-storage based (e.g. culverts, bunds, diversions) will alleviate flood impact rather than flood peaks; and
- d) Strategic flood alleviation works that are storage-based, e.g. major flood storage areas, dams.

6.2.5 Generalized Criteria for Water-Control Structures

A large number of structures are designed using return periods (Chow et al., 1988). Table 6.3 presents generalized criteria for water control structures which may be used as reference by local engineers when designing the water related control structures.

Table 6.3 Generalized Design Criteria for Water Control Structures (source: Chow et al., 1988)

Type of structures	Return period [T]	Estimated Limiting Value [ELV]
Highway culverts		
Low traffic	5-10	-
Intermediate traffic	10-25	-
High traffic	50-100	-
Highway bridges		
Secondary system	10-50	-
Primary system	50-100	-
Farm drainage		
Culverts	5-50	-
Ditches	5-50	-
Urban Drainage		
Storm sewers in small cities	2-25	-
Storm sewers in large cities	25-50	-
Airfields		
Low traffic	5-10	-
Intermediate traffic	10-25	-
High traffic	50-100	-
Bunds		
On farm	2-50	-
Around cities	50-100	-
Dam with no likelihood of Loss of life (low hazard)		
Small dams	50-100	-
Intermediate dams	100+	-
Large dams	-	50-100%
Dam with high likelihood of considerable loss of life (high hazard)		
Small dam	-	50-100%
Intermediate dams	-	100%
Large dams	-	100%
Dam with probable loss of life (significant hazard)		
Small dams	100+	50%
Intermediate dams	-	50-100%

Design criteria based on return periods for the Malaysian practice are shown in Table 6.4. More detailed explanation of the criteria is obtainable from MSMA (2000) and complementary DID design manuals (Urban Drainage Manual (2000) and Guidelines for River Development, 1973).

Table 6.4 Generalized Criteria for the Selection of Return Period (T)

System	Return Period (T)	Consideration
Drain	2- 20 yr	Minor drainage system
	25-100 yr	Major drainage system
River	100 yr	Urban area
	50 yr	Agricultural area
	5 yr	Forest area

6.3 FREEBOARD

Freeboard (F) is defined as the vertical distance between the water surface and top of the channel when the channel is carrying the design flow at a normal depth. The freeboard (Figure 6.2) is the distance between the calculated water surface and top of the channel lining or bank.

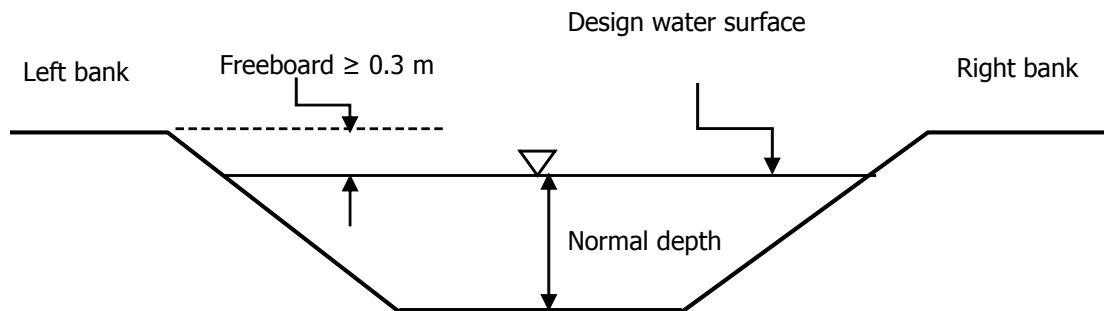


Figure 6.2 Freeboard of the Channel Design

Freeboard is to provide protection to the structure against uncertainty in the design parameters. Freeboards for unlined channels can be estimated using empirical formula (Chow, 1959 and Chin, 2000) while those for grass-lined channels may be obtained from Chin (2000) and ASCE (1992).

The minimum freeboard is normally 30 cm at the maximum design water surface elevation and an additional freeboard equal to the super-elevation of the water surface should be provided around bends. The U.S. Bureau of Reclamation recommends a minimum freeboard of 0.3 m for small channels. For larger channels however, the freeboard is best estimated using formulae (see section 6.3.1).

Floodway has been arbitrarily defined as that part of the cross-section that includes the channel and will pass the 100-year return period flood without increasing the water level more than 0.30m above the existing 100-year flood level. Floodway fringe is the area between the floodway and the 100-year floodplain limit.

Development is often allowed in the floodway fringe which then may not be available to convey floodwater. Communities often require the floodway fringe be developed and that the channel may be improved. In this case, there will be no change in the 100-year return period for the water surface elevation. Whenever possible, no development is to be permitted in the floodway that will interfere with the flow of floodwater.

Freeboard is incorporated into FPLs. It is the difference between the flood event upon which the FPL is based and the FPL itself. Freeboard is to provide reasonable certainty that the reduced risk exposure obtained by selecting a particular flood as the basis of FPL is actually provided, considering the following factors:

- a) Uncertainties in the estimates of flood levels. These can arise from a relatively short database of past floods and past storm surges in coastal waters, together with uncertainties and simplifications in the models used to predict flood discharges and flood levels;
- b) Differences in water levels across the floodplain because of 'local factors'. These factors are not able to be determined in floodplain modelling, which assumes a static water level;
- c) Increases in water level as a result of wave action are not determined in floodplain modelling. Wave action can be of two types: wind-induced waves across fetches of open water and waves induced by boats and vehicles moving through flooded areas. For example, wave action may be important in the wide floodplains as a wind with a fetch 2 km long could readily generate waves up to 0.5 m high;
- d) Changes in rainfall patterns and ocean water levels as a result of climate change.
- e) The cumulative effect of subsequent infill development of the existing zoned land.

In effect, freeboard acts as a factor of safety but should never be relied on to manage risk in events larger than the flood used to derive the FPL. In the majority of circumstances a freeboard of 0.5 m would be acceptable for new residential development controls. However, freeboard may be different for:

- a) Different land uses, although the adoption of a different flood event for deriving a FPL with the same freeboard would provide a more realistic indication of risk exposure;
- b) Different parts of the floodplain where factors influencing freeboard, as indicated above, may vary with location; and
- c) Mitigation works of different types relative to development controls.

Mitigation works may be exposed to additional risks due to their nature of construction than required for new developments, resulting in the need for bigger freeboard.

Earth bunds for instance need to consider the following:

- a) Post construction settlement, which effectively reduces the long term level of the bund;
- b) Surface erosion due to vehicle, animal or pedestrian crossing can result in surface erosion reducing its level;
- c) The potential for significant surface shrinkage cracking and associated additional risk of failure where good grass cover and an appropriate moisture content cannot be maintained; and
- d) The performance of earthen bunds when overtopped is characterised by relatively quick vertical erosion resulting in an embankment breach. This will allow in more water quickly resulting in relatively fast rising flooding and hence difficult evacuation.

These can all add up to the total general freeboard requirements. This means that a larger freeboard is necessary for earthen bunds compared to that for development control purposes or for concrete bund (wall).

6.3.1 Freeboard for Channel Design

Channels are usually designed for subcritical uniform flow conditions. Chutes and some concrete channels are designed for supercritical flow. Channels are generally designed to avoid critical depth. This is because as the depth of flow approaches critical, large standing waves are formed and this will require a larger channel to contain that flow depth.

To avoid standing waves, the Froude number should normally be less than 0.6 for subcritical flow or greater than 1.4 for supercritical flow.

The recommended minimum freeboard, F to be applied is based on the description by Chin (2000) and calculated as follows:

$$F = 0.55\sqrt{Cy} \quad (6.2)$$

Where, y is the normal water depth, C is a coefficient that varies from 1.5 at a flow of $0.57\text{m}^3/\text{s}$ to 2.5 for a flow of $85\text{m}^3/\text{s}$ or more.

Additional freeboard must be provided to accommodate the superelevation effect of the water occurring at channel bends. Applying the momentum equation to the flow around a channel bend, the superelevation, h_s , of the water surface can be estimated by

$$h_s = \frac{V^2 T}{gr_c} \quad (6.3)$$

Where, V is the velocity in the channel, T is the top-width of the channel, and r_c is the radius of curvature of the centreline of the channel. Equation (6.3) is valid only for subcritical flow conditions. In this case the elevation of the water surface at the outer channel bank will be $h_s/2$ higher than the centreline water-surface elevation. The elevation of the water surface at the inner channel bank will be $h_s/2$ lower than the centreline water elevation.

In channels with subcritical flow, the minimum required freeboard is the larger of 1ft (0.3 m) or that calculated using Equation 6.2. In channels with supercritical flows, the required freeboard is the larger of 2 ft (0.6 m) or the result of Equation 6.2.

In all instances, the freeboard required is additional to any increase in the water surface due to superelevation or channel curvature. The Federal Emergency Management Agency (FEMA, US) for example, recommends that bunds must have freeboard requirements of 3 ft (1 m), 3.5ft (1.01 m), or 4 ft (1.2 m) minimum depending on location relative to end of bund, and/or other structures.

Example 2: Calculation to estimate the Freeboard of Channel

Note:

Freeboard is defined as the vertical distance between the water surface and the top of the channel when the channel is carrying the design flow at normal depth. It should be sufficient to prevent waves or fluctuation in the water surface from overflowing the banks. It is to account for the uncertainty in the design, construction and operation.

Problem:

A trapezoidal channel is designed to carry $12\text{m}^3/\text{s}$ through a slightly sinuous route. The channel is to have side slopes and to be excavated in coarse alluvium with normal flow depth 0.68 m. Determine the total depth of channel to be excavated.

Solution:

The required freeboard can be estimated using the following equation,

$$F = 0.55\sqrt{Cy}$$

F is the freeboard in meters, C is a coefficient that varies from 1.5 at a flow of 0.57 m³/s to 2.5 for a flow of 85 m³/s, and y is the design flow depth in meters.

$$y = 0.68, C = 1.6 \text{ (interpolation between 1.5 to 2.5 for flow 0.57 m}^3\text{/s to 85 m}^3\text{/s)}$$

$$F = 0.55\sqrt{1.6(0.68)}$$

$$F = 0.573 = 0.57 \text{ m}$$

The total depth of the channel to be excavated is therefore equal to the normal depth plus the freeboard (0.68 m + 0.57 m = 1.25 m).

6.3.2 Freeboard for Hydraulic Structures

Equation 6.1 is applicable and recommended for estimating freeboard for the hydraulic structures.

Freeboard is not required by insurance standards, but communities are encouraged to adopt at least a one-foot (0.3 m) freeboard. This is to account for the one-foot (0.3m) rise built into the concept of designating a floodway and the encroachment requirements where floodways have not been designated. Freeboard can result in significantly lower flood insurance rates due to lower flood risks.

For hydraulic structures, the freeboard is the vertical distance between a design maximum water level and the top of a structure such as a channel, bund, floodwall and dam.

The freeboard is a safety factor intended to accommodate the possible effect of unpredictable obstructions, such as debris blockage that could increase water levels above the design water surface.

Nautical distance is the distance between the water line and the uppermost full deck of a ship. For dams, the terms "net freeboard", "dry freeboard", "flood freeboard" or "residual freeboard" refers to the vertical distance between the estimated maximum water level and the top of a dam. "Gross freeboard" or "total freeboard" is the vertical distance between the maximum planned controlled retention water level and the top of a dam.

Bridge freeboard should be based on a 50 year flood frequency. When the drainage area produces unusually large debris, additional freeboard to protect the structure is desirable. If the drainage area produces very little debris the freeboard criteria may be reduced.

Freeboard is the required clearance between the lower limit of superstructure and the design high water surface elevation. An appropriate amount of freeboard allows for the safe passage of debris through the structure. The required structure grade elevation is obtained by adding freeboard and superstructure depth to the design high water elevation. As a guide, the freeboard for bridge structures practiced in the US are shown in Table 6.5.

Malaysian practice presently does not set any standard value for minimum freeboard. Thus, if necessary, local engineers may adopt the usual international practice of 0.3 m as the minimum freeboard. This is the distance (clearance) between the soffit (lowest limit) of bridge structure and the design high water surface elevation. For a bridge crossing a waterway such as a river that receives discharge contribution from significantly large drainage areas, the minimum freeboard (shown in Table 6.5) is recommended. The 0.3 m minimum freeboard (International practice) is also

applicable for other structures (such as culverts) crossing the river. The application of minimum freeboard for a bridge structure is shown in Figure 6.3.

For navigation, the higher the clearance the better it is for the safe passage of the navigating vessels. This clearance is normally taken as the distance between the highest tide level and the soffit of the bridge. In flat areas, an arch bridge may be economical to achieve the required freeboard.

The minimum clearance recommended for river crossing structures is shown in Table 6.6 (Guidelines for River Development, DID 1973).

Table 6.5

Structure Type	Minimum Freeboard
Bridges with drainage area $> 2.6 \text{ km}^2$	0.6 m
Bridges with drainage area $< 2.6 \text{ km}^2$	0.3 m
Temporary bridges	0.3 m

Table 6.6 Minimum Clearance for River Crossing Structures
(Guideline for River Development, DID 1973)

River Width	Minimum Height Clearance	Minimum Width Clearance
< 15 meter	3.5 m	8 m from river banks (left and right)
15 meter – 20 meter	4.0 m	10 m from river banks (left and right)
> 20 meter	4.5 m	10 m from river banks (left and right)

Estimation of the minimum elevation of dam crest requires information of the maximum reservoir storage. The Minimum Dam Crest Elevation (MDCE) is equal to the Maximum Reservoir Elevation (MaxRE) plus the Minimum Dam Crest Freeboard (FB). The maximum reservoir elevation is calculated from the maximum reservoir storage. The minimum FB is 0.3 meter.

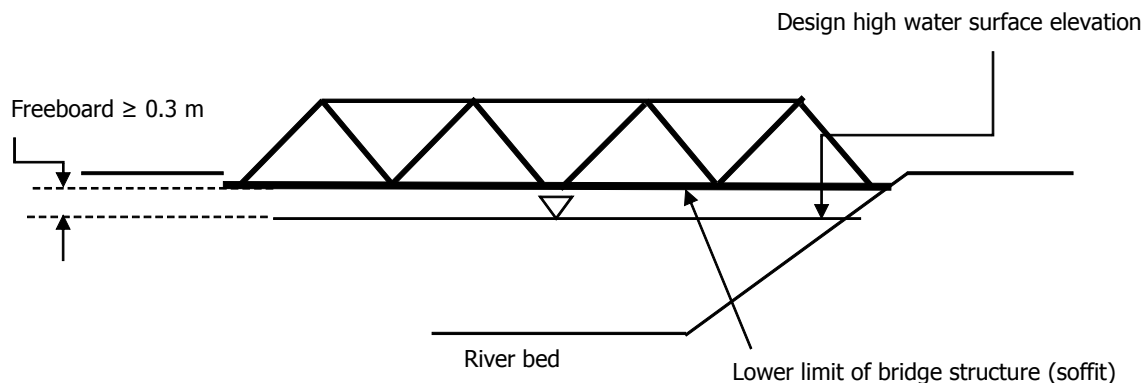


Figure 6.3 Freeboard for the Bridge Crossing

6.4 BUILT UP PLATFORM LEVEL

Platform level for flood protection is associated with Flood Planning Level (FPL). FPL is an important criterion in the management of flood risks (New South Wales, Australia (2002)).

FPLs are derived from a combination of flood events say, an historic flood or floods of certain Average Exceedence Probability (AEP) and a freeboard. FPLs do not, however, ensure that development is located in areas where it will neither have significant adverse impacts on flooding nor do they address personal danger issues. These issues need to be considered strategically in studies and are managed through appropriate land use restrictions and could also be based on emergency response planning and assessment.

It is important to consider flood behaviour and land use attributes in determining areas and conditions for development, including selecting FPLs. For example, historical practice in New South Wales, Australia has generally seen the adoption of a single FPL for development control (NSW, 2002). This tended to focus on the 1% AEP event and resulted in the popular perception that this event defines the limit of flooding. This perception precluded assessment of the risk levels associated with rarer floods that may be more critical for a particular location.

A floodplain risk management study involves determining appropriate land uses and densities and selecting both flood events and freeboards upon which FPLs for different purposes are based. Therefore decisions on FPLs are based upon a detailed understanding of flood behaviour across the full range of floods, their likelihood of occurrence and their associated consequences in terms of danger to personal safety and social, economic, environmental and cultural issues.

Selection of the flood event upon which the FPL is based and associated development controls, such as minimum fill and floor levels as well as the needs to ensure that risk to life is effectively managed for the full range of floods. A flood larger than that which is used to derive the FPL will result in increased risk to life and property.

A 100-year flood is normally recommended as the base flood for flood insurance purposes. This has also become widely accepted as the standard criteria for flood mitigation planning and design.

However for the structural method of flood-damage mitigation that encourages development and urbanization, higher design flood must be much greater than the 100-year flood could be considered.

The standard project flood is about half the probable maximum flood for an area with a return period of about 500 years.

FPLs do not, however, ensure that development is located in areas where it will neither have significant adverse impacts on flooding nor do they address personal danger issues.

These issues need to be considered strategically in studies and are managed through appropriate land use restrictions and an emergency response planning.

Future flood risks can be managed strategically through a combination of the following:

- a) Appropriate zonings and controls to ensure that development is restricted to areas where it will not significantly impact on flood behaviour in the flood event used to derive the FPL, and that development type, scale and controls result in manageable continuing risks;
- b) Adopting FPLs for new developments (minimum floor level) to reduce the likelihood of properties and building flooding and associated damages to an acceptable level; and
- c) Effective management of personal safety in rare events.

Therefore development controls, including FPLs for future development, are aimed at reducing the likelihood of flood damages to properties and buildings and reduce the exposure of people to dangerous flood situations.

As it is generally not feasible, nor is it socially, environmentally, and economically desirable to safeguard development against the PMF, a continuing risk from rare floods remains. Selection of a flood event upon which a FPL is based is therefore essentially a matter of balancing the following:

- a) The social, economic, environmental and cultural costs of restricting land use in flood prone areas; and,
- b) The social, economic, environmental and cultural benefits of a reduction in the frequency, inconvenience, damage and danger to people caused by flooding.

The relevance of these issues varies with location in the floodplain and between the different types of developments. What may be appropriate for one land use may be inappropriate for another. Similarly for the same land use elsewhere with a different flood risk exposure.

FPLs selected for planning purposes are derived from a combination of the adopted flood levels plus freeboard, as determined in the floodplain management studies and incorporated in the floodplain risks management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risks. It should also take into account the social, economic and ecological consequences associated with floods of different severities.

Different FPLs may be appropriate for different categories of land use and for different flood plans. The concept of FPLs supersedes the "standard flood event". As FPLs do not necessarily extend to the limits of flood prone land, floodplain risks management plans may apply to the flood prone land beyond that which is defined by the FPLs.

6.4.1 Rural and Agricultural Land Use

New developments and relatively undeveloped areas provide more flexibility in decision making than the already developed areas. Greenfield sites in particular, provide an excellent opportunity to set appropriate development limits and conditions including FPLs, to reduce continuing risks to an acceptable level.

However, as land is developed, the options for changing its use and management are greatly reduced. This is due to the significant investment, both public and private, in the existing development and associated infrastructure, such as buildings, roads, drainage, water supply, sewerage and electricity. The scale of existing investment is often such that the development cannot reasonably be abandoned even if it does have a high potential for flood damage.

FPLs are made up to the selection of an appropriate flood event and an associated freeboard. There are a range of factors to be assessed in selecting the flood event upon which the FPL is based. There is also a range of factors that affect the selection of freeboard. Generally however, it is 0.5m for residential developments.

An appropriate FPL for new residential developments will generally be based upon the 1% AEP flood. While there is potential to vary this, it should only be allowed where it can be clearly demonstrated that the situation is exceptional. In general, the FPL (minimum floor level) for standard residential developments would be based on the 1% AEP flood event plus a freeboard (typically 0.5m) with minimum fill levels at the 1% AEP flood level.

Higher FPLs may be necessary for aged care facilities and other types of developments with particular evacuation or emergency response issues. Consideration should also be given to using the Probable Maximum Flood (PMF) as FPL when selecting the site and developing emergency response facilities such as police stations and hospitals. Also, critical infrastructure such as power supply, major telephone exchanges and water supply system, if possible.

6.4.2 Urban and Commercial Area

The decision to adopt appropriate FPLs for commercial and industrial developments relates more to the economic benefits versus costs. Therefore, there is greater potential for FPLs for these developments to be based on event more common than the 1% AEP flood level.

However, danger to personal safety and that of personnel clients still requires careful consideration. This is particularly so where more frequent events are used as the basis for FPLs. An FPL for flood mitigation work to protect an existing development from flooding, such as a bund, needs to consider the range of issues and additional issues relating to freeboard.

The FPL for mitigation works may be different from that for future development due to a range of factors which vary with location. These include the economics of the works, financial and technical feasibility, potential environmental impacts and physical limitations of the site. Community concerns and potential impacts elsewhere in the floodplain and the height (level) that floods can raise to relative ground levels in the area are also important considerations.

6.4.3 Tidal Area

In tidal areas, some towns have bunds with crest levels providing protection for 2% to 10% AEP events, whilst FPLs for development controls behind bunds are based upon the 1% AEP flood.

In tidal areas flooding can be from high tides or from water inland or combination of both. The choice of protection is based on probabilistic consideration.

In most circumstances, overtopping or failure of works such as bunds can result in catastrophic damage and undue danger to personal safety. An asset management plan with fail safe maintenance program is essential for all bunds together with sound local flood response plans to address the inevitable overtopping provided for in most bund designs.

Unless a bund is designed to exclude the PMF, considerable care must be taken to inform residents that it could be overtopped at some time in the future. These should be clearly explained to residents as to the purpose of and the need for a local flood plan to address bund overtopping or failure. Without this understanding and appreciation, the community may develop a false sense of security which may lead to increased danger to personal safety.

Risks to life issues relate to the consequences of full range of floods including the floods used to derive the FPL or rarer floods.

Climate modelling studies generally estimate that global temperatures will rise a few degrees (°C) in the next century. Such a warming is likely to raise sea level by expanding ocean water, and melting glaciers.

By ratifying the United Nations Framework Convention on Climate Change, more than 120 countries have agreed to implement measures for adapting to rising sea level and other effects of changing climate. Since the design and location of coastal structures involve decisions that cannot be easily reversed, people responsible for these must either plan for adaptation now or risk losing the opportunity for a meaningful response. Nevertheless, the value of planning for sea level rise depends upon the probability that the sea will actually rise by the estimated and projected magnitude.

The probability-based projections should be developed for Malaysia. This can be added to local tide trend monitoring and to estimate future sea level at particular locations and time. This will assist in determining the appropriate FPL or the platform level well before that eventuality occurs.

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Appendix 6(A): Basic Principles and Approaches

No.	Principles and Approaches
1	As far as possible, human interference into the processes of nature should be reversed, compensated and, in the future prevented. It is necessary to promote and harmonise changes in water policies and land-use practices, as well as environmental protection and nature conservation, in order to improve flood management in the frame of Integrated River Basin Management.
2	This should cover the entire catchment area of watercourses and promote the coordinated development, management and conservation of actions regarding water, land and related resources. Such a holistic approach is based on multilateral, including inter-disciplinary planning for the whole catchment areas.
3	Considering the evolution and trends, the approach to natural hazards requires a change of paradigm. One must shift from defensive action against hazards to management of the risk and living with floods.
4	Human uses of floodplains should be adapted to the existing hazards. Appropriate instruments and measures should be developed to reduce the risk of flood damages and for all flooding related problems: flooding, rising groundwater tables, sewage network disruption, erosion, mass deposition, landslides, ice flows, pollution, etc.
5	Mitigation and non-structural measures tend to be potentially more efficient and long term more sustainable solutions to water related problems and should be enhanced, in particular to reduce the vulnerability of human beings and goods exposed to flood risk.
6	Structural measures (defence structures) will remain important elements and should primarily focus on the protection of human health and safety, and valuable goods and property. Requirements of nature conservation and landscape management should also be taken into account. We will have to keep in mind that flood protection is never absolute, and may generate a false sense of security. The concept of residual risk, including potential failure or breach, should therefore be taken into consideration.
7	The major part of population and goods are located in big urban areas so efforts for avoiding flood problems should also be focused on these urban areas. River overflowing does not always cause urban floods; they can also be caused by high rain intensities over the city combined with inappropriate sewer systems. Special attention should be taken to the present drain-age of rainwater, for instance the capacity of the sewer systems of our cities.
8	A specific preparedness to alert, rescue and safety measures should be planned and implemented at all levels, including the public, by maintaining regular basic information and continuous ongoing training actions. With appropriate and timely information, preparedness, everyone who may suffer from the consequences of flood events should be able to take if possible his/her own precautions and thus seriously limit flood damages. To this end, appropriate information and forecasting systems should be established by the competent authority.

Appendix 6(A): Basic Principles and Approaches (continued)

No.	Basic Principles and Approaches
9	Everyone who may suffer from the consequences of flood events should also take if possible his/her own pre-cautions. To this end, appropriate information and forecasting systems should be established by the competent authority.
10	Solidarity is essential; one should not pass on water management problems in one region to another. The appropriate strategy consists of a three-step approach: retaining, storing and draining. (First make every effort to retain rainfall at the spot, store excess water locally, only then let the water be discharged to the watercourse). Flood prevention has also to be based on the precautionary principle.
11	In flood prone areas, preventive measures should be taken to reduce possible adverse effects of floods on aquatic and terrestrial ecosystems, such as water and soil pollution.
12	All appropriate action should be taken to create legal, administrative and economic frameworks that are stable and enabling and within which the public, private and voluntary sectors can each make their contribution to flood prevention, dam safety and the reduction of adverse impacts of dangerous flood events on human health and safety and valuable goods and property, and on the aquatic and terrestrial environment.
13	Priority should be given to integrated water management measures for the whole catchment area rather than to the management of floods.
14	The impact of all major human activities concerning flood prevention and protection in the catchment areas on society as a whole should be properly considered. All major undertakings with the potential of adversely affecting human health or significantly affecting water quality or quantity, biological communities, landscape, climatic factors, architectural and archaeological heritage, or the relationship between them should be subject to Environmental Impact Assessment (EIA) and if suitable e.g. because of the size or impact of the building activity authorisation procedures. EIA should also be applied on an international scale, in particular with regard to activities with a potential transboundary effect on health and aquatic ecosystems.
15	Physical planning as well as urban and rural development and construction should take into account the requirements of flood prevention and reduction, including the provision of retention areas. The real development is to be surveyed by monitoring of urban settlement in areas that may seriously be affected by floods.
16	In setting up these frameworks local problems, needs and knowledge, and local decision making mechanisms should be duly taken into consideration.
17	An information policy that covers risk communication and facilitates public participation in decision making should be developed.
18	More research on floods is necessary for a better understanding of effective measures for preventing and managing floods. This research should include modelling and data sharing as well as for forecasting. There is a clear need for a better definition of interfaces between different data sources and specific requirements for data exchange. Existing models and modelling practices should be compared by applying and evaluating them within the same river basin.
19	Training for professional engineers, scientists, technologists, economists, ecologists, etc. involved in their careers in flood management is much more diffuse, but some professional bodies require an annual programme of Continuing Professional Development (CPD) to be undertaken as a part of registration. There are many CPD courses, seminars and conferences available internationally. Staff of the local authorities, land use planners and rescue services should also be included in training and education programmes.

Appendix 6(B): Implementation the Best Practices of Flood Mitigation Principles and Approaches

Best Practices Integrated River Basin Approach	Description <p>Need of integrated approach, comprehensive action plan, transboundary cooperation and financial instrument.</p> <p>A good combination of structural measures, preventive measures and operative measures during flood events are necessary: building codes and legislation to keep structures away from flood-prone areas, appropriate land use, adequately designed floodplains and flood-control structures planning, mitigation, early-warning systems, correct risk communication and preparedness of the populations how to act during floods. In some cases even relocation of extremely endangered activities and buildings may be advisable.</p> <p>Development of preliminary flood protection strategy should include respectively evaluation of associated costs, technical feasibility assessment, environmental impact assessment, social acceptability and thus in a sustainable way by taking a river basin integrated and long term view, probably of the order of 50 or 100 years.</p> <p>There is a need for interdisciplinary cooperation at all government and local levels for a coordination of sectorial policies regarding environmental protection, physical planning, land use planning, agriculture, transport and urban development, and a coordination regarding all phases of risk management (risk assessment, mitigation planning and implementation of measures). Therefore, a holistic approach is necessary throughout the river basin. A financial instrument that can both reduce the financial risk for individuals, enterprises and even whole societies and increase the awareness of being at risk, is flood insurance. The establishment of national funds could be considered to partially cover damage of floods.</p>
Public Awareness, Participation and Insurance	<p>All measures linked to public information and awareness raising is most effective when they involve participation at all levels. Public participation in decision making is a cornerstone of successful implementation of integrated and comprehensive action plans, both to improve the quality and the implementation of the decisions, and to give the public the opportunity to express its concerns and to enable authorities to take due account of such concerns.</p> <p>The public should become aware that there is a need to adapt or even restrict uses, such as for industrial, agricultural, tourist or private purposes, in areas at risk of flooding to reduce the potential for damage. It will be essential to outline the likelihood of flooding and possible weak links in each flood protection measure and therefore increase the awareness of per-sons potentially at risk.</p> <p>Besides public and individual measures, insurance can be an important factor in increasing the awareness and reducing the financial risk for individuals, enterprises and even whole societies where natural hazards are concerned. Proper insurance can considerably mitigate the effects that extreme events have on them and can prevent them from being ruined.</p>

Appendix 6(B): Implementation the Best Practices of Flood Mitigation Principles and Approaches (continued)

Best Practices Retention of Water and Non-Structural Measures	Description
	<p>The storage effect of vegetation, soil, ground and wetlands has an important mitigating effect particularly in minor or medium scale floods. Each of these storage media is capable of retaining certain quantities of water for a certain length of time. A large natural storage capacity provides slow rises in water levels and comparatively minor floods. Retaining water on the natural media should have priority over swift water run-off. In some cases, in the event of heavy and lasting rainfall, natural storage impact is less relevant as regards the reduction in flow, but is still extremely beneficial when it comes to reducing sediment yield.</p> <p>The non-structural measures include restricting development in flood prone areas, flood proofing the existing structures in the flood prone areas, temporary evacuation of flood threatened areas and reduction of runoff by watershed management.</p> <p>Non-structural means also include guidelines that describe the level of protection, free board, built up platform level, flood proofing for basement car park, wet pond, lakes, reservoir and gross pollutant traps.</p> <p>Non-structural measures potentially tend to be more efficient and long term sustainable solution to water related problems should be enhanced, in particular to reduce the vulnerability of human beings and goods exposed to flood risk.</p>
Landuse, Zoning and Risk Assessment	<p>Knowledge concerning extent and evolution of floods and water related problems, simulate different high water incidences, study and compare zoning scenarios, and integrate this risk assessment, via identification and mapping of hazards and high-risk areas into land-use, emergency and rescue planning policies. Simultaneously, this would allow assessing effectiveness, thus priority of the flood protection measures along the whole longitudinal profile of a river, in view of informing the frontage population of the potential risks including remaining risks that occur, for example, as a result of a dam break, dyke break.</p> <p>Immediate flood plains should be identified and designated by law as priority sites for flood retention or to restore, as far as reasonable, mobility to waterways. The purpose is to discourage protective bank construction, embankments, impoundment and undermining, constructions or installations and, in general, any construction or works likely form an obstacle to the natural flow of waterways that cannot be justified by the protection of densely populated areas.</p> <p>Identify and reduce the vulnerability of existing infrastructures and all networks located in flood prone areas (water supplies, energy systems, transportation and communication networks, public facilities, etc.), and particularly transport network which may suffer massive interruptions or hinder the evacuation and the arrival of emergency services.</p>

Best Practices Structural Measures and Their Impacts	Description
	<p>The structural measures include the construction of bunds, poldering, bunds, revetments, barrages, channel diversion, pump houses, culverts, detention, retention, and dam. Structural measures (defence structures) will remain important elements with primary focus on the protection of human health and safety, valuable goods and property.</p> <p>Flood events of the recent past have shown the vulnerability of the flood protecting structures and that of the emergency organisations in some cases. Examples vary in a broad range. Some practice shows that in those cases where flood defences were developed to withstand the 1/100 years floods, simultaneously the lead time of the forecast were sufficient and adequately trained and prepared organisations defended those against even 1/300-1/500 year floods.</p> <p>The performance of the defences could be extended successfully by appropriate countermeasures such as the erection of temporary heightening and supporting structures to avoid over-topping, to stability loss and hydraulic failure of the foundation soil of the defences. On the other hand, efficient dams and dykes cannot provide reliable safety against floods which exceed their designed capacities. Contrary to this, near dam or dyke protected areas; a false sense of security is given to populations and properties "encouraged" locating on surrounding floodplains, thus causing disasters. Nevertheless, even after all the non-structural measures have been implemented there is still a natural risk of floods that might be reduced by means of technical flood protection.</p> <p>However, flood protection is never absolute; only a certain level of protection against flooding can be reached. The concept of residual risk should therefore be taken into consideration for each flood control structure. That means clearly define the design level of protection to which the flood control structure might be reliably defended, or local conditions that might weaken it, determine flood risks in protected floodplain basin related to the performance characteristics, the overtopping and failure probability of the flood defence structures and explain it to the public.</p> <p>Complement the flood protection in residential areas with limited space and where necessary, by flood protection walls, mobile closures, superstructures or simple sandbags, bearing in mind that their implementation must refer to a systematic planning co-ordination. The use of non permanent forms of barrier for flood protection can provide much needed flexibility and increased opportunities for effective management of a wide range of flood events.</p>

Best Practices Early Warning, Forecast System and Flood Emergency	Description
	<p>Flood forecasting can be effectively combined with other measures for flood prevention such as retention, land use and structural Measures, flood emergency and public awareness.</p> <p>An effective and reliable system of flood forecasting and warning dissemination should be set up to inform, at respective level, flood authorities and citizens in threatened areas. Classical and new media such as official warnings, state and private broadcasting services, satellite based communication system, alarm calls on the radio (switching on radios by remote control), mobile telephones, the Internet and teletext etc should be used, tested and performed according to technological progress. Alarm and action plan must be adapted to local conditions.</p> <p>Comprehensive national and local contingency plans to respond to flood events should be properly prepared in due time and maintained in operational status everywhere flooding might occur due to direct flooding, dam or dike break or other water related problems, etc, even in a very rare event case, in order to increase response capabilities and preparedness of organisations obliged to perform flood fighting activities.</p> <p>The personnel of the organisation that is responsible for the maintenance and the operation of defences should establish, maintain and train an effective organisation of flood emergency operation. The organisation should be structured task wise at each (local/regional/national) level, the personal responsibilities and the delegations of powers should be clearly defined, securing that the emergency operations of a defence section providing flood prevention for a separated floodplain basin, are conducted by an experienced and trained manager. Similarly structured emergency organisation is needed to serve as logistical basis for those operating the defences and to be prepared to perform disaster management in the floodplains (both in open and protected ones).</p>

Best Practices Prevention of Pollution	Description
	<p>The impact of floods has considerable environmental and health consequences, in particular given the very specific vulnerability of domestic water supplies and the physical infrastructure necessary for sanitation. The disruption of water distribution and sewage systems during floods contribute greatly to severe financial and health risks.</p> <p>Preventive measures should be taken to reduce possible adverse effects of floods on these infrastructures. Alternative solutions should be planned and implemented to guarantee the operation of water distribution and sewage systems. In flood prone areas, preventive measures should also be taken to reduce possible adverse effects of floods on aquatic and terrestrial ecosystems, such as water and soil pollution: i.e. minimise diffuse pollution arising from surface water runoff, minimise the amount of surface water runoff and infiltration entering foul and surface water sewerage systems, and maintaining recharge to groundwater subject to minimising the risk of pollution to groundwater.</p> <p>Emergency management planning and operation against the harmful impacts of water pollution on ecosystems during minor and major floods should be properly prepared in due time and maintained in operational status, particularly to support effective measures and evacuation plans to secure or remove hazardous materials where appropriate. The coordination of information systems and existing forms of assistance, i.e. mainly authorities, fire services, and aid organisations is needed, regular training should be implemented.</p>

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CHAPTER 7 FLOOD MITIGATION STRUCTURAL MEASURES

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7 FLOOD MITIGATION STRUCTURAL MEASURES

7.1 INTRODUCTION

Structural measures in flood management system refers to a choice of solution to flood problems and issues by installing structures and implementing physical improvement works directly related to the cause of flooding. It is a major flood management strategy to manage increases in large volumes of water maybe due to development. For prevailing flood problems, structural measures can, relatively, provide immediate relief compared to non-structural measures is effective only after a longer period of time. For long-term solutions and planning for flood issues, the choice of options on the types of structural measures can be made in concurrence with suitable non-structural approach. For example, implementing minimum river improvement works but at the same time installing flood warning facilities for the affected community until adequate financing is available for the full flood mitigation system is constructed. The term structural measures are usually used in the context that installing them are beyond the capacity of individuals and the public. As such structural measures are referred to flood mitigation systems constructed by the Government or private developers.

The type of structural measure depends on the technical strategies adopted to manage the flood flow. Some of the flood flow management strategies and related structural components are as follows:

- i) Regulate Water Level:
 - Barrage, tidal gate, flap gates, lock
- ii) Store and controlled release of flood water:
 - Dam, reservoir, detention and retention ponds, bund, inlet and outlet and spillway
- iii) Improve flow efficiency and controlled flows:
 - River channelization and improvement works, flood wall, weir, control gate, culverts
- iv) Re-route the flood flow:
 - River diversion, diversion channels, flood bypass (open channel and tunnel), intake structures, bridge and culvert
- v) Forced removal (non-gravity flow) of excess water:
 - Pumps, pump house, inlet and outlet structures
- vi) Delineation and separation:
 - Polder, ring bund, linear bund

7.2 OBJECTIVES OF THE STRUCTURAL MEASURES

Each of the structures mentioned above are designed for a specific function but when combined with others, they form a system that reduces excess floodwater from the flood affected area. This chapter focuses on how to select structural measures for use in a particular flood management system. The structures serve two objectives outlined below:

- Protective. This is to protect a building or facility from damage during a flood event. It could partly eliminate damage or minimize it by reducing exposure to hazards, facilitating restoration of facilities and preserving their functionality or by restricting its exposure to some limited area. Examples are dams, bunds and landslide containment structures.
- Preventive. Preventive measures are designed in anticipation of potential flood problem. It ensures that future development is protected from flooding and that it does not increase flood damage.

7.3 CONSTRAINTS

7.3.1 Land-use

The prevailing regional and local development plans will have direct influence on the choice of flood management strategies and systems particularly for structural measures. The constraints are mainly due to limited land available for river widening, construction of new channels, bunds and detention ponds.

7.3.2 Social and Economics

Whilst Government lands may be available for installing the works, illegal settlers on these lands often prove to be major constraints for implementing them. Alternative resettlement sites need to be provided before physical works can progress. In many cases, addressing flood issues for a particular area requires structural measures in the upstream or downstream areas that do not suffer from such issues. This too creates social issues in the form of resistance and even resentment of those communities that will have to sacrifice some parts of their lands for the benefit others. In addition they will also have to bear with inconveniences during the construction works.

Economics of flood mitigation projects are complex. Sometimes costly structural measures seem to be for the benefit of a few people in pockets of flood prone areas. Economic justification for an option to resettle a small number of people instead of installing structural measures that affect many is often not easy when compared to social justification. More often social issues and intangible benefits of structural measures far outweigh economic justification. In Kuala Lumpur for example, the floods may directly affect a small area but the impact, even for a flash flood, is far reaching upon the population of the city and economic investments.

The economic value of a flood mitigation management system should be assessed from a total lifecycle cost of the system. The designer should aim to minimise the total cost of the system, within practical, social, environmental and legislative constraints. For example, lined/piped drains occupy less land area but are relatively more expensive to construct than open waterways systems. Certain types of designs may have low capital costs but this is offset by high maintenance costs later.

7.4 ADVANTAGES AND DISADVANTAGES

Structural measures have their advantages and disadvantages (Table 7.1) and how appropriate they are would depend on the situation.

Table 7.1 Advantages and Shortcomings for Structural Measure

Advantages of Structural Measure	Shortcomings of Structural Measure
May provide the greatest amount of protection for land area used	May disturb the land and disrupt natural water flows, often destroying wildlife habitat
May be the only practical solution in some circumstances (e.g. land limitation)	They require regular maintenance, which if neglected, can have disastrous consequences
Can incorporate other benefits into structural project design such as water supply and recreation	Although built to some flood protection level, it may be surmounted by larger floods which could cause extensive damage. It can create a false sense of security as the public believe that no flood can ever reach them
Regional detention may be more cost-efficient and effective than requiring numerous small detention basins	Although unintended in many circumstances, it can promote more intensive land use and development in the floodplain

7.5 WATER LEVEL REGULATING STRUCTURES

7.5.1 Barrages

A barrage is a structure built across a river to store and increases the water level on its upstream side. It can be located at the river estuary or at the upstream sections of a river. All barrages are designed to retain minimum upstream water level and there are also those designed to provide protection from tidal inundation. Barrages are intended to achieve one or more of the following objectives:

- Urban regeneration;
- Tidal power generation;
- Water storage;
- Improvement of water quality;
- Tidal surge protection;
- Silt exclusion; and
- Traffic management.



Figure 7.1 Sungai Muda Barrage

7.5.2 Tidal Gates

Tidal gate is to prevent saline water from flowing to the upstream. It is also to manage changes of water levels due to tidal fluctuations.



Figure 7.2 Tidal Gates at Sg. Junjung, Bukit Tambun, Pulau Pinang

7.5.3 Flood Gates

Floodgates are adjustable gates to control water flow in reservoir, river, stream or bund systems. It may be designed to set spillway crest heights in dams, to adjust flow rates in sluices and canals, or to stop water flow entirely as part of a bund or storm surge system. Most of these devices operate by controlling the water surface elevation being stored or routed, and are also known as crest gates. In the case of flood bypass systems, floodgates are sometimes used to lower the water levels in a main river or channel by allowing more water to flow into a flood bypass or detention basin when the main river or canal is approaching a flood stage.

Floodgates are installed at the end of outlet structure to prevent reversed flow of flood water from the connecting channel on the downstream of the structure when its level is higher, such as shown in Figure 7.3.



Figure 7.3 Floodgate Installed in Kemubu Project

7.5.4 Lock

For river navigation, lock gates are installed to allow boats to travel across a water level control structure. The water level upstream and downstream of this control structure differs. The lock structure allows boats to cross this point by a sequence of gate operations that either lifts the boat to the higher water level or *vice versa*. An example of a navigation lock is at Tasik Chini, Pekan, Pahang Darul Makmur constructed by DID in 1998 and completed in 1999.

7.6 DAM

A dam could be multi-purpose, such as for flood control, hydro-power, irrigation, or for water supply. A dam designed for irrigation or hydro-power may not be able to help solve flood problems. However, flood moderation should be explicit to the reservoir's multi-functions.

DID presently manages more than 15 dams located in various states for irrigation, flood mitigation and silt retention. The Batu Dam in Kuala Lumpur, Bekok in Johor and Timah Tasoh in Perlis are dams primarily for flood control. The Old Repas Dam, the New Repas Dam and Perting Dam in Bentong, Pahang are examples of silt control dams.

The degree of mitigation provided by a flood control reservoir depends on the combination of dam storage, spillway capacity and the pattern of flood inflows. The main purpose of storage is to decrease the flood peak without reducing the total volume of floodwater. Reduction of the flood peak is achieved by increasing the duration of dam releases at lower rates. For dams equipped with gates or valves, the way in which these controls are operated will determine the rate of release and the degree of downstream mitigation.

The protection achieved by a surface reservoir is greatest in the area immediately downstream of the dam. Protection further downstream is reduced by tributary flows and by run-off from land adjacent to the river. Protection may also decrease over time if the reservoir capacity is diminished by siltation. Surface reservoirs have the greatest potential to mitigate floods when they are empty.



Figure 7.4 Klang Gate Dam and Batu Dam

Flood mitigation reservoirs are mostly used on small and moderate-sized streams. The large areas of land required to store the flood flows of major rivers are generally no longer available, especially where it involves the flooding of valuable agricultural lands. Many sites that are geologically and topographically suitable may require very considerable and expensive land acquisition and the displacement of large populations. The cost of large reservoirs can only be justified where they protect heavily developed urban areas and are the only practical means for significantly reducing flood damages. It is usual practice to reserve a component of the available storage capacity in multi-purpose dams for flood mitigation purposes. In such cases, careful coordination is necessary to permit flood mitigation reservoirs to serve also for water supply or irrigation purposes.

The major disadvantage of flood mitigation reservoirs is that downstream residents often do not appreciate that it can only control floods up to the peak rate for which it was designed. Complementary land use controls need therefore to be enforced to prevent unwarranted development and encroachment on the downstream floodplain.

7.6.1 Spillways

A spillway is a structure to control the release of flood flows from a dam or bund into a downstream area so that the water does not overflow, damage or destroy the dam. Except during flood periods, water does not normally flow over a spillway. In contrast, an intake is a structure used to release water on a regular basis for water supply and hydroelectricity generation. Floodgates and fuse plugs may be designed into spillways to regulate water flow and dam height. The term "spillway" may refer to bypasses of dams or outlets of channels used during high-water and outlet channels carved through natural dams such as moraines.

A spillway is located at the top of the reservoir pool. Dams may also have bottom outlets with valves or gates which may be operated to release flood flow. Some dams may not have overflow spillways and so rely entirely on the bottom outlets. There are two types of spillways namely controlled and uncontrolled spillways.

A controlled spillway has mechanical structures or gates to regulate the rates of flows. This type of design allows nearly the full height of the dam to be used for water storage all year-round, and flood waters can be released as required by opening one or more gates.

An uncontrolled spillway, in contrast, does not have gates; when the water rises above the lip or crest of the spillway, it begins to be released from the reservoir. The rate of discharge is dependent on the hydraulic head above the spillway when it overflows.



Figure 7.5 Spillway at Batu Dam, Malaysia

7.7 RIVER CHANNELIZATION AND IMPROVEMENT WORKS

The purpose of channel improvement is to increase the discharge or carrying capacity of a stream so as to enable the water to flow off faster, thus decreasing the height and duration of floods as well as reducing the frequency of flood. There are two ways in which the discharge of a stream can be increased:

- By increasing the cross-section or size of the channel; and
- By increasing the velocity or rate of flow of the water.

Improvement of channel capacity can be accomplished by excavation to increase depth, width or both. It can also be by removing debris or other obstructions, channel lining using concrete or rubble masonry, providing more uniform cross sections, eliminating unnecessary bends and constructing emergency bypass channels to supplement the carrying capacity of an existing waterway.

Natural watercourses normally have limited capacity, which may be exceeded annually, with excess floodwaters overflowing onto the floodplain. Hydraulic improvements to the watercourse or constructing flood channels within the floodplain would enable the flood waters to be conveyed to lower level as would occur naturally. In urban areas, such works also permit the optimization of land use through improved residual drainage.

The various types of river and channel improvement include:

- straightening, deepening or widening of the channel;
- removing vegetation or debris;
- lining the channel;
- raising abutment or widening the span of bridges and culverts that restrict flow;
- removing barriers that interfere with flow.



Figure 7.6 Sungai Batu River Improvement Works, Kuala Lumpur



Figure 7.7 River Improvement Works Sungai Klang

The function of river and channel improvements is similar to bunds and floodwalls in that they can be used to protect a specific site or region. It can also provide added positive benefits such as improved navigation and recreation.

River and channel improvements are likely to be most effective on steeper, smaller streams with overgrown banks and narrow floodplains. Channel modifications are unlikely to have any significant effect in flooding situations where there are extensive areas of overbank flooding, or where flooding effects are dominated by tide levels.

River training works are structural measures of various kinds which are undertaken in order to provide a more effective channel for the passage of flood flows and sediment loads. The river needs to be trained by straightening, widening and provision of linings in order to increase its capacity to meet the flood under design extreme events. Such works may be designed either to retard the flow rates along a river bank, in order to reduce erosive velocities and increase the deposition of sediments, or to provide protection of the bank against erosion or scouring.

7.7.1 Widening of Channels

By making a channel wider the cross sectional area of flow is increased so that the channel will convey greater flood peak to lower level. The use of two (or more) stage channels (compound channel) is favoured above a general widening approach as it can accommodate better at low and high flows (EA, 2003). This is usually achieved by constructing a 'berm' which is widened at a higher level of the channel above the river bed, thus allowing low flows to continue in their natural size channel (river central channel or main channel) and higher flows to occupy a greater area as the water levels rise (in the floodplain). Berms can offer good environmental habitats on the ground conditions locally. This form of river widening also allows for retention of meanders, pools and riffles in the lower stage of the channel whilst more hydraulically efficient conditions are managed within the higher wider channel shapes. Regular maintenance of channels is essential, such as removal of scrubs on the berm, which could block flows. Grass turving or other form of vegetation is also acceptable since it gives little resistance to the flow.

River widening and deepening (Figure 7.8(b)) for river flood mitigation works where possible should be avoided except under permissible conditions. Constructing a bund (Figure 7.8(c)) on the other hand would require a wider berm that provides greater area for conveyance and storage at higher design water level.

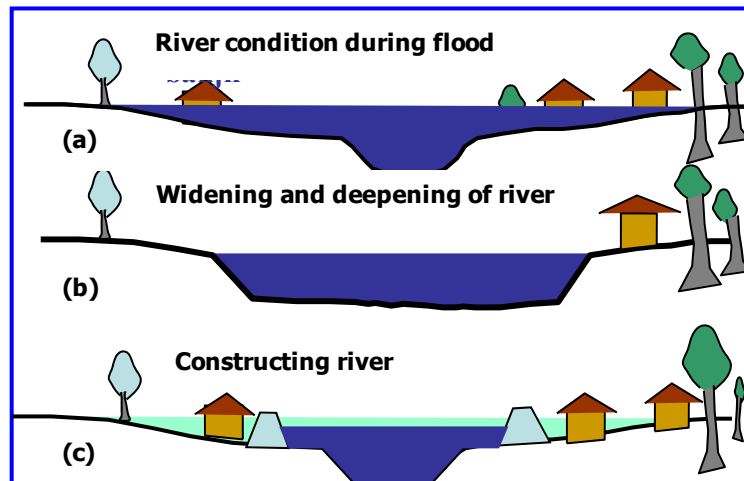


Figure 7.8 Concept Plan of DID River Works for Flood Mitigation That Need

7.7.2 Deepening of Channels

Channel deepening to lower the channel bed. It is used to reduce local flood levels but requires long-term maintenance. Rivers tend to develop a natural bed gradient over time as hills erode and valleys develop (EA, 2003). By seeking to change the gradient we work against natural processes, such as siltation, which will return the bed to a stable regime. Local deepening alone will not increase conveyance if downstream conditions influences control the water level. Water will simply flow at a slower rate (EA, 2003). For these reasons channel deepening is a less favoured engineering option in many parts of the world. Instead widening of channel is preferred to deepening because it attenuates flows.

Deepening though, may not necessarily attenuate the outflow discharge but can increase the peak outflow discharge. However, deepening can be an effective option on steeper watercourses where other options are constrained, for example, by the proximity of an-going development such as in an urbanized area, or by the need to resolve local flow constriction points such as bridges. Channel deepening is unlikely to offer any environmental benefits; it is more likely to do damage to habitats.

Another disadvantage of river deepening which is noteworthy is that if the water levels are not well managed during the course of a river deepening, it can lead to reduction in the biodiversity such as grazing marshes (EA, 2003).

Figure 7.9 illustrates widening/deepening of a river channel for flood mitigation by DID. Figure 7.10 shows completed DID improvement works at Sungai Klang at Puchong, Selangor which comprises river widening or deepening and bank stabilization.



Figure 7.9 Widening and Deepening of River in Progress



Figure 7.10 Completed Improvement Works to Sungai Klang at Puchong, Selangor

7.8 RIVER DIVERSION AND FLOOD BYPASS

A flood bypass is a man-made structure designed to convey excess floodwaters from a river and stream to reduce the risk of flooding on the natural water course near a key point of interest such as a city. Flood bypasses (or floodways) often comprise diversion components such as weirs or spillways at their head or point of origin. The main body of a flood bypass often lies in a natural floodplain. It is normal to design a flood bypass to such capacity to ensure the combined flow from the original river and stream and the flood bypass will not exceed the expected maximum flood flow of the river and the stream.

Flood bypasses typically operate during major floods in a similar manner as detention basins. Since the area of a flood bypass is significantly larger than the cross-sectional area of the original river and stream channel from which water is diverted, the velocity of water in a flood bypass will be significantly lower than the velocity of the flood water in the original system. These low velocities often cause increased sediment deposition in the flood bypass. Thus it is important to incorporate a maintenance program for the entire flood bypass system when it is not active during floods.

When not used to convey water, flood bypasses are sometimes used for agricultural or environmental abatement purposes. Land occupied by the flood bypasses is often owned by the public authority, which may be rented to farmers or ranchers, who in turn will plant crops for herd livestock feed off the floodplain. Since the flood bypass is subject to sedimentation during flood events, the land is often very productive and even loss of crops due to flooding can sometimes be recovered by the high yield of the land during non-flood periods.

One of a unique innovative example of a man-made food bypass structure is the SMART Tunnel.

7.8.1 Creating Flood (Bypass) Channels

Flood channels are channels designed to transmit flood flows across a floodplain via an additional route to the natural channel. They may take flood flows away from a built up area where widening the channel may not be possible. Flood channels should as far as possible be built as natural channels as they can offer considerable opportunities for wildlife habitat creation (EA, 2003).

Figure 7.11 shows a concept of flood channel to reduce the flow in channel AB bypassing it to point C at another channel system. The total flow meets again at the channel downstream of point B and D. Figure 7.12 below shows examples of flood channels constructed in urban areas.

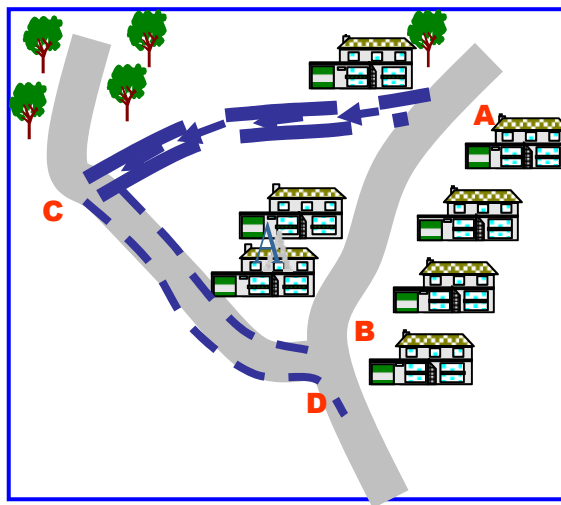


Figure 7.11 A Concept of Flood Bypass Channel

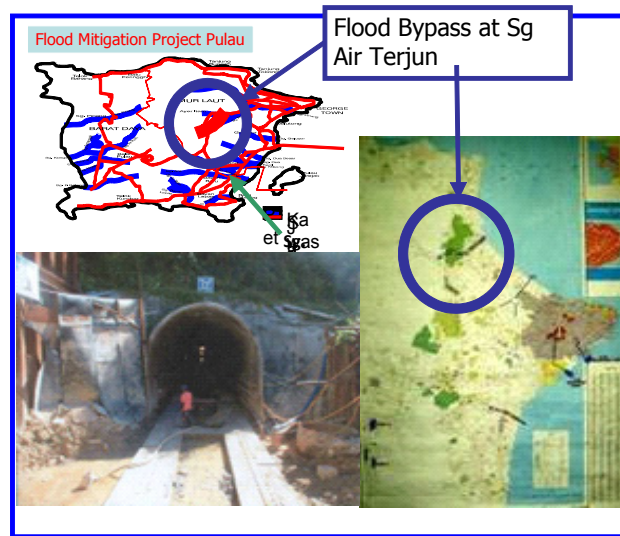


Figure 7.12 Flood Bypass Channel (Tunnel) at Sungai Air Terjun, Pulau Pinang

7.8.2 SMART Tunnel

Stormwater Management and Road Tunnel (SMART Tunnel) is a unique flood bypass system in the world. It combines stormwater management with traffic. This SMART TUNNEL is the longest stormwater tunnel in South East Asia and second longest in Asia. The project aims to provide partial solution to flood problems that often plague the city of Kuala Lumpur by reducing the floodwaters from entering the city. The tunnel is in fact a diversion tunnel or a flood bypass where downstream flooding is prevented by regulating the release of the floodwater.

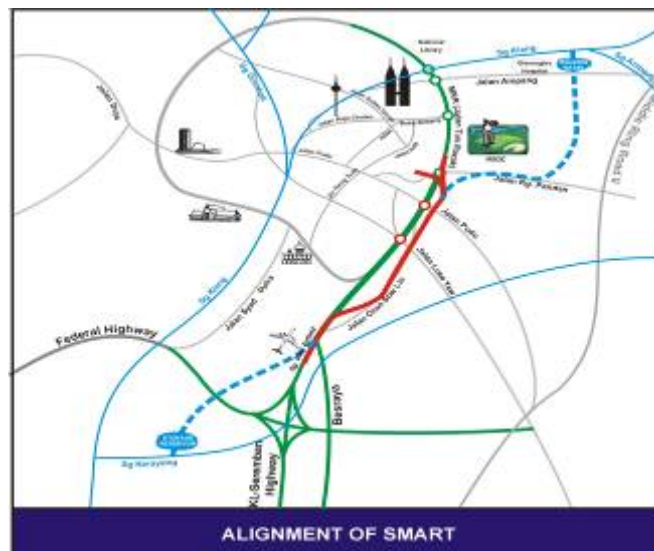


Figure 7.13 SMART Tunnel Alignments



Figure 7.14 Illustration of How SMART Tunnel Would Divert Excess Floodwaters from the Ampang and Klang Rivers to the Kampung Berembang Holding Ponds



Figure 7.15 Views of Upper Deck and Lower Deck in the SMART TUNNEL

7.8.3 Bypass Structures

Bypass channels are additional or alternate channels that a river or stream can utilize above certain flood flow levels. Such structures will increase the river discharge capacity to alleviate flood. In the past, these structures were concrete-lined designed with the least frictional resistance. Recent options however, prefer channels designed to duplicate natural channels. This is to allow for seasonal or permanent habitat for fish and wildlife. In some cases, the main waterway may be allowed to reclaim the secondary channels that have been converted to agriculture or other uses.

While a dam is constructed to “catch” or impound floodwaters, a bypass channel replaces this function by creating an alternative overflow or “storage” channel for floodwaters. In addition to increasing the flood flow capacity of a system, bypass channels may provide temporary fish and wildlife habitat or additional farmland or parkland when not needed to convey floodwaters. One disadvantage is that the bypass often requires substantial land area.

7.8.4 Diversion Structures

Diversion structures are built to intercept and divert subsurface flows away from disturbed areas, active gullies and critically eroding areas. These structures are also constructed on slopes to reduce the slope length or to intercept flow while carrying the runoff to a stable outlet point. Advantages of a diversion structures are as follows:

- Reducing flow volume across the disturbed area, thereby reducing the potential for erosion;
- Breaking up the concentration of water on long slopes;
- Allowing sediment basins or traps to function efficiently by maintaining a separation between clean water and sediment-laden water; and
- Easy construction using equipment available at most construction sites.

7.9 RETENTION AND DETENTION PONDS

Every cubic meter of water not drained away immediately to the next body of water is a gain for the water regime while taking away some of the burden contributing to floods. Storage in vegetation, soil, ground and wetlands has an important mitigating effect particularly on the minor or medium-scale floods. Each of these storage media is capable of retaining certain quantity of water for a certain length of time. A large natural storage provides a slow rise in the water level, thus preventing comparatively minor floods. Retaining water on the natural media should have priority over swift water runoff. In some cases, in the event of heavy and lasting rainfall, natural storage impact is less relevant as regards reduction in flow, but is still extremely beneficial for reducing sediment yield.

The function of a detention pond is to reduce peak discharge by temporarily storing the water and gradually releasing it via an outlet control structure or other release mechanisms. Thus time for water retention is the factor that differentiates between the function of detention ponds and that of retention ponds. Detention ponds hold runoff for a short period before releasing it to natural watercourse, while retention ponds hold runoff for an extended time period. Retention ponds (or wet ponds) maintain a permanent pool, while detention ponds (or dry ponds) contain water only in the aftermath of runoff events.

There are two types of detention ponds: in-line or off-line. In-line ponds can be designed by widening a channel to provide additional storage while off-line ponds have side flow weirs to receive water overflowing from the adjacent channel.



Figure 7.16 Batu Retention Pond, Kuala Lumpur



Figure 7.17 Typical Retention Pond

7.9.1 Detention Basin Design Guidelines

A detention basin is used to reduce the peak inflow by temporarily storing the excess storm-water and then releasing the water volume at allowable rates over an extended period. The objective of this section is to outline the design guidelines in order to determine the detention basin storage volume required. Design of a storm-water detention basin requires both hydrologic and hydraulic information. Basic hydrologic data are inflow hydrograph and allowable release. In order to determine the volume required, the inflow hydrograph needs to be developed first. Hydraulic data are geometry of the basin and outlet structure. Two common methods for determining the detention basin size are the Modified Rational Method and the TR-55 Method.

Modified Rational Method. The simplest but least accurate detention routing method is the Modified Rational Method. The basis of this method is described in below. To find the required volume, the Modified Rational Method uses a trial method to find the critical storage for a given drainage area. For instance, the peak rate for a 100-year storm is the product of the runoff coefficient times the drainage area in acres times the intensity of a 100-year storm for a calculated time of concentration. However, the critical storage volume may be a different duration, which needs to be determined. The storage volume is determined by the critical (inflow) duration, and using a constant outfall release rate. For the example shows below, the allowable release rate was set at $0.283 \text{ m}^3/\text{sec}$ (10 cfs) (Q_5 pre-developed condition at t_c of 15 minutes). The inflow hydrographs are developed using varying durations multiplied by the discharges for each Q_{100} . The outflow hydrograph for each duration multiplied by the constant Q_5 , is subtracted from the inflow hydrograph. The highest remaining storage volume is therefore selected as the final basin volume. There are two steps of design using the Modified Rational Method:

Step 1: Collect the data for the drainage area: drainage area, time of concentration, runoff coefficient, and allowable release rate. A site to be developed is an existing 4.81 ha (11.88 acres) undeveloped site with an average slope (Soil Group D, $C = 0.22$ for Q_5) that is to be an industrial area ($C = 0.9$). The outlet is a small, lined channel with a capacity of $0.425 \text{ m}^3/\text{sec}$ (15 cfs). The t_c is 15 minutes.

Step 2: Obtain the recurrence interval for the design storm and the intensity-duration relationship for the design frequency. A series of peak flows and runoff volumes are then calculated, beginning with the time of concentration of the drainage area and increased storm durations. The allowable release rate for a detention basin needs to stay under $0.425 \text{ m}^3/\text{sec}$ (15 cfs) and should not exceed the 5-year pre-developed condition at the duration of 15 minutes. The maximum allowable release rate is $0.255 \text{ m}^3/\text{sec}$ (9 cfs), the pre-developed peak flow for a 5-year frequency storm at the proposed point of discharge.

7.10 BUNDS, POLDERING AND BUNDING SYSTEM

7.10.1 Bunds

Bund is "a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practice to contain, control or divert the flow of water so as to provide protection from temporary flood" (Definition by The Federal Emergency Management Agency (FEMA) has defined a bund in the National Flood Insurance Program (NFIP) regulations at 44 *CFR* Source: ASFPM White Paper 2007 1 of 10 *Adopted by the Board - 2/13/07* National Flood Policy Challenges; Bunds: The Double-edged Sword; ASFPM White Paper)

Bunds are different compared to dams or other flood protection structures. They are built parallel to a body of water (most often a river) to protect lives and properties behind them from floods. A dam built for flood protection is usually designed to lessen the amount of water going downstream of the dam during flood by containing excess water and releasing it slowly over time. Bunds are specific for flood protection while dams may serve purposes other than flood control, such as providing water for irrigation, community water supply, recreation and hydroelectric power.

Artificial bunds are constructed to prevent flooding of the adjoining countryside and are used to confine flow of the river, causing higher and faster water flow. Bunds are usually built by piling earth on a cleared, level surface. Broad at the base, they taper to a level top where temporary embankments or sandbags can be placed. Because flood discharge intensity increases in bunds on both sides of the river banks, and because silt deposits raise the level of riverbeds, a proper planning of bunds and auxiliary measures is vital. Sections are often set back from the river to form a wider channel and flood valley basins are divided by multiple bunds to prevent a single breach from flooding a large area. Artificial bunds require substantial engineering. Their surface must be protected from erosion, so they are planted with vegetation such as cow grass in order to bind the earth together. On the land side of high bunds, a low terrace of earth known as a banquette is usually added as anti-erosion measure. On the river side, erosion from strong waves or currents presents an even greater threat to the integrity of the bund. The effects of erosion are countered by planting willows, weighted matting or concrete revetments. Separate ditches or drainage tiles are constructed to ensure that the foundation does not become waterlogged. Manmade improvements using bunds or dikes can minimize flood damage.

7.10.1.1 Procedure of Construction of Bunds

The procedure to construct a bund are as follows:

- i) Conduct a geotechnical study based on a thorough review of available data including analysis of aerial photographs. Initiate preliminary subsurface explorations.
- ii) Analyze preliminary exploration data and establish preliminary soil profiles, borrow locations, and embankment sections.
- iii) Initiate final exploration to provide:
 - a. Additional information on soil profiles.
 - b. Undisturbed strengths of foundation materials.
 - c. More detailed information on borrow areas and other required excavations.
- iv) Using the information obtained in Step iii:
 - a. Determine both embankment and foundation soil parameters and refine preliminary sections.
 - b. Where needed, note all possible problem areas.
 - c. Compute rough quantities of suitable material and refine borrow area locations.
- v) Divide the entire bund into reaches of similar foundation conditions, embankment height, and fill material and assign a typical trial section to each reach.

- vi) Analyze each trial section as needed for:
 - a. Under seepage and through seepage.
 - b. Slope stability.
 - c. Settlement.
 - d. Trafficability of the bund surface.
- vii) Design special treatment to preclude any problems as determined from Step vi. Determine surfacing requirements for the bund based on its expected future use.
- viii) Based on the results of Step vii, establish final sections for each reach.
- ix) Compute final quantities needed; determine final borrow area locations.
- x) Design embankment slope protection.

7.10.1.2 Classification of Bunds

Classification of bund is based on location (area) and use. Bunds are classified according to the area they protect (urban or agricultural) because of different requirements for each. As used in this manual, urban and agricultural bunds are defined as follows:

- Urban bunds provide protection from flooding in communities, including industrial, commercial, and residential facilities.
- Agricultural bunds provide protection from flooding in lands used for agricultural purposes.

Table 7.2 Bunds Classified According to Use

Type	Definition
Mainline and tributary bunds	Bunds that lie along a mainstream and its tributaries, respectively.
Ring bunds	Bunds that completely encircle or "ring" an area subject to inundation from all directions.
Setback bunds	Bunds that are built landward of existing bunds, usually because the existing bunds have suffered distress or are in some way being endangered, as by river migration.
Sub-bunds	Bunds built for the purpose of under seepage control. Sub-bunds encircle areas behind the main bund which are subject, during high-water stages, to high uplift pressures and possibly the development of sand boils. They normally tie into the main bund, thus providing a basin that can be flooded during high-water stages, thereby counterbalancing excess head beneath the top stratum within the basin. Sub-bunds are rarely employed as the use of relief wells or seepage berms make them unnecessary except in emergencies.
Spur bunds	Bunds that project from the main bund and serve to protect the main bund from the erosive action of stream currents. Spur bunds are not true bunds but training dikes.

7.10.1.3 Causes of Bund Failure

The principal causes of bund failure are:

- Overtopping;
- Surface erosion;
- Internal erosion (piping); and
- Slides within the bund embankment or foundation soils.

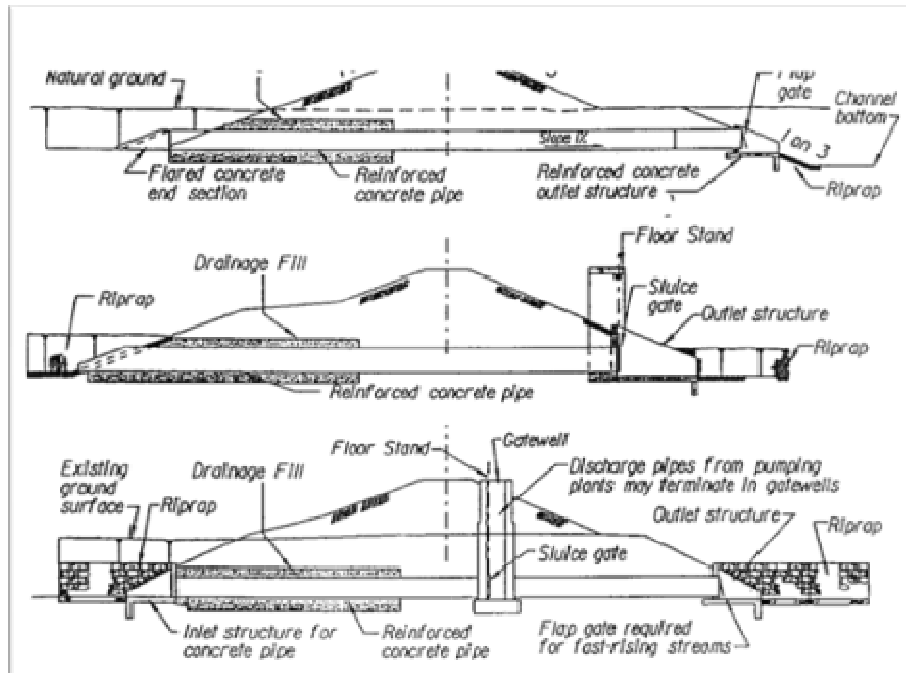


Figure 7.18 Typical Section, Damages, and Structure Trough Bunds



Figure 7.19 Bund or Bund System

7.10.2 Poldering and Bunding System

Flood polders should preferably be used as extensive grasslands or to restore alluvial forests at selected locations of the floodplains to lower flood peaks. Poldering is the provision of a ring bund surrounding the area to be protected. This is normally carried out for an area which has high damage potential but for which the cost of an overall basin-wide protection would be prohibitive. It includes the provision of internal drainage for the area to be protected and the evacuation of flood water by pumping during periods of high river flows.



Figure 7.20 Bund Systems along Pt. Tok Dahaman near Kg. Baharu, Bukit Tambun, Pulau Pinang

7.10.3 Embankment

The embankment is the most easily available form of structural measure for dealing with flood problems. However, embankments, even if properly designed, constructed and maintained (which often are not), often fail to provide protection during abnormal floods when such protection is needed the most. Although during periods of mild or tolerable floods when they generally provide effective protection, the embankments prevent the protected area from receiving benefits of flood in terms of silt fertilizing value and improved soil moisture. Embankments are known to produce other adverse effects in the long run. However, people reeling under flood fury often regard them as a quick method of providing protection against floods. Care has to be taken to improve their design and performance so as to avoid or at least minimize the adverse effects. Suggestions for this would include:

- Keeping proper distance between the two walls of an embankment;
- Ensuring proper maintenance;
- Providing properly designed sluice gates on embankment at appropriate places; and
- Widening and strengthening of portions of embankments used by flood victims as places of temporary shelters during flood.

7.10.4 Flood Wall

A floodwall is a man-made vertical barrier designed to temporarily contain the waters of a river or a waterway which may rise to unusual levels during seasonal or extreme weather events. Floodwalls are mainly used where space is scarcely available, such as in cities where constructing a bund that would require space for its slope would interfere with the existing buildings, historical architecture, or commercial exploitation of embankments.

Floodwalls are nowadays constructed from pre-fabricated concrete elements with "flood gates or flood flap gates" which are large openings to provide local drainage outflows. These gates are closed during periods of flooding.

7.10.4.1 Constructing Flood Banks or Walls

Flood banks and walls in effect is a form of “deepening” a river channel such that a greater conveyance capacity is achieved without flooding of the area behind the flood bank, although upstream levels will also be raised (EA, 2003). Flow velocities can be increased by the reduced friction of smooth walls or grass banks. There is a balance to be drawn between additional depth and the loss of conveyance through the area to be protected from flooding but higher flow velocities within the channel compared with floodplain flows and loss of storage usually make this as an effective solution.

Figure 7.21 shows the inclusion of grass flood bank in one of Kuala Lumpur flood mitigation project. The flood bank is an effective way to contain flood flows.



Figure 7.21 River Canalization with Grass Flood Bank

7.10.5 Setting Back Flood Banks or Walls

Changes in land use or attitudes in areas protected by flood banks and walls can offer the opportunity to move the position of the defence away from the watercourse to increase conveyance. With increasing flood risk it may be more acceptable to allow agricultural land, parks or recreation areas or land released by redevelopment to flood in return for a higher or retained standard of protection elsewhere (EA. 2003). The degree of benefit that this provides for flood management will depend on the proximity of risk areas upstream, the river gradient and the additional flow area obtained.

Figure 7.22 shows an excellent example of how some this can be practiced. It shows clearly the river section, the main river channel, the floodplain serving as additional water conveyance and storage area. Take note of the storage ponds in the floodplain. It shows how river can be designed for storage and conveyance. The bund as the first defence and the super bund as the second defence against flood level overtopping into the densely developed area. The system configuration also provides opportunities for the public to appreciate the river.

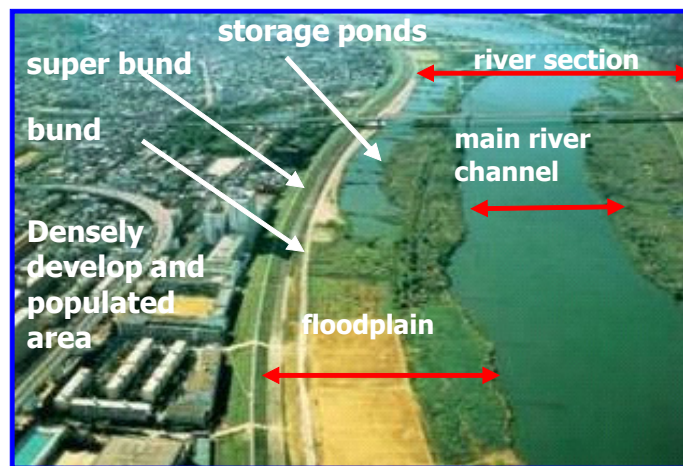


Figure 7.22 An Excellent Example of Two Stage River Channel to Contain Flood Flow

7.11 REVETMENT SYSTEMS

A revetment is a facet of erosion resistant material, such as stone or concrete that is built to protect a scarp, embankment or other shoreline feature against erosion. The major components of a revetment are the armour layer, filter and toe. The armour layer provides the basic protection against wave action while the filter layer supports the armour provides for the passage of water through the structure and prevents the underlying soil from being washed through the armour. Toe protection prevents displacement of the seaward edge of the revetment.

A revetment may also be a cladding that is constructed on a sloping soil bank to protect and stabilize its surface against erosion due to current or wave action. It usually accommodates surface water drainage and groundwater movement or subsoil drainage in the underlying bank conditions.

7.11.1 Components of Revetment

The components of a typical revetment are illustrated schematically in the cross-section shown in Figure 7.23. The revetment comprises the armour layer and the under-layer. Its performance is essentially dependent on the nature of the subsoil as well as the effectiveness of the crest, toe and edge construction.

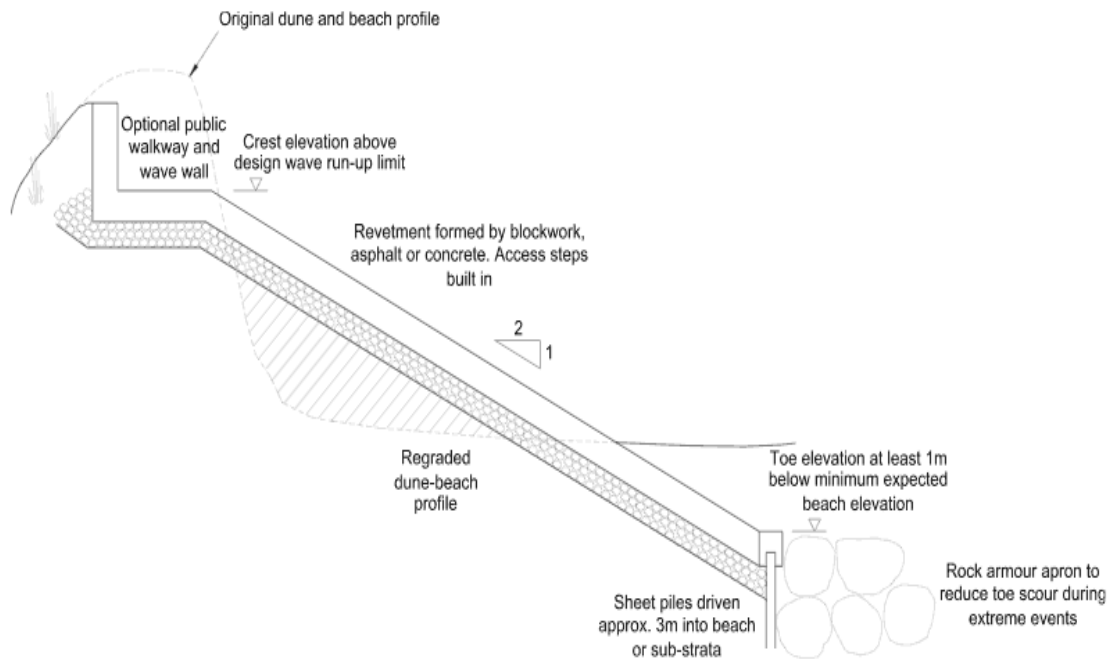


Figure 7.23 Typical Cross Section of a Revetment

7.11.2 Armour Layer

The armour layer (or cover layer) provides protection against the direct erosive forces of currents, wave action and other external effects. It also exerts a positive normal stress on the subsoil formation that can enhance its stability against shallow failure. Two key engineering properties which affect the performance of the armour layer under current or wave action are:

- a) Permeability — which determines the degree to which external water motion and pressure due to currents or waves are felt by the under-layer and the subsoil
- b) Flexibility — which enables the armour layer to accommodate minor deformations due to settlement, loss or migration of underlying material, thus maintaining the composite integrity of the revetment.

7.11.3 Under-layer

The under-layer includes all material between the armour layer and subsoil formation. It may consist of granular material, or a geotextile, or a combination of both. The component materials are generally selected to perform one or more of the functions listed below. An essential part of the design process is therefore to properly identify the particular functions which the under-layer expected to achieve. Although revetments sometimes fail through junction of the armour layer during extreme conditions of loading, revetment failure occurs most frequently due to failure of the under-layer. This is generally as a result of the cumulative (as distinct from sudden) action of hydraulic forces within it and inadequate provision for these forces in the design.

The functions which the under-layer can perform are as follows:-

- a) To act as a filter to restrain movement of the formation soil due to water movement into and out of the subsoil.
- b) To provide a drainage zone parallel to the slope of the revetment to assist drainage of the under-layer and the subsoil.
- c) To protect the formation from erosion by flow over its surface — parallel to the slope of the revetment.
- d) To regulate an uneven soil surface to provide an even foundation for the revetment.
- e) To separate the armour layer and other parts of the under-layer from the subsoil.
- f) To provide secondary protection in case of loss of the armour layer.
- g) To dissipate energy of internal flow in the under-layer caused by wave or current action (this function is normally utilized only in bank protection applications subject to high current or wave attack).

7.11.4 Design Approach

The design procedure for revetments is as follows:

- a) Identification of design conditions (design loads; function of protection)
- b) Preliminary selection of revetment type
- c) Assessment of geotechnical stability of bank
- d) Check on subsoil bearing capacity
- e) Design of armour layer
- f) Design of under-layer
- g) Detailing of crest, toe and edge

Steps b to f are likely to be iterative.

7.11.5 Design of Armour Layer

7.11.5.1 Types of Armour

Types of armour construction commonly used in Malaysian:

- a) Stone
 - i. Rip-rap or rock armour occasionally grouted
 - ii. Hand-pitched stone
 - iii. Masonry, random or dressed
 - iv. Gabion or wire mesh mattresses
- b) Concrete
 - i. Plain precast blocks, open-jointed or grouted interlocking blocks
 - ii. Cable-tied or geotextile-bonded blocks
 - iii. Cast in-situ slabs and monolithic structures
 - iv. Fabric containers
- c) Geotextiles
 - i. Grassed composites — mats, fabrics and meshes
 - ii. Three-dimensional retaining mats and grids
 - iii. Two-dimensional fabrics
- d) Asphalt
 - i. Open stone asphalt-filled geotextile mat
 - ii. Open or dense stone asphalt



Figure 7.24 Revetment System



Figure 7.25 Basalt Revetment, Pulau Besar, Melaka



Figure 7.26 Rock Revetment, Kg Pasir Pandak, Kuching, Sarawak

The types of slope protection or revetment commonly used for bank shore protection and stabilization include:

- a) Rock and rubble riprap;
- b) Wire-enclosed rock;
- c) Precast concrete block;
- d) Grouted rock;
- e) Concrete slope protection;
- f) Grouted fabric slope pavement;
- g) Sand/cement bags; and
- h) Soil cement.

Description of each of these revetment types is included in this section.

a. Rock and Rubble Riprap

Riprap is described as a layer or a facing of rock, dumped or hand-placed to prevent erosion, scour or sloughing of a structure or embankment. Materials other than rock are also referred to as riprap; these include rubble, broken concrete slabs and preformed concrete shapes (slabs, blocks, rectangular prisms). These materials are similar to rock in that they can be hand placed or dumped onto an embankment to form a flexible revetment.

b. Wire-Enclosed Rock

Wire-enclosed rock, or gabion, revetments consist of rectangular wire-mesh baskets filled with rock. These revetments are formed by filling pre-assembled wire baskets with rock and anchoring them to the channel bottom or bank. Wire-enclosed rock revetments are generally of two types distinguished by shape namely mattresses and blocks. In mattress designs, the individual wire mesh units are laid end-to-end and side to-side to form a mattress layer on the channel bed or bank. The gabion baskets comprising the mattress generally have a depth dimension that is much smaller than their width or length. Block gabions, in contrast, are more equal-dimensional, having depths that are approximately the same as their widths and of the same order of magnitude as their lengths. They are typically rectangular or trapezoidal in shape. Block gabion revetments are formed by stacking the individual gabion blocks in a stepped fashion.

c. Precast Concrete Block

Precast concrete block revetments consist of preformed sections which are butted together or joined in some fashion to form a continuous blanket or mat. The concrete blocks, which make up the mats, differ in shape and method of articulation but share certain common features. These features include flexibility, rapid installation and provisions for establishment of vegetation within the revetment. The permeable nature of these revetments permits free draining of the bank materials; the flexibility, although limited, allows the mattress to conform to minor changes in the bank geometry. Their limited flexibility, however, makes them subject to undermining in environments characterized by large and relatively rapid fluctuations in the surface elevation of the channel bed and/or bank. Unlike wire-enclosed rock, the open nature of the precast concrete blocks does promote volunteering of vegetation within the revetment.

d. Grouted Rock

Grouted rock revetment consists of rock slope protection having voids filled with concrete grout to form a monolithic armour. Grouted rock is a rigid revetment; it will not conform to changes in the bank geometry due to settlement. As with other monolithic revetments, grouted rock is particularly susceptible to failure from undermining and the subsequent loss of the supporting bank material. Although it is rigid, grouted rock is not strong; therefore, the loss of even a small area of bank support can cause failure of large portions of the revetment.

An alternative to grouted rock is partially grouted rock. In general, the objective of partially grouted rock is to increase the stability of the riprap without sacrificing all of the flexibility. As with fully grouted rock, partially grouted rock may be well suited for areas where rock of sufficient size is not available to construct a loose riprap revetment. The grout for partially grouted rock is placed on the riprap leaving significant voids in the riprap matrix and considerable open space on the surface. The holes in the grout allow for drainage of pore water so a filter is required. The grout forms conglomerates of rock so that the stability against particle erosion is greatly improved and, as with fully grouted riprap, a smaller thickness of stone can be used. Although not as flexible as riprap, partially grouted rock will conform somewhat to bank settlement and toe exposure.

e. Concrete Slope Protection

Concrete pavement revetments (concrete slope pavement) are cast in place on a prepared slope to provide the necessary bank protection. Like grouted rock, concrete pavement is a rigid revetment that does not conform to changes in bank geometry due to a removal of foundation support by subsidence, undermining, outward displacement by hydrostatic pressure, slide action, or erosion of the supporting embankment at its ends. The loss of even small sections of the supporting embankment can cause complete failure of the revetment system. Concrete pavement revetments are also among the most expensive bank protection designs. In the past, concrete pavement has been best utilized as a subaqueous revetment (on the bank below the water surface) with vegetation or some other less expensive upper-bank treatment.

f. Grouted Fabric Slope Pavement

Grouted fabric slope pavement revetments are constructed by injecting sand-cement mortar between two layers of double-woven fabric that has first been positioned on the slope to be protected. Mortar may be injected into this fabric envelope either underwater or in the dry. The fabric enclosure prevents dilution of the mortar during placement underwater. The two layers of fabric act first as the top and bottom form to hold the mortar in place while it hardens. This fabric, to which the mortar remains tightly bonded, then acts as tensile reinforcing to hold the mortar in place on the slope. These revetments are analogous to slope paving with reinforced concrete. The bottom layer of fabric acts as a filter cloth underlay to prevent loss of soil particles through any cracks that may develop in the revetment as a result of soil subsidence. Often, greater relief of hydrostatic uplift is provided by weep holes or filter points that are normally woven into the fabric and remain unobstructed by mortar during the filling operation. One advantage to this type of revetment protection is that the concrete can be pumped into tight locations where there is little room for equipment such as under existing bridges to protect the abutments.

g. Sand-Cement Bags

Sand-cement bags generally consist of a dry mix of sand and cement placed in burlap or other suitable bag. They are hand placed in contact with adjacent bags. They require firm support from the protected bank. Usually a filter fabric is placed underneath this type of riprap. Adequate protection of the terminals and toe is essential.

The riprap has little flexibility and low tensile strength and is susceptible to damage particularly on flatter slopes where the area of contact between the bags is less.

h. Soil-Cement

Soil-cement generally consists of a dry mix of sand and cement and admixtures batched in a central mixing plant. It is usually transported, placed by equipment capable of producing the width and thickness required and compacted to the required density. Control of the moisture and time after introduction of the mixing water is critical. Curing is required. This results in a rigid protection. Soil-cement can be placed either as a lining or in stepped horizontal layers. The stepped horizontal layers are extremely stable, provided that toe scour protection has been incorporated into the design.

7.11.6 Rock Riprap Revetment Design Procedure

Rock riprap design procedure outlined in the following sections comprises of three primary sections: preliminary data analysis, rock sizing, and revetment detail design.

7.11.6.1 Preliminary Data Analysis

Step 1. Compile all necessary field data (e.g. channel cross section surveys, soils data, aerial photographs, history of problems at site).

Step 2. Determine design discharge.

Step 3. Develop design cross sections.

7.11.6.2 Rock Sizing

The rock sizing procedures described in the following paragraphs are designed to prevent riprap failure from particle erosion.

Step 4. Compute design water surface.

- a. When evaluating the design water surface, Manning's "n" should be estimated first. If a riprap lining is being designed for the entire channel perimeter, an estimate of the rock size may be required to determine the roughness coefficient "n". If the design section is a regular trapezoidal shape and flow can be assumed to be uniform, use design charts such as recommended.
- b. If the design section is irregular or flow is not uniform, backwater procedures must be used to determine the design water surface. Computer methods such as WSPRO (38) and HEC-RAS are recommended.
- c. Any backwater analysis conducted must be based on conveyance weighting of flows in the main channel, right bank and left bank.

Step 5. Determine design average velocity and depth.

- a. Average velocity and depth should be determined for the design section in conjunction with the computations of step 4. In general, the average depth and velocity in the main flow channel should be used.
- b. If riprap is being designed to protect channel banks, abutments or piers located in the floodplain, average floodplain depths and velocities should be used.

Step 6. Compute the bank angle correction factor K1

Step 7. Determine riprap size required to resist particle erosion equation.

- a. Initially assume no corrections.
- b. Evaluate correction factor for rock riprap specific gravity and stability factor ($C = C_{sg} C_{sf}$).
- c. If designing riprap for piers or abutments apply pier/abutment correction (CP/A) or 3.38.
- d. Compute corrected rock riprap size as: $D'50 = C (CP/A) D50$

Step 8. If entire channel perimeter is being stabilized and an assumed D50 was used in determination of Manning's 'n' for backwater computations, return to step 4 and repeat steps 4 through 7.

Step 9. If surface waves are to be evaluated

- a. Determine significant wave height
- b. Use respective chart to determine rock size required to resist wave action

Step 10. Select final D50 riprap size, set material gradation and determine riprap layer thickness

7.11.6.3 Revetment Details

Step 11. Determine longitudinal extent of protection required.

Step 12. Determine appropriate vertical extent of revetment.

Step 13. Design filter layer.

- a. Determine appropriate filter material size, and gradation.
- b. Determine layer thickness.

Step 14. Design edge details (flanks and toe).

7.12 BRIDGES AND CROSSINGS

A bridge is preferred compared to a culvert in order to accommodate greater flood discharges and to avoid unnecessary constriction to flow. Designs of bridge will vary depending on the function of the bridge and the nature of the terrain where it is to be constructed. The bridge construction and modifications to relieve hydraulic constriction are also flood mitigation system options.

The DID has prepared a guideline for approval of development proposal near and within the river reserve. Data to be submitted include key plan, site plan, and location plan with information (supported by photographs where possible) for buildings, Mean High Water Spring, channel system, topographic features and spot levels. All these should be certificated by Registered Surveyor. The submitting engineer acting on behalf of the developer must also present hydrological and hydraulics analyses. Special consideration must be given for operation and maintenance (O&M) needs of the river by providing sufficient reserve width and access. Further details can be obtained from the Guidelines for River Development (Garispanduan Pembangunan Sungai) and Stream Crossing Guidelines (DID 2008).

7.12.1 Data Collection

Various information as listed below are required for the hydrological and hydraulic analyses to determine the flood levels before the bridge design is carried out.

- Cross section of the river (Computation of water level)
- Hydrological data (Rainfall runoff analysis)
- Downstream water level (To check for backwater effect)
- Topographical map (Catchment characteristics)
- Proposed alignment of the location (Bridge properties)
- Contour and spot height (Flood extent)

Some of the data listed below may be obtained from Jabatan Kerja Raya (JKR) for the proposed alignment:

- Proposed alignment of the proposed location
- Contour of the proposed location
- Ground levels along the proposed location
- Aerial photo of the project area

7.12.2 Flood Characteristics

Records of floods that have occurred in the basin may be obtained from the DID. Data and information required for the design of flood mitigation structures include:

- Hydrological analysis (Monthly rainfall data)
- Design storm (ARI)
- Aerial Reduction factor (ARF)
- Catchments delineation
- Rainfall runoff model
- Calibration
- Selection of Runoff Curve Number (CN)

7.12.3 Hydrodynamic Model Development

There are many hydrodynamic (hydraulic and hydrologic) models available. One of them is InfoWorks RS (River Simulation) developed by the Wallingford (UK) Software for steady and unsteady flows. Most of the softwares have the capability to compute afflux caused by constriction at bridges. GIS information can be included in the softwares as a base map to enhance the model development. For example, the software can simulate water levels along a river including effects of bridge crossings on possible flooding. The main inputs to the model are:

- River cross-sections at bridges or selected locations (available from the survey details).
- Inflow hydrographs for various sub-catchments of the catchment.
- Downstream boundary conditions
- Contour map from the Survey and Mapping Department (JUPEM)

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8 FLOOD MITIGATION NON-STRUCTURAL MEASURES

8.1 INTRODUCTION

Flood mitigation programs aims at controlling and reducing the negative impacts of future flood events on society and the environment. There are two major aspects of flood mitigation programs. One is structural measures and the other, non-structural measures. A combined perspective of both these measures is collectively referred to as catchment management. This is discussed in Chapter 3.7.

Structural measures refer to physical activities undertaken to reduce the levels and extent of floods in a particular area or region. These include construction of flood detention ponds and dams, improving river hydraulic capacities, constructing new channels and building flood protection walls and bunds. Implementing structural measures to completely prevent flood events is limited by available funds and economic as well as environmental viability. The practical approach is to plan and design structural measures based on acceptable levels of protection and affordability. This is often expressed statistically as providing systems that can protect an area for a specific probability of flood flow event of say, 1:100 years return interval. Events beyond this return interval will cause flooding.

Non-structural measures are necessary to complement the limitations of implementing and operating structural measures for flood mitigation. It includes managing a river catchment such that future development within it does not increase the frequency and intensity of floods. Non-structural measures also aim to increase public awareness and acceptance that floods can and will recur as well as increasing their state of preparedness for such eventualities. It is also to provide as much support as possible for public safety, security and comfort prior to, during and after a flood event.

In general, non-structural measures for flood mitigation involves planning, programming, setting policies, co-ordination, facilitating, rising awareness, assisting and strengthening the society to face the threats and impacts of floods. It also covers educating, training, regulating, reporting, forecasting, warning and informing those at risks. In addition, non-structural measures include insuring, assessing, financing, relieving and rehabilitating.

The order in which the non-structural measures are applied is of primary importance. An ideal sequence would be to first develop public awareness that leads to political will, followed by drafting and passing the laws and regulations. Next is to propose risk-reducing measures, and, finally, to offer education and training. Ultimately, market-oriented conditions to develop the flood insurance industry should be encouraged. This will allow for spreading the cost of potentially high flood damages over a long period of time and shared by a large number of people.

Other non-structural measures and mitigating actions are aimed at reducing physical vulnerability, vulnerability of the economy, and strengthening the social structure of the community. These actions can be undertaken at individual, community, and state levels. Non-governmental organizations should be encouraged to participate actively in this aspect.

8.2 FLOODPLAIN MANAGEMENT

8.2.1 What are Floodplains?

Floodplains are areas adjacent to rivers and coasts susceptible to flooding during periods of heavy rain and high river flows, or severe sea conditions. Flooding is a natural process but the development of land in floodplains has resulted in a risk of flooding to properties and other assets. Figure 8.1 shows the flood plain zone for a 1:100 years ARI. Floodplains can be divided into two types: those with flood defences and those without. Flooding on floodplains that are not protected occurs relatively slowly as the river or sea level rises. However, flooding in protected areas tends to occur very rapidly when defences are overtopped or breached.

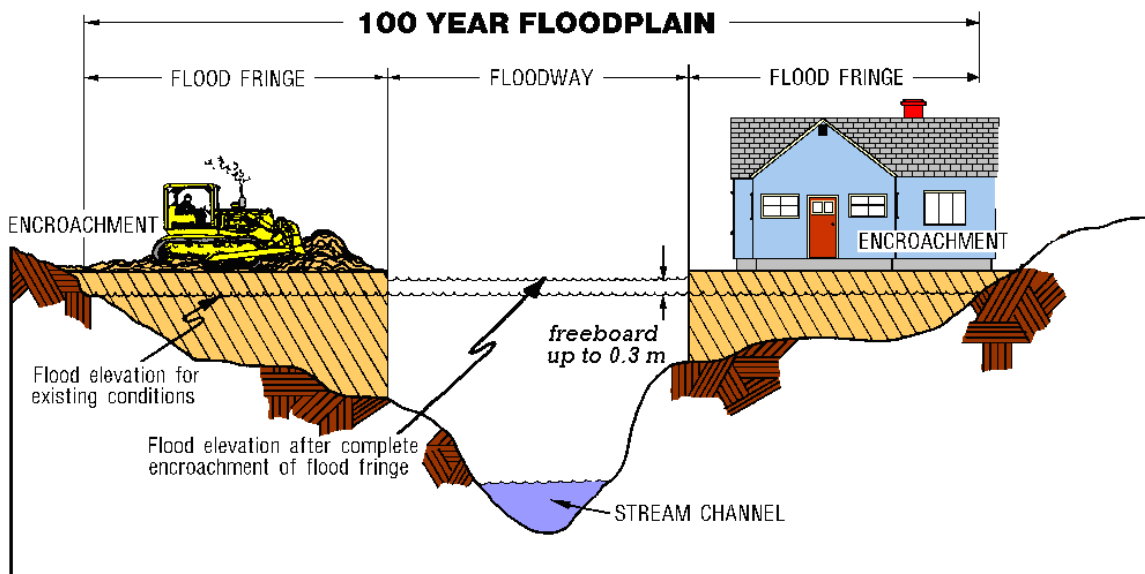


Figure 8.1 Flood Plain Area

- **Floodplains on rivers**
The natural function of floodplains on rivers is to store floodwater and also permit the passage of floodwater downstream. Developments (and residents) in the floodplain are thus clearly at risk of flooding. The developments also reduce flood storage capacity of the plains and cause more floodwater to pass downstream. It also impedes the flow of floodwater, thereby raising flood levels upstream.

The canalization of some rivers and construction of flood defences have changed the natural regime and the level of flood risk in adjacent floodplains. Whilst the risk of flooding may have been reduced in these areas, it cannot be totally eliminated.

- **Floodplains on the coast**
The natural function of floodplains on the coast is to provide a buffer between the sea and the land during periods of extreme bad weather where sea levels may be high and waves conditions severe.

Construction of flood defences on the coasts has resulted in very large areas of land being protected from the sea. These defences form a hard barrier that require constant maintenance and repair as a result of attack by the seawater.

- **Floodplain definition**
In Malaysia there is yet an official definition of a floodplain. In general it is all the areas that can be affected by all types and nature of flood events. Quantitatively, the definition of a floodplain can be based on the magnitude of particular flood events (the “defined flood events”). For example, in the UK a flood with a 1 in 100 chance of occurring in any year is used for rivers and non-tidal areas. For coastal and tidal areas the figure is 1 in 200. Larger floods than these can still occur and there are considerations to extend the definition based on the estimated flood with a 1 in 1000 chance of occurring in any year.
- **Standard of protection against flooding**
In general it is not economically or practically feasible to provide for a total flood protection. Instead, flood mitigation systems planning and design are based on defined flood events (for example, designed for a flood with a 1 in 100 chance of occurring in any year). The choice of a specific chance of occurring represents a compromise between the financial affordability and the acceptable risk for floods larger than that defined in the planning and design.

8.2.2 Floodplains — A National Asset

Although the risks of living and developing in the floodplains are obvious, it continues to attract human settlement and development. This is because the social, economic and environmental benefits often far outweigh the risk of periodic flooding. Some of the reasons that make floodplains attractive for development include:

- Relatively flat land, thus relatively easy to develop;
- Easy access to water for water supply, waste disposal, hydropower and river transport;
- Relatively easy to construct transportation infrastructure for roads, canals and railways;
- Relatively easy to construct river crossing points; and
- The plains often are good quality agricultural land.

As a result, floodplains continue to be used by existing settlements, new developments, agriculture, and transport links. In addition, floodplains provide amenity and recreation areas, many of which are important for the local tourist industry.

8.2.3 Floodplains — A National Liability

The capital value of assets potentially at risk in the floodplains of Malaysia is well in excess of billions of Ringgit. At present, the Annual Average Damages (AAD) due to floods is estimated to be about RM 290 Million.

It is estimated that 4.82 million people (about 20% of the population) are directly affected by flooding. In addition to this are those using transport links crossing the floodplains and those working in businesses that are affected when flooding occurs.

Thus, there is a huge national cost associated with the use of floodplains, which is likely to increase as floodplain development continues and the impacts of climate change become more apparent. An important challenge to floodplain management is to ensure that costs are manageable for a more sustainable environment.

8.2.4 Objectives of Floodplain Management

Floodplain management has commonly the following objectives:

- To limit to acceptable levels the effect of flooding on the well-being, health and safety individuals and communities;
- To limit to acceptable levels the damage caused by flooding to property and other assets;
- To ensure the natural function of the floodplains (to convey and store floodwater) is preserved together with flood dependent ecosystems; and
- To encourage the planning and use of floodplains as a valuable and sustainable resource capable of multiple but compatible land uses to the benefit of the community.

In addition, (i) the stakeholders must be aware of how floodplains are managed and be able to contribute to it; (ii) floodplain management must be integrated with catchments and shoreline management and urban drainage; and (iii) there must be integration between all the agencies involved in the floodplain management.

8.2.5 Floodplain Management — A Planning Process

Land use change is the primary factor affecting surface runoff and consequently flood characteristics. Careful land use planning is therefore an important component of non-structural approach in flood management. The planning of land use and the control of development is the responsibility of local planning authorities, including the planning of land use in floodplains. Considerations that must be taken into account in floodplain land use and development planning include:

- Needs for local development including residential, commercial and amenity land uses;
- Availability of suitable sites;
- Local infrastructure including the ability of existing infrastructure to serve future growth and the need for new infrastructure;
- Desired uses of the floodplains by the local community;
- Risk of flooding and management of flood risks including flood alleviation infrastructure; and
- Flood emergency management.

A floodplain management should integrate with the land use policy and planning process for a long-term development strategy. These requirements must be incorporated in the statutory land use plans with appropriate guidance on development control as well as the community's opinion on how best to manage floodplains for the benefit of present and future generations.

8.2.6 Responsibilities for Floodplain Management

Agencies involved in the floodplain management include the following:

- Local Authority and District Office: General responsibilities within the local communities including planning. Also responsible for some water courses in their district and also in flood emergency planning and response; and
- The Department of Irrigation and Drainage that is responsible for matters pertaining to river and coastal management and flood mitigation.

8.3 FLOOD MAPPING

8.3.1 Definitions

The following definitions are used in the manual.

- Flood is a temporary covering of water over land not normally covered by water. This includes floods from rivers and floods from the sea in the coastal areas.
- Flood risk is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with that flood event
- Flood hazard map shows areas which could be flooded based on three probabilities of occurrence namely low, medium, and high. This is complemented with information of the type of flood, its extent, water depths or water level, where appropriate, flow velocity or the relevant water flow direction.
- Flood risk maps indicate the potential adverse consequences associated with floods for different quantified probabilities. These are then related to the indicative number of potentially affected inhabitants, type of economic activity of the potentially affected area and the potential accidental pollution from certain installations that may be affected.
- Flood plain maps indicate the geographical (spatial) areas which could be flooded based on one or several probabilities of occurrence. The probability ranges from very low (extreme events scenarios, say 1:1000 years), medium (greater than or equal to 1 in 100 years), and to high (say, less than 1:20 years).
- Damage is the negative effect of an event or process

Flood mapping in Malaysia is still at the early development stages. In Europe, the current practice for flood mapping contains characteristics as shown in Table 8.1.

Table 8.1 Flood Mapping Characteristic

	Flood hazard map	Flood risk map
Content	Flood parameters such as <ul style="list-style-type: none"> • flood extent according to probability classes, • according to past events • flood depth • flow velocity • flood propagation • degree of danger 	Risk parameters such as <ul style="list-style-type: none"> • assets at risk • Flood vulnerability • Probable damage • Probable loss (per unit time)
Purpose and use	<ul style="list-style-type: none"> • Land use planning and land management • Watershed management • Water management planning • Hazard assessment on local bunds • Emergency planning and management • Planning of technical measures • Overall awareness building 	<ul style="list-style-type: none"> • Basis for policy dialogue • Priority setting for measures • Flood Risk Management Strategy (prevention, mitigation) • Emergency management (e.g. the determination of main assets) • Overall awareness building
Scale	<ul style="list-style-type: none"> • Local level: 1:5,000 to 1:25,000: various parameters • National level, whole river basin: 1:50,000 to 1:1,000,000: in general only flood extent 	<ul style="list-style-type: none"> • 1:5,000 to 1:25,000 • 1:50,000 to 1:1000,000
Accuracy	<ul style="list-style-type: none"> • high: cadastre level for detailed maps • low: whole river basin, national level 	<ul style="list-style-type: none"> • high: cadastre level • low: whole river basin, national level
Target group / use	<ul style="list-style-type: none"> • National, regional or local land-use planning • Flood managers • Emergency services • Forest services (watershed management) • Public at large 	<ul style="list-style-type: none"> • Insurance • National, regional or local emergency services • National, regional or local water and land use managers

8.3.2 Flood Hazard Mapping

Flood Hazard Maps provides information mainly for operational institutions and the general public. In its simplest form, it provides general information on the extent (the boundary) flood-prone areas based on flood event records such as that compiled by the Hydrology and Water Resources Division of the Department of Irrigation and Drainage. This is usually plotted on cadastral sheets (revenue sheets). Superimposing the flood area plan on a topographical or a landuse map would provide more information. It will show the indicative number of houses and lands affected, the roads and other infrastructure affected and, from the contour lines, the depths and levels of the flood. At the same time, this plan will show areas (or public buildings such as schools and hospitals) not affected by floods but may be cut-off by flood water from access roads and other facilities. It could also show factories and other installations that may pose pollution and other hazards during floods. Some examples are petrol stations, chemical factories and storage facilities, sewerage treatment plants, power transmission lines and power supply sub-stations.

With more information gathered over time, the boundary of flood areas can be determined based on a chosen specific probability of occurrence. The direction of flood water fronts and recession can be included and even the rate of flood level rise and recession and their respective flow velocities indicated.

A Flood Hazard Map does not provide information on quantified risks in association with monetary values. However it is very useful for various end-users. For the planner it provides a quick reference for better informed decision-making. For example, for planning of future growth, for deciding on location of flood-sensitive facilities and for planning of flood mitigation works. For the flood rescue teams, the Flood Hazard Maps can be used for strategic planning of rescue operations, rescue route planning and equipment choice and determining safe and accessible locations for evacuees.

For the general public and businesses, the Flood Hazard Maps will be useful to mitigate personal losses. It helps to show the best escape route as well as alternatives to the nearest safe areas. It also helps in deciding the arrangement and storage of personal belongings and for selection flood-proofing methods. The map could also show the safe locations to park their cars when flood levels begin to rise. Places to avoid are also indicated such as open drains, edges of roads and bridges that may be hidden under the flood water surface.

Flood Hazard Maps can be developed in stages from one with basic information to more sophisticated levels. In Europe, the requirements of Flood Hazard Map are that it should include historic as well as potential future flood events of different probability, illustrating the intensity and magnitude of hazard in a selected scale and at the basis of considerations and determinations in land use control, flood proofing of constructions and flood awareness and preparedness.

The maps shall cover the geographical areas which could be flooded for the following scenarios;

- a) Floods with a low probability, or extreme event scenarios
- b) Floods with a medium probability (likely return period greater and equal to 100 years)
- c) Floods with a high probability, where appropriate.

8.4 Flood Risk Mapping

A Flood Risk Map provides a quantified assessment of risks associated with floods. It is primarily a tool for use by policy makers in deciding the level of investments in a potentially flood prone area. For example, the Government can use it to assess economic and social viability for certain investments such as for flood mitigation projects or for large social development projects. Businesses may use it to decide on new or future investment ventures and insurance companies will need it to develop flood insurance packages that are fair to all parties.

A flood risk map uses the similar data and information as in flood hazard maps but with higher degrees of accuracy and with more indicators of potential losses or adverse effects such as health, environment and economic activities. However, since the basic data and information are similar and that there is yet to be a universally accepted definition of Flood Risk Maps, some Flood Hazard Maps have been misleadingly depicted by the publishers as Flood Risks Maps (refer to Appendix 8.3).

To overcome this unintentional misnomer and to differentiate the two, in Europe, the European Flood Directive defines flood risk as follows:

“Flood risk is the combination of the probability of a flood event and of the potential adverse consequence to human health, the environment and economic activity associated with a flood event”

a) The concept of Flood Risk

Following the definition above, Flood Risk is defined as the product of the consequence of flooding and the probability of flooding. This can be expressed as:

$$\text{Flood Risk} = C \times Ph \quad (8.1)$$

where C is the potential adverse consequence (incorporating exposure and vulnerability factors) and Ph is the probability of the hazardous process. The Flood Risk is expressed as a potential loss in a particular area (e.g. ha, km²) within a given period of time (usually one year).

The potential adverse consequence is expressed as:

$$C = V \times S \times E \quad (8.2)$$

Where V, S and E are the vulnerability parameters:

V = value of the element at risk in monetary terms or numbers of human life

S = susceptibility: damaging effect on element at risk (as a function of magnitude of hazard; e.g. depth-damage and damage-duration curves. The susceptibility value ranges from 0 to 1; where susceptibility increases with the value)

E = exposure: the probability of the element at risk being present when the event occurs. The exposure values ranges from 0 to 1; where higher value indicates higher exposure.

Subsequently and using the expressions above, the following information can be then mapped and derived:

- Individual element vulnerability parameters (V) in terms of values (RM or numbers) as defined above for:
 - Population: number of people, special groups, etc
 - Economic assets and activity: private property, lifelines, infrastructure, etc; type of production, number of jobs, etc.
 - Environmental issues: installations potentially damaging the environment
- Potential adverse consequence (flood damage; loss per unit area) = $V \times S \times E$
- Flood Risk (loss per unit area in a given period of time) ($C \times Ph$)

An important point to remember evaluating assessing risks is that Risk is unlikely to remain constant over time. For better decision making, it is necessary to predict changes of risk in the future. Some causes of changes of the risks are well recognized for example:

- Vulnerability parameter can change rapidly.
- Increasing vulnerability- development, increased value of assets at risk, land use, "risky" responses of people during the flood, decreased capacity for recovery
- Decreasing vulnerability – resettlement/moving assets out, reducing sensitivity of assets, better flood warning systems, changing use of land, organised behaviour of people during the flood, improved capacity for recovery.
- Permanent, semi-permanent or non-permanent flood defences (deterioration, maintenance, new works)
- The hazard parameters can change due to;
 - Climate (natural variability, climate change)
 - Environmental change (deforestation, reforestation, major forest fires)
 - Erosion rate (changing geological exposures)
 - Human intervention

b) Mapping the assets at risk (Vulnerability Maps)

Mapping the assets at risk is to provide information on population, assets and economic activity, and environmental issues, potentially affected by a flood (vulnerability parameters).

The following information can be mapped with regard to flood risks:

i. Population

- Distribution of population (either people per municipality, postal code or address/building, or average number of people per building/property)
- Distribution of particular vulnerable groups (homes for the elderly, location of schools, hospitals, sports facilities, other infrastructure with concentration of people, concentration of tourists)
- Distribution of buildings
- Social vulnerability based on social groups and economic conditions

ii. Assets and economic activity

- Criteria may help identify the economic activities concern
- Various classifications for land-use exist, and can be adapted according to needs
- The hazard map serves as well as a vulnerability map (water depth of a 100-year flood overlay on land use map)

iii. Potentially affected installation causing pollution

A non-exhaustive list of installations of interest in this regard is:

- Chemical industry and respective warehouses
- Petroleum industry and storage facilities for oil product
- Thermo-electric power stations; oil, gas and coal
- Fuel/gas stations
- Agricultural warehouses for fertilizers, herbicides, pesticides, poisonous substances, nutrients
- Special dump sites for chemical or industrial waste
- Sanitary landfills
- Waste water treatment plants

The potential impacts of flooded installations as listed above on particular environmental assets may include the following:

- Potential damage to habitat and wildlife
- Loss of unique habitat and rare wildlife
- Loss of National parks and other protected areas like wetlands and virgin forest

A map may be used for the following:

- Basis to determine damage and risk
- Emergency management
- Planning of flood defence measures
- Land use planning and land management
- On small scale (large areas): priority setting

Scale considerations may include:

- Overview information on village and town level. On large areas only the approximate population per municipality, village, or town can be represented. Scale is of the order of 1:100,000 to 1: 500,000. Only feasible for large flood plains
- Broad-scale infrastructure like road or rail network, or agriculture and forestry may use small to medium scales (1:100,000 to 1:250,000)
- Detailed information about individual buildings, social structures or social groups or about individual facilities require maps with a large scale (1:5,000 to 1:25,000; city or village plan)

The main considerations in developing an FRM are:

- Hydraulic and Hydrologic data;
- Hydrologic analysis;
- Hydraulic analysis;
- GIS process; and
- Software selection

8.4.1 Process for Flood Risk Map Development

Based on the definition, a flood risk map may be prepared such as shown in Figure 8.2. Although called 'risk map' (see APPENDIX 8.D), the map actually depicts flood hazards more than flood risks. The elements shown in the model example have been adapted in our local flood hazard projects.

Types of data and their need have been explained in Chapter 5 of this manual. These are however produced here with regard to flood risk mapping.

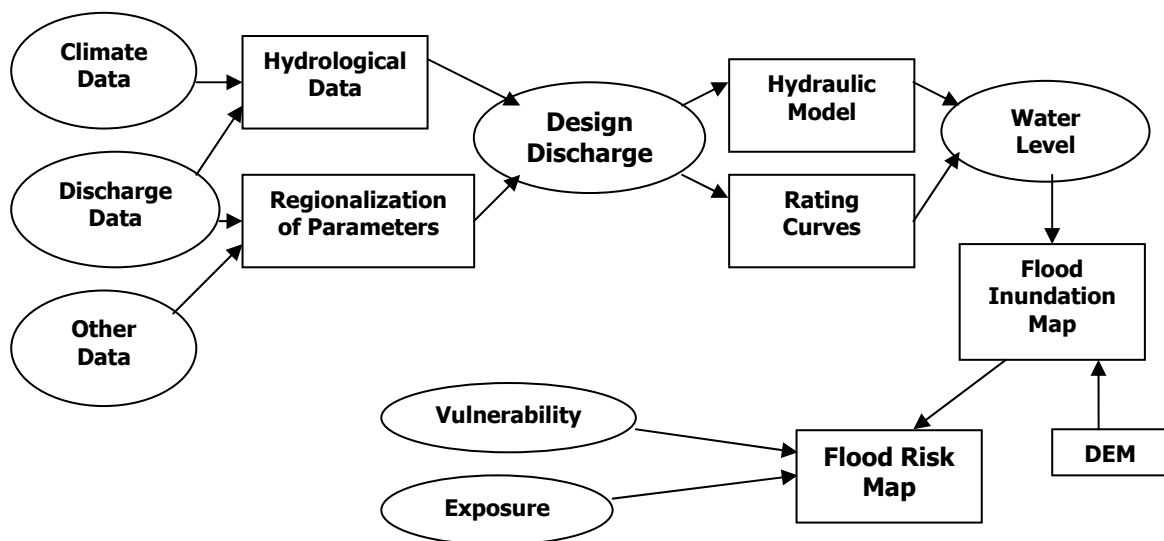


Figure 8.2 Conceptual Model for Creating Flood Risk Maps

Modelling flood behaviour is to understand the flow of water during floods. In modelling terms, the flow can be represented as 1-D flow. However, when the water overflows into the floodplain, more complex patterns will occur. Preferably the flow should be modelled as 2-D flow but due to complexity, a quasi 2-D approach should be acceptable. Various hydraulic model developers are putting much effort to combine 1-D and 2-D simulations into one single model.

The process for developing a Flood Risk Map (FRM) is discussed here (see APPENDIX 8.D). The main considerations in developing an FRM are:

- Hydraulic data (river cross-sections and presence of hydraulics structures) and Hydrologic data (rainfall, water level, discharge, tidal record, historical flood record, land use)
- Hydrologic analysis - Hydrologic components of the model should include:
 - Sub-catchments delineation;
 - Rainfall distribution;
 - Land use changes;
 - Development of rainfall runoff model;
 - Calibration and verification; and
 - Production of suitable hydrographs based on various ARI scenarios.
- Hydraulic analysis - Hydraulic components of the model should include:
 - River model plus their tributaries;
 - Structures in the river;
 - Infrastructure within the floodplain;
 - Flood plain representation;
 - Boundary conditions, upstream and downstream;
 - Calibration and verification for various events focusing on flood level either in the river or in the floodplain;
 - Identifying suitable roughness in the river and floodplain; and
 - Combination with ground model to produce flood extent.
- GIS process

Combination of hydraulic, hydrologic and GIS tools has become a necessity in producing FRM. Hydraulic and hydrologic models should be able to predict the discharge and water levels along the river and floodplain. The water level data can then be exported to GIS tools/GIS function in the hydrodynamic software to produce the extent of flood. Basin data required for this process are ground data, digital elevation model (DEM) or digital terrain model (DTM). Various techniques such as LIDAR, aerial photographs and topographic maps are available to capture the basin data.

- Software selection - For guidance purposes, a list of software recommended for the development of FRM is given below:
 - a) InfoWorks RS;
 - b) Mike 11;
 - c) ISIS;
 - d) XP SWMM; and
 - e) HEC-RAS.

8.4.2 Information of Flood Risks to be Included in the Local Plans

8.4.2.1 Summary of Information

Spatial information about flood risk is summarized below. These should preferably be added directly to the proposed map:

a) Flood risk areas and probability of flooding

Areas at risk from flooding should be clearly illustrated on a map (or maps) of the planning district. The maps should indicate the probability of flooding and the source of information such as:

- Reports of flood studies conducted in the area; and
- Indicative Floodplain Maps produced by the DID

b) Existing flood defences and standard of protection

Information on the location of flood defences and the standard of protection may be difficult to obtain because:

- Flood defences are not all owned by one organization, although common owners include the DID, local authorities and private landowners; and
- Flood defences have often been provided as parts of schemes intended to provide a certain standard of protection when the scheme was first designed. Changes in the river catchments, new flood data and improvements in design methods would change the effective standard of protection provided, and the present standard is often not known.

c) Flood management policies

The policies that guide the plan and assist with individual planning decisions with regard to flood risk should be contained in the plan. The policies include:

- Flood management, from CFMPs and SMPs;
- Development in different zones of the floodplain;
- Infrastructure design in flood risk areas;
- Development control; and
- Building controls

Whilst it is recognized that such development will continue to take place, more detailed advice is given on how to take account of flooding when planning new developments.

d) Proposed flood management measures

Present and future flood risks for coastal cells and river catchments are identified in CFMPs/SMPs. These high level plans are used to develop overall flood management policies for these areas, and identify options which could achieve these policies. For example, if the policy is to provide a certain standard of flood protection for all urban areas, the CFMP/SMP must identify feasible options for achieving this policy. Each option will consist of a package of measures.

e) Link with the Flood Emergency Plan

A Flood Emergency Plan (FEP) to address residual flood risk is essential, covering flood warning arrangements, preparedness for floods, response to flood emergencies and recovery from flooding. Such a plan should be complementary to the flood management measures contained in the Local Plan.

Specific links between Local Plans and FEPs include the following:

- Information: Local Plans will contain information on flood risk areas and land use which can be used directly in flood emergency planning;
- Community awareness: The consultation process for land use planning (including the floodplain) will help to raise the awareness of flood risk amongst the general public. Flood-prone communities should be made particularly aware of the consultation process associated with planning in flood risk areas. This should be directly linked to flood emergency planning so that individuals and communities are made as aware as possible of their responsibilities before, during and after floods. A programme of regular re-education of people living in flood-prone areas is also needed to maintain this awareness; and
- Planning issues: The policies and measures in the Local Plan should be consistent with the requirements of flood emergency planning. For example, vulnerable developments such as old peoples' homes should not be permitted in flood risk areas. In addition, access for the emergency services during flood emergencies must be taken into account in land use planning.

8.4.2.2 Specific Issues of Concern

The following issues should be considered in the preparation of the Local Plan.

a) Future Planning Considerations

The planning horizon for flood defences is typically 50 years while that for land use is only 10 years. In order to encompass the possibility of large-scale land use change and urban redevelopment, the planning horizon for floodplain management should be at least 30 years, but not more than 50 years.

b) Cumulative Effects

A common problem with many floodplains is the cumulative effect of developments. These developments may be little affected by floods individually but the effect could be significant cumulatively. Such cumulative effects can be due to the following:

- Progressive blocking of floodways and flow paths by individual developments.
- Ad hoc filling of floodplain areas, thus reducing flood storage capacity of the floodplain.
- Increase in the at-risk population living and working in the more hazardous areas of the floodplain.

c) Protection of infrastructure

Essential infrastructure services, such as water supply, sewerage, telephone and electric power need to be protected at the onset of a flood. This is to facilitate clean-up and recovery services, thereby minimizing social disruption to the community. Telephone network is of particular importance during a flood and protection should be a high priority.

d) Larger floods

When planning for future floods, implications of the full range of floods that could occur must be considered. Structural flood management measures are designed to provide protection from floods with a specific probability of occurrence. These are inadequate for larger floods thus both the Local Plan and the Flood Emergency Plan must consider the implications of such floods.

e) Islands

Formation of islands (higher grounds surrounded by flood water) in the floodplain during a flood is always potentially hazardous and must be avoided. People trapped on the island may be safe for small floods, but are at high risk in extreme floods. Development of land that becomes isolated prior to inundation would increase the load on emergency services during flood events. Furthermore, rescue work for people on these islands may be risky.

f) Detention Basins

Flood detention basins are used as a means of controlling peak discharges from newly urbanized areas. There is a potential hazard to downstream areas associated with the overtopping and breaking of the detention basin bunds. Research has shown the design criteria for detention basins do not always achieve their flood mitigation objectives (HR Wallingford, 2001). Those involved in land use planning and development control should be aware of these shortcomings and the impacts they can have on flood risks.

8.4.2.3 Identification and Selection Option to Reduce Flood Risk

Flood risks comprise three components: flood hazards, exposure of economic activities and vulnerability of the society affected by floods. It is crucial to fully explore these components. Based on the objectives of flood management, suitability of various options to meet those objectives should be examined.

Each one of the possible options of reducing flood hazard would have its functional efficiency, economic viability and environmental acceptability. Similarly flood risks could also be reduced by preventing exposure to flooding. Another approach would be increasing resilience of the society to withstand the adverse impacts. The last approach by reducing vulnerability plays key role in dealing with residual risks and the strategy to live with floods.

Table 8.2 below is a list of options for reducing each constituent of flood risks. This is not an exhaustive list but pointers to the possible means.

Table 8.2 List of Option for Reducing Each Constituent of Flood Risk

Reduce hazard	Reduce Exposure	Reduce Vulnerability
<ul style="list-style-type: none"> • Retaining water where it falls (increasing infiltration, rooftop storing) • Retention basins (natural wet lands or depressions, manmade e.g., school play grounds, household underground tanks) • Dams and reservoirs • Diversion channel • Land use management (e.g., house building codes in urban areas, infrastructure building practices, appropriate landscape planning) 	<ul style="list-style-type: none"> • Structural measures on the river (Dykes, river training work such as channelization, flood walls, raised infrastructures such as roads and railways) • Structural and non-structural measures/actions by individual (flood proofing) • Land regulation • Flood emergency measures (flood warning and evacuation) 	<ul style="list-style-type: none"> • Physical: by improving the infrastructure, well-being, occupational opportunities and living environment • Constitutional: by facilitating equal participation opportunities, education and awareness, providing adequate skills and social support system • Motivational: by building awareness and facilitating self organization

8.5 LAND USE PLANNING AND ZONING

Land use management employs two principal options: zoning control and development/building control. Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area (Table 8.3). As an illustration, Figure 8.3 shows the division of flood risk zones for a generic floodplain in United Kingdom.

Table 8.3 Land Use in Flood Risk Area (EXCIMAP, 2007)

		Degree of Risk				
		Little/none	Low to Medium	High		
Land Use	Annual risk			Non-functional : Development	Non-functional : Undeveloped	Functional
	Tidal	< 1 in 1000	1 in 1000 to 1 in 200	> 1 in 200	> 1 in 200	> 1 in 200
	Non-tidal	< 1 in 1000	1 in 1000 to 1 in 100	> 1 in 100	> 1 in 100	> 1 in 100
Open space/recreation		✓	✓	✓	✓	✓
Essential transport and utilities		✓	✓	✓ (1)	(1)	✓ (1)
Residential		✓	✓	✓ (2)	(3)	
Commercial/industrial		✓	✓	✓ (2)	(3)	
Caravan park		✓	✓	✓ (2)		
Public institution		✓	✓			
Hospitals		✓				
Homes for the elderly		✓				
Schools		✓	✓ (4)			
Police		✓				
Telephone exchanges		✓				
Emergency Service		✓				

Notes:

- (1) Should be operational in a flood. Compensation works needed to avoid an increase in flood risk elsewhere.
- (2) Assuming appropriate flood defences are provided.
- (3) Limited developments permitted in certain circumstances.
- (4) But not main school buildings and access routes.

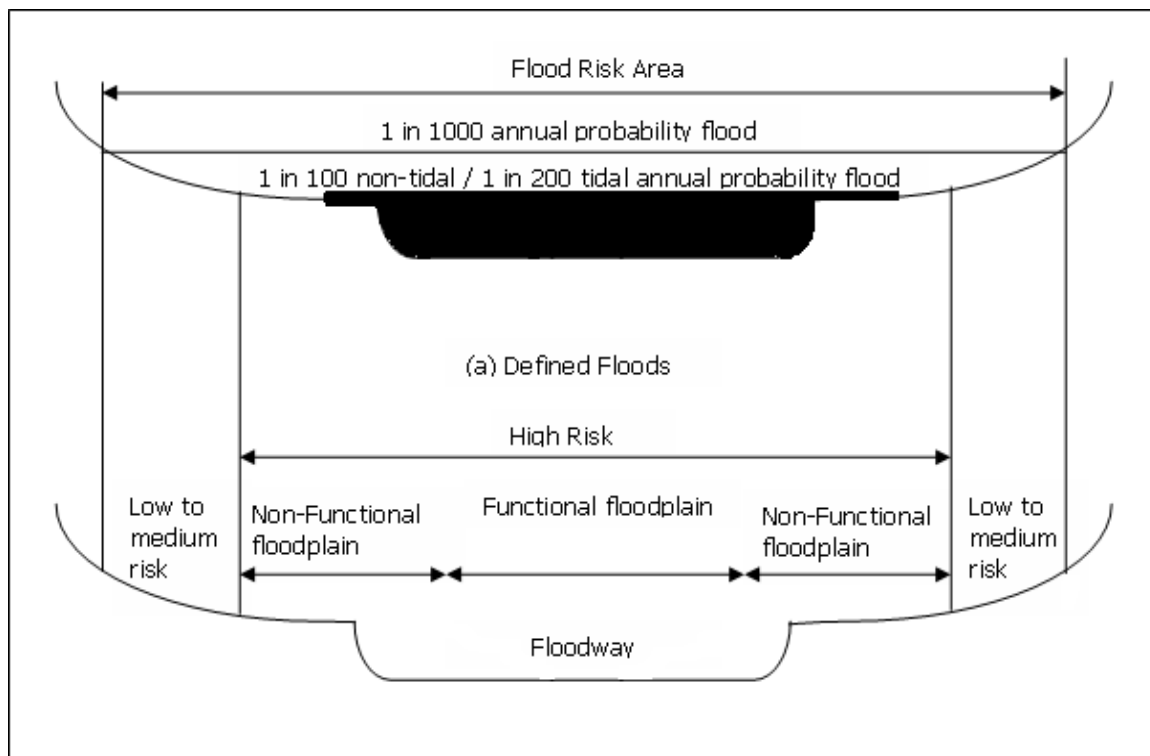


Figure 8.3 Example of Flood zones across floodplain (Ramsbottom, 2003)

8.5.1 Flood Zones

Matching of land use to flood hazard is very important as it can maximize the benefits of using the floodplain and minimize the aftermath when flooding occurs.

Table 8.4 Guidance on Different Land-use in Different

No.	Types of Land-use	Guidance Information
1	Open Space and Recreation	These can be sited in high flood risk zones but utmost care must be taken to avoid obstructions to flood flow. Fences and hedges should be avoided as they can trap debris and create blockages. Recreation associated facilities like sports halls and courts should be allowed to flood to prevent floodplain storage loss. Landscaping associated with open space and recreation (e.g. golf courses) should be carefully designed to avoid worsening of flood conditions. Car parks should be avoided in the functional floodplain because of the risk of damage to vehicles, the risk of people being trapped in vehicles, and the risk of vehicles being swept away, causing damage and blockages elsewhere.
2	Essential Transport and Utilities	These include railway stations, electricity sub-stations, etc and should be sited outside flood risk zones. However, it is inevitable that some development regarding essential transport and utilities (e.g. road crossings over rivers, electricity pylons) will occur in high risk zones. Mitigation works will be needed in those cases to ensure that there is no increase of flood risk anywhere else. Roads should be constructed on viaducts whenever possible. Embanked sections of roads should include compensatory storage to prevent an increase in flood risk.
3	Residential	Residential development should only be permitted in already developed high risk zones that have adequate flood defences or where such defences would be provided. Such residential development must be approved by the DID. Issues to consider for approval flood refuge centre locations, safe evacuation routes availability, cost of clean-up after a flood, adequacy of flood damage limiting measures (e.g. raised floor levels, use of ground floor for non-habitable use, etc), minimization of risk to human safety and property damage (e.g. site planning, street layout, housing density, house designs) and vulnerability of residential occupants (e.g. senior citizens, those with impaired mobility).
4	Commercial and Industrial	Location of commercial buildings like shops and offices should be considered in relation to the potential of damage to goods and property. Commercial and industrial developments that involve the processing or storage of pollutants must be sited at no-flood risk zones to prevent pollution incidents from happening. Examples of potential pollutant handlers are petrochemical plants, garages, waste disposal industries, paint, herbicide and pesticide manufacturers.
5	Public Institutions	These include civic centre, prisons and the like. Public institutions should be sited outside of high flood risk zones. Some of these may even be used as emergency refuge centre so such designated public institutions should be sited in the little or no-flood risk zones.

Table 8.4 Guidance on Different Land-use in Different (continued)

No.	Types of Land-use	Guidance Information
6	Hospitals and Homes for the Elderly	Such organizations must be sited outside of flood risk zones. Existing hospitals and homes for the elderly in flood risk zones should be relocated as soon as possible.
7	Schools	Schools should be placed outside of any flood risk zones. Only parts of the school like fields, courts and car parks can be sited in low to medium flood risk zones. Schools used as emergency refuge centres should be located in a no flood risk zone. Existing schools in any flood risk zones must be evacuation plans in place.
8	Police and Other Emergency Services	The police and other emergency services should be able to function at all times during a flood event so it is essential that these services be located outside of flood risk zones. Facilities needed during flood events include emergency service operating centres, fire stations, accident and medical care centres.
9	Communications Centres and Telephone Exchanges	Communication is vital in a flood emergency. Therefore, it is imperative that all communication-related institutions be sited outside of flood risk zones.

8.5.2 Land-use Planning

Risk-conscious land-use planning and land management is an important contribution to sustainable development (Table 8.5).

Table 8.5 Land-use Planning

Level-/scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
National / regional 1:100,000 - 1:500,000	<ul style="list-style-type: none"> • High-level spatial planning • Allocation of land for development • Suitability of land for different types of development • Planning of national infrastructure 	<ul style="list-style-type: none"> • Decision makers • Land-use and spatial planners • Simplified maps 	<ul style="list-style-type: none"> • Flood extent • Flood risks • sites of environmental vulnerability • Pollution risks • Assets at risk 	<ul style="list-style-type: none"> • Some indicators (to define) allowing to evaluate the hazard (considered useful if available or derivable, although a requirement in some contexts)
Local 1:5,000 - 1:25,000 (cadastre level)	<ul style="list-style-type: none"> • Specific city or village planning • Watershed management • Meeting specific needs of planners as a basis or guidance for decisions 	<ul style="list-style-type: none"> • City, village planners • Rural planners • Local authorities • Simplified maps 	<ul style="list-style-type: none"> • Flood extent and depth (typically for a range of event probabilities) either ignoring flood defences or assume a breach of defences 	<ul style="list-style-type: none"> • Various flood parameters (e.g., depth, velocity, duration, erosion and debris accumulation, protected areas, etc.) and / or Hazard classes (in terms of probability and intensity), particularly where the planning process is linked to this type of information

Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution are attributed to inappropriate urbanisation of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.

On the basis of an objective assessment of hazard, economic, social, and environmental factors, the responsible authority should impose appropriate conditions to ensure future development is compatible with the prevailing flood situation. There are three basic types of floodplain development:

- restricting use of the floodplain and leaving it in its original unoccupied state
- preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose
- preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation

Any floodplain development should be institutionally accompanied by:

- legal measures that enforce zoning, density and pace of development
- taxation measures that may guide development away from hazard areas
- government action that may alter existing land use or require compulsory purchase of the flood-prone land

By using development and land use policies and other non-structural measures, the following flood management solutions can be offered for different situations in the land development process:

(i) For protecting existing development:

- flood control works
- flood warning and evacuation
- flood proofing

(ii) For removal or conversion of existing development:

- public acquisition
- urban redevelopment
- non-conforming uses
- conversion of use or occupancy
- reconstruction of public facilities

(iii) For discouraging development:

- public information
- publication of warning signs
- tax-assessment practices
- financing policies
- public facility extensions
- increased flood insurance costs

(iv) For regulating flood plain use:

- zoning ordinances
- floodplain regulation
- waste disposal regulation
- groundwater quality protection regulation
- subdivision ordinances
- building ordinances
- education of population densities
- prohibit of squatter settlement in flood prone areas
- prohibiting specific functions of land
- relocating elements that block the floodway
- regulating the building material
- providing escape routes to higher places
- state regulated and sponsored insurance policy

Certainly, there are differences between remedial management plans and preventive management plans. Non-structural measures, such as floodplain regulation, subdivision regulation, land acquisition, and other activities to preserve the natural and beneficial functions of the drainage ways, are most appropriate and cost-effective in preventive situations dealing with new developments.

8.6 FLOOD-PROOFING

The danger of flood water is associated with a number of different parameters creating different types of clearly recognizable hazards. These parameters are: depth of water, duration of inundation, velocity of water flow, rate of rise of river level, frequency of occurrence and critical time of rainfall. Flood proofing is not a replacement for land use control. It reduces substantially post-flood clean-up operations.

Flood-proofing is actually a structural measure in flood management but undertaken by individual residents or the community in the flood plain. Flood-proofing means making a building watertight or substantially impermeable to floodwaters (Arizona Department of Water Resources, 2000), usually done for non-residential buildings like commercial structures, garages and warehouses. It can be done in place of elevating a structure as a means of protection from base flood. Design for a flood-proofed building must account for the following factors:

- Flood warning time;
- Uses of the building;
- Mode of entry and exit of the building or site;
- Floodwater velocities;
- Flood depths;
- Debris impact potential;
- Flood frequency; and
- Maintenance.

8.6.1 Flood-Proofing Requirements

The regulations should allow non-residential buildings (commercial structures, garages and warehouses) the option to flood-proof rather than elevate as a means of protection from the base flood. Flood-proofing requirements include:

- a) Non-residential construction, new or substantial improvement, must be flood-proofed at or above the RFE so that the structure is watertight with walls substantially impermeable to the passage of water
- b) The structural components must be capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy
- c) The structure design must be certified by a registered professional engineer that the above requirements are satisfied

For flood insurance purposes, flood-proofing must be in-place and require no human intervention to be effective. There are two types of flood-proofing depending upon the nature of the facility to be protected: *wet flood-proofing*, which allows water to enter the structure with little or no damage and *dry flood-proofing*, which prevents floodwater from entering the facility up to a specified level.

8.6.2 Flood-Proofing Method of Buildings

Flood-proofing of individual buildings is practical for flood-prone areas. An industrial plant may be protected by a ring bund. Buildings can be constructed such that the ground floor is reserved for vehicles that can be moved out, and the high value contents stored on floors above the flood level. Important public utility structures might be designed as watertight enclosures so that their normal function can continue even when surrounded by floodwater. As a guide, the maximum flood protection level is 600 mm (two feet) above the slab (IAFSM, 2006). The walls and slab floor are not built to withstand the type of pressures exerted by deeper water. Often it is better to allow deep water into the house than to risk losing the walls or floor due to hydrostatic pressures. Figure 8.4 shows an example of individual building flood-proofing.

Vulnerability analysis of buildings depends on the type of building (conventional, modern and traditional), and includes evaluation of the resistance to the force of water (hydrostatic load, uplift, hydrodynamic load) and of the changes of material characteristics when immersed in water (quality of mortar, presence of fine sands and expansive clay at foundations).

Public buildings that are used as shelters must have floor space above the expected flood level. This can be done by constructing the building on natural or artificial high grounds, by placing the building on columns and stilts or by providing access from outside via staircase to the upper floors. In areas where floodwaters are shallow and slow moving, temporary barriers composed of sand bags may be used to protect individual buildings. Examples of flood proofing by UNESCO, 1995 are;

- Relocation - moving a building to high ground, above flood level
- Elevation - raising a building so that flood waters will go under it
- Floodwalls – building a wall to keep flood water from reaching a building
- Dry flood proofing – making the walls of the building and the openings watertight
- Wet flood proofing – altering a building to minimize damage when flood waters enter

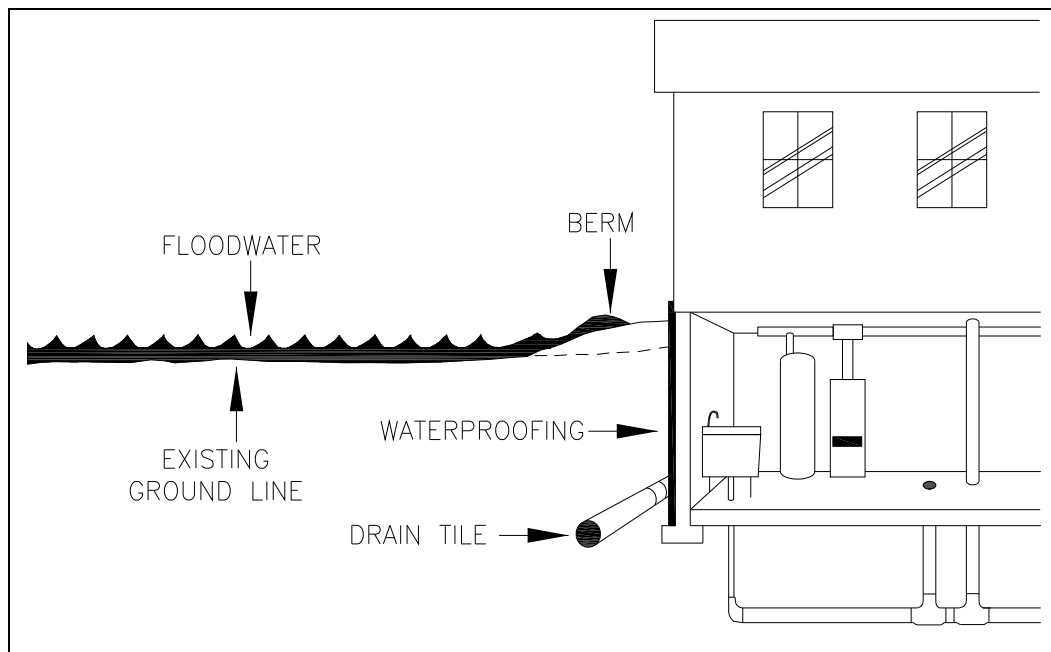


Figure 8.4 Flood-proofing for an Individual Building (The Illinois Association for Floodplain and Stormwater Management, 2006)

8.6.3 Wet Flood-Proofing

Wet flood-proofing may be used where the structure itself would sustain little or no damage from a flood and the uses of the facility can be protected from damage. Wet flood-proofing is to allow the flood water into the building and removing everything that can be damaged by a flood. There are several ways to modify a building so that floodwaters are allowed inside but with minimal damage to the building and its contents. The options of wet-proofing range from a simple arrangement of moving a few valuable items to total building renovation of the flood-affected parts.

Wet flood-proofing allows floodwaters to enter and exit the structure by design and to equalize the water pressure on the inside to the water pressure on the outside. Utilities should be raised to 300 mm (one foot) above the BFE so that after a flood only minimal cleanup and repair is necessary. The flood-proofing must be certified by a registered professional engineer or architect. A simple guide is that it must have a minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding and the bottom of all openings must be no higher than 300 mm (one foot) above grade. Wet flood-proofing is not feasible for single-storey houses because the flooded areas will be in the living areas.

Wet flood-proofing has one advantage over the other approaches and that is no matter how little is done, potential for damage will be reduced.

8.6.4 Dry Flood-Proofing

Dry flood-proofing attempts to prevent flood water into a building. Dry flood-proofing consists of designing the structure to prevent seepage, collapse, cracking of walls, buckling of floors, and back up from sewer lines. Walls and floors must be capable of withstanding hydrostatic pressure and all openings must be located at least one foot above Base Flood Elevation (BFE). The building must have sufficient weight to resist floatation. Dry flood-proofing may involve placing a small bund or berm entirely around a property or constructing a building with impermeable walls to 300 mm (one foot) above BFE. This method of flood-proofing must be certified by a registered professional engineer.

Dry flood-proofing is appropriate for buildings on concrete slab floors without basements and without cracks. To ensure the slab is watertight and sound, an engineering analysis is recommended. These walls are sealed with plastic sheeting covered by brick facing for protection against sunlight and punctures. Dry flood-proofing is not recommended for keeping surface water out of a basement. The water pressure can break the walls and floor. It is very tempting for the owner of a dry flood-proofed building to try to keep the flood out if floodwaters get deeper than 600 – 900 mm (two to three feet). This should be avoided as it can result in collapsed walls, buckled floors, and danger to the occupants.

8.6.5 Flood-Resistant Material

All parts of a building exposed to floodwaters must be constructed of flood-resistant materials. Flood-resistant materials include building products that can withstand direct or 72 hr contact with floodwaters without sustaining damage that requires more than low-cost cosmetic repair. Some common types of flood-resistant materials are listed below:

- Concrete, concrete products, glazed brick
- Clay, ceramic tile
- Galvanized or stainless steel nails, hurricane clips, connectors
- Indoor-outdoor carpeting with synthetic backing
- Vinyl, rubber
- Metal doors and window frames
- Polyester-epoxy paint
- Stone, slate, or cast stone
- Mastic, silicone, polyurethane flooring
- Water resistant glue
- Pressure treated or naturally decay-resistant lumber

8.6.6 Damage without Flood-Proofing

Electrocution is a cause of flood deaths, claiming lives in flooded areas that carry a live current created when electrical components short out. Floods can also damage floors and stairs, creating secondary hazards such as unsafe structures and fires.

Floodwaters carry whatever is on the ground that the upstream runoff picks up including dirt, oil, animal waste, and lawn, farm as well as industrial chemicals. Pastures and areas where cattle and hogs are kept can contribute polluted waters to the receiving streams. Overloaded sewer lines will back up into low lying areas and some homes. Even though diluted by flood waters, raw sewage can be a breeding ground for bacteria, such as E. Coli, and other disease-causing agents. Another type of health problem comes after the water has receded. Stagnant pools become breeding grounds for mosquitoes and wet areas of a building that have not been cleaned breed mould and mildew. A building that is not thoroughly and properly cleaned becomes a health hazard, especially for young children and the elderly.

Due to the relatively low velocities and shallow flood depths in the area, the most common type of building damage inflicted by a flood is caused by soaking. When soaked, many materials change their composition or shape. Soaking can cause extensive damage to household goods. Electrical appliances and gasoline engines will not work safely until they are professionally dried and cleaned. In short, while a building may look sound and unharmed after a flood, the water could have caused extensive damage. To properly clean a flooded building, the walls and floors should be stripped, cleaned, and allowed to dry before being recovered. This is time consuming and expensive. The advice always is that it is better to be prepared and prevent flood damage.

8.6.7 Basement Protection

Basement flooding caused by saturated ground can be avoided by installing a footing drain around the foundation (see Figure 8.5). The drain collects the seepage and directs it to a sump. When the sump fills, water is pumped out, usually onto the ground and away from the building. Depending on local conditions, the drain and pumping system may have to handle large volumes of water. Groundwater can seep into basements around pipes or through cracks in the walls or floor. This may be difficult to determine if the walls are covered with panels or other types of finishing. The best way to deal with a groundwater problem is to waterproof the walls and relieve the water pressure through a footing drain system and sump. Footing drains are typically installed around the perimeter of the house, along the foundation. If this is not possible, drains can be installed on the interior of the basement, along the basement walls, and directed toward the sump pump pit.

Cracks can be repaired and the walls can be waterproofed from inside or outside. Waterproofing on the outside is more effective because groundwater pressure forces the sealant into the foundation. The best technique is to dig a ditch around the basement wall so an epoxy sealant can be applied to the exterior walls. This can be done by the handyman (many home maintenance manuals have instructions for this) or a waterproofing company. Basements and the lower floors of split levels can be protected from surface water by constructing low walls around stairwells or using backfill. Waterproofed walls, sewer backup protection, drain tile and a sump pump are a must. The drains and pumps can keep up with the seepage before it gets through the berm and reaches the house.

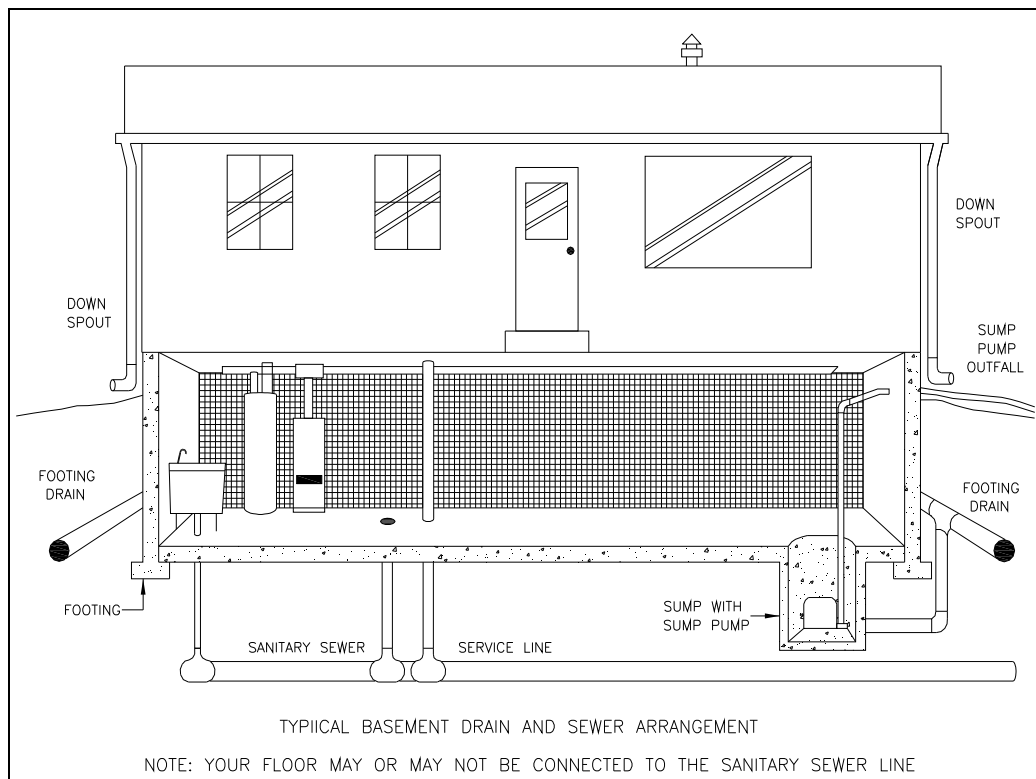


Figure 8.5 Typical Basement Protection (IAFSM, 2006)

8.6.7.1 Basement Car Park Flood-Proofing

The term basement means any area of the building having its floor below ground level on all sides. Walkout basements, daylight basements, or terrace levels are not considered basements in flood management because their floors are at sub-grade on three sides with the downhill side at or above grade. However, they are considered as the lowest floor of a building for floodplain management and insurance rating purposes. If these areas are used only for parking, access, or storage and they meet local authority requirements, they can be regulated as enclosures below an elevated building and not considered to be the lowest floor.

The walls of enclosed areas are subject to flood damage from hydrostatic and hydrodynamic forces. One of the problems often associated with enclosures is that owners can be tempted to convert enclosures below the Regulatory Flood Elevation (RFE) into areas that can sustain damage in a flood. However, the regulations allow certain uses such as building access, vehicle parking, and storage in enclosures below the RFE only if openings are installed to allow the entry and exit of floodwaters. Utilities that serve the building must also be protected from flood damage. Finishing such as carpeting, panelling, insulation (both cellulose and fibreglass), and gypsum wallboard (also known as drywall and sheet rock) must also be used.

a) Design Criteria

Enclosures below the RFE and used solely for parking vehicles, building access, and storage must have openings that allow floodwaters to enter and exit. This prevents solid walls from collapsing by equalizing the hydrostatic flood forces on the walls. In order to ensure the openings are properly installed, the builder is required to have the design certified by a registered professional engineer.

The following criteria must be met:

- i. Bottom of openings no higher than 300 mm (one foot) above the adjacent grade.
- ii. There must be a minimum of two openings on different sides of each enclosed area. If a building has more than one enclosed area, each area must have openings on exterior walls to allow floodwater to directly enter and exit.
- iii. A minimum of two openings must have a total net area of not less than one 6.5 sq. cm. (1 square inch) for every 0.1 sq.m (1 square foot) of enclosed area that is subject to flooding.

8.6.8 Flood Proofing of Infrastructure

Flood damage to infrastructure elements can be caused by direct water forces, by erosion, or by a combination of both.

Road and railways may be damaged easily by water scouring in two ways: the foundation can be washed away and the construction itself compromised. A vulnerable part of railway system is the compacted bed on which the tracks are laid.

Insufficient openings in bridges will lead to higher water levels upstream. The river bed upstream and downstream of the bridge should be consolidated by erosion prevention measures. Most techniques that prevent river bed erosion fix the stream bed by stabilizing the bunds (by means of masonry or vegetation).

The physical damage of water supply systems is concentrated on the intake points and the locations where the main supply crosses riverbed. The quality of potable water in conduits is affected by silting and pollution. The problem of water contamination can be easily solved by constructing the pipes above the flood level. The same principle applies to electrical supplies, sewer pipes and telephone lines. Elevation above flood level secures the continuity of operation of those systems during floods.

The application of elevated walkways greatly improves accessibility between houses and important public buildings, such as flood shelters. For proper functioning, these walkways have to be raised above the average flood level.

8.7 FLOOD FORECASTING AND WARNING SYSTEMS

8.7.1 An Integrated System

Establishing a viable flood forecasting and warning system for a community at risk requires the combination of data, forecast tools, and trained forecasters. A flood-forecast system must provide sufficient lead time for the community to respond. Increasing lead time increases the potential to lower the level of damages and loss of life. Forecasts must be sufficiently accurate to promote confidence so that the community will respond when warned.

Implementation of an end-to-end flood forecast, warning and response system consists of many components that must be linked for successful operation. Interaction of the components of the integrated flood forecast system could be represented as a chain composed of many links. Each link must be present and functional if benefits are to be achieved.

Essential links or components of an integrated flood forecasting, warning and response system consist of a Data Source, Communications, Forecasts, Decision Support, Notification (often referred to as dissemination), Coordination, and Actions (or responses). To achieve this, it is important that all of the components of the system be functional. If any component is dysfunctional, then this weak link could break the chain, resulting in an ineffective warning and response process.

In the overall design of the integrated system, the factors that should be considered include:

- Basin Characteristics
- Flood History
- Environmental Factors
- Economic Factors
- Communities At Risk
- System Identification
- Benefit-Cost Analysis
- Evaluating Existing Capabilities
- Identification of Key Users and Collaborators
- Determination of Specific Forecast System Requirements
- Integration with Other Water Resources Monitoring System

The detail information on flood forecasting and warning system applied in Malaysia by DID is discussed in Volume 4: Hydrology and Water Resources, Chapter 9.

8.7.2 Forecast Models

There are a large number of public domain and proprietary models available for use in flood forecasting. Sometimes the model can be simply a statistical rainfall-runoff relation with a routing equation, while other models can be much more complex. Hydrological models can be classified as lumped, semi-distributed or distributed, or single events or continuous events. Probabilistic models that take data uncertainties into account are also available. Model selection will depend on available data, basin characteristics, and the needs of the local user community.

A lumped model treats the watershed as a single unit for inputting data and calculating runoff. The calculations are statistically related to the underlying hydrological processes as a spatially averaged process. Models based on scaling unit hydrographs fall into this category. Some lumped models allow the watershed to be subdivided or for some parameters to be physically estimated and modelled. When subdivisions of a basin are combined to produce a forecast, this modelling approach is termed semi-distributed. Depending on the forecast needs and characteristics of the watershed, a lumped model may be all that is required.

A distributed model simulates the key hydrological processes that occur in a watershed using distributed data inputs and processes. For forecasting purposes these commonly include precipitation, interception, infiltration, interflow, and baseflow. Overland flow and channel routing may be incorporated into the model or calculated in a hydraulic model. Distributed models require much more data and knowledge of the watershed processes than lumped models. When the model is first established, precipitation and land cover characteristics may be the only distributed features.

Hydraulic models used in channel routing calculate the travel time of flood wave and its attenuation. These models use the standard equations for unsteady, non-uniform flow with various simplifications depending on the channel characteristics, available data and accuracy requirements. Storage-flow relations are often incorporated into the hydrological models. One-dimensional unsteady flow hydraulic models can be used to route flows through multiple channels or in situations where overland flow is a serious concern.

Probabilistic forecasts are typically derived using hydrological process models wherein statistical distributions are used to describe the uncertainty of input data and basin conditions such as precipitation data and soil moisture conditions. A large number of model projections are produced that can be statistically analysed to allow for a better understanding of the uncertainty of the forecasted future water conditions. This approach is rapidly gaining popularity, as it provides the decision-maker with the probability of an extreme event to occur, not just that it might occur.

Simplified probabilistic methodologies that provide a range of possible forecasts have existed for some time. This is achieved by the forecaster making assumptions concerning future precipitation to determine runoff under normal, lower, or upper deciles conditions. More modern approaches, which tend to be in the pilot testing stage, attempt to better quantify the uncertainty associated with the forecasted meteorological conditions and to directly link this uncertainty to the uncertainty of the flood estimate.

8.7.3 Hydrological Forecasting

A hydrological forecast is the estimation of future states of the hydrological phenomena. The necessity for such forecasts increases with a country's expanding economy and utilization of its water resources. However, hydrological forecasts are essential for the mitigation of natural disasters, such as floods or droughts, at all levels of national development.

Hydrological forecasts are valuable for the rational regulation of runoff, the utilization of river energy, inland navigation, irrigation, water supplies, and water quality management. Forecasts are also of great importance in coping with dangerous phenomena in rivers. As a result of advanced flood warnings, steps can be taken to prevent loss of life and damage to property, so that the disruption of activities and the destruction brought by these natural calamities can be kept to a minimum.

- a) Characteristics of Forecasts
- b) Accuracy and Timeless
- c) The Hydrological Forecasting Service
- d) Sophistication of Hydrological Forecasting
- e) Hydrological Forecasting Knowledge

8.7.4 Forecasts

In order to produce a flood forecast for the communities and locations at risk, there must be a hydrological modelling capability that uses the meteorological and hydrological data. Hydrological models use real-time precipitation and streamflow data. The models translate observed conditions into future stream conditions. Hydrological models or procedures vary in complexity, accuracy and ease of use. Simple hydrological models consist of tables, graphs or empirically derived relationships. More sophisticated hydrological modelling systems use in-situ data, remotely sensed data, and multiple hydrological models that are integrated to produce very accurate hydrological forecasts.

Due to advances in the Geographic Information Systems and the availability of geo-referenced data, parameters of some of the hydrological models can now be estimated without having to rely exclusively on historical hydrological data for model calibration. The evolution of personal computer technology has paved the way for quite complex modelling systems to be run on them. These systems are user friendly, easy to maintain, and more affordable.

Current hydrological forecast systems are not only affordable but are also powerful. The degree of success associated with these systems is dependent on the amount of training received by the hydrologists using them. These systems are capable of producing a broad range of forecasts of stream conditions that will occur in a few hours to seasonal probabilistic outlooks targeted for months in advance for the larger river systems. Model system selection depends on the amount of data available, complexity of the hydrological processes to be modelled, accuracy and reliability required, lead-time required, type and frequency of floods that are expected to occur, and user requirements.

Hydraulic models are often used to translate hydrologically model-derived streamflow to water level conditions. Hydraulic models are useful for forecasting the streamflow conditions of large rivers where sufficient lead-time is accorded through translation of the upstream water levels to the downstream communities at risk. Such models can be interfaced with GIS to provide dynamic water level conditions. These types of forecast products can be invaluable to communities and emergency organizations, as they provide very precise information about the areas that are prone to inundation.

a) Flood Forecasting

The need for flood forecasts and warnings is the most common reason for the establishment of a hydrological forecasting service. This is obvious because floods are probably the most dangerous hydrological phenomenon that can cause considerable loss of human lives and property every year throughout the world. The choice of a proper method for flood forecasting depends on:

- The type of flood;
- The degree of development of the forecasting service, i.e., the observation networks and the telecommunications and data-processing facilities;
- The length and quality of data records; and
- The availability of qualified personnel.

A forecast of the following flood parameters is commonly required:

- River stage and flow maximum values and their changes over time (the hydrograph), including the time when the river first reaches the flood level, the time of occurrence of the peak stage/flow and its duration, and when a warning level will be surpassed
- Total volume of the flood wave;
- Velocity of the wave crest propagation along the river channel and impact and coincidence of the tributary inflow;
- Extent of the flooded area and its variation in space and time; and
- Influence of storm surge, floating debris, reservoir or sluice operation of flood wave propagation.

For the most common floods resulting from heavy rainfall, the following forecasting techniques may be applied: correlation, moisture index, crest-stage relationship, estimation of discharge as a function of channel storage, conceptual models, and river routing. Dynamic routing techniques, that provide solutions to the full dynamic equations, will require a high speed computer with considerable memory to produce a timely forecast. Other techniques may require a less powerful computational machine.

b) Flash Floods

In a rapidly responding small catchment (time of concentration less than 6 hours), intense rainfall can create flash floods so rapidly that those affected get caught in great surprise. In the situation, flood forecasting procedures used in large streams cannot be implemented rapidly and effectively enough with sufficient lead time. Moreover, flood is difficult to estimate because of high spatial and temporal variability of the intense rainfall causing flash floods. The use of radar and satellites, coupled with ground surveillance offer the best chance of a sufficiently accurate rainfall forecast of areal basis.

There is no single panacea for forecasting flash floods because the problems are site specific. Flash-flood warnings may be viewed using anyone or the combination of the following approaches:

- Self-help forecast programmes;
- Flash-flood alarm systems; and
- Generalized watches and warnings.

i) Forecast Programmes

Self-help flash-flood warning systems may be operated by the local community to avoid delay in both data collection and forecast dissemination. A local coordinator should be trained to prepare flash-flood warnings with pre-planned procedures prepared by qualified forecast personnel. The procedures are employed when real time data of forecast rainfall indicate a potential for flooding. Multiple-regression equations provide an operationally simple flash flood forecasting technique, although it is suitable for different flood producing conditions of rainfall and soil moisture.

Nowadays, microprocessors may be used for automation of data collection and processing to produce warnings of flash flood efficiently. Automatic rainfall and stage (water level) readings can be sent by telemetry directly to computer that can monitor data collection, compute flood potential or flood forecast, or even raise an alarm. Such facility permits simple conceptual streamflow models to be used instead of manual computation. However, the most critical part of the self-help system is to maintain an active community participation in the planning and educating the public to receive and act immediately when warned.

ii) Alarm Systems

A flash flood alarm system is an automated version of the self-help flood warning system. A stage sensor is installed upstream of a forecast area and is linked by land or radio telemetry to a reception point in the community. This reception has an audible and visual internal alarm which can relay contact to actuate an external alarm when the sensor senses a pre-set critical stage. Although it is possible to get information from installed rain gauges, it is more difficult to determine the critical rainfall than the critical river stage because it is most difficult to translate intense rainfall into critical flash flood levels.

iii) Watches and Warnings

When neither of the first two approaches is feasible (usually where well-defined streams are non-existent), more generalized warnings are given if meteorological conditions conducive to heavy rainfalls are observed or forecasted for an area such that a watch may be issued on radio and/or television. This will alert the residents in the affected area to the potential occurrence of rainfall that could cause flooding. When such a situation is reported, a warning will follow, advising the residents to take necessary precautions against flooding.

iv) Flash Floods and Water Quality

Flash floods in particular can have a strong influence on water quality in a water supply catchment. A flash flood upstream of an intake of a water treatment works can induce high sediment loads and debris to the treatment works, and if forecasted, could readily alert the operators of the works. Alternatively the sediments could also damage the sanitary system due to blocked pipes, back

pressure in sewer, or the groundwater system due to oily or toxic substances present in the sediment loads.

8.7.5 Dissemination of Forecasts and Warnings

Forecast and warning dissemination is extremely important. Frequently, the lack of ability to disseminate warnings to the population at risk is the weakest link in the integrated system. Forecasts and warnings must reach users without delay and with sufficient lead-time to permit response actions to take place. Dissemination of forecasts and warnings can be achieved through a variety of communication methods. An inventory of the various communications media used by the forecast system will reveal the competency of the dissemination process. How are warnings transmitted to the public, to the flood control agencies, to the emergency services and civil protection organizations? Are communication systems reliable? What types of communication modes are used (such as satellite, radio, meteor bursts, telephone or internet)? How are communications lines maintained? Are there backup modes of communication? In what format are warnings transmitted? Do users understand the content of the warnings? These are a few of the questions that need to be answered in assessing the performance of dissemination systems.

The method for distributing information about the state of rivers, lakes, reservoirs, and hydrological analyses, forecasts, and warnings, depends on the requirements of the users, the degree of urgency, the channels of communication, and the facilities that the hydrological forecasting service has at its disposal.

A daily hydrological bulletin, comprising the following, would be useful as a source of general information for the majority of users interested in conditions over large areas:

- A hydro-synoptic chart of the basin showing, in figures, the stages, discharges, and water temperatures for rivers, lakes, and reservoirs, including the actual volume of water stored in the reservoirs. These data would refer to a given time period and would use various symbols for the rise and fall of river stages by designated zones, and other pertinent hydrological characteristics;
- Alternatively, a table containing all the above data related to the observation stations could be used;
- A short survey of the state of water bodies and of tendencies toward changes in their regime in the near future; and
- Medium and long-term hydrological forecasts.

Besides the daily bulletins, it may be useful to issue weekly or monthly bulletins that would contain a short survey of the hydrological regime during the respective periods. It would provide the necessary figures and data, including medium- and long-term forecasts with a lead time of a week, or a month. Part of the information contained in the bulletins may be distributed to the general public by means of radio, television, and the press.

In addition to bulletins, some users will require more specific information and forecasts. The content, format, time of delivery, and channel of communications of specialized information should be agreed upon by the hydrological forecasting service and by interested users. With an increase in the temporal resolution of data, for rivers that crest in less than 24 hours, more frequent forecasts may be warranted.

All of the above methods of information dissemination may be related to normal hydrological conditions based on routine operations. Another group of methods is applied under extreme conditions, e.g., floods, droughts, or other disasters in a state of emergency. In Malaysia, JPS is normally designated to coordinate actions in a state of emergency in term of flood disaster. This organization becomes the most important user of hydrological information during the disaster, and it is especially important that all details concerning the information transmission to this user should be agreed upon in advance.

Generally, information under emergency conditions is transmitted to users more often, e.g., every one to two hours instead of the routine 24-hour transmission. Also, the information is more specific in the disaster-affected area. Flash-flood warnings are an extreme case where the most important requirement is the dissemination directly to users in the shortest possible time. Processed information in the form of bulletins, analyses, forecasts, and warnings is distributed by central and regional hydrological forecasting centres.

8.7.6 Alternatives Method of Flood Forecasting and Warning System

The URBS model is a semi-distributed non-linear model, and is used extensively for flood forecasting. URBS combines the rainfall-runoff and runoff-routing components of the modelling process and allows users to configure the model to match the characteristics of individual catchments. The model is robust, developed for use in a real time environment and has several features which readily lend itself to application as a flood forecasting model. The URBS model will eventually be one of a suite of hydrological and hydraulic models available to forecasters in the RFMMC. The conceptual runoff routing model, URBS is a computer based, hydrologic modelling program that enables the simulation of catchment storage and runoff response by a network of conceptual storages representing the stream network and reservoirs. The URBS model combines two hydrological modelling processes into one model which are rainfall runoff modelling, which converts the gross rainfall into net or excess rainfall and runoff routing modelling, which takes the excess rainfall as input and converts it into flow.

The URBS model has several features that readily lend themselves to application as a flood-forecasting model:

- Enhanced data management. Input data such as rainfall and water level data are separate to the model and are accessed during running;
- Robust performance. The model still runs if key gauging station data is missing;
- Forecast rainfall. Forecast rainfall can be added to the model with a variety of techniques using results from external sources;
- Linked ratings. Known stage-discharge relationships can be incorporated into the model to produce both flow and height results at gauging stations. Dependent ratings, where the upstream water level is dependent on downstream water level can also be used;
- Reservoir behaviour. Runoff can be routed through reservoirs using known storage characteristics and simple operating rules applied;
- Matching. This feature forces the model to fit the observed data at gauging stations thereby improving the forecast accuracy at downstream locations; and
- Adaptability. One of the key features of the model is that it can be readily incorporated into any flood forecasting system.

8.8 FLOOD RESPONSE

The success of co-ordination between the different agencies and authorities in a flood emergency response can mean the difference between life and death for victims of floods.

Emergency response can be considered as a series of sub-plans that address communication and public information management, search and rescue co-ordination, shelter management, stockpiling and distributing of food and supplies, contacting and requesting additional support, debris management, financial management, volunteers co-ordination and donations management.

The foundations of a flood emergency action are a mobilization plan, comprehensive disaster plan and well co-ordinate and trained flood fighting corps. A flood fighting corps may be mobilized to a state of alert with various stages: mobilization, preparation and stand-by and dismissal. It is useful to have powers to call up the inhabitants when high water threatens, with preference given to volunteers.

Organization and training of search and rescue teams are done locally, regionally or nationally but in real flood conditions, participation of volunteers, citizens and relatives is significant, thus requiring the co-ordination to develop as the action proceeds.

The Policy and Mechanism on National Disaster and Relief Management, Directive No. 20 (1997) by the National Security Council outlines the mechanism for managing all disasters including floods. Under this directive all agencies are required to prepare its own Standard Operating Procedures for disaster response particularly within their areas of responsibilities and sector. For floods there is the Standard Operating Procedures for Flood Disaster Operations Volume 1 (SOP) by the National Security Division of the Prime Minister's Department (2001).

8.8.1 Scope

This Directive No. 20 covers all aspects of preparation for and actions during and after a disaster.

8.8.2 Objective

The objective of the SOP is to facilitate flood disaster management as intensive and effective as possible to prevent and reduce loss of lives and assets and reduce post flood repair works. The SOP is also for uniformity of rescue and relief operational procedures amongst the relevant agencies.

8.8.3 Preparedness and Alertness

The expected uniformity of the state of preparedness, alertness and effectiveness for disaster management, A Disaster Management and Relief Committee (DMRC) is established at the Federal, State and District levels. The membership of the DMRC includes all relevant agencies at each of those levels.

8.8.4 Responsibility During Flood Disaster

When a flood disaster occurs, and depending on the scale of the disaster, the relevant DMRC for administering relief works as follows:

- Rescuing and evacuating floods victim;
- Equipping the evacuation centres;
- Supplying food;
- Provide the clean water and infrastructure; and
- Provide the medical and health treatment.

8.8.5 Command and Control

Command and Control of the disaster relief operations is the responsibility of the Disaster Operations Control Centre (DOCC) (*Pusat Kawalan Operasi Bencana* (PKOB)). At the ground level, rescue and relief operations are the responsibility of the On-Scene Control Post (OSCP) (*Pusat Kawalan Tempat Kejadian* (PKTK)). This the Officer-in-Charge of Police District (OCPD) at the District level, the Chief Police Officer at the State level and the Director of Internal Security and Public Order of the Royal Malaysian Police at the Federal Level.

8.8.6 Disaster Operations Control Centre (PKOB)

In a disaster situation, the DOCC will hold coordination meetings, makes decisions and issues directives based on reports received from the ground. It monitors and supervises all the relief works and reports to higher authorities. Initiating the DOCC at the different levels is dependent on the scale of the disaster. At the on-set of a disaster (Phase I), the District Level DOCC will be operationalise first. If the scale of the disaster is beyond the District level capacity to manage or involves other Districts in the State (Phase II), the State DOCC will get into the action. Similarly, if the scale of the disaster requires Federal intervention or involves other States as well (Phase III), the Federal DOCC will be activated.

8.8.7 On-Scene Control Post (OSCP) (Pusat Kawalan Tempat Kejadian (PKTK)) and Forward Base (Pangkalan Hadapan)

Command and control at the flood location is under the authority of the respective OSCP. It is the centre to ensure a unified and coordinated action taken by various agencies involved in search and rescue works as well as aiding the floods victims. In situations involving large flood coverage areas, the Commander may establish forward bases to be better positioned for rescue and relief works.

8.8.8 Types of Escalation

Forecasts of inclement weather provided by the Malaysian Meteorological Services and flood warnings from the DID are transmitted to the Security Divisions of the District, State and Federal authority. This is categorised into three hazard escalation levels:

- a) Caution Situation (Green): The situation when the weather changes from normal to heavy rains that and can cause river water level to rise. At this stage, the operational division will be prompted to be ready for eventualities without interrupting the normal activities of the community.
- b) Warning Situation (Amber): This is the situation when continuous rain occurs and water levels continue to rise in the main rivers. The level of preparedness should be at its highest and ready to operate within short notice period.
- c) Danger Situation (Red): This is the danger situation when the floods start to occur and the operational division fully mobilised.

8.8.9 Flood Evacuation Plan in Malaysia

The DID has established standard procedures for monitoring flood levels in rivers. For instance, for Sg. Kuantan two (2) locations have been selected upstream of the Kuantan Town: Bukit Kenau and Pasir Kemudi. Any rise in the water level at these stations will give sufficient time for warnings or evacuation if necessary, before the floodwaters reach Kuantan.

In an impending flood situation, the DID will first trigger operation at the DID Flood Operation Room upon receipt of warnings of heavy continuous rain and rising of water levels in the rivers. The Department will then communicate with the State Flood Operation Centre, informing them of the approaching floodwaters. The various departments or agencies are then prompted to mobilize. The evacuation centres, facilities and related services will then be coordinated (see APPENDIX 8.B).

8.8.10 Emergency Facilities

Pre-determined buildings (usually schools and community halls) should be used as emergency refuge centres that can be immediately utilized to shelter displaced residents. More shelters should be erected if need be, with temporary health care established.

8.8.11 Financial Assistance

A special loan facility should be set up by the government for self-help and self-organized reconstruction and repair of damaged houses or buildings. The victims should receive the loans meant for them. Relief donation programme can also be initiated nationally or internationally to secure more funds to assist in the recovery process (Asian Development Bank, 2007).

8.8.12 Infrastructure Rehabilitation

The government should initiate flood damage assessment, restoration and repair or reconstruction of various infrastructure, electricity supply, water supply and telecommunications as soon as the water has receded. Some structures or buildings are better left unrepaired if flood recurrence is highly possible (UN, 2001). Cleaning up of debris and sediment from the surrounding should also be undertaken.

8.8.13 House re-construction

There may be cases of very poor citizens whose homes are destroyed by the flood but would not be adequately supported by government loans. Under the circumstances, help could be in the form of construction of a new house, or supply of construction materials, or even technical assistance.

8.8.14 River Rehabilitation

Once other aspects of the recovery process have commenced, river rehabilitation should be next on the agenda. Steps should be taken to re-establish destroyed hydrometric stations and installation of other equipment necessary for monitoring and flood detection. Debris and rocks blocking the channels should be cleared and damaged bridges and culverts rebuilt.

8.8.15 Public Information

The public should be made aware by relevant authorities by all possible means and the media in particular can play their role in the post-flood recovery process. Flood issues could cover the information as follows:

- General post-flood safety information (such as turning off the electricity)
- Health and mental health precautions
- Clean up and repair advice
- How to dispose of garbage and debris
- Application for a permit to reconstruct
- Property protection measures
- Procedure to apply for an insurance claim
- Dealing with repair contractors
- Sources of assistance and how to apply
- What the government is doing to reduce flood damage in the future

8.9 FLOOD DAMAGE ASSESSMENT

Flood damage assessment is needed right after a flood event has occurred in order to compile damage data and situation reports to be sent to the federal government for aid reasons. Initial Damage Assessment and Preliminary Damage Assessment can enable success of comprehensive long-term community recovery and mitigation (Mills, 2007).

Since flood damage assessment needs to be quick, the Initial Damage Assessments can be fast-tracked to the appropriate authority through vulnerability analysis. Risk maps help in highlighting vulnerable areas and so the likely impacts can be evaluated beforehand to facilitate information flow. Five common activities have been identified that will establish and maintain a 'best practice' approach (DID, 2003). The activities are listed as follows:

- Flood damage assessment teams enter the affected area very shortly after a flood has occurred - While there must be some sensitivity to those affected by the flood, the data to be collected is best collected while flood marks are fresh, damaged possessions and property are clearly visible.
- Flood damage assessment teams should consist of professionals with broad knowledge of flood behaviour and able to value the damaged possessions.
- The flood damage assessment must cover all possible sources of damage - Direct damages will include residential, commercial, industrial properties together with infrastructure and motor vehicles. Indirect damages especially clean-up costs, travel disruptions and loss of income/wages must also be included in the data collection.
- The assessment teams must be able to access information regarding any insurance information, 'community service' or charitable payments.
- All data collected must be documented in a consistent form to a National Standard - This standardization is essential to the development of 'Stage-Damage Curves', essential in the Potential Damages assessment process described below. It should be noted that this standardization is not always complied with, leading to some disparity in the quality of flood damages estimation. Once the data is collected, a total actual damage for the particular flood can be calculated. The data should then be analyzed to provide a stage/damage relationship-flood depth above floor or above ground equating to a specific damage value. This stage/damage relationship is very site specific and can only be applied to the location where the flood occurred. If the relationship is applied to another location or stage/damage relationships are imported from another country, the resulting damages estimates will be of limited value without additional work adjusting the valuations used in the initial damages calculations.

In general, the following procedure needs to be satisfied for assessing potential damages, whereas actual damages are estimated on the basis of a field survey:

- Identification of potential damage areas, according to the physical characteristics of the area such as land use, topography, drainage area, outfall system and the capacity of the existing stormwater drainage system. Maps are usually prepared to visualize the results of the identification process.
- Selection of damage categories, which are considered appropriate for each damage area under investigation. Those are: public and private clean-up, structural and vehicular damage, damage of contents, traffic related losses and tax revenue losses.
- Developing unit cost relationships for various damage categories evaluation of the hydraulic conditions such as the volume of pounding areas, street conveyance capacities, storm sewer capacities and inlet capacities.
- Determination of the extent of flooding expected for several storms of different frequencies of occurrence.

- Estimating damages for the “do-nothing” alternative for different storm frequencies.
- Plotting corresponding damages versus probability, in or to measure the area under the curve which represents the average annual damage (base-line damage).
- Estimating residual damages in a similar manner, for various alternative plans under study.
- Calculating annual benefit as the difference between the estimated annual damage before and after the capital improvement.

8.9.1 Flood Damages

There are tangible and intangible costs of flooding. Tangible costs can be quantified in monetary terms, e.g. damage to goods and possessions, loss of income or services during the flood aftermath, etc. Intangible damages represent the increased levels of physical, emotional and psychological illness in flood affected people attributed to a flooding episode and are less easy to quantify in monetary terms.

8.9.2 Tangible and Intangible Damages

The most basic division of flood damages is into tangible and intangible damage categories. Tangible damages are readily measured in monetary terms. Tangible damages include, among others, the damage or costs caused by floodwaters wetting goods and possessions and damage to roads and other infrastructure, the loss of commercial income, the loss of production in industrial concerns (direct tangible damages) and the loss of wages and extra outlays incurred during clean-up operations and in the post-flood recovery period (indirect tangible damages).

Intangible damages include damage to the environment and the increased levels of emotional stress and mental and physical illness caused by a flood, such as large financial outlays to replace flood damaged possessions or possibly having to find new means of earning a living. It is difficult to

quantify intangible damages in financial terms, however intangible damages are real and represent a significant cost to flood affected persons and the community. It is possible to dimension the problem, approximately, by estimating how many flood-affected people may require additional medical treatment for depression or the ecological cost of the loss of a local environmental feature.

The emotional costs on flood victims can be quite severe and the strain may linger for several years after the event. Flood-aware communities can be expected to suffer less social and financial disruption than communities with a low level of flood awareness. This is, however, not always the case. An extreme or sudden flood event can have deleterious effects on even the most aware of communities.

8.9.3 Direct Damages

Direct tangible damages are caused by floodwaters wetting goods and possessions, thereby either damaging them irreparably or reducing their value. Some items might be capable of repair; other items will be damaged beyond repair. In the first case, the direct damage is equal to the cost of repairs plus the loss in value of the repaired item. In the second case, the direct damage is equal to the pre-flood value of the item or its replacement cost. It may be that direct damages are not immediately apparent, as what may be thought to be repairable may have to be scrapped eventually, due to long-term damage.

The direct damage to a property (residential, commercial or industrial, urban or rural) is commonly divided into the categories of Contents, Structural and External damage. Contents damages generally refers to the impacts on items such as floor coverings, bedding, furniture, commercial stock, industrial output, equipment and machinery. Structural damage refers to damage to the structural fabric of buildings and includes damage to roads and infrastructure. External damage refers to all items external to buildings, including damage to parked motor vehicles.

Direct damages also include the loss of crops, the loss of value to damaged crops, infrastructure damage (roads, irrigation systems) and damage to machinery and equipment.

8.9.4 Indirect Damages

Indirect damages are the additional financial losses caused by the flood. These can include:

- The extra cost of food and accommodation for evacuees;
- Any loss of wages by employees;
- Any loss of investment in the affected areas where flood exposure may limit development or economic advancement;
- The loss of actual and/or prospective production or sales by flood-affected agricultural, commercial and industrial establishments; and
- Opportunity losses caused by the closure or limited operation of commercial, industrial or public facilities. These must be offset by increased economic activity in other localities.

This is not an exhaustive list of indirect damages - the full extent of these will only become apparent during the damage data collection exercise.

Indirect damage can be divided into general categories such as clean-up costs, financial costs and opportunity costs. Clean-up costs may also be considered a direct flood damage, particularly when those involved are employed by relevant authorities and that workforce would normally be employed in other activities. Financial costs usually refer to loss of wages, loss of production and loss of income inflicted on flood victims and businesses. Opportunity costs refer to the absence or reduced levels of service provided by public authorities and commercial/industrial facilities. Opportunity costs are imposed on the community, including those with properties outside the floodplain.

8.9.5 Actual and Potential Damages

Flood damages can be divided into actual and potential damages. Actual damages are the damages caused by an actual flood and are calculated directly through valuations of property lost, the cost required to repair a property and the costs met in satisfying the indirect costs associated with a flood.

Potential damages are the maximum damages that could eventuate should a flood occur. In assessing potential damages, it is initially assumed that no actions are taken by the flood-affected population before or during the flood to reduce damage, such as lifting or shifting items to flood free locations, and moving motor vehicles.

8.9.6 Damage Reduction Factors

Damage Reduction Factors are used to convert potential damage estimates to likely actual damage estimates. Damage Reduction Factors are based on, amongst other factors, the length of the flood warning period and the flood awareness of the affected population. The longer the warning period, the greater the time available for evacuating goods and possessions; the more flood aware the population, the more effective these measures will be.

Stage-damage curves reflect average damages, however even for properties of the same type, there is typically a widespread variation in damage from property to property. Thus, when using stage-damage curves to assess damage in an un-surveyed property, the estimate is necessarily approximate. Further inaccuracies creep into damage estimates from uncertainties in flood, ground and floor levels. If the estimation procedures are soundly based, there should be no gross bias in the total damage estimate.

8.9.7 Average Annual Damage (AAD)

To compare the benefit and effectiveness of proposed mitigation measures, it is necessary to first estimate the flood damage that would be caused by different sizes of floods that might occur now, and second, estimate the reduced flood damage that would be caused by those floods after specific mitigation measures were implemented. For comprehensive cost/benefit analysis, this requires the estimation of the Average Annual Damage for the area concerned.

Over a long period, a flood prone community will be subject to a succession of floods. Table 8.6 below indicates the probability of experiencing a flood of a certain magnitude over an expected lifetime of 70 years.

AAD is a convenient yardstick to compare the economic benefits of various proposed mitigation measures. AAD is equal to the total damage caused by all floods over a long period divided by the number of years in that period. (It is assumed that the development situation does not change over the period of analysis).

Table 8.6 Probability of Experiencing a Given Size Flood One or More Times in 70 Years

Likelihood of Occurrence in any Year (AEP)	Percentage Probability of Experiencing	
	At least Once	At Least Twice
10% (1 chance in 10)	99.9%	99.3%
5% (1 chance in 20)	97.2%	86.4%
2% (1 chance in 50)	75.7%	40.8%
1% (1 chance in 100)	50.5%	15.6%
0.5% (1 chance in 200)	29.6%	4.9%

Note: AEP: Annual Exceedence Probability

8.9.7.1 The Estimation of Average Annual Damage

The actual sequence of floods that will occur at a particular flood prone location is not generally a known factor. However, it is known that, on average, the 20 year Average Recurrence Interval (ARI) or Return Period event will occur once every twenty years, the 50 year ARI event will occur *on average* once every 50 years, etc. Further, by examining a range of floods, it is possible to estimate the potential and actual damages caused by floods of different severities (see APPENDIX 8.E).

8.9.8 Guideline and Procedures

8.9.8.1 Data and Information Needs

The data and information needs for the range of flood damage estimations, as well as the basic differences between the methods, are described list below.

The main data and information needs are:

- Property data, including type of property and number of properties;
- Flood maps for either the particular event or for floods of various return periods; and
- Flood data, including depth, velocity and times of inundation.

This data is essential for all damages studies and must be collected as soon as physically possible after a flood. Experience across many nations has shown that quick data collection is essential as:

- Data may be lost if people move away from affected areas;
- Flood marks may be lost with time so accurate estimates of depth are lost;
- Residents may be confused regarding which particular flood is being investigated, particularly if there have been a number of recent events; and
- There can be variations from flood to flood that must be identified and recorded for future, more detailed investigations.

8.9.8.2 Determination of Actual Damages

There are two basic steps associated with an actual flood damage survey. The first step involves identifying every property that was inundated by floodwaters and recording the depth of inundation or the level to which floodwaters rose. The second step involves recording in detail, the extent of damage, to buildings and properties.

In the second step, the more detailed data collection is conducted a few weeks after the first data collection. Preliminary analysis of the initial data may be useful before the second survey, allowing the targeting of particular data in the second step.

Actual damage surveys are made difficult by the fact that, at the time of the survey, many flood-affected occupants are still dazed by the flood episode and confused as to the contents of dwellings and work areas. Further, many items may have already been discarded during the clean-up process. These items have to be identified and their value established, sight-unseen. In these circumstances, the survey form needs to contain a detailed list of items likely to occur in each area. The person conducting the survey then leads the occupant through this list to ascertain the pre-flood contents of the area and an indication of their value.

Basic flood damage data to be collected from urban areas relates to the number and type of flooded properties and depths of flooding within buildings and across grounds. Each property that is covered, either fully or partially, by floodwaters needs to be included in the survey, irrespective of whether or not buildings are flooded above floor level.

8.9.8.3 Determination of Potential Damages

Studies to determine potential flood damage are necessary for areas that have no recent records of damage in an actual flood or where major flooding has not occurred for a significant period. These estimates also cover floods greater than may have previously occurred. In a potential damage survey, a sample of representative properties is first identified and then damages to these properties are determined, either by questionnaire or through personal inspection.

In a potential damage survey, the value estimates damage on an item-by-item basis for each room of selected types of buildings. This is typically done for three or four possible flood depths (typically about 5 cm, 0.5 m, 1.0 m and 2.0 m above floor level). The damage estimates are made on the basis that no furniture and/or fittings are shifted should a flood occur. Detailed survey forms are required to record this data.

Actual and potential flood damage data can be presented as stage-damage curves for different property types. Such curves relate contents damage to depth of flooding above floor level. These curves are generally derived from numerous damage studies on similar areas throughout the region or nation. Stage-damage curves can be derived for residential, commercial, rural and public properties. However industrial properties have many inherent differences that may make stage-damage curves non-viable.

To determine the flood damage over a specific area, it is necessary to know the number of flooded properties, the type of flooded properties and the depth of flooding above floor level. The number of flooded properties can be determined from flood studies, flood maps, aerial photographs or from a street-by-street inspection. It is generally very difficult to discriminate property types or floor levels from aerial photographs. Knowledge of flood levels and floor levels throughout the flooded area will enable flood depths over the floor to be calculated for each building.

Floor level data may be estimated from building plans (if available), by measuring floor height above ground level or by estimation based on contour maps. The appropriate stage-damage curve allows the damage to be estimated for each property. A computer model or a spreadsheet is typically used to combine all these data and estimate the flood damage for different flood levels up to and including the PMF.

For example in the Klang Basin which this is Malaysia's principle conurbation, with the cities of Kuala Lumpur, Shah Alam and others on the floodplain of the Klang River and its tributaries. There are thousands of potentially affected properties - agricultural, industrial, commercial and residential, let alone the public infrastructure and public services - on the flood prone areas. The flood hazard varies throughout the Basin, with community awareness being generally low. Flooding causes considerable disruption to community activities, resulting in high levels of political interest and involvement. Any flooding incident gives rise to political pressure to "do something" to stop the flooding however all mitigation works in such a built up area will be very costly and difficult to implement. In this case, a Rapid Assessment Method will only provide an approximation of the damages and benefits; the Detailed Assessment Method must be adopted for a case such as this.

8.10 POST-FLOOD RECOVERY

Post-flood recovery aims to provide assistance to those affected by floods. The actions taken must ensure that those who remain seriously affected by the floods, particularly in terms of housing and services, receive prompt assistance. Several ways are recommended and the suitability of the combination is up to the authority in charge to manage.

Flood recovery refers to clean-up, welfare, restoration of services and other forms of assistance provided by local authorities and voluntary organizations after a flood. Recovery functions may be divided into those which deal with human welfare and those relating to infrastructure and facilities. The local Flood Emergency Plan should contain details of initial cleanup and recovery operations.

Flood recovery includes:

a) Short term

- Rest and information centres.
- Support to the vulnerable.
- Provision of cleaning materials and dustcarts.
- Provision of waste disposal sites.
- Advice on insurance and money matters
- Cleaning and re-opening roads.
- Building safety and environmental health checks.
- Provision of information to affected residents.

b) Medium term

- Establish recovery strategy.
- Drying out and repairs to properties.
- Recovery of businesses.
- Temporary housing.
- Road repairs.
- Provision of information to affected residents.
- Fund raising to support flood victims.

c) Long term

- It may take over a year for residents and businesses to return to flood affected properties.
- Provision of information to affected residents.
- Lessons learnt and preparation for future floods.
- Re-evaluate defences. This might lead to improving the defences or, where improvement is not a practical option, considering alternative measures such as improved flood warning,
- Review planning status. It may be advisable, for example, not to permit any further development in the flood risk area.

8.10.1 Post Flood Analysis

Post flood analysis will cover aim, background, rainfall distribution, duration, water level (stage), flood prone area, flood victims, death and properties losses and conclusion. Data and information needed for the analysis are as follows:

- rainfall from each station (represented in date, month and year)
- rainfall recurrence interval period
- highest yearly water level
- rainfall and water rise hydrographs
- mean monthly rainfall
- rainfall isohyets in each state (daily, monthly and yearly)
- photographs of flooding

See APPENDIX 8.F for an example of Post Flood Analysis.

8.11 FLOOD INSURANCE

Flood insurance is a special type of insurance coverage for homes and businesses that will cover the property in the event of a flood. Flood insurance can be costly depending on where the property is located. Unlike a standard homeowner's policy, flood insurance covers losses to the property caused by flooding. Flood insurance enables the property owners, subject to potential flooding, to spread an uncertain but large loss over a long period of time. It also provides mechanisms of spreading flood loss over a large area and a large number of individuals. A standard flood policy may provide coverage for the following:

- structural damage
- furnace, water heater and air conditioner
- flood debris clean up
- floor surfaces such as carpeting and tile

Flood insurance is a complementary tool of hazard reduction. The purpose of flood insurance is to provide compensation for losses caused by flood when damages are not avoidable at acceptable cost. In most countries coverage is fragmented and property owners have to purchase different policies in order to insure against all major disasters. Some of the countries that practise flood insurance schemes are Belgium (Flanders), United Kingdom, Ireland, South Florida, and United State

of America.

It is expected the central government should provide financial and political support. Some of the DID roles in these flood insurance policies are to provide the flood hazard manual and risk and damage assessment. (See Appendix 8.G for example for house owner/householder policy of Food Insurance Policy in Malaysia-Malaysia Assurance Alliance Berhad, MAA).

Federally subsidized flood insurance programs may be available for property located in flood-prone areas. Property located in designated flood hazard areas should not qualify for federally insured financing or federal grants unless flood insurance is obtained. Such a program is the most effective tool in discouraging unwise urban development. The program is based on field and office work that should produce the flood hazard boundary maps and the insurance premium rate maps.

Flood Insurance Study (FIS) should be conducted to compile and present of flood risk data for specific watercourses, lakes and coastal flood hazard areas within a community. The report should include:

- an appraisal of the district's flood problems (purpose of the study, historic floods, area and rivers studied, engineering method employed, etc)
- a vicinity map of communities
- photographs of historic floods if available
- tables summarizing various study data
- computed flood profiles for various return periods

After the FIS report, Flood Insurance Rate Maps (FIRM) should be created based on the information in the FIS report. FIRM for each district usually contain physical features such as major highways, secondary roads, lakes, railroads, streams and other water bodies, spatial distribution of flood hazard areas, base flood elevations, and areas subject to inundation by floods of 100-year return period and above. FIRMs may also contain regulatory floodway areas and velocities. FIRMs are to be made publicly available so that anyone beside insurance agents and brokers who wants to understand the local flood hazards can obtain them.

8.12 Public Education and Awareness Campaigns

The public needs to be made aware of the fact that all codes of practices including those relevant to floods give a minimum standard to be complied with and that contractor or developers usually work to the absolute minimum they can in order to win contracts and save on costs. The public must be made aware of the nature of the minimum standard and the level of protection afforded by it. Once they understand the risks and costs involved, only then will they have the initiative to investigate other options.

One way of educating the public is not to call bunds system a flood protection device, while the term 'flood damage reduction' can be used instead, which implies flooding may still occur (Goodwin, 2007).

The solution to this is that a comprehensive flood hazard map should be made available publicly with the limitations and meanings of different zones clearly stated. Residual risk areas created by bunds systems must be easily identifiable.

8.12.1 Public Participation

Public and community participation are two important elements of an effective social mobilization and public awareness program. This program should be community-specific, based on assessment of information needed, integrated with existing disaster warning and response systems, focused towards information on prevention, mitigation and long-term recovery, established as on-going process, and addressed towards the most vulnerable people.

Co-ordination between the community agencies, representing its citizens and the municipal authorities is essential. Specific tasks are vested with the community, while others belong to the authorities. The capacity of the community determines how much should be executed by outsiders. Once coordination is established, all those concerned need to develop knowledge and skills that can reduce the possibility of damage and death during floods. The practice of learning while doing is accepted in community participation, but formal training programs are preferable.

The following participants may be expected to take part:

(i) At community level

- Local leaders
- Voluntary fire brigade
- Red Crescent and similar societies
- Various community groups (youth organizations, environmental groups, etc.)
- Religious organizations
- Local builders and craftsmen
- Housing cooperatives
- Volunteers

(ii) In local government

- town or district planners
- architects and engineers
- building inspectors
- contractors
- public health officers
- medical staff
- public utility staff
- social workers
- media
- police
- army

(iii) At national level

- politicians and lawmakers
- civil servants
- mapping agencies
- development planners
- university faculty
- research institutes
- professional organizations
- trade unions
- non-governmental organizations
- media
- banks

- insurance companies
- hydro-meteorological services

(iv) At international level

- international banks
- relief agencies
- investors
- multinational corporations
- charity organizations

(v) Community participation should be ensured in several domains such as:

- establishing own goals and priorities
- clarifying the problems
- public debating on proposed solutions
- monitoring the process of master planning on the basis of two-way communication
- physical survey of the area and its structures
- surveillance (including data acquisition)
- socio-economic survey, followed by mapping the socio-economic conditions of the community
- administrative and managerial skills of the community leadership
- providing contributions in kind such as labour, building material and transport
- identification of local community requirements and resource mobilization based of self-assessment of each community. Those are items such as sand, bags, labour, pumps, boats, generators, funding contributions etc.

The objective is to create a partnership between the government and the people so that disaster preparedness is recognized as a joint responsibility

8.12.2 Public Information and Education

Every community in a flood-prone environment should be “flood-adapted”, based on acceptance of the fact that living in a floodplain must inevitably bring the consequences of sporadic flooding.

One of the most useful activities of is an active participation of general public, officials and planners in information campaign, tailored to the needs of the community. A variety of media can be used, such as local radio and TV stations, Internet, newspapers, pamphlets and posters, schools and exhibitions. In developing countries, use of warning boards and different illustration, placed or distributed at local community centres or main road intersection, may prove to be the most efficient communication medium.

The messages are more easily believed when they are repeated on regular basis and transferred to community members through channels they trust. It has been recognized that by disseminating the risk information, confidence and a sense of security among the people is established. Non-governmental organizations (NGO), voluntary or socio-cultural organizations, may also play an important role in this aspect.

The following question messages should be included:

- what is hazard?
- how will the hazard affect the community?
- what are the vulnerabilities of the settlement?
- how can the vulnerabilities be reduced?
- what damages can be expected?
- what actions are to be taken immediately after disaster?
- how to act in response to flood warning?

- how can the residents protect themselves in a disaster?
- how to get safe drinking water if supplies are interrupted?
- how to access help?
- where are buildings in less vulnerable locations?
- where are alternative food supplies?

Dissemination of public information on a regular basis is very important. General public should also be knowledgeable on how taxes and other local revenues are allocated and used to provide solutions to problems associated with flooding.

8.12.3 DID Website Information

Another way of communicating with the public is by using contemporary electronic means such as electronic bulletin board, mail box and web site with a page on frequently asked questions (FAQs). Users of open electronic communication means should agree to abide by the rules of electronic communication means, meaning not to use profanity, not to advertise or promote any product or services, and not to change the purpose of discussion.

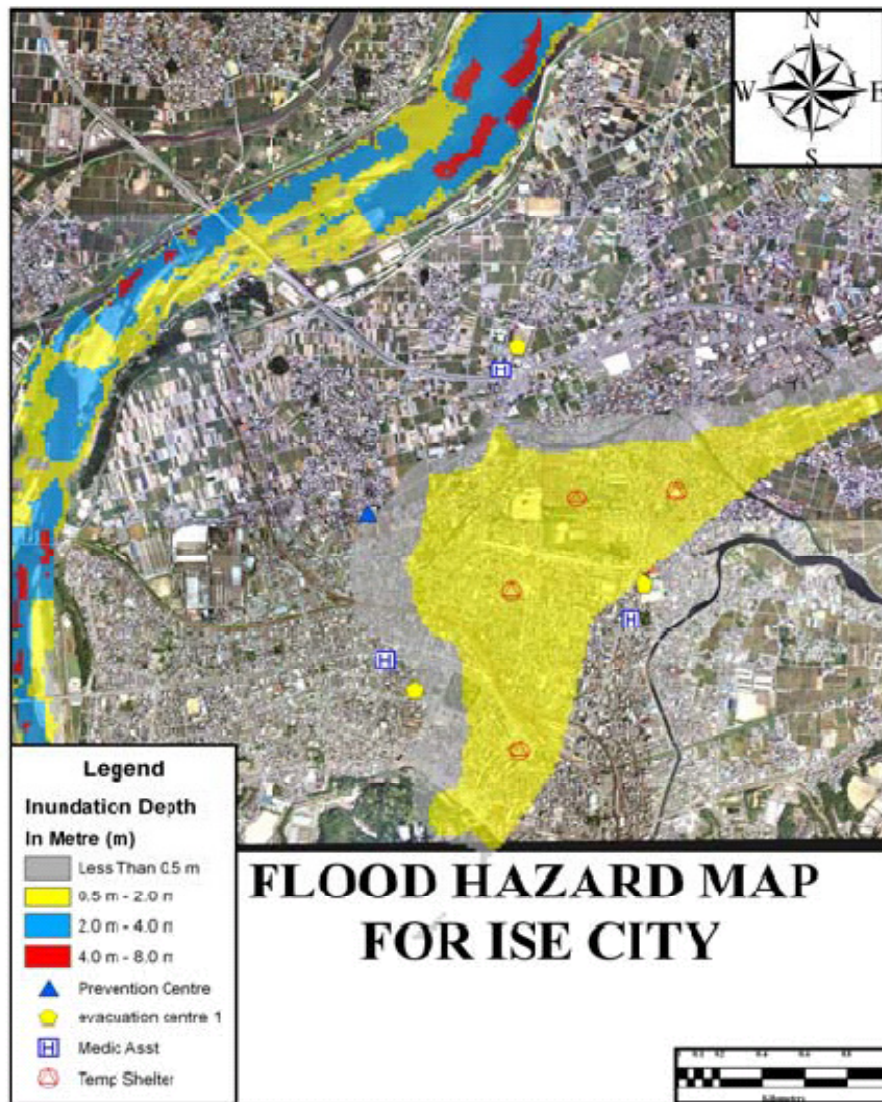
The official website for Department of Irrigation and Drainage (DID) under the Ministry of Natural Resources and Environment is <http://www.water.gov.my> while the Flood Mitigation Division of DID is responsible for formulating flood mitigation programmed throughout the country.

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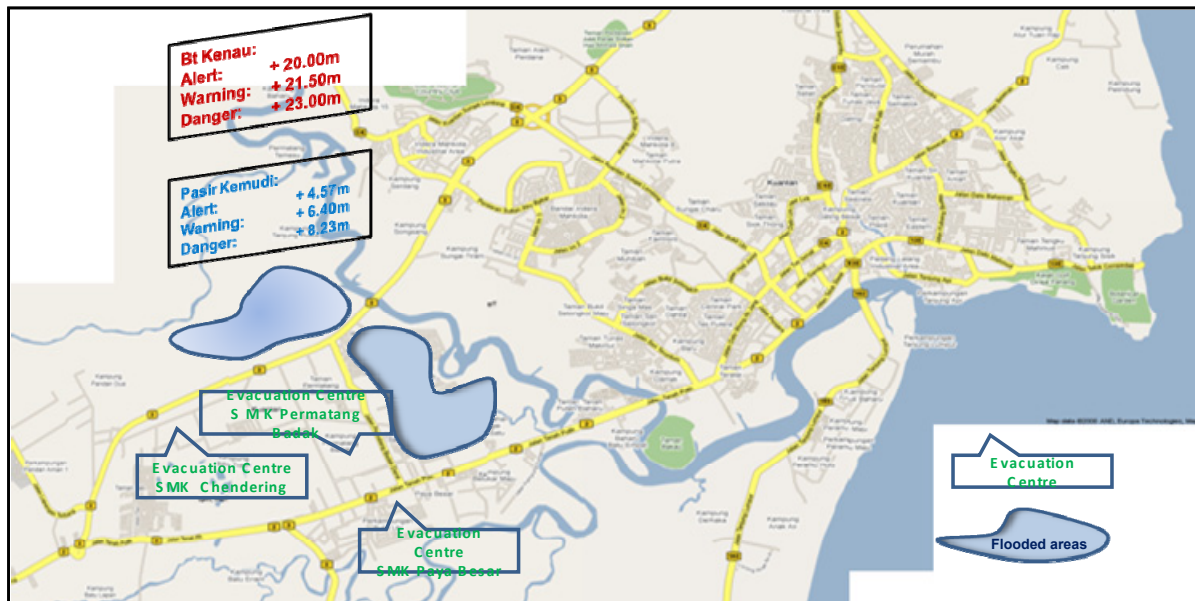
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APPENDIX 8.A EXAMPLE OF A FLOOD HAZARD MAP



Flood Hazard Map for ISE City

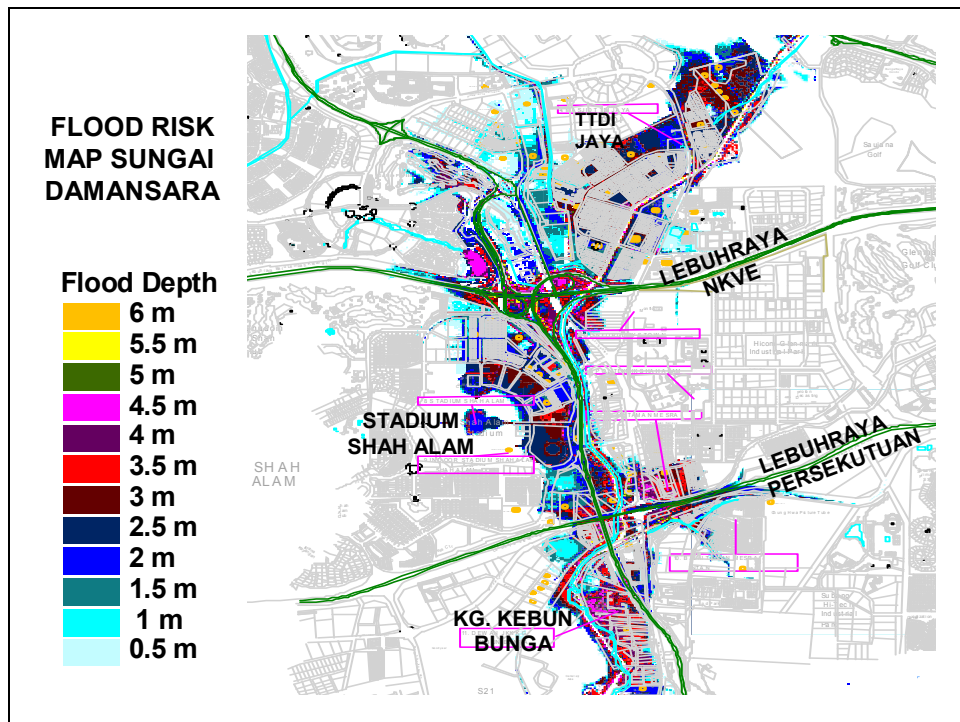
APPENDIX 8.B EXAMPLE OF A FLOOD HAZARD MAP SHOWING LOCATIONS OF RELIEFCENTRES



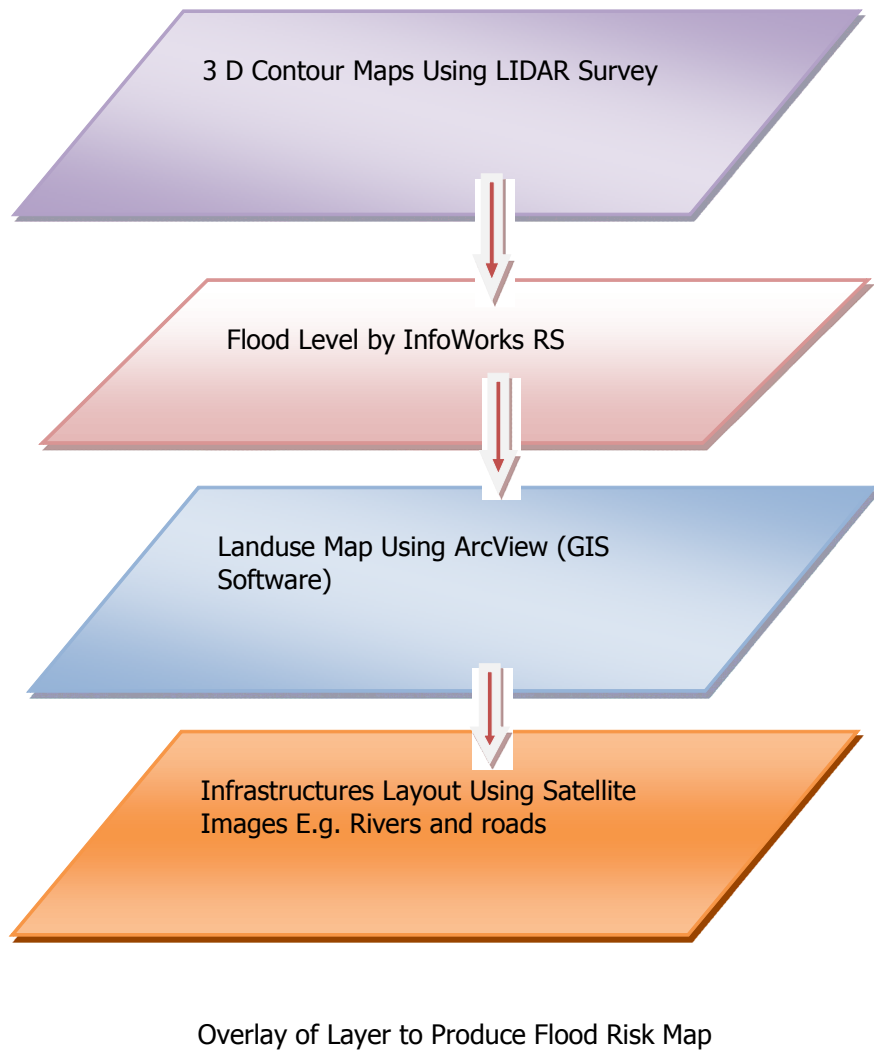
APPENDIX 8.C FLOOD MAPPING**Table 8.C Summary of Flood Maps Availability in Selected Countries**

	Coverage	Historical Event	Hazard Zones	Risk Zones	Emergency Planning	Spatial Planning	Construction	Awareness	Insurance	Determine Insurability	Premium Determination	Probability - damage curves
Switzerland	National		X	X	X	X	X					
France	National		X	X		X	X	X				
Spain	Per Region		X	X	X	X						
Italy	Per Region		X	X								
Belgium	National		X	X					X			
Austria	National		X			X						
Hungary	National		X		X	X						
Luxembourg	National		X			X						
Slovenia	National		X									
United Kingdom	National		X			X		X	X			
Germany	Per Region		X			X	X	X				
Finland			X		X	X	X					
Norway	Most exposed		X		X	X						
Sweden	10000 km total		X		X	X						
Latvia	10-100 km reach		X		X	X						
Poland	Per Region		X		X	X						
Romania	National		X		X	X						
Slovakia	National		X		X	X						
Lithuania	National		X		X	X						
Ireland	National	X				X		X	X			
Estonia		X										
Greece		X										
Czech Republic	National				X							
Bulgaria	National				X							
RMS Inc	UK,BE, GR		X	X								X
EUROFLOOD	GR,FR,UK,IT		X	X								X
Rodda	Czech Republic		X	X								X
FRAT	Czech Republic		X								X	
SIGRA	Italy - major river		X								X	
MacGIS	Czech Republic		X							X		
HORA	Austria		X							X		
ZURS	Germany		X							X		

APPENDIX 8.D FLOOD RISK MAP



Flood Risk Map (example of Sg. Damansara)



APPENDIX 8.E WORKED EXAMPLES FOR FLOOD DAMAGES

Rapid Assessment - Urban Area

A major town in Peninsular Malaysia is subject to flooding and based on maps of floods of various return periods, it is estimated that the properties can be categorised as below:

Property Type	Number In 5% AEP Flood	Number In 1% AEP Flood	Number in extreme Flood
Residential			
Kampungs	46	167	240
Bungalow	58	140	360
Terraces houses	25	300	350
Fiat/Apartments	20	88	100
Commercial			
Small Commercial	20	70	120
Medium Commercial	10	25	30
Large Commercial Complexes	1	4	20

From the 'Flood Damage Assessment of 26 April 2001 Flooding affecting the Klang Valley' by KTAT (2003), the following potential damages values have been established for the various property types:

Property Type	Damages In RM
Residential	
Kampung Houses	9,225
Bungalow	11,360
Terraces houses	10,260
Flat/Apartments	6,600
Commercial	
Small	12,000
Medium	24,000
Large (Complexes)	160,000

Applying the Potential Damages to the number of properties, and then applying an 80% potential to actual ratio, and also indirect and intangible damages of 40%, the Calculations give:

Flood Event	Potential Direct Damages RM	Estimated Actual Damages RM	Infrastructure Damages RM	Indirect Damages RM	Total Damages RM
In 5%AEP Flood	2,111,730	1,689,384	750,000	975,754	3,415,138
In 1% AEP Flood	8,869,775	7,095,820	2,000,000	3,638,328	12,734,148
Extreme Flood	15,914,600	12,731,680	8,000,000	8,292,672	29,024,352

Calculating AAD, the estimated AAD using RAM for this town is RM616,948; this can be rounded to RM617,000 to reflect the innate inaccuracy of the process. A sample worksheet is attached that shows the full RAM calculation from the Excel Spreadsheet. The calculation spreadsheet is available in the floppy diskette attached to this guideline. It should be noted that once the spreadsheet is established and all formulae verified correct the actual calculation of AAD takes less than 5 minutes.

Sample AAD Worksheet for RAM

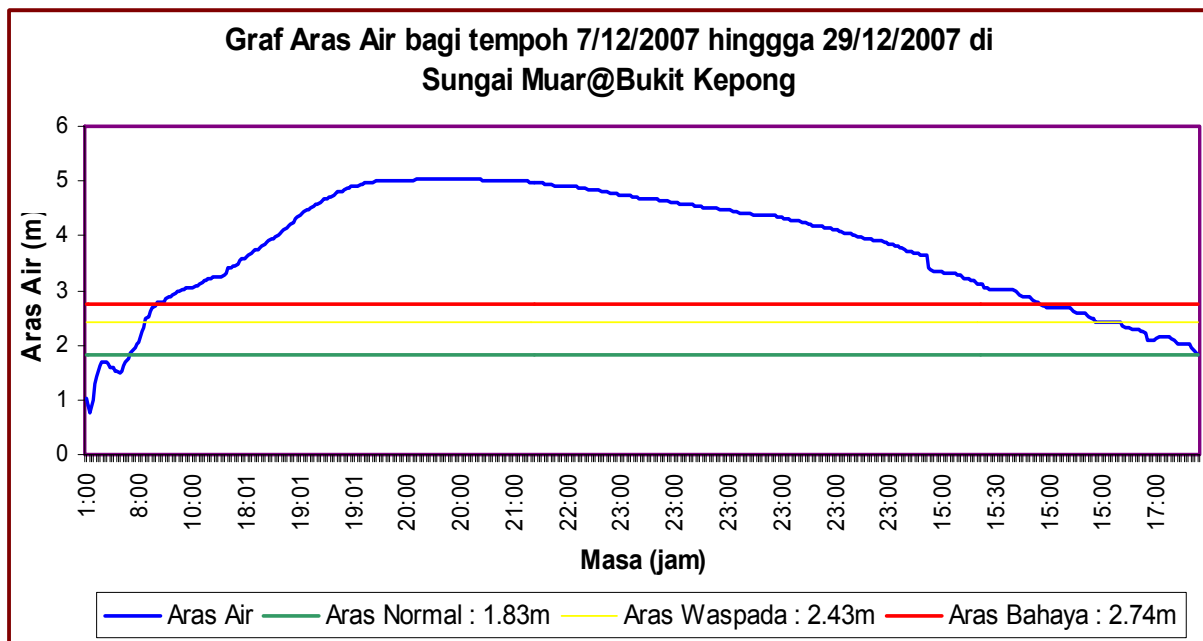
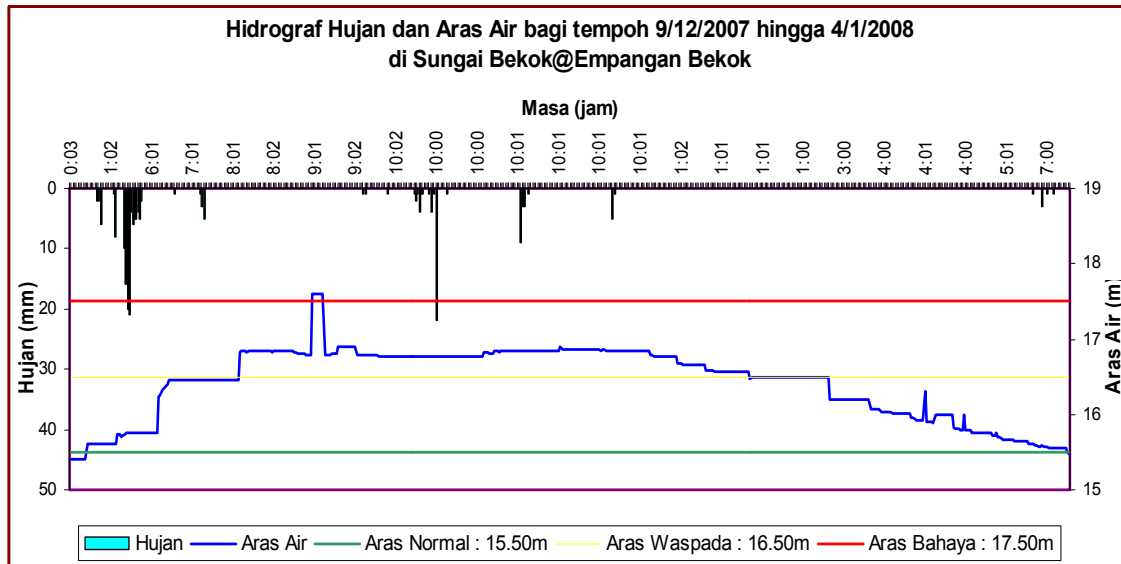
Type of Property	Damage Unit Value (RM)	Number of Properties Damage		
		In 5% AEP Flood	In 1% AEP Flood I	Extreme Flood Flood II
Residential				
Kampung Houses	9,225	46	167	240
Bungalow	11,360	58	140	360
Terraces houses	10,260	25	300	350
Flat/Apartments	6,600	20	88	100
Commercial				
Small	12,000	20	70	120
Medium	24,000	10	25	30
Large (Complexes)	160,000	1	4	20

Flood Event	Potential Direct Damages	Estimated Actual Damages	Infrastructure Damages	Indirect & Intangible Damages	Total Damages
In 5% AEP Flood	2,111,730	1,689,384	750,000	975,754	3,415,138
In 1% AEP Flood	8,869,775	7,095,820	2,000,000	3,638,328	12,734,148
Extreme Flood	15,914,600	12,731,680	8,000,000	8,292,672	29,024,352
Notes.		<i>P/A = 0.8 Flash = 1.0 flood</i>	<i>Note: these are assumed values only</i>	<i>ID = Total D * 0.4</i>	45,173,638

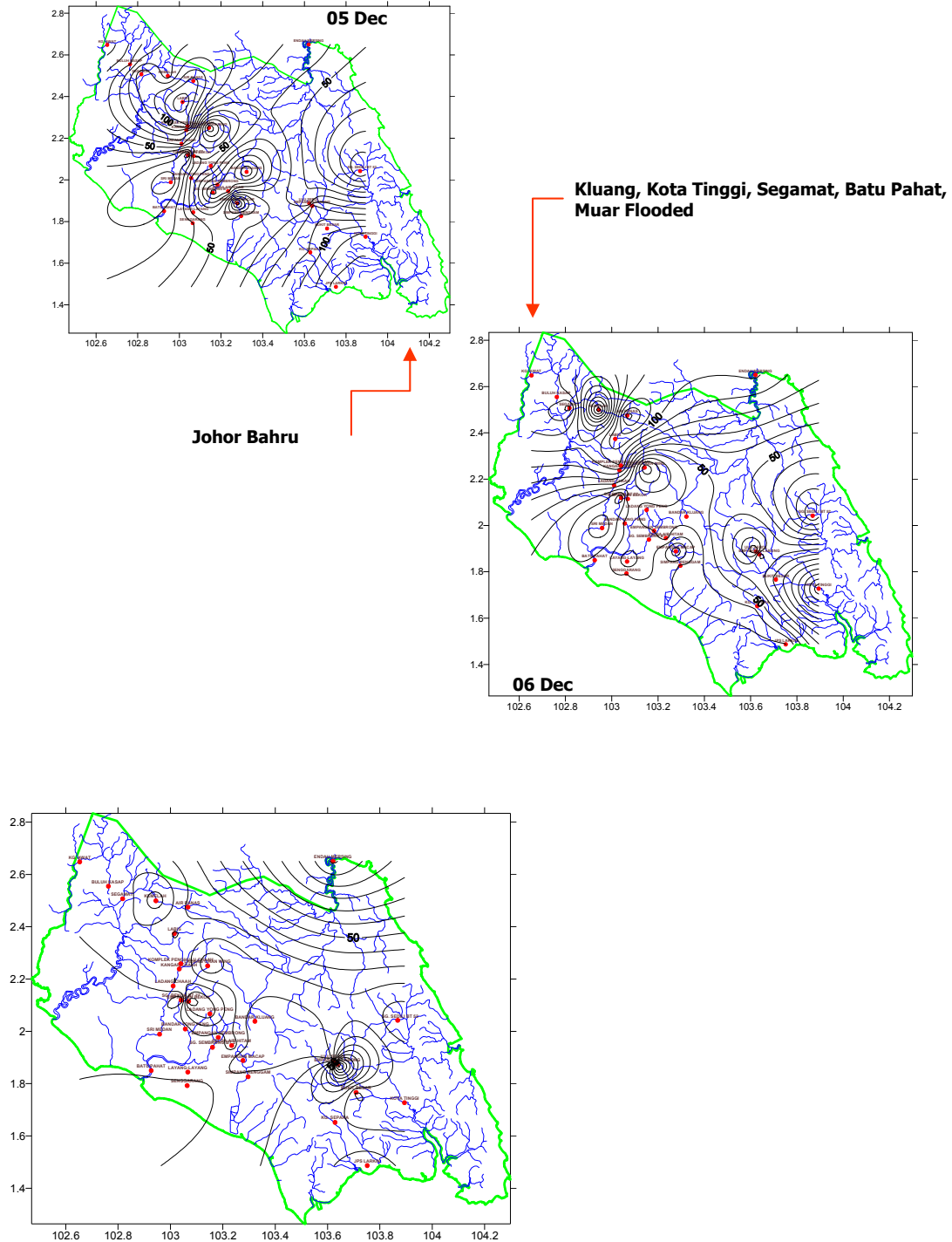
Probability %	Probability	Damages	AAD
10	0.1	0	
5	0.05	3,415,138	85,378
1	0.01	12,734,148	322,986
0.001	0.00001	29,024,352	208,584
Total AAD			616,948

APPENDIX 8.F EXAMPLE OF POST FLOOD REPORT

Rainfall Hydrographs and Water Levels in the Main Rivers of Johor State During the Floods of December 2007 and January 2008



Rainfall Isohyets for Johor State during the December 2007 Floods



Flood Area in December 2006

Catchment Area	District	Flood Area (km²)	Maximum Depth of Water(m)	Flood Duration (m)
Sg Tiram	Kg. Sg. Tiram	2	1	1
	Kg. Sg Rendan Laut	0.25	1.2	1
	Kg. Nam Hg	0.25	1	1
Sg Pulai	Kg Pulai	1	1.4	1
Sg Skudai	Kg Lorong Aris	0.25	1	1
	Kg Pasir	1	1	2
	Kg Laut	2	2	5
	Kg Sepakat baru	1	1	1
	Taman Senai Utama	2	0.75	1
	Taman Mewah	1	1	1
	Kg Separa	0.7	1.4	1
	Kg Baru Sengkang	1	0.75	1

Road and Bridges Affected by Floods of December 2006

Catchment Area	District	Road length been flooded (km)	Maximum Depth of Water (m)	Flood Duration (m)
Sg. Skudai	Jln Kulai - Sengkang	0.8	0.75	1
Sg. Tiram	Jln Tiram - Taman Bukit Jaya	0.7	1	1
Sg Pulai	Jln Kg Ulu Pulai	0.5	0.5	4

APPENDIX 8.G EXAMPLE OF A FLOOD INSURANCE POLICY (Malaysian Assurance Alliance Berhad)

In consideration of the payment by the Participant to the Company of an additional contribution the Company agrees that notwithstanding anything stated to the contrary condition No. 6 of the Certificate, this coverage extends to cover loss or damage directly caused by fire or otherwise occasioned by or through or in consequence of Flood (including overflow of the sea) subject to the following Excess Clause and Special Conditions attached hereto.

Note : Flood for the purpose of this extension shall mean overflowing or deviation from their normal channels of either natural or artificial water courses bursting or overflowing of public water mains and any other flow or accumulation of water originating from outside the building covered or containing the property covered but excluding loss or damage caused by subsidence or landslide.

Provided always that all the conditions of this Certificate shall apply (except and in so far as they may be hereby expressly varied) and that any reference there in to loss or damage by fire shall be deemed to apply also to loss or damage directly caused by and any of the perils which this coverage extends to include by virtue of this endorsement.

Excess Clause

It is understood and agreed that as regards loss or damage to any buildings hereby covered directly caused by the perils to which this Clause is hereinbefore stated to apply, the Company's liability shall be limited to its rateable proportion of the amount by which such loss or damage exceed either:-

- a) 1% of the total sums covered against such peril on said buildings by Certificates in the name of Participant, or
- b) The first RM2,500.00 of each and every loss, which ever shall be the less. It is further agreed that this Clause shall apply separately to:
 - (i) each building, for which purpose all building covered at the same address will be regarded as one building
 - (ii) each incident giving rises to such loss or damage and that for the purpose here of an incident shall not be considered to be terminated until there have been 7 consecutive days' freedom from the peril concerned and that only thereafter shall the Clause apply afresh.

Special Conditions

1. This endorsement does not extend the coverage under this Certificate to cover :-
 - (a) Consequential loss of any kind
 - (b) Loss or damage caused by hail whether driven by wind or not
 - (c) Loss or damage caused by subsidence or landslip except when this is occasioned by earthquake or volcanic eruption provided that these perils are covered against by this Certificate
 - (d) Loss or damage caused by explosion except as provided in condition 8 (h) of the Certificate
 - (e) Loss by reason of any ordinance or law regulating the construction or repair of buildings
2. The Company shall not be liable under this extension for loss or damage which at the time of the happening of such loss or damage is covered by or would but for existence of this extension be covered by any other existing Certificate or Policies except in respect of any excess beyond the amount which would have been payable under such other Certificate or Policies had this coverage not been affected.
3. Unless specifically and separately stated this endorsement does not cover metal smoke stacks awnings blinds signs or other outdoor fixture or fitting of any description.

Subject otherwise to the terms and conditions of the Certificate.

CHAPTER 9 RIVER MORPHOLOGY AND CHARACTERISTICS

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9 RIVER MORPHOLOGY AND CHARACTERISTICS

9.1 INTRODUCTION

River morphology is a special subject on the physical characteristics of river and channels. It studies the shapes of rivers due to hydraulics and sedimentation and erosion processes. Siltation and sedimentation processes refer to the off-site movement and deposition of the product of soil erosion. The soil entrained by the action of water erosion moves downslope under the influence of the various transport mechanisms in operation and eventually becomes deposited as sediment or silt when the transportation forces become ineffective.

Urbanization normally brings about an increase in the discharge of a river due to increase in impervious area. As a result, the sediment transporting capacity of the river also increases causing changes to the river equilibrium. Recurrence of flooding has been linked to the high rate of sedimentation in the river channel. Causes of failures are numerous. One example is riverbed degradation or erosion that causes instability of structures in rivers. Erosion and sedimentation in rivers involve a dynamic process of interaction between the flowing water and sediment bed. An understanding of this interaction that causes sediment movement and hence cross-sectional changes is important to control the erosion and sedimentation within allowable limits to ensure the stability of the river channel.

Deposition of sediments derived mainly from development has important impact on the flood carrying capacity of the rivers. Deposition occurs when the flow regime allows settling of transported material. This in turn results in accretion of the bed and hence a reduction of the flow capacity.

Sediment also builds up in areas of the river channel where there is a loss of velocity or where back current occurs. This is a natural process accounting for meandering of river channel by deposition on the convex section of the banks and erosion on its concave bank. However, when a river is fed with surplus sediment, the speed of this natural process is increased hence scour and erosion of the outer bends is increased. This adds more sediment to the river load. In developed areas, where the movement of the river needs to be confined, protection works is required to prevent this scour.

Erosion along certain stretches of the river can be severe and requires special attention. Such occurrences are generally caused by deepening and widening of the channel through increased upstream discharge or deprivation of sediment from upstream due to sand mining activities or channel widening or riverbed retrogression due to downstream channel improvement works or their combination thereof.

9.2 RIVER CHARACTERISTICS

9.2.1 Channel Geometry

Channel geometry, river characteristics and the river flow are inherently related. Parameters like discharge, sediment loads, bed materials, topography, local climate, riparian vegetation and land use affect morphological change of a river. Likewise, changes in the geometry of the channel can impact river velocity and discharge. The flow velocity is directly related to the hydraulic radius (cross-sectional area divided by the wetted perimeter) and channel slope, and inversely related to channel roughness. Besides that, other characteristics such as depth, width, boundary shear and turbulence need to be considered for a certain flow rate to transport a certain sediment load without eroding the banks. All of these characteristics are inter-related.

If the boundary shear stress on the banks is too great, the bank material will erode, the channel section will widen and the flow parameters (velocity, depth, etc.) will change. If the boundary shear stress is a little less than the maximum, nothing much will happen and if it is much less, the channel will tend to narrow. However, the process whereby a channel narrows is not clear. This is in contrast with the process of channel widening (due to erosion or scour). This can happen rapidly and is to be "expected". This process can be observed in any flood. The narrowing process is much slower and more subtle. The process occurs in unsteady and non-uniform flow conditions. Observers have put together evidence that channels have narrowed over a period.

Rivers can be divided into three main sections i.e. upper reach, middle reach and lower reach. The upper reach section (usually in mountainous area) often has high erosion process and can be referred to as the sediment production area. The middle reach is located between mountain foothills until river plain zone and functions as sediment delivery conveyance media. The lower reach is usually influenced by tidal effect and acts as sediment settling zone. From a flood mitigation aspect, the lower reach is the most critical zone followed by the middle reach and implies the needs to desilt sediments for better conveyance.

9.2.2 Channel Morphology

Channel morphology is determined by gradient, topography, discharge and sediment load. It is classified into straight channel, sinuous (wandering) channel, meandering channels and braided channel as shown in Table 9.1 (Morisawa, 1985).

- **Straight Channel**
A straight channel has a single channel with pools and riffles and its central line of flow gently meanders. Its sinuosity is less than 1.05. Sinuosity is the ratio of the length of the meander along its centreline of flow and the straight line length of the river basin. The channel width-depth ratio is not more than 40. Sediment load takes a form of either bed load or suspended load. When river erosive behaviour is strong, river width and water depth are both increased. When river depositional behaviour is strong, skew shoals are formed.
- **Sinuuous Channel**
As with a straight channel, a sinuous channel consists of a single channel with pools and riffles. Its centreline of flow meanders with sinuosity at more than 1.05. The width-depth ratio, which refers to water surface width at the time of mean annual discharge (bankfull discharge for 2 years ARI), is smaller than 40. Sediment load takes a mixed form of bed load and suspended load. Like straight channel, its strong erosive behaviour leads to channel widening and increased incision and its strong depositional behaviour forms skew shoals.
- **Meandering Channel**
A meandering channel consists of a single channel with sinuosity and width-depth ratio of not more than 1.5 and less than 40 respectively. Sediment load takes either a form of suspended or a mix of both suspended and bed load. Its strong erosive behaviour leads to channel widening and increased incision while its strong depositional behaviour results in formation of point bars on its inner meandering.
- **Braided Channel**
A braided channel consists of two or three channels. Its sinuosity and width-depth ratio are more than 1.3 and more than 40 respectively. The type of sediment transportation is mainly bed load. The strong erosive behaviour widens channel while strong depositional behaviour leads to channel aggradations and formation of mid-channel bars.

- Anastomosing Channel

An anastomosing channel consists of several channels with stable islands and its sinuosity and width-depth ratio are more than 2 and less than 10 respectively.

In terms of flood mitigation requirements, two types of channels require special attention i.e. meandering channel and braided channel.

Table 9.1 Types and Characteristics of Channels

Type	Morphology	Sinuosity	Load type	Width/Depth Ratio	Erosive Behaviour	Depositional Behaviour
Straight	Single channel with pools and riffles: meandering talweg	< 1.05	Suspended, mixed or bed load	< 40	Minor channel widening and incision	Skew shoals
Sinuuous	Single channel with pools and riffles: meandering talweg	> 1.05 > 1.5	Mixed load	< 40	Increased channel widening and incision	Skew shoals
Meande ring	Single channel (may be inner point bar channel)	> 1.5	Suspended or mixed load	< 40	Channel incision; meander widening	Point bar formation
Braided	Two or more channels with bars and small islands	> 1.3	Bed load	< 40	Channel widening	Channel aggradation: mid-channel bar formation
Anasto mosing	Two or more channels with large, stable islands	> 2.0	Suspended	< 40	Slow meander widening	Slow bank accretion

9.2.3 Meandering

Natural channel formation is the best morphological type to be maintained along any section. The traditional solution for floods is to break up meandering sections to ease flow of water by constructing flood by-pass channel (straightening works). This provides effective flood relief flow but this technique does not balance with the overall river management requirements. A better approach would be to maintain the natural channel to serve the annual flood discharge (say 2 years ARI) and for flood flows to pass through the by-pass channel through a weir as shown in Figure 9.1.

This technique maintains the natural channel formation as much as possible specifically for environmental sustainability and prevent major disturbance to the natural habitat and the ecosystem.

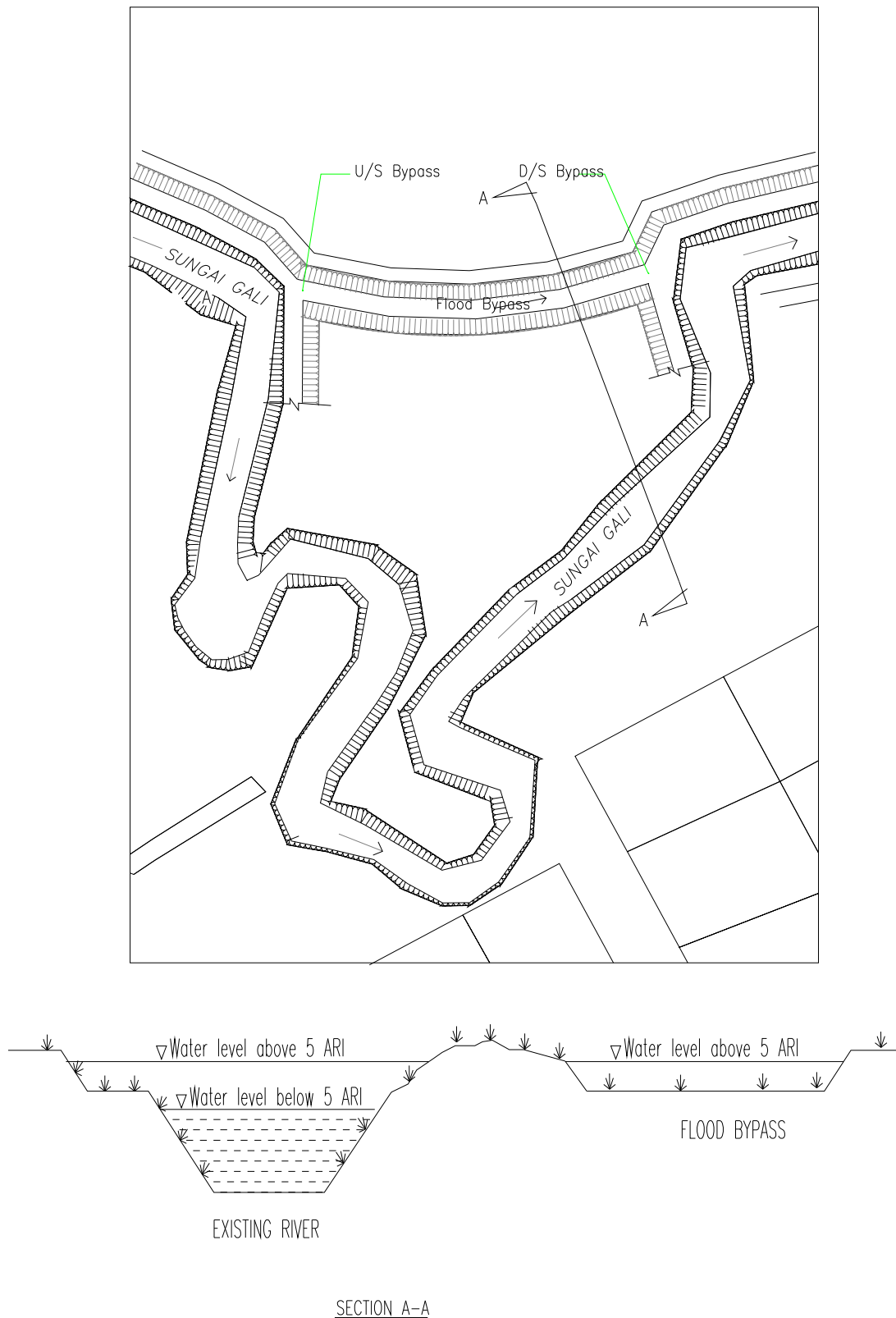


Figure 9.1 Example of Eco-Friendly Flood By Pass Sg. Gali, Raub, Pahang

9.2.4 Braiding

Figure 9.2 show an example of a braided channel. At low flow, there could be just one filament of flow wandering between the dunes left behind from the previous flood flow. At higher flow, several filaments will combine and branch to make a network. The filaments at low flow will transport sediment, will enlarge, and will make their paths continuous so that at moderate flow, the network will tend to be preserved, even enlarged. At higher flood flow, however, all the passages between dunes will take flow and all or most of the dunes will be submerged. The complex, low-flow network of flow filaments becomes even more complex. The bed configuration may be more a function of this complex flow network with deposition forming bars and erosion forming channels. This can cause flooding to occur.

9.2.5 Bends and Meanders

The banks are not as easily erodible (some clay in the bank material). If the sediment loads is finer, and if the dunes that form are not as large, the river will not be braided, and the flow section will be more coherent than it was in the braided channel. However, even if in a straight reach, the flow would probably not be perfectly uniform, the streamlines exactly parallel, the boundary shear pattern unchanging from section to section. Moreover, the bank material would not fully be homogeneous. Where the bank is more easily eroded, or the boundary shear on the bank is greater than usual, or both, the bank will be eroded at certain discharge. Bank erosion will add to the sediment load, and likely to be deposited on the bed just downstream. The bank and bed geometry will tend to deflect the flow away from the bank and towards the opposite side. The boundary shear on this side will then be greater than normal and the opposite bank will erode as shown in Figure 9.3. This is the reason for straight reach of stream being uncommon. The turning (or reflection) of the flow from one side unto the other tends to make the sinuosity (or zigzaggedness) of the stream regular. However, non-homogeneity of the bank material causes more erosion in some places than in others, resulting in irregularity. Gradually, the bank curvatures intensify into "meanders".

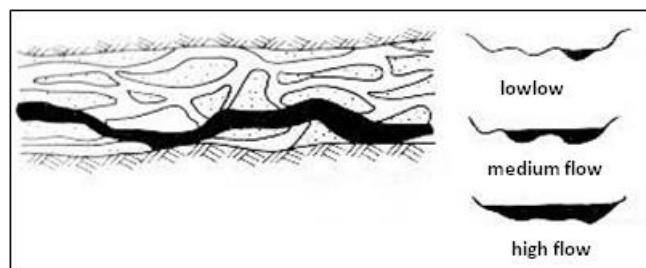


Figure 9.2 Braided Streams

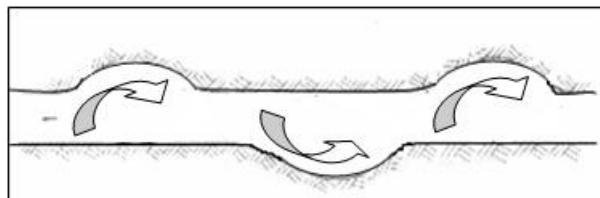


Figure 9.3 Straight to Sinuous Stream Alignment

9.2.6 Bank Caving

In a large flood, the bank shear will be greater and the banks eroded; more in some places than others. Subsequently the entire reach is widened. Extensive bank caving adds a large additional supply of sediment to the reach. This cause sediment supply to exceed the river transport capacity and results in aggradations of the bed of the stream as illustrated in Figure 9.4. This is likely to occur over a longer river stretch so that the entire riverbed level is raised.

Unless the river is deeply incised, bank overflow occurs and spreads over the flood plain as in Figure 9.5. Both situations show that the flooding can occur when the reach are not wide and deep enough.

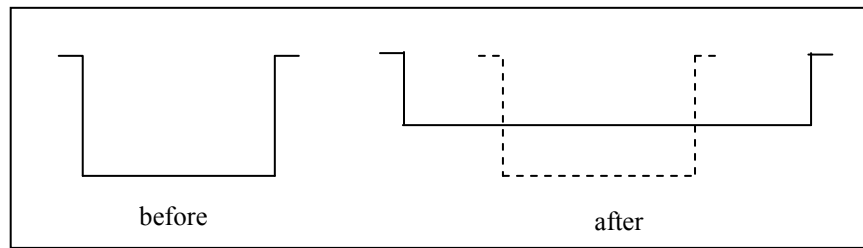


Figure 9.4 Bank Caving and Deposition, Flow within Banks

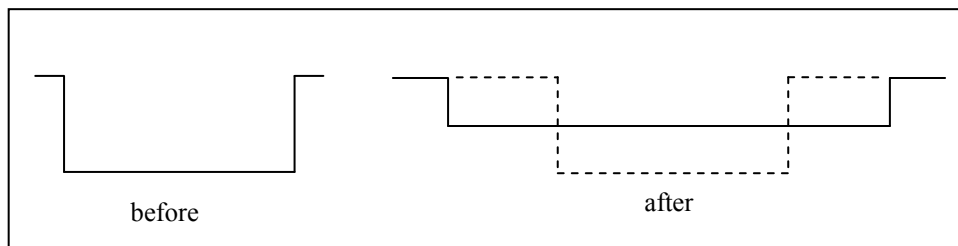


Figure 9.5 Bank Caving and Deposition, Flow Out of Bank

9.2.7 Other River Characteristics

The state of equilibrium is when the supply of sediment is equal to the capacity of the movement and that the bank shear cannot exceed the bank resistance to erosion. It can be quantified using explicit, approximate equations to describe the necessary relationships. It can be shown that:

For the same bank material and sediment concentration and composition, the width-depth ratio (B/y) of the flow section increases with the discharge (Figure 9.6), and the slope decreases unless there is a marked change in the dunes and n value. The width-depth ratio shows the relationship that the deeper the reach, the lesser the chances of flooding as the flows will be retained before it goes into the main river.

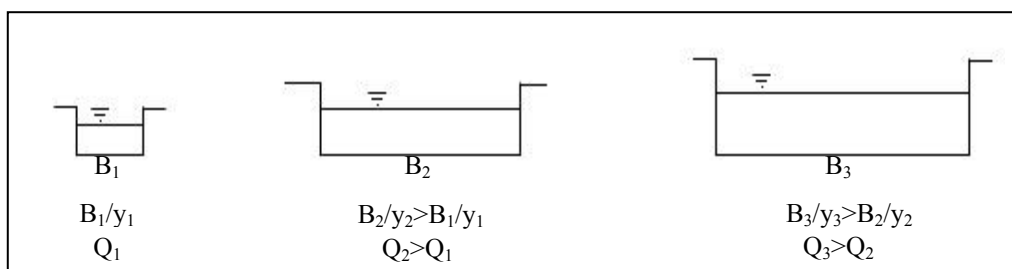


Figure 9.6 Increases in Width/Depth Ratio with Discharge

If groundwater seeps into a stream, the tendency for a "concave-up" water surface profile is increased as shown in Figure 9.7. As flow increases downstream because of seepage, the sediment concentration decreases and the slope and velocity reduces.

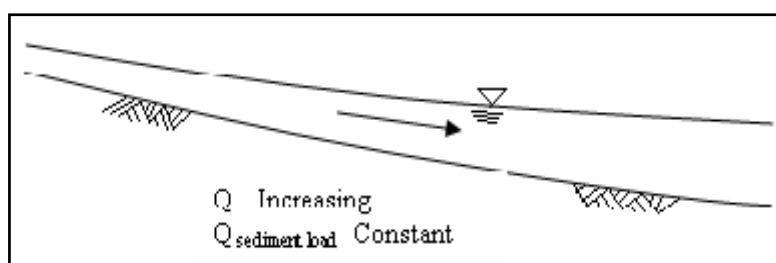


Figure 9.7 Decreases in Slope with Increasing Discharge, Sediment Load Constant

9.3 RIVER BANK STABILITY ANALYSES

Streambank stability studies have focused mainly on riverbanks composed of cohesive materials such as massive silt or clay or loess-derived alluvium. Several methods of slope stability analysis have been applied to riverbanks and specific methods developed based on a more realistic geometry of natural eroding riverbanks. However, all the bank stability analyses were developed using methods derived from classical saturated soil mechanics. In these approaches, the effects of negative pore water pressures in the unsaturated portion of the bank, in terms of stability, have been neglected. Table 9.2 showed the critical water velocity against bank material.

Table 9.2 Water Velocity against Bank Material

Cover	Side Slope Range %	Permissible Velocity (m/s)
Tall Fescue	< 5	1.52
	5 - 10	1.22
	> 10	0.91
Grass Mixture	< 5	1.22
Reed Canary grass	5 - 10	0.91
Redtop	<5	0.76
Alfalfa		
Red fescue		

The need to understand the causes of channel instability are:

- To select appropriate flood management strategies. Erosion and sedimentation occurring in riverine processes can be accelerated when a channel becomes unstable (i.e. clearing of vegetation). Catchment clearing increase surface water run-off into a waterway. The channel needs to be wider and deeper to accommodate the increased flow.
- Deposition of sediment from the channel or through broad catchment erosion can cause the filling of river pools, smothering of aquatic habitat, reduction of channel capacity.
- Channel deepening can be initiated by a change in the natural slope of a waterway, a decrease in the sediment being transported from upstream or an increase in stream flow.
- Upstream progressive bed erosion can occur due to the resulting steeper slope of the channel and consequent increase in the velocity and force of flows.
- High velocity flows from the tributary can cause bank erosion and scour in the receiving waterway.

Many techniques are available to solve specific bank stability problem due to resisting erosive forces and geotechnical failure. Some techniques to control the riverbed are:

- Stabilize channel alignment;
- Protect stream bank; and
- Rebuild habitat.

These techniques are shown in Table 2.1, Stream Stabilization Techniques, Volume 2, Chapter 3.3.3, "River Management Manual". Bank protection measures are addressed in the Volume 3, Chapter 3.3, "River Engineering Manual".

9.3.1 Riverbank Erosion

Riverbank erosion involves the removal, transportation and deposition of bank material along streams and rivers. It is a process associated with flood events. It is initiated by bank scouring along the river during high velocity streamflows, possibly assisted by wind and wave actions. Streambank erosion and deposition are part of the normal processes of stream geomorphology that also include bed scouring, sediment deposition and sediment re-entrainment and re-position.

Riverbank erosion occurs when the stresses applied by streamflow energy exceed the shear resistance of the riverbank materials. Major factors influencing the rate and amount of bank erosion that can cause flooding are;

- Velocity;
- Flow rate;
- Flow depth and duration of the flood flow causing the event;
- The height and slope of the riverbank;
- The properties of the riverbank material;
- The curvature and plan shape of the stream channel that influence the direction of erosive flow onto the bank;
- The existence of natural or artificial features which cause localized increase in flow velocity or concentrate flow against the bank; and
- The nature and extent of vegetative or other protection or armouring of the bank face.

Riverbank erosion occurs most extensively on floodplain reaches and its most direct adverse consequence is the loss of prime agricultural land. Bank erosion may also damage or destroy bridges, roads and other infrastructure. The eroded material provides a source of sediment for deposition further downstream where it may reduce stream capacity and increase flooding potential. Eroded sediment also promotes silt accumulation in reservoirs, behind weirs and other control structure. It also impairs downstream water quality.

The occurrence and severity of riverbank erosion can be strongly influenced by land use in the watershed along the stream banks. Poor land-use practices and inadequate land-use planning and management on the watershed above an erosion site can increase the rates and volumes of flood events. It can also bring down an accumulation of debris or sediment that may aggravate erosion at critical locations. When vertical erosion occurs, the channel is deepened and thus the river is able to hold more water. When lateral erosion occurs, the sides are eroded and the channel is widened. There are four major mechanics of riverbank erosion:

- Abrasion/corrosion

Rocks that are carried in the river grind and erode the river banks and bed. Some of the rocks at the sides and on the bed of the channel are washed away. This type of erosion widens the channel through lateral erosion and deepens the channel by vertical erosion.

- Hydraulic action

Water travelling at a high speed may enter the line of weakness of rock when it hits against these rocks at the side of the channel. The force could cause the rock to break and the broken pieces swept away.

- Attrition

When materials in the water collide with each other, they break and become smaller particles. These particles become smoother and rounded.

- Solution/corrosion

The river water may also dissolve the minerals in the rock and carry down in the river. Limestone may be dissolved quickly in the river water, especially when there is high concentration, to form soluble calcium hydrogen carbonate.

Channel erosion is likely to occur due to high velocity where erosion of river banks can generally be seen at the outer banks of meanders. This could result in bank caving in some cases. Although the natural river traverses through a meandering course this phenomena is more pronounce at the lower reach of the river, where it assumes a sinusoidal form.

Bank or bed erosion can also be seen at or downstream of structures such as bridges. Turbulence due to bridge piles or constriction of bridge abutments can undermine the stability of bridge foundations and subsequently their safety.

General scouring of channel bed is usually minimum due to low discharge velocities except at certain locations due to interference. On the other hand, bank erosion at outer bends, bank and bed erosion at structures, though localized in nature, require bank/bed protection works. Where large river reserves are available, bank erosion prevention works may not be critical and therefore can be accorded lower repair and maintenance priority.

River becomes unstable during major flood event. Actions of flood water to the banks and beds may alter channel formation slowly and continuous major floods may change the channel alignment permanently (straight to sinuous to meandering to straight and ox-bow lake). To get good stability, natural rivers may form its own natural bunds especially along middle reach and lower reach.

Having wide river reserve offer more options for the river stability and flood mitigation works. Compound sections can be built to serve both the daily flow and flood flow requirements. Low flow channel consists of section to cater up to 5 years ARI (minor flood and natural environment) while compound sections up to 100 years ARI (major flood). Some developed nations installed design compound sections of up to 200 years ARI with low flow channels retained in its original form and allowed for the natural propagation of channel morphology.

9.4 EROSION AND SEDIMENTATION

Urban development usually removes forests within a basin that results in soil erosion and sedimentation. River bank and bed erosion indicate channel instabilities. During high flow and floods, channel erosion continues causing the bed and banks under considerably great stress. The direct impacts of erosion and sedimentation in an urban basin are:

- Flooding caused by reduced river/channel or drain capacity.
- Damage to riverside developments from sediment deposition.

As mentioned earlier, sediments are generated from upstream reach i.e. sediment production areas, then convey through middle reach and settle down at lower reach. Most of the major desilting works are at the lower reach and minor at the middle reach. In terms of flood management, it is good practice to implement erosion control practices or programs (ESC) at the upper reach or in any open area to reduce sedimentation and therefore reducing the need for river desilting works.

Sedimentation analysis involves the study of sediments and the mechanisms by which they are transported, eroded, and deposited. Sediment studies can take the form of numerical modelling studies or desktop studies. Numerical modelling studies assess the effects on sedimentation of implementing a proposed alteration to a particular study area or system (detail information regarding sediment transport modelling can refer to Volume 2, "River Management Manual" and Volume 4, "Hydrology and Water Resources Manual").

Sediment studies can range from quantitative "impact" studies to major sediment transport, scour, and deposition analyses performed by computer simulation. In addition to the data needed for steady or unsteady flow hydraulics studies, use of a sediment analysis program requires a description of the bed material (grain sizes) throughout the reaches under study. It also require defining the sediment load curve (discharge versus sediment carried) for the main river and all tributaries carrying significant sediment and water inflow. The grain size distribution of each load curve is also needed. Sediment transport studies are more data intensive than pure hydraulic studies and will normally give less precise results. Trends in deposition and erosion with rough estimates of channel geometry changes in the reach over time are often the main information derived from such studies. Sediment in the river channel is divided into bed load, suspended load and wash load. Among them, bed load is the most influential in the change of riverbed (i.e. sandy riverbed). Table 9.3 showed the various important parameters in sedimentation analysis. These parameters are important for preventing erosion and sedimentation management. They need to be taken into consideration and analysed and modelled at the design stage.

Table 9.3 Important Parameters in Sedimentation Analysis

No	Parameter	Symbol
1	Sediment transport rate	q_s
2	Mean particle size	d_{50}
3	Particle density	ρ_s
4	Density of water	ρ_w
5	Velocity of water	U
6	Particle shear force	τ
7	Slope of channel	S
8	Hydraulic radius of channel	R

9.4.1 Sediment Transport

Flow and sediment transport in river, estuary and coastal zones is important in relation to water quality, sedimentation, erosion around structures, backfilling of dredged channels, changes in near shore morphology and long and cross-shore sediment transport rates. The developments in sediment behaviour and transport research have progressed from simple phenomenological descriptions to sophisticated numerical models in which flow as well as sediment transport and behaviour.

- Erosion

Erosion or re-suspended involves particles or sediment being transported upward from the river/estuary bed into suspension. It occurs when the shear stress exceeds the critical shear stress. Transport depends on an appropriate balance of forces within the transporting medium. A reduction in the velocity of the medium or an increase in the resistance of the particles may upset this balance and cause deposition.

- Deposition

The erosional transport of sediment is shown in Figure 9.8. Transport depends on an appropriate balance of forces within the transporting medium. A reduction in the velocity of the medium, or an increase in the resistance of the particles may upset this balance and cause deposition. Deposition can also be caused by particle precipitation and flocculation. Precipitation is a process where dissolved ions become solid due to changes in temperature or chemistry of the water. Flocculation is a chemical process where salt causes the aggregation of minute clay particles into larger masses that are too heavy to remain suspended (DLWC, 2000; Pidwirny, 2002).

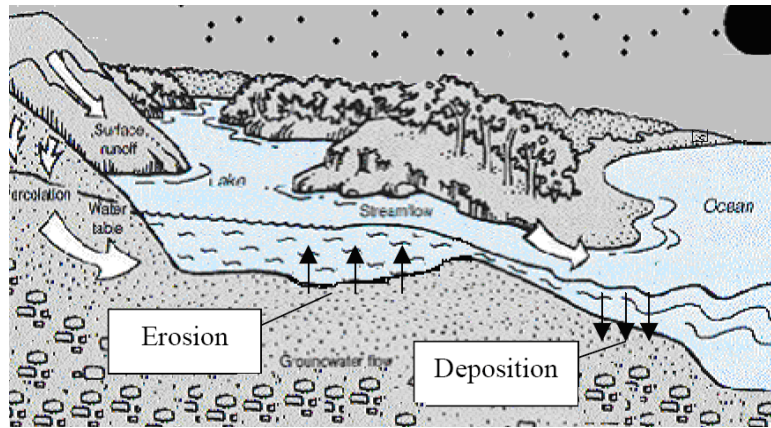


Figure 9.8 Sediment Transport

9.4.2 Modes of Sediment Transport

Sediment particles being moved by water can undergo three distinct modes of motion, as shown in Figure 9.9:

- **Suspended (suspended particle motion):**
Turbulence in water is the mechanism that maintains sediment in suspension (when the velocity is high in relation to the settling rate of particles). Suspended sediment is usually fine-grained; the transport of sand in suspension is at the higher end of the energy spectrum.
- **Bedload (rolling and/or sliding motion):**
This is the rolling or sliding of the particles along the bed. This sediment transport mode is applicable to coarser sediments (sand and gravel-sized materials) and is at the lower end of the energy spectrum.
- **Saltation (or hopping motion):**
This is an intermediate situation between bedload and suspended sediment load where particles "bounce" along the bed.

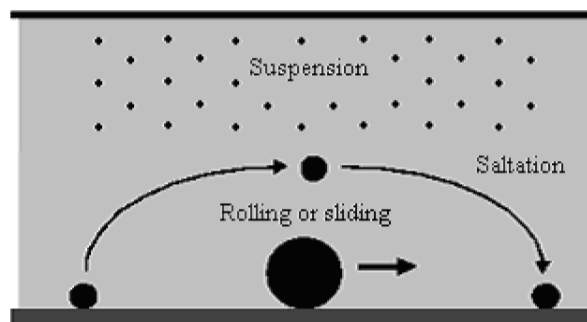


Figure 9.9 Diagrammatic Representation of the Modes of Transport (SOES, 2002)

Flowing water exerts a shear stress on the bed of an estuary, i.e. it imposes a force on the bed material in the direction of flow. The faster the water velocity, the greater the shear stresses. When the shear stress at the bed just exceeds the critical value required for initiation of motion, sediment particles will begin rolling and/or sliding whilst remaining in continuous contact with the bed.

The detail explanations about the mechanism of sediment transport and sediment transport model are discussed in subtopics 7.3 and 7.4, Chapter 7, Volume 4: Hydrology and Water Resources Manual.

9.4.3 Factors Affecting Sediment Transport

The general principle governing sediment movements is that sediment transported in the water will settle at times or places of low current, wave or tidal activity. The rate of settling depends upon the grain size of sediments and their mineralogy and chemical characteristics.

- Particle Size Effect

If the bed grains are significantly smaller or larger than the moving grain, the shear stress required for motion changes. This has the mechanical effect of changing the contact angle and the terms "hiding" and "exposed" used as shown in Figure 9.10.

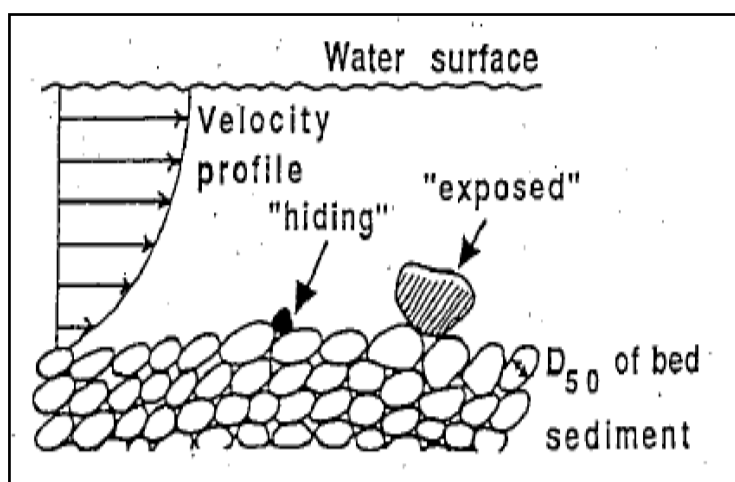


Figure 9.10 Diagrammatic Particle Size Effect on Initiation of Motion (Petroff, 2000)

- **Bedforms**

Bedforms contribute additional roughness to the flow of water in the channel. Figure 9.11 shows typical particle movement occurring in the different bedforms.

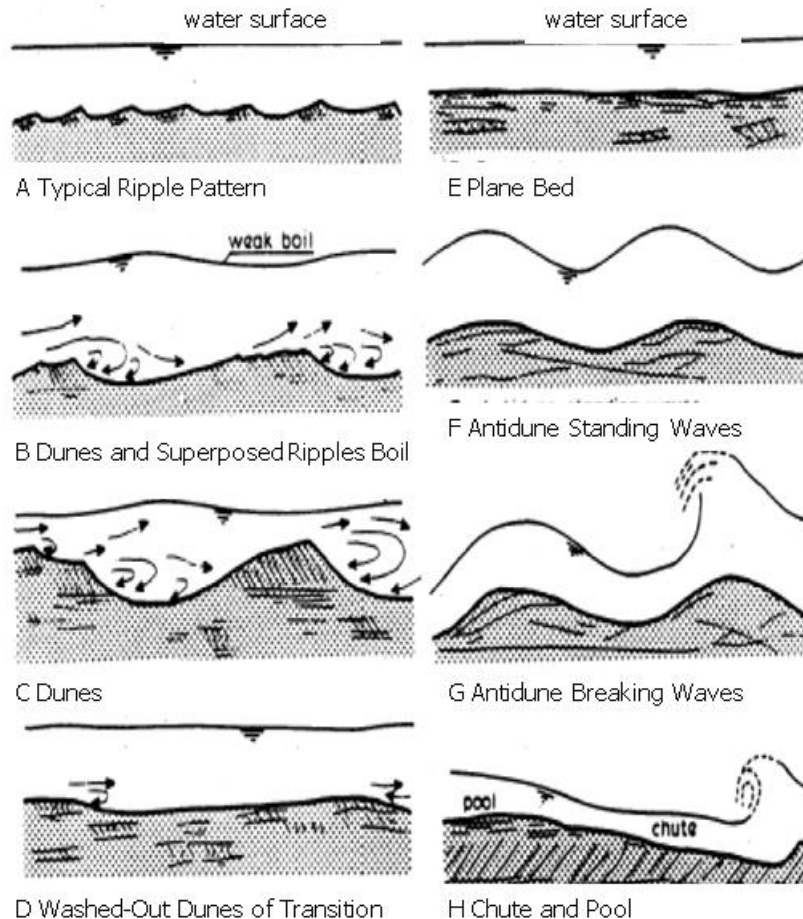


Figure 9.11 Bedforms Types (Petroff, 2000)

Sediment yield is the amount of eroded material that moves from a source to a downstream control point, such as reservoir, per unit time (Chow, 1964). The fate of eroded material within a watershed is influenced by hydrologic, topographic, vegetative and groundcover characteristics.

9.4.4 Siltation

Silt is soil or rock derived granular material of a specific grain size. Silt may occur as a soil or alternatively as suspended sediment in a water column of any surface water body. It may also exist as deposition soil at the bottom of a water body. ISO 14688 grades silts as grain particles between 0.002 mm and 0.063 mm with clay particles being smaller and sands larger than these limits.

Silt can occur as a deposit or as material transported by a stream/river. Silt is easily transported in water. Silt and clay contribute to turbidity in water. The main source of river siltation and storm sewer sedimentation in urban areas is disturbance of soil by construction activity. The main cause of river siltation in rural areas is erosion from extensive ploughing of farm fields, clear cut logging or slash and burn treatment of forests. Silts, deposited by annual floods along the river, provides the rich and fertile soil that sustained the ancient civilization. A decrease in silt due to a system of bunds has contributed to the disappearance of protective wetlands and barrier islands in the delta region.

As described in Chapter 7: Flood Mitigation Structural Measures, the design criteria of retention/detention pond and diversion structure is beneficial for reducing sediment yield and allowing sediment basins and traps to function efficiently. Barrages and flood control dam can be designed to trap silt from migrating downstream of these structures. The explanation of design criteria and construction are in Chapter 10.

9.4.5 Sediment Transport Equations

It is important to understand the limits of sediment transport equations when applying them. Each sediment transport function and its applicability are briefly presented in the following paragraphs. Further information on each function and the actual equations associated with each function are given in the Hydraulics Reference Manual in Manual No. 54 (ASCE, 1975). The four equations available to compute sediment transport relationship in HEC-RAS are the Ackers-White, Engelund-Hansen, Meyer-Peter-Müller and Yang functions. Each function was developed from laboratory flume and/or field studies of sediment in motion. Each equation is generally applicable for a range of sands or gravels or both.

a) Ackers-White Function

The Ackers-White sediment transport equation was developed from more than one thousand laboratory flume studies, primarily with sands. The transport function is applicable for non-cohesive sands and for bed form configurations including ripples, dunes and plane bed. Additional experiments following Ackers and White's original publication extended the particle size range applicable for the equation to 7 mm (fine gravel).

b) Engelund-Hansen Function

The Engelund-Hansen sediment transport equation was extensively based on flume data using four median (D_{50}) sand particle diameters (0.19, 0.27, 0.45, and 0.93 mm). This transport function is most appropriate for sand-bed streams with a substantial suspended sediment load. The channel bed material should have a minimum particle diameter of 0.15 mm or greater and not have a wide variation of sand gradation about the median particle diameter. The appropriate bed form for the function is dunes.

c) Meyer-Peter-Müller Function

The Meyer-Peter-Müller sediment transport equation was based primarily on experimental flume data but has been widely and successfully applied to rivers having coarse bed material. The data used in developing Meyer-Peter-Müller were from rivers with little to no suspended sediment. Therefore the function perhaps is not applicable to rivers with appreciable suspended sediment. The equation has performed well for gravel-bed streams and for sand-bed streams not carrying significant suspended load.

d) Yang Function

The Yang sediment transport equation, also referred to as the Yang Stream Power Function, was developed from both flume and actual stream data for sand-bed streams. Particle sizes ranged from very fine sand (0.062 mm) up to coarse sand (1.7 mm). Yang later extended his method to include gravel-bed streams (Yang, 1984) up to a particle diameter of 7 mm (fine gravel). Yang equation is use to simulate the sediment transport process.

The total sediment load for a river is made up of bed load and suspended load. At flood conditions, suspended load dominates over bed load. In most large, low-sloped sand-bed rivers, the majority of sediment transported on an annual basis is mud. Two well-known formulas are shown below concerning the estimation of transport of sediment load. Equation 9.1 shows the formula by Engelund and Hansen for total sediment load.

$$q_s = 0.05 \rho_s U^2 \sqrt{\frac{d_{50}}{g \frac{\rho_s}{\rho_w} - 1}} \frac{\tau}{g(\rho_s - \rho_w) d_{50}}^{\frac{3}{2}} \quad (9.1)$$

where q_s = sediment transport rate in kg/s per unit width, d_{50} = mean particle size, ρ_s = particle density, ρ_w = density of water, g = gravitational acceleration (9.81 m/s^2), U = velocity of water, τ = particle shear force. Equation 9.1 is appropriate for sand-bed rivers with a substantial suspended load. Equation 9.2 shows the formula by Meyer-Peter-Müller for bed load.

$$q_s = \frac{1}{g} \frac{\rho_w g R S}{0.25 \rho_s^{\frac{1}{3}} \frac{\rho_s - \rho_w}{\rho_s}} \frac{0.047 g (\rho_s - \rho_w) d_{50}}{\rho_s}^{\frac{3}{2}} \quad (9.2)$$

where q_s , ρ_s , ρ_w , g , d_{50} are all as described before, R = hydraulic radius of channel, S = slope of channel. Equation 9.2 is suitable for gravel-bed rivers and sand-bed rivers that do not carry significant suspended load.

The Ackers-White model consists of the sediment transport model presented by Ackers and White. The model is partly based on dimensional analysis and partly on physical arguments. Modifications are considered. The input parameters for the approach are such as:

- kinematic viscosity (ν)
- bottom shear stress (τ_0)
- bottom shear stress velocity (v_o^*)
- dimensionless grain diameter (D^*)

The geometric medium of the characteristic grain size of one grain category results from the minimum and maximum diameter of one grain category (see Equation 9.3):

$$d_{ch,k} = \sqrt{d_{k,min} * d_{k,max}} \quad (9.3)$$

The mobility parameter (F_{gr}) can be calculated with Equation 9.4:

$$F_{gr} = \frac{v_0^{*n_{AW}}}{\sqrt{g \cdot d \cdot (s - 1)}} \cdot \frac{v_m}{\sqrt{32 \cdot \log \frac{10 \cdot Y}{d_{ch,k}}}} \quad (9.4)$$

Inserting the values of n into Equation 9.4 gives the sediment mobility parameter for coarse ($F_{gr,c}$) (Equation 9.5) and fine material ($F_{gr,f}$) (Equation 9.6):

$$F_{gr,c} = \frac{v_m}{\sqrt{32 + g \cdot d \cdot \frac{\rho_S - \rho_F}{\rho_S} \cdot \log \frac{10Y}{d_{ch,k}}}} \quad (9.5)$$

$$F_{gr,f} = \frac{v_0^*}{\sqrt{g \cdot d \cdot \frac{\rho_S - \rho_F}{\rho_S}}} \quad (9.6)$$

Equation 9.5 is the relation between shear stress and mass of the solid layer under buoyancy, and Equation 9.6 is the shear stress velocity at the bottom divided with settling rate of particles in latent fluid. The dimensionless transport parameter (G_{gr}) is the result of Equation 9.7:

$$G_{gr} = C_{AW} \cdot \frac{F_{gr}}{A_{AW}} \cdot m_{AW} \quad (9.7)$$

The volumetric concentration of sediment transport (c_G) as a mass flux per unit mass flow rate can be calculated with Equation 9.8:

$$c_G = \frac{G_{gr} \cdot \frac{\rho_S}{\rho_F} \cdot d_{ch,k}}{Y \cdot \frac{v_0^*}{v_m} \cdot n_{AW}} \quad (9.8)$$

The resultant mass of transported solids (m_S) related to a certain width and certain time is the result of Equation 9.9:

$$m_S = c_G \cdot Y \cdot v_m \cdot \rho_F \quad (9.9)$$

Sediment transport equations are used in various software to facilitate designer to estimate bed movements during flood event. Hydrodynamic modelling is part of the ingredients to achieve accurate analysis following the flood stage (unsteady flow). Models that comply these requirements induce better results and avoid cases of over design or under design. Each particular formula presented earlier has been widely used in various part of the world. Designers should choose carefully the formula that will suit a particular case and correlate it to the actual event through proper calibration using available data.

In practice, only hydrological hydrographs, flow profiles or flood plain levels are used for calibration exercises. Data from hydrographs and starting water levels are used to set the initial conditions while bed profile data and cross sections are used for boundary conditions setup. Existing technology allows for flood stage combining water and sediment movements (two phase motions) for flood profile analysis.

9.5 COMPUTER MODELS FOR SEDIMENT TRANSPORT ANALYSIS

9.5.1 HEC-RAS 4.0

HEC-RAS is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and deposition over moderate time periods. It uses a sequence of steady flow to represent discharge hydrographs. The movable bed is constrained within the limits of the wetted perimeter and the entire wetted part of the cross section is normally moved uniformly up or down (USACE, 1993).

The model is appropriate for one-dimensional, gradually varied and steady flow simulation. For a given flow, the standard steps for the equations are applied to compute system hydraulics for the entire reach. Following the step, sediment transport is computed from cross-section to cross-section, with gains or losses to the transported sediment.

HEC-RAS can be applied over long segments of rivers, ranging from 16 km to more than 160 km. Sediment deposition in reservoirs has also been evaluated using the program. However, HEC-RAS does not allow for modelling sedimentation in floodplain areas, lateral variations in channel deposition or erosion, or bankline migration.

9.5.2 SED2D

The SED2D program (USACE, 2000a) is an extensively rewritten and modernized version of the Sediment Transport in Unsteady, 2-Dimensional Flow, Horizontal Plane program (STUDH). STUDH, now SED2D, is the sediment module for the WES TABS-MD modelling system. SED2D can be used as a one- or two-dimensional model to analyze steady state or dynamic flow situations. The program can determine the exchange of material between the moving water and the stream bed. Bed shear stress due to currents or shear stress due to combined currents and wind waves can be calculated. Both clay and sand can be analyzed, but only a single effective grain size can be used during each simulation. Thus, separate simulations are needed for each effective grain size.

The program does not compute water surface elevations or velocities. These values are usually computed externally using the RMA2 program. SED2D may be applied to clay-bed or sand-bed streams where the velocities are two-dimensional in the horizontal plane (depth-average velocity). It is typically used in sediment scour, transport, and deposition studies near major obstructions to river flow, such as navigation dams or bridge crossing. SED2D permits the evaluation of complex river and reservoir geometry and has good output-visualization graphics.

9.5.3 FLUVIAL-12

The FLUVIAL-12 model (Chang, 1998) is a loose boundary 2D modelling. The modelling will involve simulation of the river bed and cross section. From the results of the modelling will identify stretches prone to meandering, river extra protection, and also changes in alluvial river geometry in terms of aggradations and degradation as well as lateral channel migration.

9.5.4 GSTARS 2.0

GSTARS 2.0 is a quasi-two-dimensional model that utilizes a stream tube approach to accommodate differential scour and deposition over the width of a cross section (Yang et al., 1998). Stream tubes are conceptual tube-like surfaces whose walls are defined by streamlines, imaginary lines which show the direction and magnitude of velocity as the tangent at every point along the line, at each instant in time. In GSTARS, hydraulic parameters and sediment routing computations are made for each stream tube, allowing the position and width of each stream tube to change. In this way, vertical and lateral variations in cross sectional elevation can be simulated. The governing equations are largely similar between HEC-RAS and GSTARS, except that GSTARS incorporates the momentum equation in backwater computations when the flow regime changes from subcritical to supercritical or vice versa. Input for GSTARS is similar to HEC-RAS, but offers a broader range of options with very few default choices built into the model.

9.5.5 RMA2

RMA2 is a two-dimensional finite element model that computes water-surface elevations and depth-averaged horizontal velocity components for free-surface turbulent flow. RMA2 is a numerical model that divides the flow domain into discrete but not necessarily uniform elements. The model uses iterative numerical approximation techniques to approach a convergent solution to the nonlinear mathematical expressions that describe two-dimensional flow. Numerical models of this type are based on a vertically-integrated form of the full three-dimensional Reynolds-averaged Navier-Stokes equations for turbulent flow. Input includes channel geometry used to build the finite element mesh; material properties and boundary conditions (eddy viscosity and roughness coefficient) for each element; and water-surface elevations calculated using HEC-RAS.

9.5.6 Other Software

Software like InfoWorks RS and MIKE 11 also provide good analytical tools for flood stage and sediment transport analysis. The software is designed for big river system covering hundreds of kilometres in length. The combination of both analysis (flood and sediment transport) should give better results for design of flood mitigation systems.

9.6 SILTATION AND SEDIMENTATION ON DIFFERENT CATCHMENTS CONDITIONS

Sediment production from the different land uses in the watershed can be estimated using a variety of techniques and references (Table 9.4). These coefficients typically represent the average annual fine sediment delivered by a stormwater conveyance system to an outlet point downstream of the land-use being measured. These outlets almost invariably maintain a direct channel to the natural stream network and so storage is negligible and delivery approaches 100%. It is difficult to discern the upland processes responsible for sediment production in these types of studies as the values represent cumulative sediment production from all upland activities.

Table 9.4 Methods Used to Calculate Sediment Production from Various Land Uses/Activities

Land-use Category	Sediment Production Element	Method	Value Used
Urban	Low density residential	TSS yield coefficient	50 kg ha ⁻¹ yr ⁻¹
	Moderate density residential	TSS yield coefficient	322 kg ha ⁻¹ yr ⁻¹
	High density residential	TSS yield coefficient	350 kg ha ⁻¹ yr ⁻¹
	Commercial	TSS yield coefficient	805 kg ha ⁻¹ yr ⁻¹
	Hatchery	Unit area discharge	Variable
Agriculture	Surface erosion	USLE	Variable
Forest/timber	Landslides	Matrix	Variable
	Soil creep	Creep rate	1 mm yr ⁻¹ over 0.25 m soil depth
Construction	Surface erosion	TSS yield coefficient	97 tonnes km ⁻² yr ⁻²
Landfill	Surface erosion	Unit area erosion	Variable
Quarry	Surface erosion	Unit area erosion	162 tonnes km ⁻² yr ⁻¹
Channel bank erosion	Enlargement	Regression analysis	Variable
Road surface erosion	Paved roads	TSS yield coefficient	50 kg ha ⁻¹ yr ⁻¹
	Gravel roads	TSS yield coefficient	97 tonnes km ⁻¹ yr ⁻¹
	Forest roads	TSS yield coefficient	97 tonnes km ⁻¹ yr ⁻¹

Sedimentation is the direct result of the loss (erosion) of sediments from other aquatic areas or land-based areas such as agriculture, forestry, construction, urbanization and recreation. Sedimentation in one area is linked to erosion or impoverishment in another area and is a natural process of all water bodies (i.e., lakes, rivers, estuaries, coastal zones, and even the deep ocean). The sedimentation activities on land-based conditions are discussed as follows:

9.6.1 Urban Land

TSS pollutant yield coefficients are often used for several of the urban sub-categories. The TSS pollutant yield coefficients are used to estimate sediment production from residential and commercial development. This includes sediment produced from all activities in those developments such as atmospheric deposition, road-surface erosion, and park and playground erosion. In newer subdivisions, stormwater retention/detention facilities may remove some fraction of the sediment that may otherwise be transported to receiving waters. The same pollutant yield coefficients can be applied to all residential land.

A number of sediment-producing processes are initiated or modified by urban activity. These include construction site erosion, road-surface erosion, and channel-bank erosion.

9.6.2 Forested Land

Small and forested channels are defined as ones in which morphology and hydraulics may be significantly influenced by individual clasts or wood materials in the channel. Such channels are headwater channels in close proximity to sediment sources so they reflect a mix of hillslope and channel processes. Sediment inputs are derived directly from adjacent hillslopes and from the channel banks. Morphologically significant sediments move mainly as bed load, mainly at low intensity and there is no standard method for measurement.

The larger clastic and woody elements in the channel form persistent structures that trap significant volumes of sediment, reducing sediment transport in the short term and substantially increasing channel stability. The presence of such structures makes modelling of sediment flux in these channels difficult. Reach scale and channel unit scale morphologies are categorized. A "disturbance cascade" is introduced to focus attention on sediment transfers through the slope channel system and to identify management practices that affect sediment dynamics and consequent channel morphology.

The dominant erosion processes in the forested region of the watershed are soil creep and landslides.

9.6.2.1 Soil Creep

Soil creep is calculated only for those slopes immediately adjacent to the channel network, where an intervening floodplain is absent. Although soil creep occurs on all slopes, it can be assumed that the delivery of soil creep from areas not immediately adjacent to channels could be neglected because its delivery rate into channels is inconsequential. Additionally, creep along channels with established floodplains are not included in the calculations because soil creep cannot be separated from channel-bank erosion. Soil creep into roadside ditches can be neglected if measured road-surface erosion rate coefficients can be obtained for this process.

9.6.2.2 Landslides

Landslides inventory can be made by evaluating conditions along several representative tributary streams where sediment delivery is nearly equivalent to sediment production. Landslide volumes can be based on length, depth and width measurements of observed landslide scars adjacent to the channels. The slides can be classified into three age categories estimated from vegetative growth:

- <5 yr - characterized by fresh scars and little or no vegetation;
- 5–10 yr - characterized by sparse vegetation consisting of sword ferns, moss, and salmonberries;
- 10–20 yr - characterized by moderately dense vegetation consisting of small alders, salmonberries, and ferns. Little or no bare dirt is present.

Delivery ratios (defined as the amount of sediment delivered by the landslide to adjacent channels) can be assigned for the three different landslide-size categories base on field estimates of original landslide volume and amount of sediment delivered to the channel as shown in Table 9.5 below.

Table 9.5 Delivery Ratios Categories

Landslide volume (m3)	Delivery ratio (%)
28	10
28-256	85
>256	65

Large landslides can be readily identified on aerial photographs available at scales ranging from 1:4800 to 1:200,000.

Landslides can be in a variety of field settings including densely forested conditions and adjacent to clear cut areas. There is no obvious correlation between observed landslide frequency and proximity to recent logging activities.

Figure 9.12 shows another way to obtain the sediment delivery ratio from any catchment in Malaysia. The total eroded sediments calculated using any erosion analysis model (USLE, RUSLE or MUSLE) should be multiplied with the indicated values.

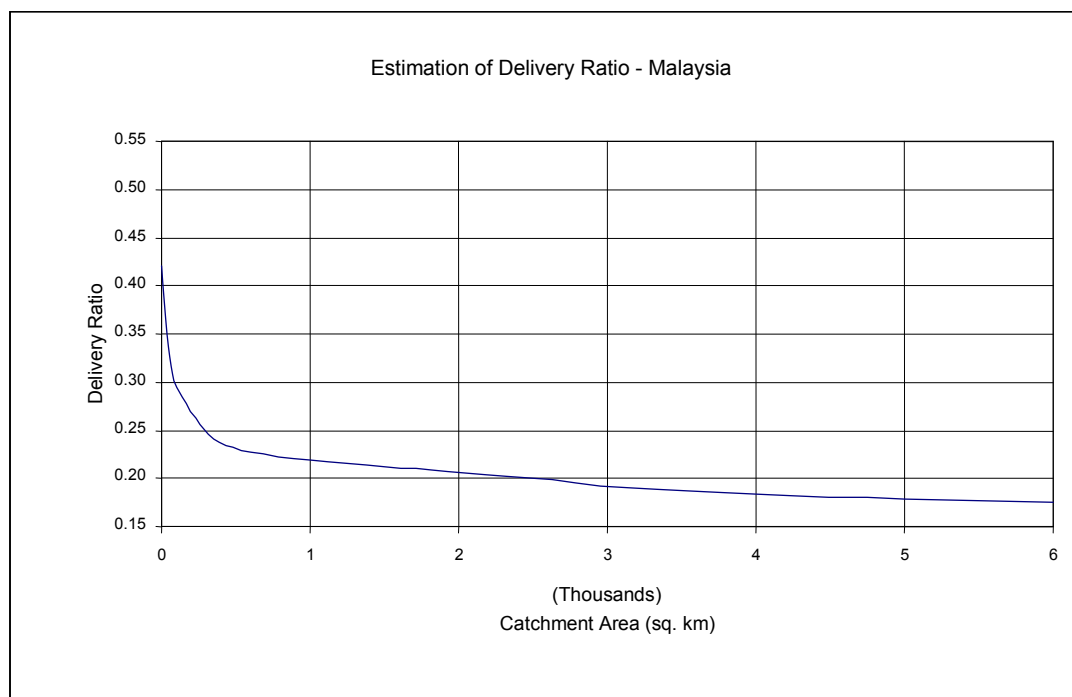


Figure 9.12 Relationship of Delivery Ratio and Catchment Area

9.6.3 Agriculture Area

Sediment production from agricultural property can be calculated using the universal soil loss equation (USLE) which incorporates rainfall, soil erodibility, vegetation, and topography. Data to determine variables in the USLE can be obtained from the Department of Agriculture and field observations of vegetative cover. This approach will tend to overestimate the contribution of this source to sediment loads, because typical reported delivery ratios are only about 10–50%.

9.6.4 Mud Flood

Mudfloods and mudflow are considered a subset of landslides and affect many of the nation's floodplains. The National Academy of Sciences (National Research Council, 1985) has defined mudflood and mudflow as follows:

- **Mudfloods:** Refers to a flood in which the water carries heavy loads of sediment (as much as 50% by volume) including coarse debris. Mudfloods typically occur in drainage channels and on alluvial lands adjacent to mountainous areas although they may occur on floodplains as well.

- **Mudflow:** Refers to a specific subset of landslides where the dominant transporting mechanism is that of a flow having sufficient viscosity to support large boulders within a matrix of smaller sized particles. Mudflows may be confined to drainage channels or may occur on unconfined on hill slopes.

Mudflows and mudfloods are often the result of rain falling on terrain that has been denuded by forest fires and brush fires and thus cannot retain runoff. In areas where ground cover has been removed, even small rains can cause mudflows and mudfloods. Steep lands with an identifiable subsoil layer of clay could break loose and start a mudflow when the clay layer becomes saturated. The most common mudflow resulting from slope failure in forested lands occurs about five to ten years after a major forest fire where established timber is killed. During the following years new growth is established. However, roots from the previous growth have deteriorated and the new roots are not strong enough to hold the soil from moving, thus starting a mudflow.

Both mudflows and mudfloods start with moving water or a stationary mass of saturated soil. Mudfloods usually originate as sheet flow or as water flowing in drainage channels, rivers or streams, and pick up sediment and debris as they flow. Mudflows often originate as a mixture of stationary soil and water. When the mixture gets wet enough, it begins to move as a mass, either as a result of gravity or when triggered by an earthquake or sudden flow of debris laden water. Mudflows may also begin as clear-water flows but incorporate sediments and other debris from the stream channel or banks and "bulk up" to flows much larger than the clear-water flow before eventually dropping the debris and attenuating. Mudflows may travel many miles from their source.

Mudflows and mudfloods may cause more severe damage than clear water flooding due to the force of the debris-filled water and the combination of debris and sediment. The force of the water often destroys pilings and other protective works, as well as structures in its path (or when structures remain intact, sediment must often be physically removed with shovels or hoses). Mud and debris may also fill drainage channels and sediment basins, causing floodwater to suddenly inundate areas outside of the floodplain.

9.6.5 Control of Sand Mining

The use of streambeds as a source of sand for the construction industry is a long time practice. Sand mining reduces the sediment loading in the river system. This can induce significant changes. Bridges may fail after such pits are opened at their vicinity. Therefore such operations should be carefully evaluated prior to their approval.

There are no general guidelines established to govern removal quantities and rates. If the stream is not aggrading, then the removal rate and quantity should not be more than the average annual yield of the size class being removed. When there is excess material in the river, the removal rate could conceivably be increased thereby alleviating deposition downstream of the mining area.

The impact of mining on a river system occurs on both upstream and downstream of the mining point. The most common effect upstream is general degradation with resultant bank failure and channel widening. Such degradation can also cause bed level lowering on the main stream which in turn can induce general degradation up to the tributary rivers in general and also affects bridges and other river structures that should be ascertained.

Scour has also been observed downstream from some channel mining operations. This is because the mining pit traps much of the inflowing bed material sediment load that the water flowing out of the pit is deficient of sediment. This sediment-starved water removes bed material from the channel and causes a general lowering of the river bed.

The river maintenance strategy can be formulated with the following procedure:

- a) If a river reach is badly silted and under capacity, a desilting or dredging operation can first be undertaken to get the channel to its required levels and sections.
- b) If aggradation occurs, control sand mining operation can be initiated. Sediment traps can be constructed upstream of the reach and planned for regular removal. This method is especially useful for avoiding massive desilting operation for rivers passing through urban centres because such operation is not only costly but also disruptive to traffic and the river beautification works on its banks.
- c) Regular surveillance of the river course should be carried out such that the quantity and rates of sediment removal can be regulated.

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10 DESIGN CRITERIA AND DESIGN CONSIDERATIONS

10.1 INTRODUCTION

The underlying principle of any design is that “the design is to fit a purpose”. “Purpose” in this context differs from “objective”. An objective of the flood mitigation project is to alleviate flood damages. Achieving this objective may not require any form of design if, say, the solution is to resettle the affected community of non-flood prone areas. “Purpose” in the context of the design principle refers to the expected function and performance of structure designed. This also implies that the design will fail if it is not designed for a particular purpose. For example, if the flood mitigation system is designed for a 1:100 year ARI (the purpose) it must be able to cope with that condition when it happens. If the more than 1:100 year ARI occurs, then the design is “expected” to fail. Similarly, take an example of a component of the system, say a retaining wall. The purpose of the retaining wall is to retain the earth behind it as well as to carry specified working loads on the retained earth under all weather and the specified river flow conditions. If that load is exceeded or flow conditions exceed the specification, again the design is expected to fail. Another example of purpose is in terms of time i.e. temporary or permanent structure. Some flood mitigation structures or facilities are installed as temporary measures (e.g. pumps) until such time the permanent solutions are installed. However, economic and logistics issues sometimes force these to remain over a very long time or beyond that is normal for “temporary”.

Such designs are also expected to fail when conditions exceed their purpose. These failures are not due to errors in design, but a mishap of purpose. These “expected failures” should also be carefully considered in the total design approach. This is the “design for failure fail” approach and this should be based on the situation that if and when it fails, it should fail gradually and with visible indications so that the community will have time to brace itself and take necessary actions to save themselves and their properties. One method applied in dams and channels are the provision of emergency spillways and “fuse-plugs” at suitable locations. When these structures overflow, it will alert operators and nearby community of the impending danger. This “design for failure” approach should also be considered as criteria for all flood mitigation designs.

10.2 CRITERIA AND LOCAL PRACTICES

In fitting the purpose, the design of a structure must meet a set of criteria throughout its designed life. Design criteria normally refer to quantitative technical requirements that must be met in the final design. However, in a general sense, criteria in flood management system design often cover general requirements and standard practices as well. In this respect, criteria will be mainly for those already established for geotechnical and structural designs. These are in the form of Standards, Codes of Practice and Guidelines. These are standards set by authorised institutions. In Malaysia this set by SIRIM and the reference standards containing the criteria are known as Malaysian Standard (MS). In practice, Standards from other countries are also applied here in Malaysia and these usually are those of the British, American and Australian Standards.

Not all aspects or components of flood mitigation design have standard criteria. In such cases the design criteria is based on the accepted practice of leading authorities in the country. These include the DID for flood mitigation, the JKR for roads and bridges, the Water Supply Departments for water supply systems and components and the Sewerage Department for sewerage systems. These institutions produce guidelines for use by developers, contractors and consultants involved in the respective industry.

For flood mitigation design in Malaysia, the recommended sources of reference for criteria and requirements from the DID are as follows:

- DID Manual
- DID Terms of References for Flood Mitigation Projects
- *Manual Saliran Mesra Alam* (MASMA, 2000)
- Masterplans for Flood Mitigation Schemes
- Flood Mitigation Study Reports

10.3 FLOOD MITIGATION SYSTEM DESIGN CRITERIA

There are no formal design criteria for flood mitigation system. The reason is that there are too many variables to consider and therefore would be impractical to develop and specify criteria for the design. The major variables are also time-based and location specific. For example, the ARI is based on historical data available at the time of the design. The value adopted for a particular design will change over time when more data are collected. For location, local constraints such as lack of available lands or for social and economic consideration, pre-determined design criteria may not be feasible without pre-design studies. Therefore the current practice is to specify flood mitigation design criteria on a project-by-project basis.

The normal design criteria for flood mitigation projects are shown below:

- Regional systems and for highly populated urban areas (cities) 1:100 years ARI.
- Local systems less than 100 ha and with main channels flowing into regional system, 1:50 years ARI.
- Urban areas within agriculture areas 1:20 to 1:50 ARI.

Whilst these are often specified and complied with, there are also cases when they cannot be met. The reasons for this are many. Usually they are due to social and economic reasons. In some heavily populated areas, the community resistance is too high to implement the system design for the specified criteria. Even when the community agrees, the economic situation at that point in time and budgetary constraints can force the criteria to be compromised. In such cases, the system design criteria will have to be lower than that specified. In these cases the design is also expected to be checked for the condition for the specified criteria. For example, the initial system design criteria may be set at 1:100 years ARI but this has to be lowered to 1:50 years ARI due to socio-economic reasons. Having designed the system for this new criterion, the system is then checked for impact based on the 1:100 years ARI. If results show that the impact is still substantial, then an added design criterion would be for the system to be complemented by a local flood warning system and safety provisions for conditions beyond the purpose of the design.

There are other design criteria for a flood mitigation system. These are more specific to the components of the system and are sometimes more in the form of requirements than quantified parameters. However, all designs shall conform to the relevant Malaysian Standards and where this are not available, the equivalent Standards of other countries shall be applied but subject to approval from the DID.

New design criteria that are expected to be introduced in the near future are those in relation to Green Technology for energy savings and considerations for climate change impacts.

The major components of a flood mitigation system are:

- a) The conveyance channel or rivers.
- b) Bunds.
- c) Access and maintenance roads.
- d) Bridges and crossings.
- e) Earth Retaining structures.
- f) Flow control structures.
- g) Dams and reservoirs.
- h) Mechanical components - gates and pumps.

10.3.1 Conveyance channels and rivers

- a) The primary design criteria for river and channel improvement works is the limiting flow velocities. For earth lined channels this is usually limited to a maximum of 2 m/s.
- b) For section design, vertical concrete faced sections are to be avoided. The preferred section should be near natural with environmentally friendly slope protection materials.
- c) The slope stability shall be design for a Factor of Safety of 2.
- d) The design shall also allow for operations and maintenance access. These can either be provided with maintenance roads on the river and channel banks. The width of these roads shall be a minimum of 3.5 m. If this is not possible, then access ramps shall be provided at suitable locations for machinery to go down to the river bed.
- e) The channels shall be designed with adequate flow freeboard. This shall be calculated using approved methodology. The minimum freeboard shall be 0.3 m above the design flow level.
- f) Where conditions above the design level can affect large populations or critical installations, flood and bund protection spillways shall be provided at suitable locations.
- g) If necessary, there shall also be provisions of space for temporary stockpile of excavated materials removed during river and channel bed maintenance.

10.3.2 Bunds

- a) Bunds shall be designed for a minimum Factor of Safety of 2.
- b) The minimum top width shall be 3.5 m to allow for operation and maintenance machinery and traffic.
- c) Overflow spillways shall be provided at appropriate location to protect bund failures for flows beyond the design flow.

10.3.3 Access and maintenance roads

- a) Access and maintenance roads shall be designed for 20 ton machinery load.
- b) Then minimum width shall be 3 m but a 3.5 m width is preferred wherever possible.

10.3.4 Bridges and crossings

- a) All bridges and crossings shall be designed to allow for the design flow.
- b) The minimum freeboard (clearance) at the design flow level shall be 0.3 m. Where floating logs are expected, this minimum clearance shall be 1 m.
- c) There shall be no piers or (vertical wall of culverts) in the middle of the river cross-section.
- d) For multiple box culverts, twin box culverts should be avoided and instead to use triple box culvert with the centre box in line with the mid-flow section of the river or channel.
- e) All bridges shall be studied for scour effects.
- f) All utility attachments shall also conform to the above criteria, where relevant.

10.3.5 Earth retaining structures

- a) Earth retaining structures shall be designed for a minimum Factor of Safety of 2.0.
- b) Special consideration shall be required to prevent differential settlement between individual units of the structure (for precast L-Shaped sections, mattress-types).

10.3.6 Flow control structures

- a) Flow control structures shall be provided with a minimum freeboard of 0.3 m.
- b) The design shall allow for ease of maintenance.
- c) It shall also be design with consideration of safety for operation and maintenance personnel during normal and flood conditions as well as the public.

10.3.7 Dams and reservoirs

- a) Dams shall be designed for ARI 1:100 years and checked for PMP and PMF conditions.
- b) The design shall also include dam-break study.
- c) It shall also provide storage allowances for water supply use.
- d) There shall also be allowances for downstream river maintenance flow especially during the dry seasons.
- e) Where necessary, the design shall also allow for public recreation facilities.

For small reservoirs and/or small basins, CDA (1999) provides the following guidelines for establishing freeboard:

- Wave conditions and set-up due to a wind with a 1/1000 Annual Exceedance Probability (AEP) with the reservoir at its maximum normal level.
- Wave conditions and set-up due to 1/100 AEP maximum annual wind with the reservoir at its maximum extreme level based on the selected IDF.

For small, low consequence dams, the above CDA (1999) guidelines may be overly conservative particularly where the dam is being designed for an IDF that has a higher AEP (e.g. 1:100 year flood) than the wind event indicated by CDA (1999). In such cases, it may be appropriate to consider the following criteria for establishing freeboard or small, low consequence dams:

- Wave conditions and set-up due to a wind with an AEP equal to that of the IDF, to a maximum of 1/1000, with the reservoir at its maximum normal level.
- Wave conditions and set-up due to a wind with a ½ AEP wind or a minimum of 0.3 m with the reservoir at its maximum extreme level based on the selected IDF. The lesser value may be adopted where other factors, such as the IDF, are deemed to be quite conservative.

10.4 DESIGN CONSIDERATIONS

The following sections outline some of the considerations of selected aspects of the system and components of a flood mitigation design.

10.4.1 Flood Control Dam

10.4.1.1 Introduction

This section provides general design criteria and design considerations of flood control dam.

10.4.1.2 Types of Dams

Figure 10.1 illustrates the basic types of dams, classified on the basis of the type and materials of construction. This figure illustrates gravity dams, arch dams, buttress dams, and embankment dams. Dams can also be classified according to use or hydraulic design.


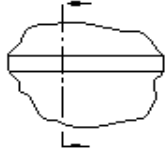

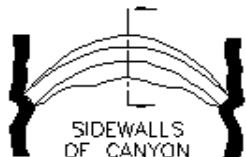
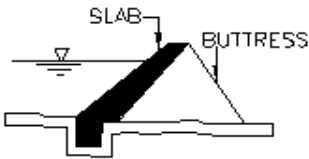
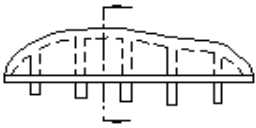
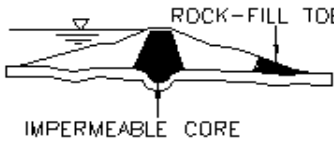
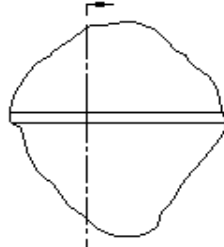
TYPE	MATERIAL OF CONSTRUCTION	TYPICAL CROSS-SECTION	PLAN VIEW
GRAVITY	CONCRETE, RUBBLE MASONRY		
ARCH	CONCRETE		
BUTTRESS	CONCRETE (ALSO TIMBER AND STEEL)		
EMBANKMENT	EARTH OR ROCK		

Figure 10.1 Basic Types of Dams (Lindsley et al., 1992)

a) Earthfilled Dams - the construction of earthfilled dams is:

i) Homogenous Dams

Homogenous dams are composed of only one kind of material (excluding the slope protection). The material used must be impervious enough to provide an adequate water barrier and the slope must be relatively flat for stability. Figure 10.2 illustrates the seepage through a completely homogenous dam. It is more common today to build modified homogenous sections in which pervious materials are placed to control steeper slopes. Three methods are used namely rockfilled toe, horizontal drainage blanket, and inclined filter drain with a horizontal drainage blanket, as illustrated in Figure 10.3. Pipe drains are also used for drainage on small dams in conjunction with a horizontal drainage blanket or a pervious zone.

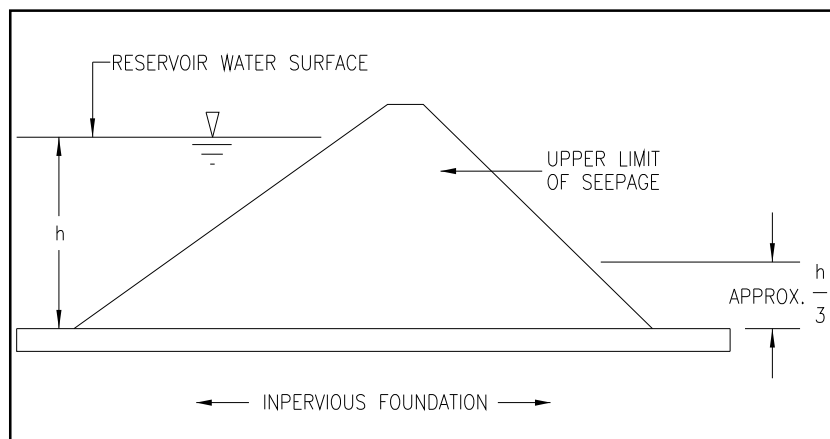


Figure 10.2 Seepage through a Completely Homogeneous Dam (from U.S/ Bureau of Reclamation, 1987)

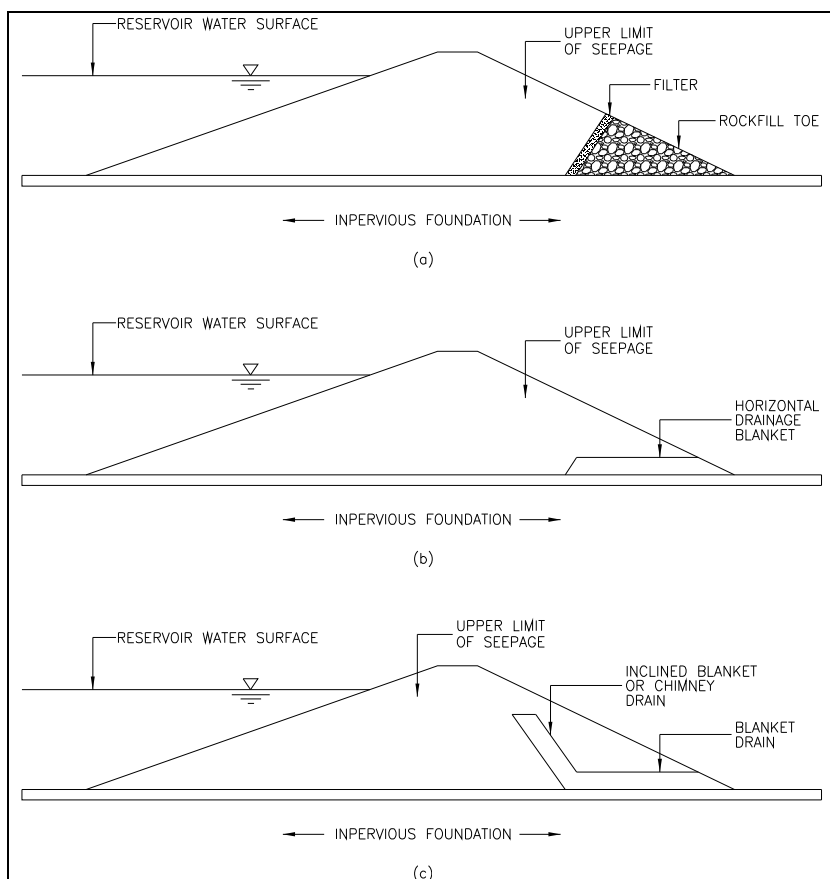


Figure 10.3 Seepage through Modified Homogeneous Dams: a) With Rockfilled Toe; (b) With Horizontal Drainage Blanket; (c) With Chimney Drain (from U.S. Bureau of Reclamation, 1987)

ii) Diaphragm Dams

For diaphragm-type earthfilled dams, the embankment is constructed of pervious materials (sand, gravel, or rock). A thin diaphragm of impermeable material is used to form a water barrier. The diaphragm may vary from a blanket on the upstream face to a central vertical core. Diaphragms may consist of earth, Portland cement concrete, bituminous concrete or other materials.

iii) Zoned embankment-type

Zoned embankment-type earthfilled dams have a central impervious core that is flanked by a zone of materials considerably more pervious, called shells. These shells enclose, support and protect the impervious core. Figure 10.4 illustrates the size range of impervious cores used in zoned embankments.

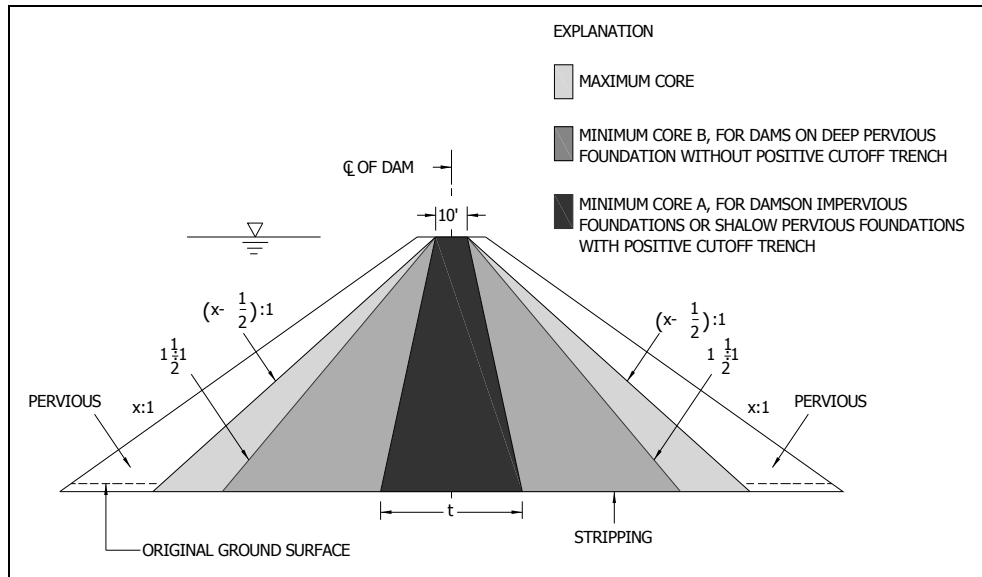


Figure 10.4 Size Range of Impervious Cores Used in Zoned Embankments (from U.S. Bureau of Reclamation, 1987)

c) Rockfilled Dams

The other type of embankment dam is the rockfilled dam that comprises rock of all sizes to provide stability and an impervious core membrane. Membranes include an upstream facing of impervious soil, a concrete slab, asphaltic concrete paving, steel plates, other impervious soil (U.S. Bureau of Reclamation, 1987). Figure 10.5 illustrates the typical maximum section of an earth core rockfilled dam using a central core. Figure 10.6 illustrates a decked rockfilled dam that has an asphaltic concrete membrane on the upstream face.

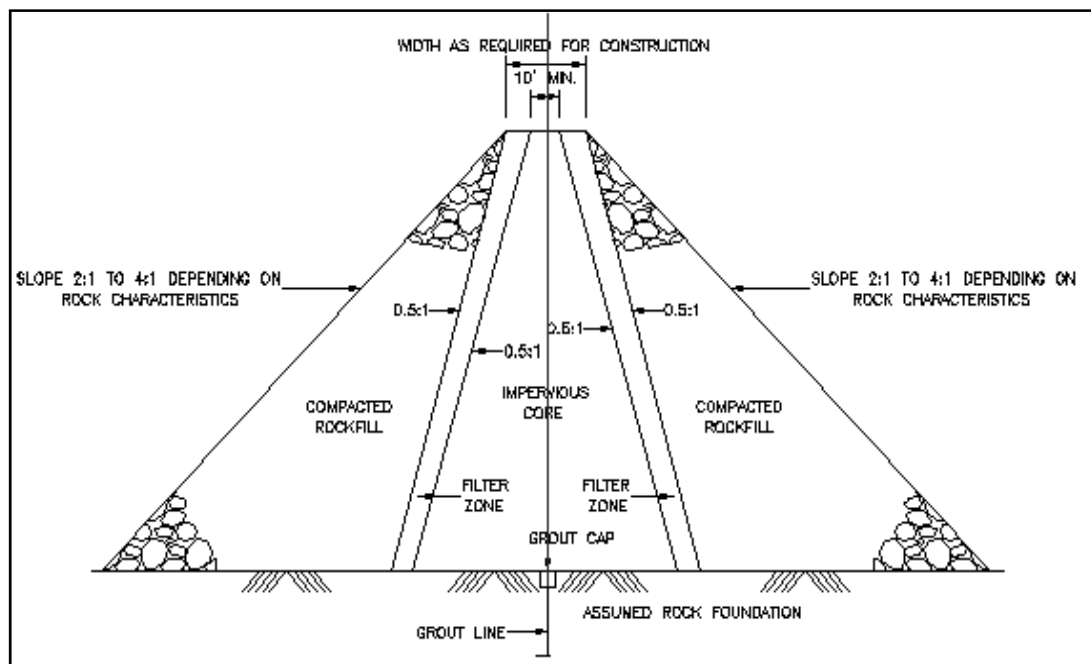


Figure 10.5 Typical Maximum Section of an Earth-Core Rockfilled Dam Using a Central Core (from U.S. Bureau of Reclamation, 1987)

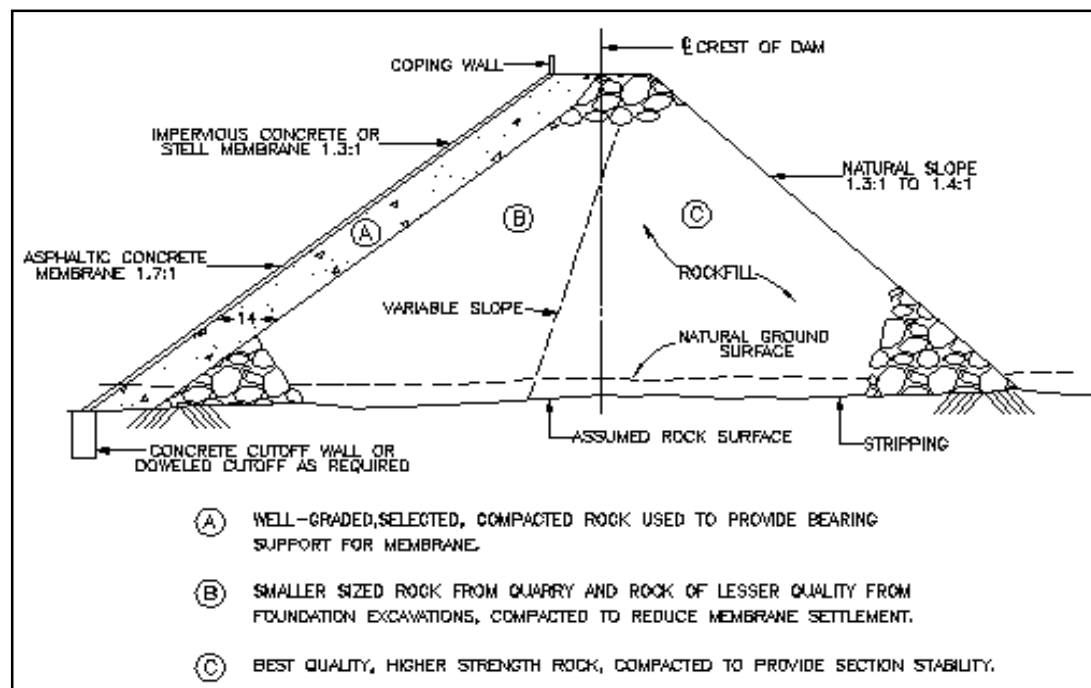


Figure 10.6 Typical Maximum Section of a Decked Rockfilled Dam (from U.S. Bureau of Reclamation, 1987)

d) Concrete Arch Dams

Concrete arch dams are used where the ratio of the width between abutments to the height is not great and where there is solid rock capable of resisting arch thrust at the abutment (foundation). Arch dams can be either single- or multiple-arch dams.

e) Concrete Buttress Dams

Concrete buttress dams consist of flat deck and multiple arch structures.

10.4.1.3 Hazard Classification of Dams

Many systems have been developed for the hazards classification of dams relating to hydrologic and seismic events (NRC, 1985). Most of these systems use dam height, volume of water impounded, and probable effects of dam failure due to the downstream for categorization. The classifications used by the U. S. Army Corps of Engineers (1982) are shown in Table 10.1.

Table 10.1 Terms for Classifying Hazard Potentials

Category	Impoundment (sq-m)	Dam Height (m)
Size of dam ^a		
Small	4.65 to 92.9	7.62 to 12.19
Intermediate	92.9 to 4645	12.19 to 30.48
Large	Over 4645	Over 30.48
Category <i>Hazard potential classification</i>	Loss of Life (Extent of Development)	Economic Loss
Low	None expected (no permanent structures for human habitation)	Minimal (undeveloped to occasional structures or agriculture)
Significant	Few (no urban development and no more than a small number of inhabitable structures)	Appreciable (notable agriculture, industry, or structures)
High	More than	Excessive (extensive community, industry, or structures)

^aCriterion that places project in largest category governs.

Source: National Research Council (1985).

The U.S. Army Corps of Engineers' (1991) policy for dam safety evaluation is that "a dam failure must not present a hazard to human life..." Dam safety evaluation must:

- Formulate any reservoir plan to comply with this safety requirement and
- Evaluate the impact of catastrophic failure of any proposed reservoir plan to confirm that their performance constraint is satisfied. The four design standards, which depend on the type of dam and risk to life, are described in Table 10.2 discusses the method for failure evaluation.

Table 10.2 Functional Design Standards for New Dams Designed by U.S. Army Corps of Engineers

<i>Standard 1:</i>	Design dam and spillway large enough to assure that the dam will not be overtopped by floods up to probable maximum categories.
<i>Standard 2:</i>	Design the dam and appurtenances so that the structure can be overtopped without failing and, insofar as practicable, without suffering serious damage.
<i>Standard 3:</i>	Design the dam and appurtenances in such a manner as to assure that breaching of the structure from overtopping would occur at a relatively gradual rate, such that the rate and magnitude of increase in flood stages downstream would be within acceptable limits, and that damage to the dam itself would be located where it could be most economically repaired.
<i>Standard 4:</i>	Keep the dam low enough and storage impoundment small enough that no serious hazard would exist downstream in the event of breaching, and so that repairs to the dam would be relatively inexpensive and simple to accomplish.

10.4.2 Design Criteria for Detention Pond

The general design requirements for detention ponds are:

- The side slope on the inside of the pond embankment cannot be greater than 1:2;
- The side slope on the outside of the pond embankment cannot be greater than 1:3;
- The crest of the pond embankment should be 3.05 meters wide to accommodate a vehicle;
- The soil used to construct the pond embankment must be compacted;
- The pond embankment must have spillway that is not placed on compacted material (if possible);
- Side slopes of the pond embankment must be protected from erosion;
- The water level must be at least 0.33 meters below the crest of the pond embankment;

For further details, refer to MSMA, Chapter 20 (Community and Regional Pond Design)

10.4.3 Design of Bunds

Design Criteria.

- Adequate design and operation and maintenance systems of bund should be in place to provide reasonable assurance that protection from the base flood exists must be provided. The following requirements must be met:

a) *Freeboard.*

- Riverine bunds (bunds) must provide a minimum freeboard of 1 m (3 feet) above the water-surface level of the base flood. An additional one foot above the minimum is required within 30.5 m in either side of the structures (such as bridges) riverward of the bund or where ever flood is constricted. An additional one- half foot above of the minimum at the upstream end of the bund, is also required.
- Particular emphasis must be placed on the effects of wave attack and overtopping on the stability of the bund. Under no circumstances, however, will a freeboard of less than 0.6 m (2 feet) above the 100-year surge elevation be accepted.

b) *Embankment Protection.*

Engineering analyses submitted must demonstrate that no appreciable erosion of the bund embankment can be expected during the base flood as a result of either currents or waves. Also that any anticipated erosion will not result in failure of the bund embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability. The factors to be addressed in such analyses include, but are not limited to are expected flow velocities (especially in constricted areas), expected wind and wave action, impacts of debris, slope protection techniques, duration of flooding at various stage and velocities, embankment and foundation materials, bund alignment, bends, and transitions and bund side slope.

c) *Embankment and Foundation Stability.*

Engineering analyses that evaluate bund embankment stability must be submitted. The analyses provided shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the bund foundation and embankment will not jeopardize embankment or foundation stability. An alternative analysis demonstrating that the bund is designed and constructed for stability against loading conditions for Case IV as defined in the U.S. Army Corps of Engineers (COE) manual. "Design and Construction of Bunds" (EM 1110-2-1913, chapter 6, Section II), may be used. The factors that shall be addressed in the analyses include: Depth of flooding, duration of flooding, embankment geometry and length of seepage path at critical location, embankment and foundation materials, embankment compaction, penetrations, other design factors affecting seepage (such as drainage layer) and other design factors affecting embankment and foundation stability (such as berms).

d) *Settlement.*

Engineering analyses must be submitted that assess the potential magnitude of future losses and freeboard as a result of bund settlement and demonstrate that freeboard will be maintained within the minimum standards. This analysis must address embankment loads, compressibility of embankment soils, compressibility of foundation soils, age of soils used in bund system and construction compaction methods. In addition detailed settlement analysis using procedures such as those described in the COE manual "Soil Mechanics Design-Settlement Analysis" (EM1100-2-1904) must be submitted.

Table 10.3 Major and Minimum Requirements

Step	Procedure
1	Conduct geological study based on a thorough review of available data including analysis of aerial photographs, initiate preliminary subsurface explorations.
2	Analyse preliminary exploration data and from analysis establish preliminary soil profiles, borrow locations and embankment sections.
3	Initiate final exploration to provide: <ul style="list-style-type: none"> a) Additional information on soils profiles b) Undisturbed strengths of foundation materials c) More detailed information on borrow areas and other required excavations
4	Using the information obtained in step 3: <ul style="list-style-type: none"> a) Determined both embankment and foundation soil parameters and refine preliminary sections where needed noting all possible problem areas b) Compute rough quantities of suitable material and refine borrow area locations.
5	Divide the entire bund into reaches of similar foundation conditions, embankment height and fill material and assign a typical trial section to each reach.
6	Analyze each trial section as needed for: <ul style="list-style-type: none"> a) Under seepage and through seepage b) Slope stability c) Settlement d) Trafficability of the bund surface
7	Design special treatment to preclude any problems as determined from Step 6. Determined surfacing requirements for the bund based on its expected future use.
8	Based on the results of Step 7 establish final sections for each reach.
9	Compute final quantities needed; determine final borrow area locations.
10	Design embankment slope protection.

10.4.4 Bridges and Crossings

Bridges must be designed so as not to form a constriction to river flows. It should also not result in scour or deposition over a relatively short time that will result in the river not able to convey the design flow. The DID and Public Works Department (*Jabatan Kerja Raya*) should be consulted for approvals of all bridge design works. The following references are recommended:

- a) Hydraulics of Bridge Water Ways; Hydraulics Design Series No 1, (FHWA 1978)
- b) Highway in the River Environment (Richardson, 1988)
- c) Design Manual for Engineering Analyses of Fluvial System for the Arizona Department of Water Resources (LSA 1985)
- e) Hydraulic Analyses Locations and Design of Bridges Volume 7 (AASHTO 1987)
- f) Technical Advisory on Scour at Bridges (FHWA, 1988)

10.4.4.1 Basic Design Criteria

The bridge opening should be designed to have minimum influence on flow characteristics as much as possible.

a) Basic Criteria

Bridge openings should be designed to have as little effect on the flow characteristics as reasonable, consistent with good bridge design and economics. However, in regard to supercritical flow with a lined channel, the bridge should not affect the flow at all, that is, there should be no projections into the design water prism that could create a hydraulic jump or flow instability in form of reflecting and standing waves.

Bridge Opening Freeboard

The distance between the design flow water surface and the bottom of the bridge deck will vary from case to case. However, the debris that may be expected must receive full consideration in setting the freeboard. There are no specific rules. Each case must be studied separately. In larger waterways, streams and on rivers where large floating debris is likely, at least a 0.9 m (3-foot) freeboard during a 100-year flood should be considered.

10.4.4.2 Operation and Maintenance

A maintenance program should be established to ensure that the system functions properly. Storm water diversion systems should be inspected to remove debris within 24 hours after a significant rainfall event since heavy storms may clog or damage the system. Flow diversion structures should also be inspected annually to ensure that they meet their hydraulic design requirements. Any damage to the vegetated lining should be repaired. All debris should be removed and properly disposed of to provide adequate flow conveyance.

10.4.5 Spillways

10.4.5.1 Functions of Spillways

The functions of spillways are for storage and detention dams to release surplus water or flood water that cannot be contained in the allotted storage space. Spillways must be hydraulically and structurally adequate. They must be located to prevent the erosion and undermining of the downstream toe of a dam. Components of spillways include the following:

- *Entrance channels* convey water from the reservoir to the control structure
- *Control structures* regulate the outflow from the reservoir
- *Discharge channels* convey flow released through the control structure to the stream bed below the dam
- *Terminal structures* provide energy dissipation of the flow to prevent erosion and scour in the downstream stream bed
- *Outlet channels* convey the spillway flow from the terminal structure to the river channel below the dam

Spillway types include (U.S. Bureau of Reclamation, 1987):

- Overfall spillways
- Ogee (overflow) spillways
- Labyrinth spillways (see U.S. Bureau of Reclamation, 1987)
- Spillway chutes
- Conduit and channel spillways
- Drop inlet (shaft or morning glory)
- Baffle apron drop spillways
- Culvert spillways
- Siphon spillways

10.4.5.2 Overflow and Free-Overfall (Straight Drop) Spillways

Free overfall (straight drop) spillways allow the flow to drop freely from the crest. These types of spillways are characterised by the following (U.S. Bureau of Reclamation, 1987):

- Suited to a thin arch or crest that has a nearly vertical downstream face.
- Flows may be free discharge or may be supported along a narrow section of the crest.
- In many cases the crest is extended in the form of an overhanging lip to direct small discharge – away from the face of the overfall section.
- The underside of the nappe is ventilated to prevent a pulsating and fluctuating jet.
- A deep plunge pool will develop at the base of the overfall as a result of scour if artificial protection is not provided.
- A hydraulic jump can form on flat aprons if the tailwater has sufficient depth.
- The major hydraulic problems with free overfall spillways are the characteristics of the control and the dissipation of flow in the downstream basin.
- Flow in the downstream basin can be dissipated by three basic approaches (U.S. Bureau of Reclamation, 1987):
 - by a hydraulic jump.
 - by impact and turbulence induced by impact blocks.
 - by a slotted grating dissipater installed immediately downstream from the control.

The hydraulic control of free-overfall spillways can be sharp-crested to provide a fully contracted vertical jet, broad-crested to cause a fully suppressed jet, or even shaped to increase crest efficiency. The discharge for these types of spillway is of the form

$$Q = CLH_e^{3/2} \quad (10.1)$$

where Q is the discharge, C is the discharge coefficient, L is the effective length of the crest, and H_e is the actual head (total energy head) on the crest including the approach velocity head:

$$H_e = H + \frac{V_a^2}{2g} \quad (10.2)$$

where H is the head due to depth of water above the spillway crest and $V_a^2/2g$ is the approach velocity head.

When crest pier and abutment are shaped to cause side contraction of the flow, the effective crest length L is less than the net crest length. The effective length of the crest is determined using

$$L = L' - 2(NK_p + K_a)H_e$$

Where L' = net length of the crest, N = number of piers, K_a = abutment contraction coefficient (approximately 0.2), and K_p = pier contraction coefficient:

- For square-nosed piers with corners rounded on a radius equal to about 0.1 of the pier thickness: $K_p = 0.02$
- For round-nosed piers: $K_p = 0.01$
- For pointed-nose piers: $K_p = 0.0$

Overflow spillways can be gated or ungated and provide for flow over an arch or arch-buttress dam, wherein the flow free-falls some distance before entering a plunge-pool energy dissipator in the tail race.

10.4.5.3 Spillway Capacity Criteria

Table 10.4 compares the various spillway capacity criteria used in the United States as of 1985. These are based on the classification used for the National Dam Inspection Program. This table illustrates the diversity of criteria of various federal, state, and local government agencies, professional societies, and privately owned firms in the United States. The spillway requirements for large high-hazard dams are fairly consistent, but there are fairly widespread differences in criteria for other classes of dams. The Institution of Civil Engineers (1978) in the United Kingdom developed the standards presented in Table 10.5.

Table 10.4 Comparison of Indicated Spillway Capacity Criteria in Used or Proposed by Federal Agencies

Federal Agencies	Hazard Class High				Hazard Class High			Hazard Class High	
	Size of Dam				Size of Dam			Size of Dam	
	Large	Large	Mediate	Small	Large	Large	Mediate	Mediate	Small
Ad Hoc	PMF	PMF	PMF	PMF	PMF	PMF	•	•	•
ICODS of PCCSET	PMF	PMF	PMF	•	•	•	•	•	•
Bureau of Reclamation	PMF	PMF	PMF	•	•	•	•	•	•
FERC	PMF	PMF	PMF	PMF	PMF	PMF	•	•	•
Forest Service	(See Corps criteria for National Dam Inspection Program)								
ICODS	PMF	PMF	PMF	•	•	•	•	•	•
National Weather Service	(Does not establish criteria for dams)								
SCS	PMP	PMP	PMP	$(P_{100} + 0.4(PMP - P_{100}))$			•	•	•
TVA	PMF	PMF	PMF	(TVA Max. Prob. Fld.)			•	•	•
Corps of Engineers (Corps Projects)	PMF	PMF	PMF	•	•	•	•	•	•
Corps of Engineers (National Inspection Program)	PMF	PMF	½ PMF to PMF	PMF	½ PMF to PMF	100 yr to ½ PMF	½ PMF to PMF	100 yr to ½ PMF	50 yr to 100 yr
Nuclear Regulatory Commission	PMF	PMF	PMF	(See Corps criteria for National Dam Inspection Program)					

Source: National Research Council (1985).

Table 10.5 Reservoir Flood and Wave Standard by Dam Category

Category	Initial reservoir condition is tolerable	Dam Design Flood Inflow			Concurrent wind speed and minimum wave surcharge allowance
		General standard is warranted	Minimum standard if rare overtopping is tolerable	Alternative standard if economic study is warranted	
(a) Reservoir where a breach will endanger lives in a community	Spilling long-term average daily inflow	Probable maximum flood (PMF)	0.5 PMF or 10,000 Year flood (take larger)	Not applicable	Winter: maximum hourly wind once in 10 years Summer: average
(b) Reservoirs where a breach: (i) may endanger lives not in a community; (ii) will result in breach will pose	Just full (i.e., no spill)	0.5 PMF or 10,000 year Flood (take larger)	0.3 PMF or 1000 Year flood (take larger)	Flood with probability that Minimizes spillway plus damage cost, inflow not to be less than minimum standard but may exceed general standard	Annual maximum hourly wind Wave surcharge Allowance not less than 0.6 m
(c) Reservoirs where a breach will pose negligible risk to life and cause limited damage	Just fill (i.e., no spill)	0.3 PMF or 1000 year flood (take larger)	0.2 PMF or 150 Year flood (take larger)		Average annual maximum hourly wind; wave surcharge allowance not less than 0.4 m
(d) Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage will be caused	Spilling long-term average daily flow	0.2 PMF or 150 year flood	Not applicable	Not applicable	Average annual maximum hourly wind; wave Surcharge allowance not less than 0.3 m

Source: *Institution of Civil Engineers (1978)*

10.4.6. Locks

The methods for improving river for the purposes of flood control and navigation are the open channel, lock and dam and canalisation. Dams create a series of slack water pools through which the traffic can move, with locks to lift the vessels from one pool to the next. The design of most lock-filling systems is usually accomplished based on model tests after a selection of an approximate design on the basis of mathematical analysis.

The two major items in the design of locks for navigation are:

- a) The determination of size
- b) The determination of the filling and emptying systems

The height of the lock is fixed by the selected upstream and downstream pool levels. The overall height of the lock chamber must equal the maximum expected difference in pool elevations plus the required draft plus freeboard.

The elevation of the bottom of the lock chamber must equal the minimum pool level in the downstream pool less the required draft. The size of the lock in the plan depends on the traffic expected to pass through it. Modern constructions favour a main lock 400 meters long and an auxiliary lock 200 meters long.

It is important that the lock approaches be protected by guide walls so that eddies and turbulence in the navigation channel as a result of flow over the dam be minimized. The use of spillway gates adjacent to the lock is restricted to emergency needs only.

Table 10.6 Orifice Coefficients for Lock-Filling Systems*

Type of system	Discharge coefficient Cd
Longitudinal conduit and lateral ports	0.85-0.95
Venturi loops	0.75-0.85
Opening main gates	0.80

* George R. Rich, Hydraulics of Lock Filling systems, Military Eng., pp 60-64, January-February 1933

10.4.7 Other Relevant Matters

Land Acquisition, Economic Analysis, Social Impact Analysis and Environmental Requirements are already standard requirements in planning and design of flood mitigation projects. However there are now more considerations required in flood mitigation projects. These considerations are expected to be beyond the direct (functional) objectives of the project. Some of these are listed below:

- a) Beautification of the areas within the project. Some examples are linear parks and public facilities.
- b) Aesthetic designs of structures and components.
- c) Provisions to encourage aquatic life. Some examples are "fish shelters".
- d) Identification of potentials for tourism.
- e) More effort in consideration for public safety not just to prevent accidents (such as falling in to the channels) but also personal safety for visitors at night.
- f) Installation of "vandal-proof" equipment and facilities. Also designs that discourage any attempts of vandalism.
- g) Applications of eco-friendly designs and "Green" designs. This is a relatively new concept. At present these are mostly developed for buildings but there are indications that all other developments will soon have to move in this direction. Some examples are efforts to reduce the use on non-renewable resources or sources of primary materials that permanently destroy the environment such as steel, earth and aggregate quarries and fuel.
- h) Designs and construction that require less labour and reduces influx of foreign labour. This is now addressed by CIDB for buildings by encouraging Integrated Building System (IBS). Some components of the system may be standardized and pre-casted or pre-fabricated.

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CHAPTER 11 FLOOD MODELLING

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11 FLOOD MODELLING

11.1 PURPOSE OF MODELLING

Flood modelling is an essential aspect of planning, design and subsequent management of floods. It is often the initial activity in any planning and design works for flood mitigation. Flood modelling provides quantitative explanation for the causes of floods. It also facilitates in developing options for flood management for both structural and non-structural measures. This is made easier if the model is flexible and responsive to the various variable parameters necessary to generate different flood scenarios. These are subsequently used to select appropriate flood management solutions.

11.2 TYPES OF MODELLING

Modelling can either be physical or numerical. A physical model is constructed as a scaled replica of the prototype using materials such as timber, plastic, metal, or concrete. It is used to represent a catchment/situation where complex inter-relationships of variables that influence hydraulics behaviour and performance under varied conditions cannot be represented by numerical models. A physical model is also used to verify results from numerical models of certain components of a flood mitigation system or structures.

An example is for the design of spillway and stilling basin for a dam. Numerical models are used to develop several design options and physical models are used to make final decisions on the selection.

The factors influencing the choice on the type of modelling are:

1) Physical model

- Flow behaviour too complex for mathematical equations
- Turbulent flow since it requires three dimensional analysis
- Study of localised problems
- New research field

2) Numerical model

- Flow can be represented by mathematical equation
- Can be relatively less expensive than physical modelling
- River basin wide coverage that could be too large to scale down physically and still maintain accuracy of results

Two main types of numerical model used in flood mitigation planning and design are hydrologic modelling and hydraulic modelling.

11.3 THE IMPORTANCE OF MODELLING

Numerical modelling is now an integral aspect of flood management. It can simulate flood impacts and flood mitigation options quickly and economically. Its applications can cover even large scale water based systems (comprising rivers, estuaries, and coastal waters) for flood management.

11.4 HYDROLOGIC AND HYDRAULIC MODELLING

Hydrologic modelling used to simulate the hydrologic processes involving precipitation, landuse, runoff, infiltration, evaporation and other parameters to estimate runoff hydrograph (flow over time) through a channel or a storage facility. Simple hydrologic models use simple rainfall-runoff relationships while more advanced models use kinematics wave formulae for runoff estimation.

Hydraulic modelling requires more precise data of the river characteristics or hydraulic structures across the river. Hydraulic equations are used to calculate water depth and velocity. Depending on the size of the river system, the hydraulic model can be one dimensional (1D), two dimensional (2D), or three dimensional (3D). A 1D model will produce results of flows in one direction and the velocity is an average value. A 2D model produces results of flows in 2 directions i.e. x and y. The velocity in either direction is an average. A 3D model produces results of flow in x, y and z directions. The velocity can be stratified vertically. Very often, a 1D or 2D model would be adequate for flood mitigation analysis for a river basin while 3D models are required for studying bridge scour, groynes, large lakes, coastal and river mouth. At present, most of the 3D softwares are developed specifically for complex structures or mainly for research projects. Type and purpose of modelling summarised in Table 11.1.

Table 11.1 Type and Purpose of Modelling (Source: Price 2003)

Type of physical based model	Usage
<ul style="list-style-type: none"> • 0D 	Rainfall-runoff, reservoir , flood routing
<ul style="list-style-type: none"> • 1D hydrostatic, sub or super critical flow, free surface or pressurised • 1D Boussinesq (First order non hydrostatic) • 1D compressible 	River, floodplain, estuaries, irrigation, water distribution, wastewater and stormwater collection, treatment works, water hammer
<ul style="list-style-type: none"> • 2D hydrostatic, vertical (depth layer, horizontal average • 2D hydrostatic , horizontal (spatial depth average, turbulence, wind (for shallow depth) pressure , Coriolis density, variation, wave stress) • 2D Boussinesq (First order non hydrostatic) • 2D wave refraction, reflection diffraction 	lake, wide river channel , floodplain, estuaries, coastal waters, groundwater
<ul style="list-style-type: none"> • 3D hydrostatic (turbulence, wind pressure, Coriolis, thermoclines density variations) • 3D non hydrostatic, (Navier-Stokes plus turbulence) 	lake, river channel, channel floodplain, estuaries, coastal waters, treatment processes, river channel; - flood plain interaction , structures

Most of the user-friendly computer simulation models for flood mitigation incorporate both hydrologic and hydraulic modules. Many of the models are now in public domain and can be downloaded from the web sites. However, these softwares are usually not user-friendly and hard to master. Commercial models tend to be more user-friendly but can be costly. However their updates may be regularly downloaded from their master website.

Flood simulation software normally comes complete with the hydrologic and hydraulic modules. Some models allow simulation of flood water quality assessment to analyse suspended solids, sediments, nutrients and pathogen. More sophisticated models have extra capabilities such as (i) Geographical Information System (GIS), Decision Support System (DSS), RADAR data, SCADA and other real-time or on-line facilities, (ii) routing methods to predict flood hydrograph with reasonable accuracy, (iii) hydraulic module (static and dynamic) that calculates flood depth and velocity over the entire floodplain. Latest software boasts the capabilities summarised in Table 11.2.

Table 11.2 Differences in Hydrologic and Hydraulic Modelling

Item	Hydrologic Modelling	Hydraulic Modelling
Input	Catchment area Rainfall Time of concentration Land use Soil type Rating Curve	Inflow hydrograph River cross section Roughness Hydrograph Structures Flood plain storage area Rating curve Tidal data Operation rules
Output	Design Discharge Water level (Limited location)	Design Discharge Water level Velocity

11.5 OBJECTIVE OF MODELLING

The objective of flood modelling is to study the effects of certain hydrological and hydraulic parameters on flood characteristics. These parameters can then be varied such that the desired effects (output of the model) can be achieved by designing components of the system that matched the values of those parameters.

11.6 CAPABILITY OF FLOOD MODELLING

Computer models have various capabilities and the good ones should be able to simulate the following:

1. Afflux due to bridge construction.
2. River improvement works that could transfer flood problems to downstream areas.
3. Land reclamation works that could reduce the storage capacity upstream.
4. Capacity of the current drainage system in taking the impact of new developments.
6. Effects of new dams on the downstream flood problem.
7. Development of flood warning system.
8. Development of flood forecasting system.
9. Operation of tidal control and diversion gates.
10. Study of sediment transport.
11. Effects of sand mining on river stability.
12. Water quality and pollution modelling.

11.7 DATA REQUIREMENT

Data required for a particular model vary depending on the complexity of the model. For example, software that has built-in GIS capability require spatial data to be in GIS format (ArcView or MapInfo). In this manual InfoWorks RS is shown as an example for model development based on GIS while HecRas is for non-GIS model. Data needed for model development are summarized in Table 11.3.

Table 11.3 Data Requirement for Model Development

No	Type of data	Recommended Format	Purpose of Analysis
1	Sub-catchments	GIS	Rainfall runoff analysis
2	River alignment	GIS	Hydraulic analysis
3	River Cross section	AutoCAD / GIS	Hydraulic analysis
4	3D spot height	Text, Shape file	Flood plain analysis
5	Satellite images	Imagine, MrSID	Background map
6	Structure detail	AutoCAD Drawing	Hydraulic analysis
7	Landuse	Shape file	Rainfall runoff analysis
8	Soil type	Shape file	Rainfall runoff analysis
9	Rainfall data	Text/ Spreadsheet	Rainfall runoff analysis
10	Road / building map etc	Shape file	Flood plain analysis

11.8 MODELLING PROCESSES

Hydrodynamic software normally comes complete with the hydrological and hydraulic models. This Chapter discusses only the Hydraulic Model. Detail explanation of Hydrologic Model (Rainfall – Runoff model) can be referred to MSMA – Chapter 13, HP 5 and HP 11.

Once the river network and its limits have been identified, the modelling process proceeds as follows (Figure 11.1). First, develop a Hydrologic Model (Rainfall-Runoff) to cover all tributaries. Second, develop a Hydrodynamic Model that covers the entire river network in the river system within the limit identified earlier. Figure 11.2 shows the Hydrodynamic Model for Sg. Selangor. (Note the tributaries are represented by boundary nodes)

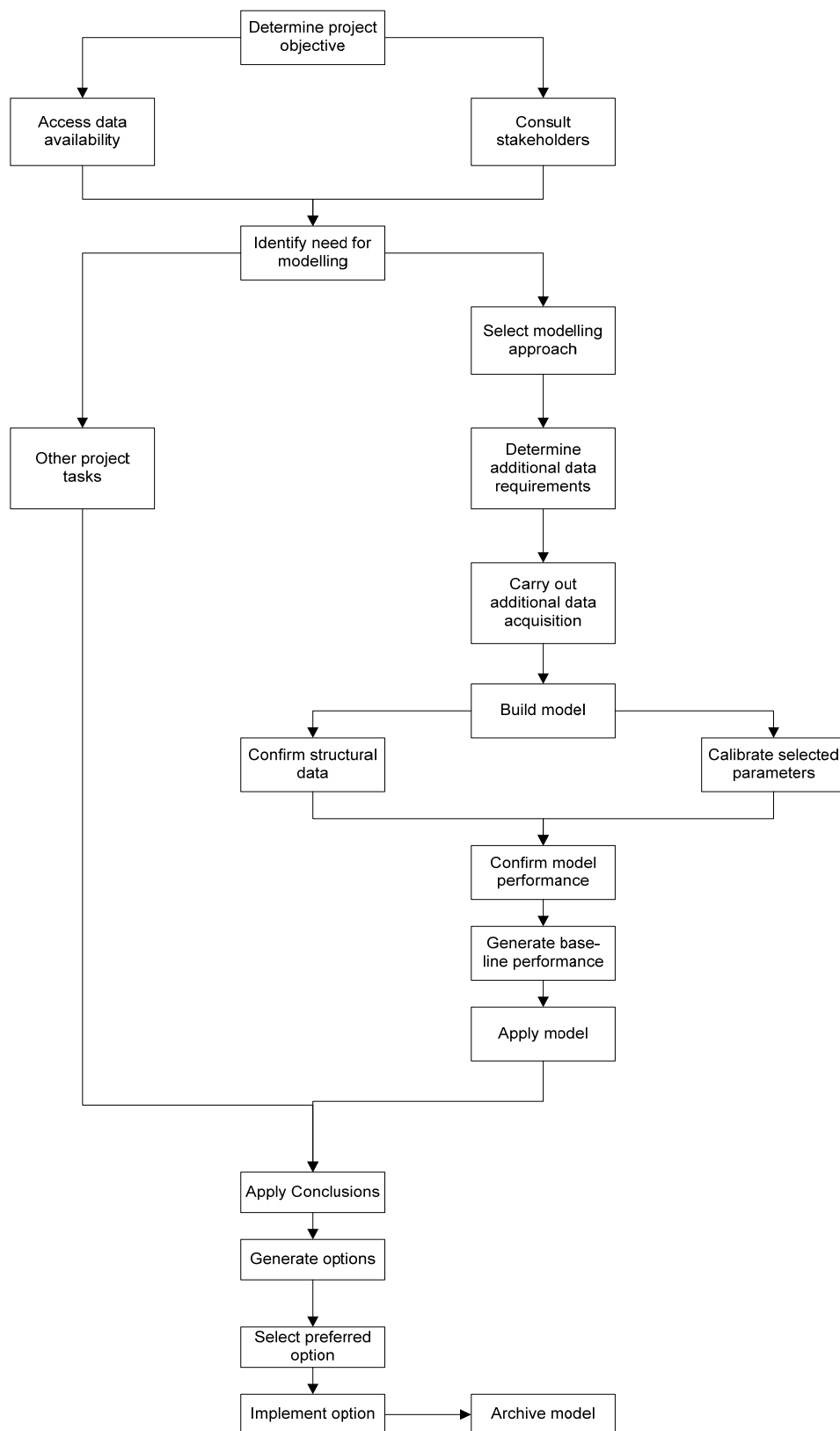


Figure 11.1 Modelling Process Chart

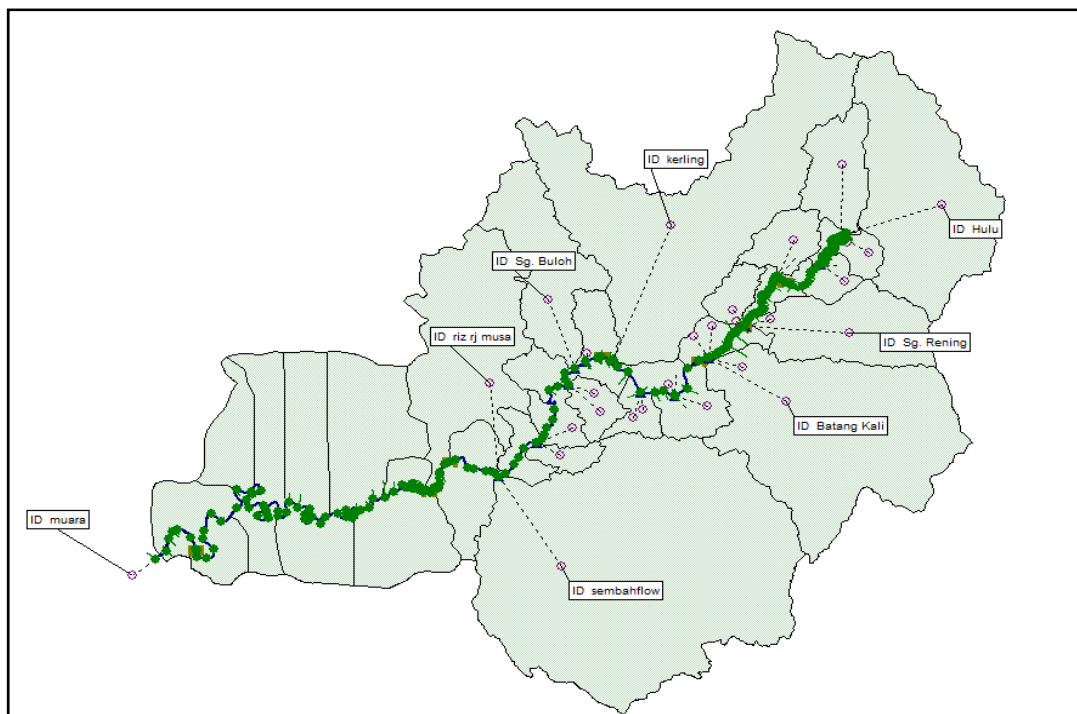


Figure 11.2 River Model for Sg. Selangor Covering the Main River and Tributaries

The Rainfall-Runoff Model for the sub-catchments explanation can be referred to MSMA – Chapter 13, HP 5 and HP 11. Figure 11.3 shows an example of a hydrograph resulting from rainfall-runoff analysis from various sub-catchments

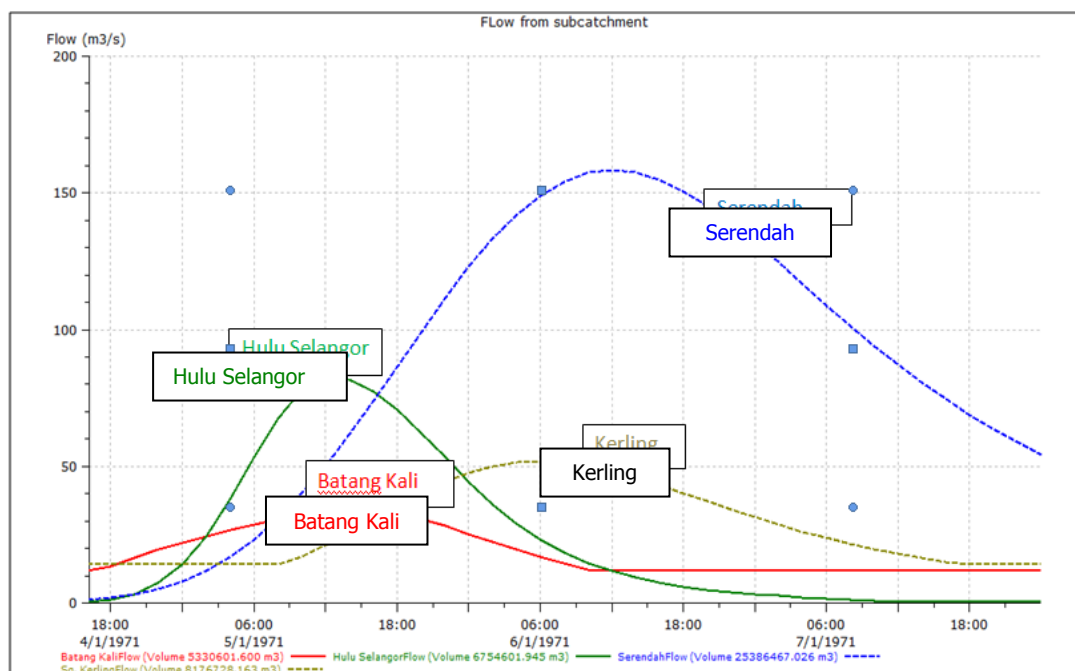


Figure 11.3 Hydrograph Resulting from Rainfall-Runoff Model from Major Sub-catchment in Sg Selangor Basin

11.8.1 River Model Components

A river model comprises two modules namely Inbank and Outbank. The Inbank Model (represented by structures) simulates flow in the river cross-sections within the limits of the riverbank. Inbank computation is simpler and straight forward. The Outbank Model (represented by storage/river network) simulates flow within the floodplain, which becomes active only after spillage has occurred over the riverbank. Detailed explanation of river modelling can be referred to Hassan A.J (2006). Figure 11.4 and Figure 11.5 show the Inbank Model and Outbank Model configured for Sg. Selangor, respectively.

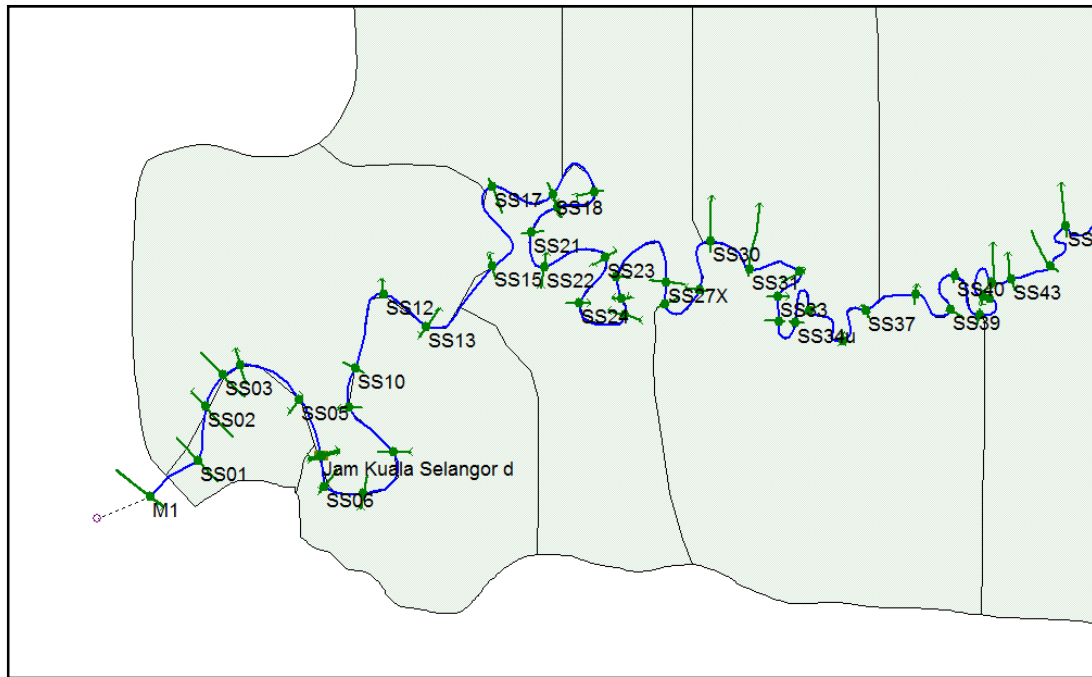


Figure 11.4 Lower part of Sg Selangor for the Inbank Model (Represented by river cross section)

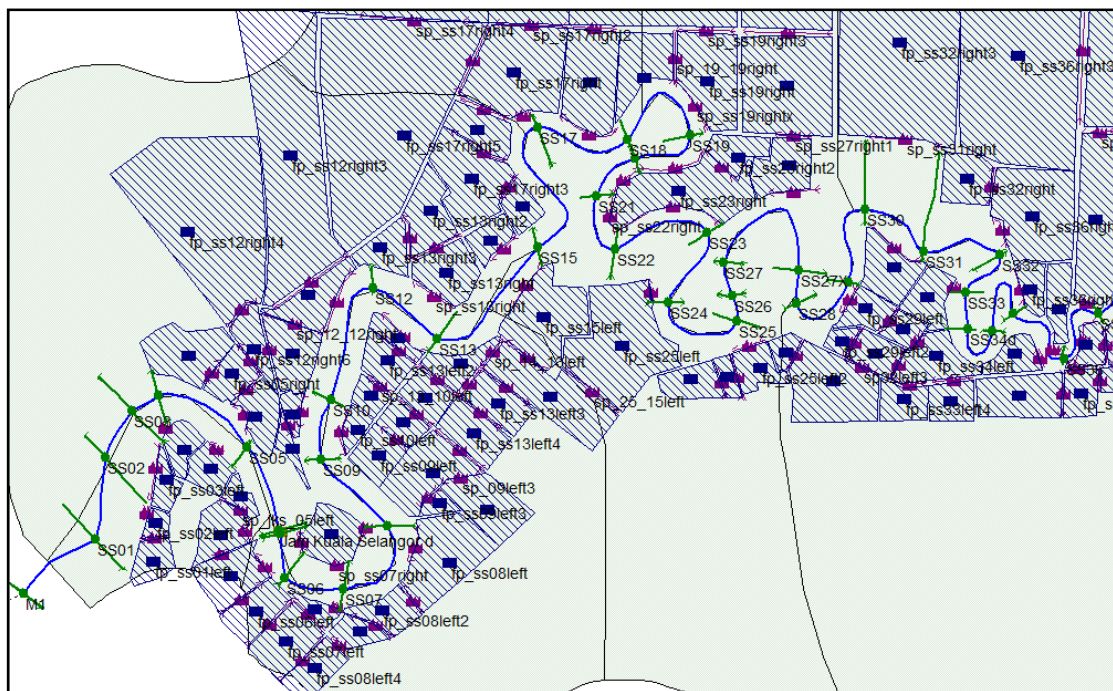


Figure 11.5 Lower Part of Sg. Selangor for the Outbank Model within the Floodplain (Represented by Storage)

Many softwares can now perform river modelling using the 2D simulation technique. The 1D and 2D combined technique is gaining popularity since the main river channel can be in 1D while the floodplain can be in 2D. This offers advantage in reduced computation time for the main river with a better accuracy in modelling the floodplain. The 2D simulation also provides hydrodynamic effect in the floodplain. Figure 11.6 and Figure 11.7 illustrate use of the 1D and 2D combined technique.

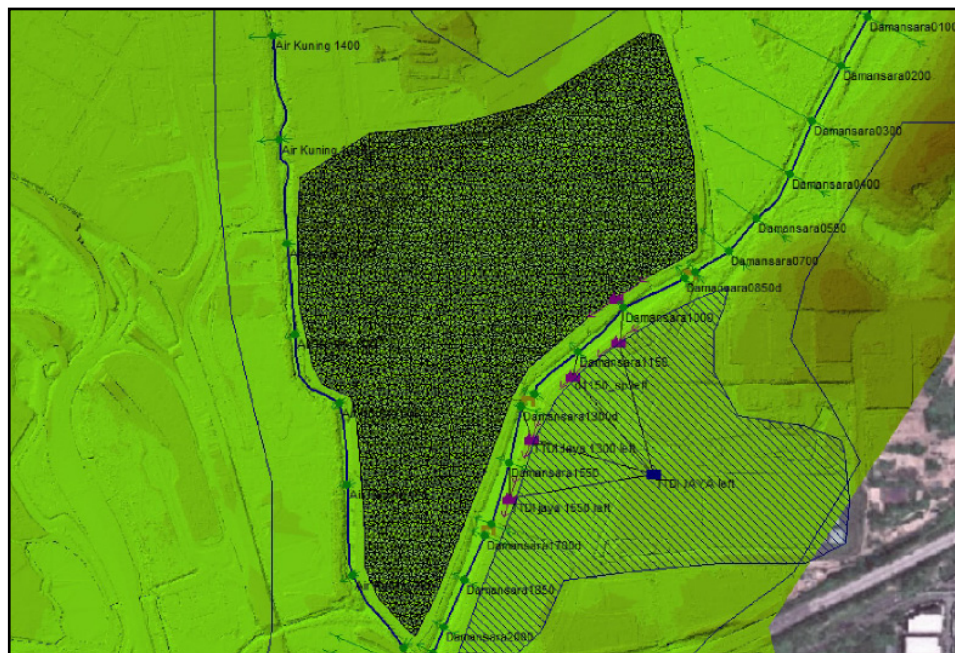


Figure 11.6 The RHS Floodplain is represented by 2D Mesh and the LHS Floodplain by Storage Area

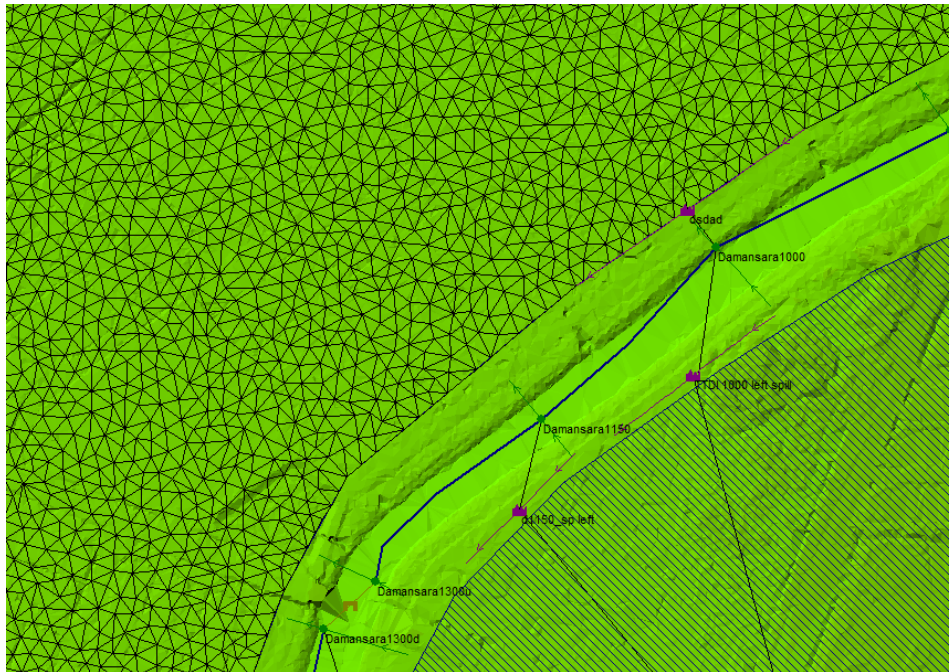


Figure 11.7 The 2D Mesh is shown in Triangulation between Spot Heights

11.8.2 Sensitivity Test

Sensitivity tests will identify parameters that influence flow or water level the most. The Manning's roughness coefficient, n or structure coefficients for example, can be changed within some acceptable range. The simulated results should then, be compared for accuracy with the observed data. This way, the modeller would know which parameters are sensitive under a particular condition. This gives a better understanding of how the model should behave under certain imposed conditions and simplify the calibration process.

11.8.3 Model Calibration

A well calibrated model minimises the error in the analysis that rely greatly on the sensitive parameters. Such error could lead to multiple errors in the predicted (simulated) results.

Listed below are some of the definitions of calibration extracted from various sources on the web:

Model calibration is the process of adjusting parameters in order to optimize agreement between the observed data and the model predictions. (Glossary of Meteorology: <http://amsglossary.allenpress.com/glossary>)

Model calibration is about changing input parameter values to the model so that the model equation will describe the field (site) situation in whatever events desired to within some acceptable accuracy. Field conditions must therefore be properly characterized in the most representative way possible. Simulation should ideally be performed to steady-state conditions but this is very difficult (Department Environmental Quality - <http://www.michigan.gov/>) for a river system, which is "live". Thus, transient simulation is often the target in a river or stream study. In steady-state conditions, a parameter to be predicted (say hydraulic head or contaminant concentration) should not change over time. In a transient system, the parameter will change with time (e.g. aquifer stressed by a well-field or a migrating contaminant plume). The modeller must "play" with the parameter variability within the acceptable range as input to the model and yet get results close to the steady-state conditions.

As a rule of thumb, the Hydrologic Model or the Hydraulic Model, like all models, must be calibrated prior to their application for design or for comparing performance scenarios (e.g. water level or hydraulic radius at a particular section) under some imposed mitigation condition (e.g. bridge crossing). Parameter calibration and validation are important in modelling to ensure the model is accurate and reliable for future events under similar river or watershed characteristics.

Calibration is used to examine the non-physical components of a flow equation under study. The characteristics of the physical components (e.g. river geometry or structure dimensions) must be correct to within their acceptable range for a meaningful calibration. If for example, the Manning's roughness coefficient for some natural river is set to 0.10 in the calibration exercise, most likely there is error in the input data of other variables (e.g. channel or model conceptualisation), by missing to consider, say, some constriction to flow at some cross-section under study, thus getting a higher predicted value of the water level somewhere downstream.

If a river system is being modelled with some structure built across it (e.g. weir or bridge), it is most likely that the Manning's roughness will not be as sensitive as the properties of the structure itself and/or the weir coefficients. Focusing on less sensitive parameters would result in erroneous prediction of the parameters of interest.

To conduct hydrological calibration for a stream without flow gauging, the modeller must have some means by which he could check on the reliability of the simulation results. An option would be to use the available calibrated parameters from some nearby gauged catchment in the same river basin as the river under study. The parameters here are then extrapolated for use at the ungauged site. Another option is to compare the results with those obtained using empirical methods (HP 4, HP5 and HP 11).

Model performance is often assessed by the "goodness of fit". Some of the methods are the sum of squared errors (SSE), error variance (EV), root mean square error (RMSE) and the efficiency index of Nash and Sutcliffe. These "goodness of fit" are evaluated from the plot of observed data against the simulated (predicted) data on 1:1 scaled graph.

Experience has shown that for inbank flow, the return period less than 5 ARI is normally used for calibration. However for floods study in the floodplain, higher return periods are used. Any model, formerly calibrated for the inbank flow must undergo the outbank flow calibration. Normally, the calibration is carried out by comparing observed hydrograph and simulated hydrograph as shown in Figure 11.8. However, when limited data is available, such as for a flood plain, comparing maximum water level for any event is acceptable.

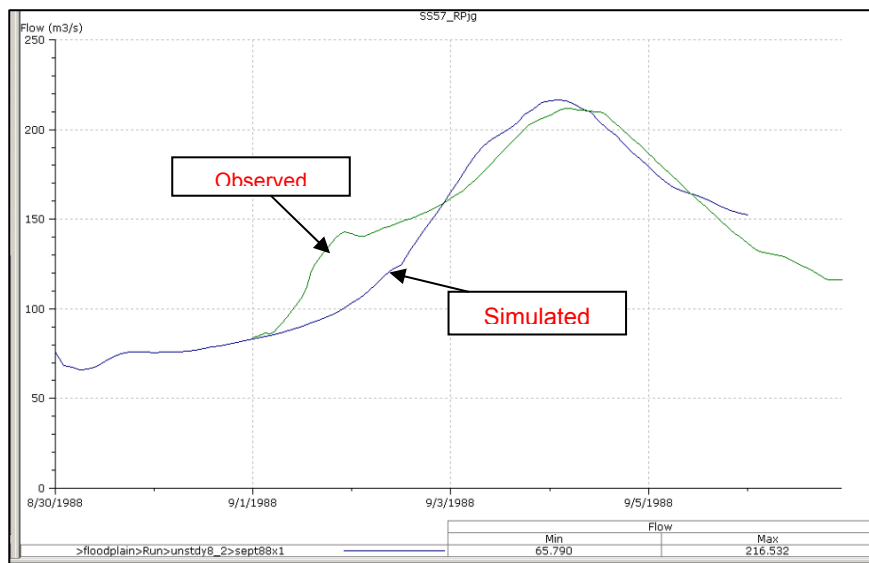


Figure 11.8 Plot Observed Versus Predicted Flow

11.8.4 Calibration of Large River System

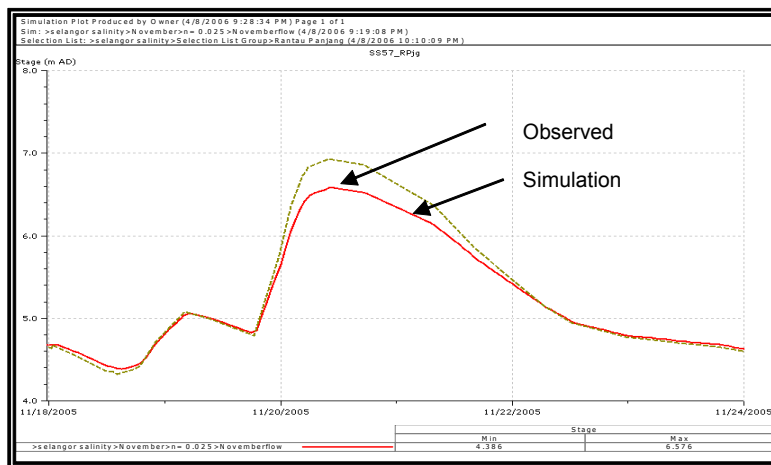
A river system comprises three main zones: Fluvial, Tidal, and Floodplain. To ensure the river model works to satisfaction, calibration has to cover all the three zones, subject to the parameter sets recommended for each zone as shown below:

- Fluvial Zone - flow and water level
- Tidal Zone - water level
- Floodplain - water level / maximum water level

11.8.5 Calibration at Fluvial Reach

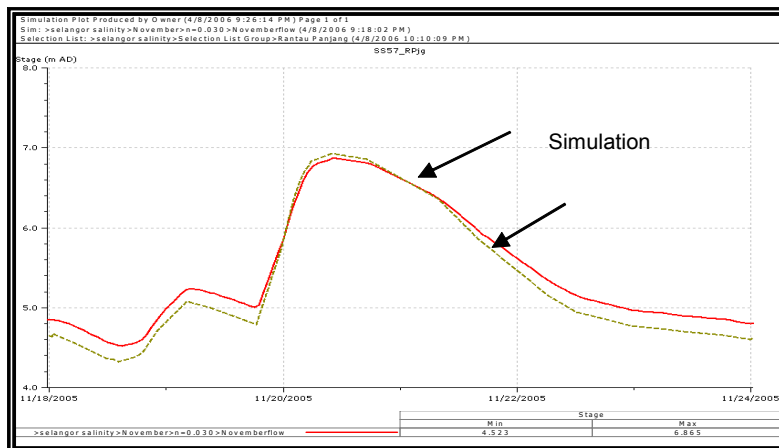
If a river is free form obstruction (e.g. bridge or weir/barrage that may cause backwater), the main parameter to be calibrated would likely be the Manning's roughness coefficient, which is the river conveyance parameter. However, if the reach under study has some structure obstructing the flow, then the modeller should consider other parameters (e.g. weir coefficients).

Figure 11.9 and Figure 11.10 show the calibration for two values of Manning's coefficient against water level performed at Rantau Panjang (Sg Selangor) during the 1971 flood. Further statistical technique used for estimating the accuracy of the calibration is shown in Table 11.4. Based on the analysis, the value of 0.025 may be accepted as the most appropriate value for Manning Roughness within the middle reach of the river (at Rantau Panjang).



Manning = 0.025

Figure 11.9 Calibration of the Manning's Coefficient Vs Water Level at Rantau Panjang (Sg Selangor) during the 1971 Flood



Manning = 0.03

Figure 11.10 Calibration of the Manning's Coefficient Vs Water Level at Rantau Panjang (Sg Selangor) during the 1971 Flood

Table 11.4 Statistical Technique Used for Estimating the Accuracy of the Calibration

Manning	Average difference	Standard deviation	Variance difference	Pearson Correlation Coefficient	Determinant coefficient
0.035	0.238	0.076	0.006	0.99775	0.99550
0.030	0.014	0.105	0.011	0.99828	0.99657
0.025	-0.222	0.139	0.019	0.99868	0.99736

11.8.6 Calibration in Tidal Affected Zone

The calibration of a river model in a tidal reach would require adequate water level data to be collected in that zone. Presently, most of the water level stations in many rivers are installed outside the tidal reaches. Therefore it is not possible to calibrate a river model for such reaches with reasonable accuracy. The parameter to focus under tidal influences is water level rather than flow since the flow here can be bi-directional.

The main input for a hydrodynamic model for river mouth application is tide information. Tide records are accessible from the Royal Malaysian Navy or the Department of Survey and Mapping while those for major ports are available from the Tide Prediction Table jointly produced by the two agencies. Some software (e.g. Tidal Harmonic Constituent) can generate water levels at the river mouth. River-mouth calibration is normally carried out at some tidal affected point located some distance away from the river mouth.

The graphs below (Figure 11.11 and Figure 11.12) are reproduced from Abd Jalil Hassan (2006) showing the calibration of the Manning's coefficient vs. water level at some tidal reach near Kg Asahan (34km upstream of river mouth of Sg. Selangor).

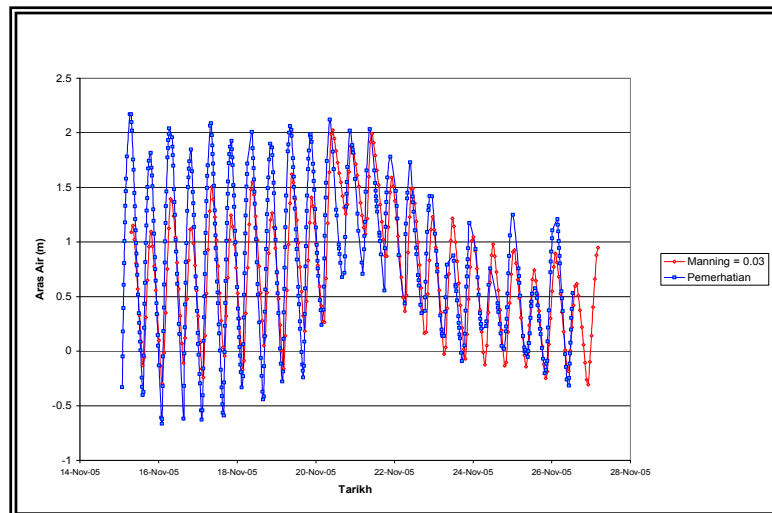


Figure 11.11 Comparison of Manning for Manning $n = 0.03$

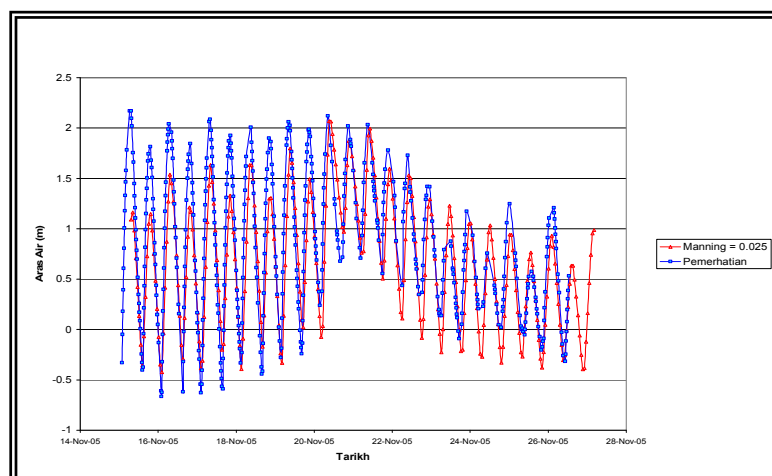


Figure 11.12 Comparison of Manning for Manning $n = 0.025$

11.8.7 Calibration in the Floodplain

Floodplain is the most difficult part of the river system to calibrate. Normally, it is not easy to obtain the hydrograph of a flood event in the floodplain. Under this circumstance, the maximum water level can be observed as a check. Parameters to calibrate in the floodplain would depend on the modelling technique used. If the inbank and outbank models are split in different sections of the system, then the spill unit coefficients representing overflow (say from the river to the floodplain) need to be calibrated. The coefficient values used for the broad crested weir could be used as a starting value for the spill unit. If 2D modelling is applied to the floodplain, then the Manning's roughness coefficient would be the parameter of concern. If the floodplain has a series of reservoir units along the river, then the spill in each of the reservoirs needs to be calibrated. Figure 11.13 below illustrates calibration of the spill coefficients against the maximum water levels. The simulated water levels can be compared with the water levels observed during the site investigation.

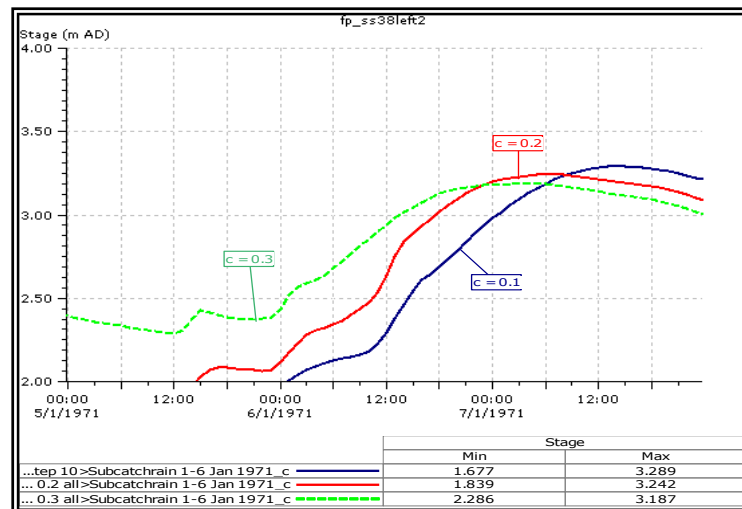


Figure 11.13 Maximum Water Levels in the Floodplain (obtained by varying weir coefficients)

11.8.8 Non-Calibrated Model

The problem of insufficient data has obstructed calibration from taking place in many flood mitigation project. It is possible that the study location has not enough gauging stations available, or some equipment may be malfunctioning, or certain parameter measurements are inaccurate or erroneous. In this situation, it is best to seek expert advice or apply the heuristic approach.

In engineering, a heuristic method is used to help in problem solving process in design. This could be, for example, a study on the performance of some system based on the size of certain equipment, or a new set of operating conditions under some specific loading condition. The benefit gained using such approach is that less time is required to solve the problem, which is considered as very valuable management cost. Because heuristics are fallible, it is important to understand their limitations, especially in the preliminary process design.

If the heuristic approach is sought for the development of a flood management model, the modeller must ensure the river's physical characteristics are considered. For example, all cross-sections describing the shape of the river must be entered into the model. Even structures existing somewhere along the river should not be left out unanalyzed.

A non-calibrated model is mainly used as a comparative tool rather than a predictive tool. It can evaluate flood impacts as a result of changes in landuse, river improvement work or proposed new structures across a river.

11.9 MODEL VERIFICATION/VALIDATION

An important step after calibration is model verification. Once calibrated, the model should be tested for different events. This process is called "model verification or validation". It is to check whether the model is still valid for new different events using the previously calibrated parameters (no adjustments to be made to the values of the calibrated parameters). The model performance is evaluated by comparing the simulated results with the observed (measured) results as described before in the calibration process. If the differences in the results are significant, then the model will need further calibration until its validity proves satisfactory.

11.10 SELECTING SOFTWARE FOR MODELLING

Table 11.5 summarizes the factors to be considered in the model selection. Although subjective, these factors should guide the model selection to match budget and time constraints. A total of twelve test specifications are given in the Manual. Further specifications may be referred to the report. The capabilities and list of commonly used Hydrodynamic models is shown in table 11.6.

Table 11.5 Various Factor to be Investigate before Selection of Software is Made

Facilities	Algorithmic equation solved Finite scheme used Solution technique adopted Data requirement and handling Model building Grid generation (2D and 3D) Results display and data comparison Networking Link to data bases GIS, MIS
Ease of use	Display of information Economy of user actions Intuitiveness of screen layout and tasks/actions Tutorials
Reliability and quality assurance	Supporting document including full description of modelling theory including treatment of recognized problems Small depths Pressurized flow Sub and super critical flow Free surface- pressurized flow transition Numerical dispersion Numerical stability Benchmarks Case histories Accreditation Independent assessment Supplier reputation User appreciation Access to demo software and ability to test run
Cost	Purchase price Familiarization /experience required Training courses Technical Support Upgrade Hardware availability and requirement

Model selection may also follow established benchmarking procedure such as reported in Benchmarking of the hydraulic river modelling software packages - Project Overview - R&D Technical Report: W5-105/TR0. Generally, software benchmarking should be based on following criteria:

- Numerical accuracy
- Capability
- Reproducibility
- Adaptability
- Form and function

Table 11.6 List of Commonly Used Hydrodynamic Models and Their Capabilities

Model	Capability								
	Hydrology	Hydrodynamic	Water Quality	Sediment	GIS capabilities	Flood Forecasting	Data input capabilities	Output	Logical Control
InfoWorks RS	Yes	Implicit Scheme	Yes	Yes	Yes	Yes - Flood Works	Import from AutoCAD, CSV /GIS	AutoCAD/ Shape File	Yes
Mike 11	Yes	Implicit Scheme	Yes	Yes	Yes	Yes – Flood Watch	Import from AutoCAD, CSV	AutoCAD	Yes
XP – SWMM	Yes	Explicit Scheme	Yes	No	Yes	No	Direct input, CSV	AutoCAD	No
HecRAS	No	Implicit Scheme	No	No	Yes	No	Direct input	No	No
ISIS	Yes	Implicit Scheme	Yes	Yes	Yes	No	Import Text	AutoCAD	Yes

Note: This information good as being published - 2008. Please refer to the product manual for detail capabilities.

REFERENCES

- [1] Environmental Agency and DEFRA (2004) -. Benchmarking of hydraulic river modelling software packages - Project overview - R&D Technical Report: W5-105/TR0 - Environmental Agency and DEFRA (Department of Environmental Flood Rural Affairs).
- [2] DID, *Best Management Practice: Hydrology and Hydraulics Modelling*
- [3] Wallingford Software (2008). InfoWorks RS Online Help
- [4] Hassan A.J (2006) Permodelan sungai dan dataran banjir untuk penjanaan peta risiko banjir. Kajian Kes Sg. Selangor – Universiti Sains Malaysia
- [5] Hassan A.J (2006) River hydrodynamic modelling – The practical Approach, NAHRIM)
- [6] Glossary of Meteorology - <http://amsglossary.allenpress.com/glossary>
- [7] About.com.Economics - <http://economics.about.com/library/glossary>
- [8] Department Environmental Quality - <http://www.michigan.gov/>

APPENDIX 11.A

Example 1: Basic River Modelling

This chapter demonstrates the process to develop a river model with a structure (bridge) across it using InfoWorks RS. Sg Juru has been chosen for the example due its small catchment area with manageable number of tributaries and structures and significant tidal influence.

Background of Sg. Juru

The Sg Juru basin (62 sq km in area) is located in Penang. The main river system comprises Sg Juru, Sg Kilang Ubi, Sg Pasir, Sg Rambai, Sg Derhaka Juru, Sg Ara and Parit Empat.

Present Problems

The river system is one of the most polluted in the country with high levels of ammonia, BOD, mercury and other heavy metals that originate from industrial discharges, pig and chicken farms waste and oil-based waste from workshops. In October 2003, a big flood occurred at the upper part of the basin. This event provided an opportunity to collect actual flood data and subsequently conduct calibration for the floodplain model.

The data collected include the following:

- River cross-sections (from Sg Permatang Jawa down to the river mouth)
- Contour map (JUPEM)
- Landuse map (DOA)
- Rainfall data (DID Hydrology Division)
- Structure crossings (survey works)
- Satellite Images (MACRES)

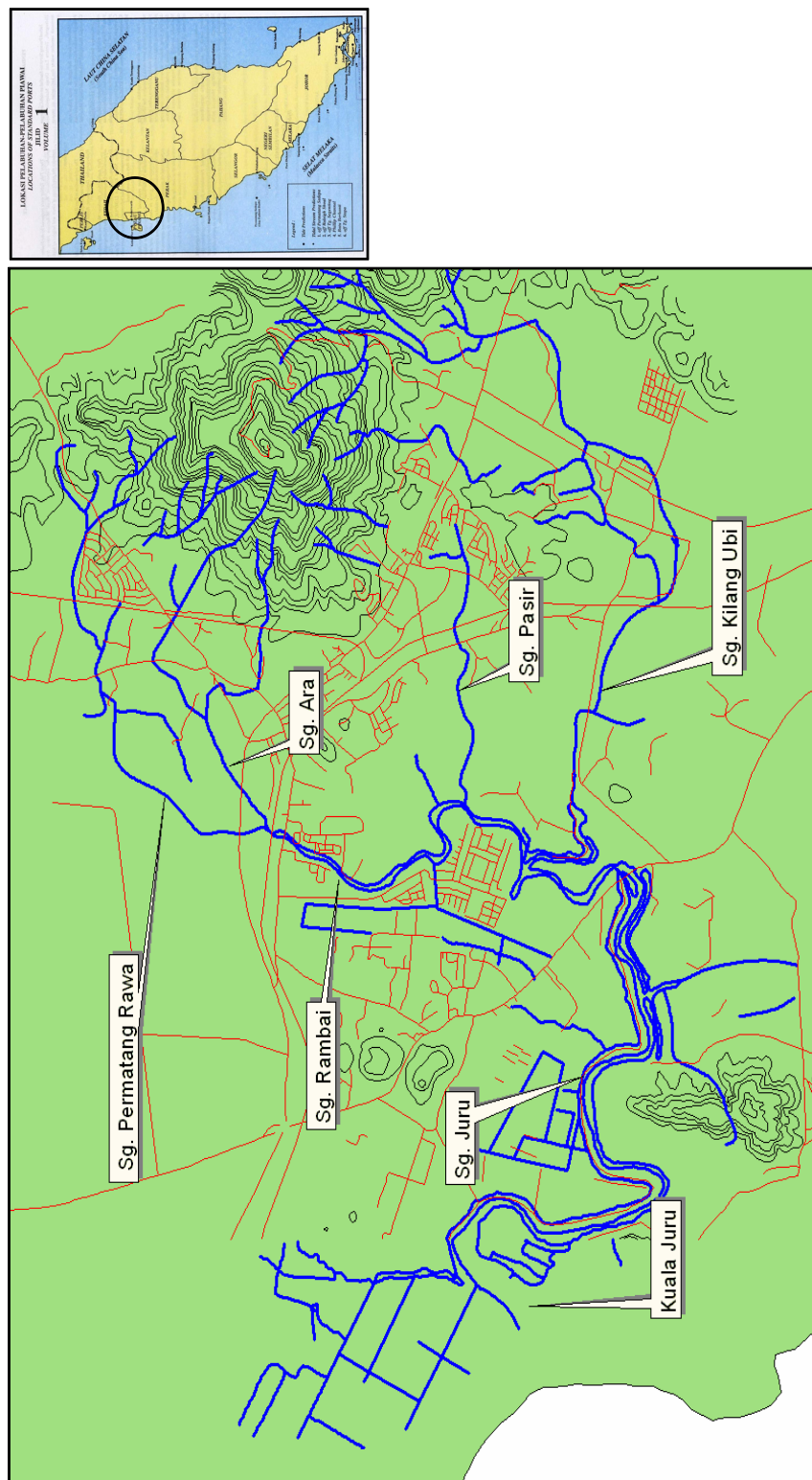


Figure 11A.1 Location of Sg. Juru Basin

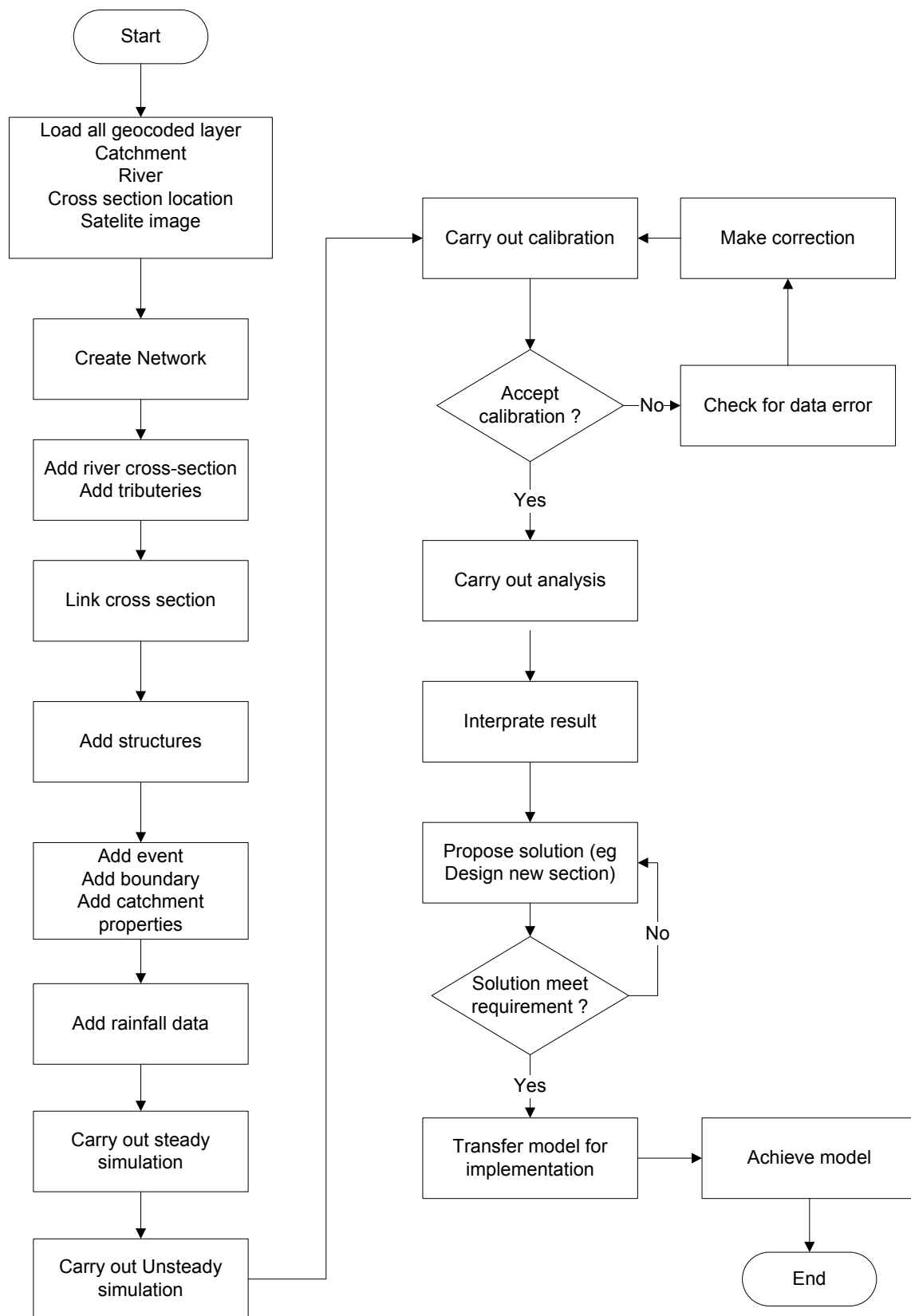
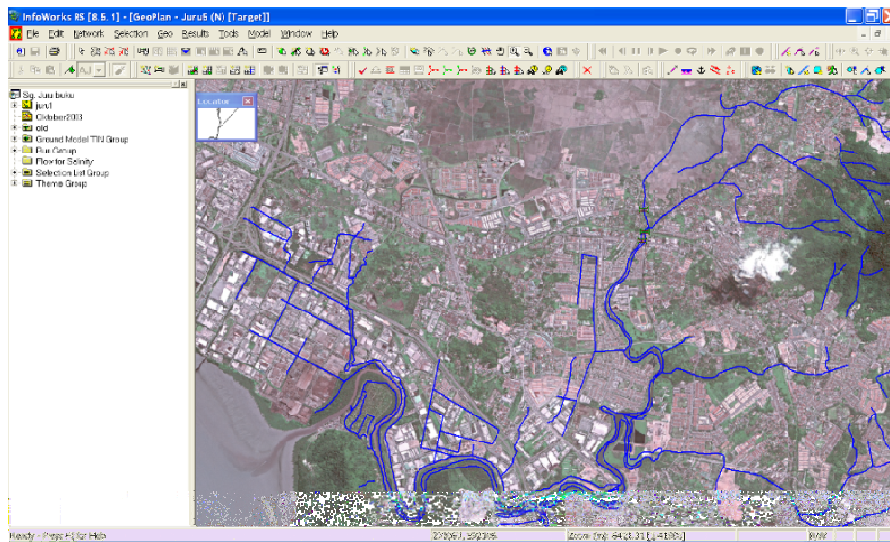


Figure 11A.2 Flow Chart for the Basic Model Development

Step 1: Model building

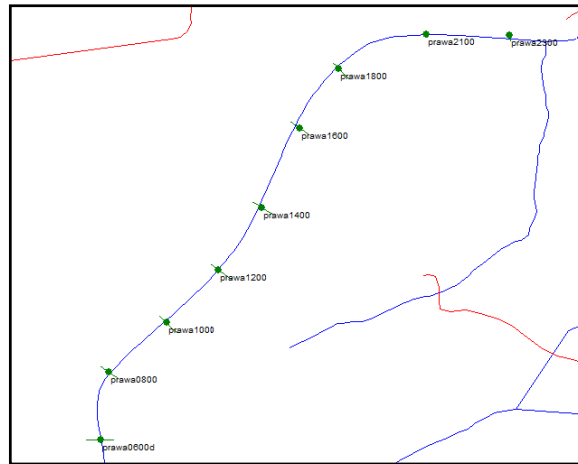
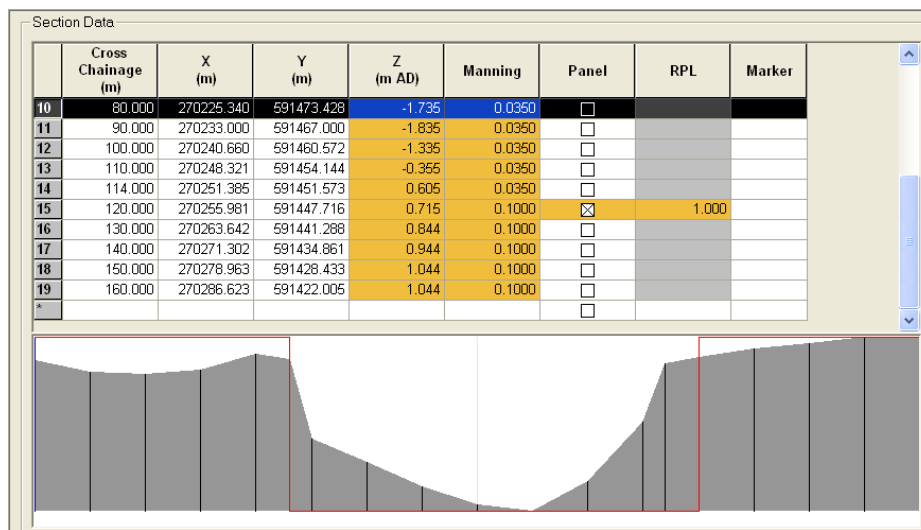
River model building should start with a Base Map and geo-coded. This will put the modelling process on a common reference point. Geo-coding allows other users to run their own models on the same coordinate system.

The modeller must then loads (into the Base Map) the layer that consist of data such as satellite image, river alignment, contour map, location of structure and sub-catchment map.

**Step 2: Other river information**

River alignment and cross-sections are first determined and are then entered into the network. The cross-sections should be reasonably spaced. Distances can be estimated using the function available from the Help Button. The cross-sections could be transferred to the network from many sources such as:

- Direct from keyboard
- From spreadsheet (Excel)
- From the 3D ground model
- From the 3D Polyline (AutoCAD)



Step 3: Linking the Cross-Sections

Cross-sections are linked using the Link Button, starting from upstream to downstream. The distance between cross-sections is measured automatically. Wherever there is a tributary, a *Junction* should be provided. The Joint between the Junctions is then inserted using the *Link* Button and *Connectivity Selection*.



Step 4: Inserting Structures

A structure (bridge, gate, or weir) is then inserted between a river cross-section and a junction. In this example, a bridge (taken from the US Bureau of Public Roads) is used. The bridge parameters include soffit level, pier type, and width and these are used to calculate afflux (see the spreadsheet below).

	Cross Chainage (m)	Z (m AD)	Manning	Marker
1	3 669	2.080	0.0250	
2	22 344	2.080	0.0250	
3	23 844	0.420	0.0250	
4	25 244	-0.010	0.0250	
5	26 844	0.350	0.0250	
6	29 244	2.210	0.0250	
7	31 727	2.210	0.0250	
8	51 727	2.210	0.0250	
9	55 015	2.210	0.0250	
10				

	Left (m)	Right (m)	Soffit Height (m AD)	Spring Height (m AD)
1	22 344	29 244	2.000	1.500
10				

Step 5: Boundary condition

Boundary conditions are required at all end points of the main river and its tributaries, upstream or downstream. The upstream boundary conditions are normally represented by:

- Flow vs. Time
- Rainfall Runoff Model
 - Unit Hydrograph
 - Simple Runoff Model
 - Probabilistic Distribution Model

Reinfall Profile: Observed
 Profile Type: Depth
 Data Interpolation: Bar
 Repeat: Extend
☒ Time Increments
 Hydrograph Start: 04 October 2003 08:00:00
 Hydrograph Interval (hours): 0.200
☒ Absolute Time

	Date-Time	Rainfall (mm)
1	04 October 2003 08:00:00	2.000
2	04 October 2003 08:12:00	2.000
3	04 October 2003 08:24:00	2.000
4	04 October 2003 08:36:00	2.000
5	04 October 2003 08:48:00	2.000
6	04 October 2003 09:00:00	1.800
7	04 October 2003 09:12:00	1.800
8	04 October 2003 09:24:00	1.800
9	04 October 2003 09:36:00	1.800
10	04 October 2003 09:48:00	1.800
11	04 October 2003 10:00:00	0.600
12	04 October 2003 10:12:00	0.600
13	04 October 2003 10:24:00	0.600

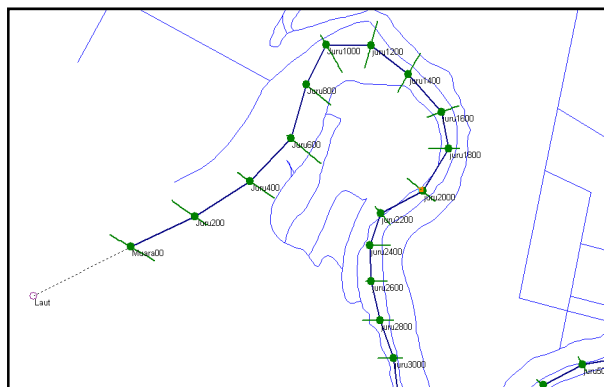
Rainfall data, T_c , and landuse data (as % of the pervious to impervious area) are entered into the Rainfall-Runoff Model in the Catchment Property Data Sheet as shown above.

Areal Reduction Factor	
ARF method	No ARF #D
ARF	0.000 #D
Runoff	
US SCS Type	Curve Number
Percent. Runoff (%)	
Curve Number	67.600
Impervious Fraction/Extent	
Impervious CN	
Pervious CN	
Event Data	
Hydrograph Interval (hours)	0.200

Downstream boundary conditions are normally represented by:

- Stage vs. Time
- Stage vs. Discharge Curve (Rating Curve)
- Tidal harmonic constituents

The harmonic constituents will enable the modeller to simulate tides at the river mouth for any date. Tidal constituents for a standard port are available from Tide Table produced by the Royal Malaysian Navy (JUPEM). In this analysis, the Dermaga Butterworth tidal constituents are used since the study location is very close to Kuala Juru.

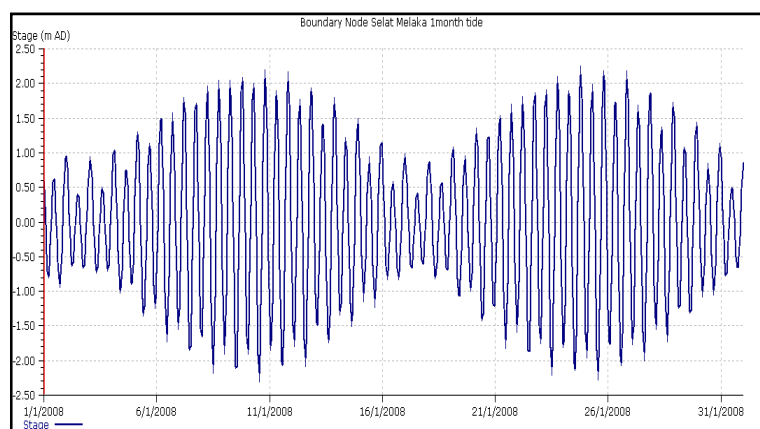


Values of M1, S2, K1, and O1 provided by the Navy in the Tide Table will produce tide information within 80-85% accuracy. To achieve higher accuracy, additional harmonic constituents may be obtained from the DID Coastal Division.

Identifier			
Boundary Dermaga Butterworth		Network Node Type	
Network Node			
Mean Sea Level			
Level (m AD)		0.000	
Harmonic Constituent			
	Code	Amplitude (m)	Phase Lag (degree)
1	M2	0.600	27.000
2	S2	0.360	68.000
3	K1	0.190	355.000
4	O1	0.050	288.000

General Data / Surge / Notes /

Example of tidal constituents for Dermaga Butterworth



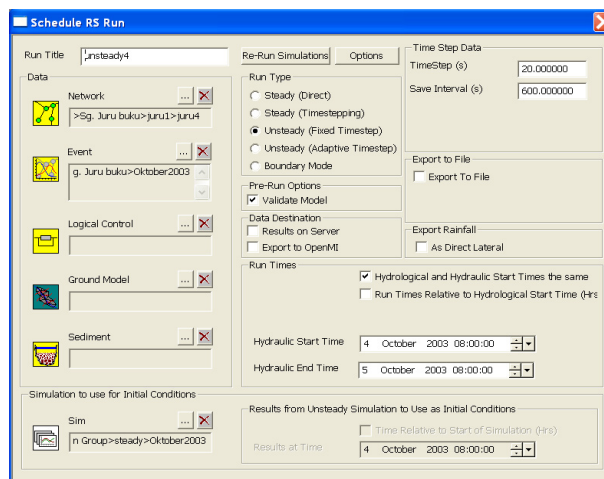
Thus, tide fluctuations were produced (as shown above) using the Tidal Harmonic Constituents at Kuala Juru.

Step 6: Model stabilization

This is one of the most important processes in the development of a river hydrodynamic model. All the data entered should be checked to ensure stability during simulation. Various factors that can cause instability of the model are sudden change in river bed, constriction, sudden gate closure and opening. The data should be examined to ensure smooth transition. Distance between cross sections shall be at recommended spacing. As a guide, more cross-sections are required for a steep slope or where constriction is significant. During simulation, the time step must be kept small. Reducing the time step or adding more cross sections allow for increase in the simulation time.

Step 7: Simulation

Once stabilised with no signs of error, the model is ready for simulation for various flood events. Select the network and the flood event desired and specify the simulation duration and absolute date.



Step 8: Calibration / verification

Despite the constraint in the absence of water level stations in the flooded area, it is fortunate the DID had measured the maximum water levels in the affected area during the flood and their data are now used to compare with our simulated water levels (shown below from IWRS).

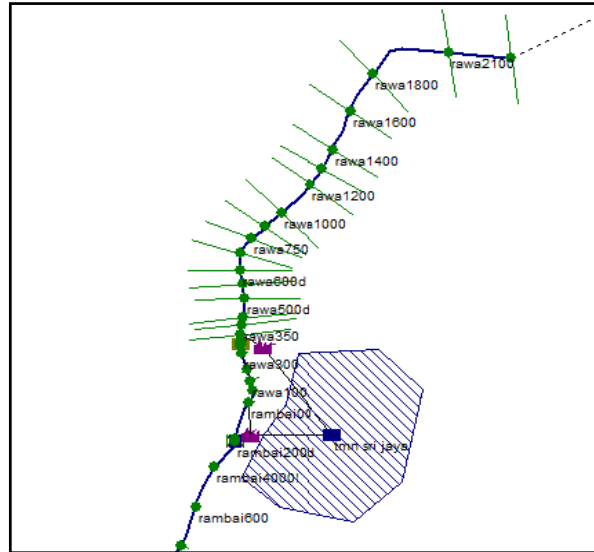
Location	Highest Water Level (Observed by DID)	Node	Highest Water Level (Simulated)	Difference (m)
Middle of Ptg Rawa Road	2.560	prawa350	4.26	1.70
Railway Bridge	2.250	prawa00	4.099	1.89
Top of Concrete Wall P/Ai	4.640	prawa1800	4.651	0.011
LTB (ground)	2.770	prawa550d	4.268	1.498
LTB (ground)	2.750	prawa750	4.281	1.53
Taman Sri Jaya	1.900	prawa200	4.114	2.214
Taman Makok	1.800	Not part of the model	-	
Taman Sri Rambai	1.790	Not part of the model	-	

From the comparison above, the difference obtained between the observed and simulated maximum water levels appears to be too high, inferring that some correction is required for calibration.

Step 9: Correction Considered for Calibration

From site inspection, it was found that the flooded area included a paddy field and the river cross-section survey is inadequate in terms of length of the cross-section intervals. Shorter intervals along the cross-section would have been better since the river is wide. River bank overflow is possible during the flood but this was not considered in the model. With overflow, results of water levels downstream should be lower.

To account for this, the cross section was extended by 300m on each side of the riverbank to consider overflow not only over the road but also into the housing zone in the surrounding low lying area. The road level was used as control height.



The results after these modifications are tabulated below:

Location	Highest Water Level (Observed)	Node	Highest Water Level (Simulation)	Difference (m)	%
Middle of Ptg Rawa Road	2.560	prawa350	2.585	0.025	1
Railway Bridge	2.250	prawa00	2.526	0.276	12.3
Concrete Roof P/Ai	4.640	prawa1800	4.113	-0.527	11.4
LTB (ground)	2.770	prawa550d	2.605	-0.165	6
LTB (ground)	2.750	prawa750	2.634	-0.116	4.2
Taman Sri Jaya	1.900	Tmn Sri Jaya (reservoir)	1.986	0.086	4.5
Taman Makok	1.800	Not part of the model	1.558	-0.242	13.4
Taman Sri Rambai	1.790	Not part of the model	1.654	-0.136	7.6

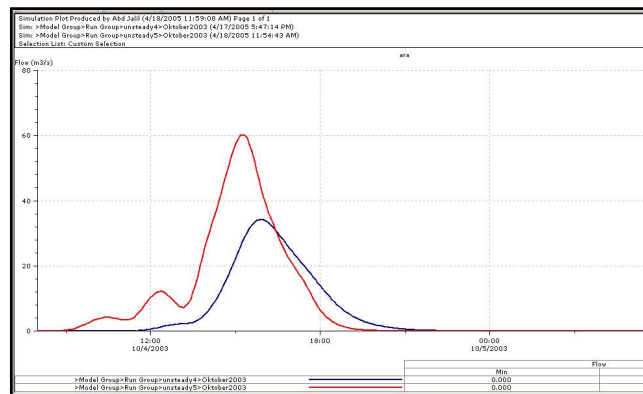
The results show improvement in the difference of the water levels as compared to the previous simulation. The percentage difference within 10% and therefore acceptable.

Analysis and design

The effect of urbanisation that affects the hydrodynamic modelling is discussed below. In the exercise, a section design is considered and the effect of urbanisation on the design is evaluated.

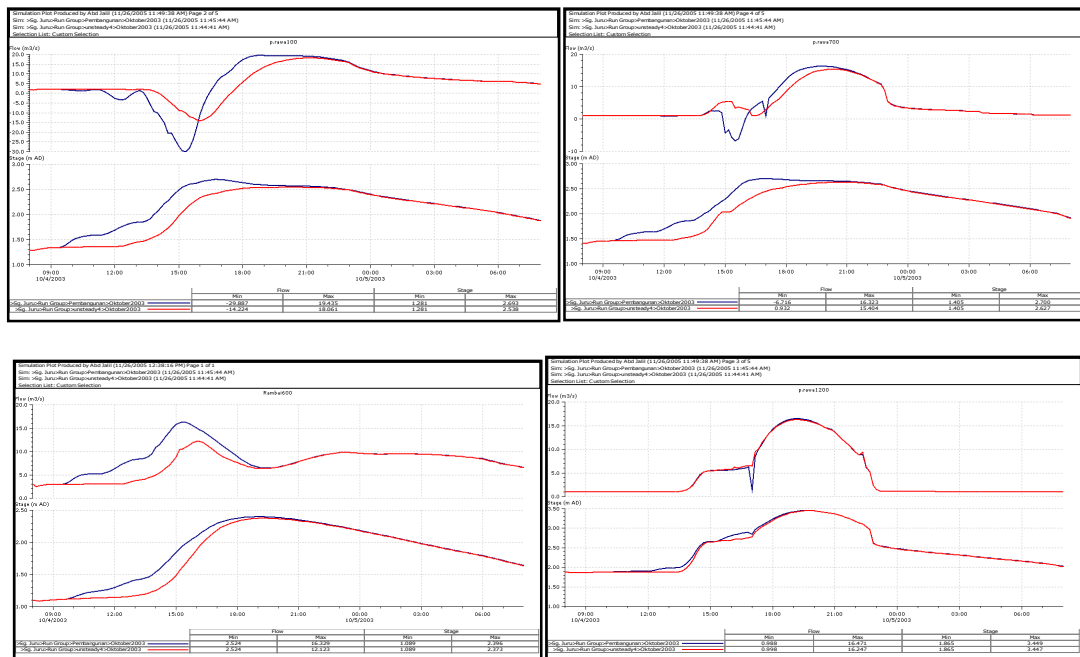
Let us assume Sg. Ara catchment will change from being semi-developed to fully developed area. Since the model uses CN to describe landuse, we need to adjust the semi-developed CN value to suit the fully developed landscape. Tc values will also need to be adjusted since Tc value is dependent on the landuse and slope of the river.

The model is then run for this condition taking into consideration the overflow over the extended riverbank and the surrounding lower lying areas as well as the resulting changes in the river flow from the Sg Ara catchments. The results of this simulation are depicted in the following graphs.



Inflow hydrographs obtained as a result of changing landuse

The results along the river are shown below:



APPENDIX 11.B**Example 2: River Design Problem**

Problem: Sg Permatang Rawa is subject to flooding. Improvement in the river cross-section to reduce flood risks around the village is recommended. Is this recommendation acceptable?

Solution: First decide on the degree of protection level (ARI) for the area. Rainfall intensity can be estimated from the IDF curve applicable (see MSMA). From the hydrologic analysis it is estimated that the peak flow is about $30 \text{ m}^3/\text{s}$.

Using a simple trapezoidal section and Manning's equation, the possible design dimensions of the cross-section can be as follows:

Base width	=	8m
Section depth	=	2m
Bed gradient	=	1:1000
Riverbank gradient	=	1:2
Manning	=	0.03

Assume invert level = 0.0m (same as the existing level), then produce the particulars in the following table.

Chainage	Base Level	Difference
2300	2.3	0
2100	2.1	0.2
1800	1.8	0.3
1600	1.6	0.2
1400	1.4	0.2
1200	1.2	0.2
1000	1	0.2
800	0.8	0.2
600	0.6	0.2
400	0.4	0.2
350	0.35	0.05
300	0.3	0.05
200	0.2	0.1
100	0.1	0.1
0	0	0.1

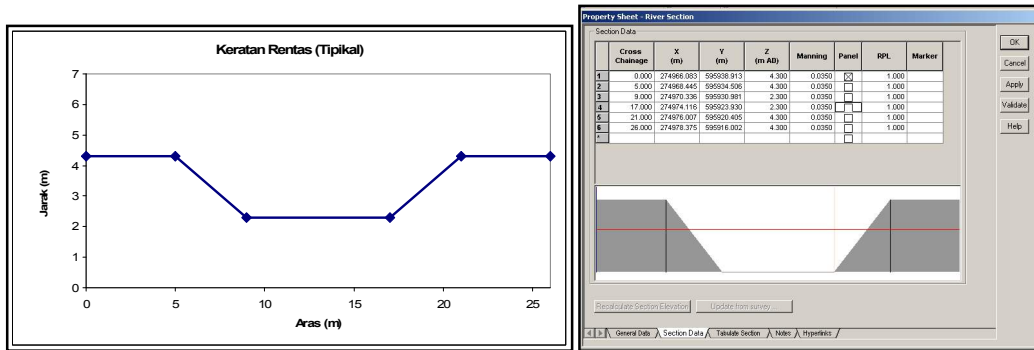
For the given slope above, the depth at upstream is 2.3 m.

Using a simple spreadsheet, estimate the bed levels for all sections along the river.

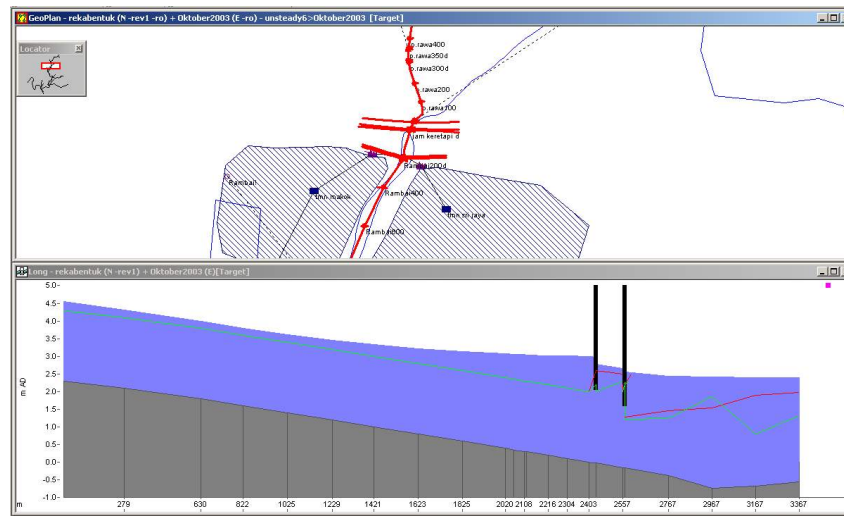
Table 11A.1 Maximum water levels in the Design Section

Node	MAX STAGE (m AD)	BUND LEVEL (m) + (Freeboard = 0.3m)
p.rawa0000	2.991	3.291
p.rawa0100	3.008	3.308
p.rawa0200	3.024	3.324
p.rawa0300	3.046	3.346
p.rawa0400	3.071	3.371
p.rawa600	3.133	3.433
p.rawa800	3.218	3.518
p.rawa1000	3.329	3.629
p.rawa1200	3.46	3.76
p.rawa1400	3.623	3.923
p.rawa1600	3.803	4.103
p.rawa1800	3.983	4.283
p.rawa2100	4.318	4.618
p.rawa2300	4.561	4.861

The proposed shape of the cross section is thus obtained as shown.



All sections along Sg Permatang Rawa were replaced with the new design sections above. Carry out another simulation. The results obtained are shown in the graphs below.



Water level profile along the river (black lines represent bridges) is similar to M1 curve. Note that the water level now is above left bank indicating overflow situation. Thus improving the cross-section alone is not adequate for flood relief.

Also note that the water level is nearly parallel to the river bed. However, it curves at a distance of 1600 m upstream and this is the backwater effect of the structures (bridges or culverts).

A possible solution is to build a bund to prevent water from flowing over the riverbanks. The DID requirement for a minimum freeboard is 0.3 m (Refer to Chapter 10 for further details).

An easy method to obtain the bund level is to add the freeboard value to the highest flood water level at each node.

Next, export the maximum water level to any spreadsheet program. Add a new column to insert the *freeboard* values for the bund level.

The next issue is the water level downstream of the river improvement works.

Compare the results from the original network with results of the design.

Comparison Report - Maximum			
Object	>Model Group>Run Group>unsteady4>October2003	>Model Group>Run Group>unsteady4>October2003	Differences
Max Stage (m AD)			
jam keretapi u	2.977	2.422	0.554
jln pdg lalang kiri			
jlnpdg lalang kanan			
Mekok_Rambai			
p.rawa00	2.991	2.437	0.554
p.rawa100	3.008	2.451	0.557
p.rawa1000	3.329	2.890	0.439
p.rawa1200	3.460	3.397	0.063
p.rawa1400	3.623	3.547	0.076
p.rawa1600	3.803	3.694	0.109
p.rawa1800	3.983	4.129	-0.146
p.rawa200	3.024	2.456	0.568
p.rawa2100	4.318		
p.rawa2300	4.561	5.087	-0.526
p.rawa300d	3.046	2.480	0.566
p.rawa300u	3.049	2.505	0.544
p.rawa350d	3.061	2.516	0.544
p.rawa350u	3.061		
p.rawa400	3.071	2.517	0.554
p.rawa600	3.133		
p.rawa800	3.218	2.603	0.616
Rambai1	2.400	2.347	0.053
Rambai00	2.991	2.437	0.554
Rambai1000_JUNCT			
Rambai1000d	2.400	2.347	0.053
Rambai1000u	2.400	2.347	0.053
Rambai1200	2.352	2.315	0.037
rambai1400	2.313	2.289	0.024
rambai1600	2.292	2.274	0.018
Rambai200d	2.556	2.381	0.174
Rambai200u	2.664	2.389	0.275
Rambai200u2	2.653	2.385	0.268
Rambai400	2.446	2.358	0.087
Rambai600	2.418	2.352	0.066
Rambai800	2.408	2.349	0.058
rawa us			
rawa_d	3.061	2.516	0.544
rb1600b_JUNCT			

What about the residential areas? Check the results from the Storage Area. This is shown in Table 11A.2.

Table 11A.2 Maximum Water Levels in the Floodplain (Residential Area)

Node	Highest Level, Design (M AD)	Highest Level, Original (M AD)	Difference (M)
Tmn Makok	1.738	1.54	0.198
Tmn Sri Jaya	2.056	1.975	0.081
Tmn Sri Rambai	1.738	1.649	0.089

Based on the results, it can be seen that that widening and deepening works along the Sg Permatang Rawa has caused the water level in Sg Rambai and the residential areas downstream to rise by 100mm to 200mm. This indicates that flood may occur even more frequently downstream and therefore increased the potential of more damages.

This issue must be resolve and the options could be to improve the downstream section of the river to cater for higher flows.

The example shows how hydrodynamic river models can serve as an analysis tool in providing a better understanding of the flood behaviour in a river system and used to study the options for improvement works that can be considered for flood mitigation.

APPENDIX 11.C**Example 3: Studying the Impact of Flood Mitigation Structures to Flood Level and Delineation of Flood Map**

This is a case study of a flood issue in TTDI Jaya and Kg Kebun Bunga, Shah Alam Selangor. TTDI Jaya is situated along Sg. Damansara which is frequently flooded. A flood wall was constructed along the river to prevent river water from spilling into the housing area. However on 26 Feb 2006, a big flood occurred in that area, overtopping the wall. Flood damage was around RM 45 Million. Following this, and using results from hydrodynamic models, the wall height was increased from 8.5 m to 9.5 m. Several bridges across the river will be re-designed for improved flood passageway under the bridge.



Sg. Damansara



Wall along TTDI Jaya



Sg. Damansara



Wall along TTDI Jaya



Flood impacts (26 Feb 2006)

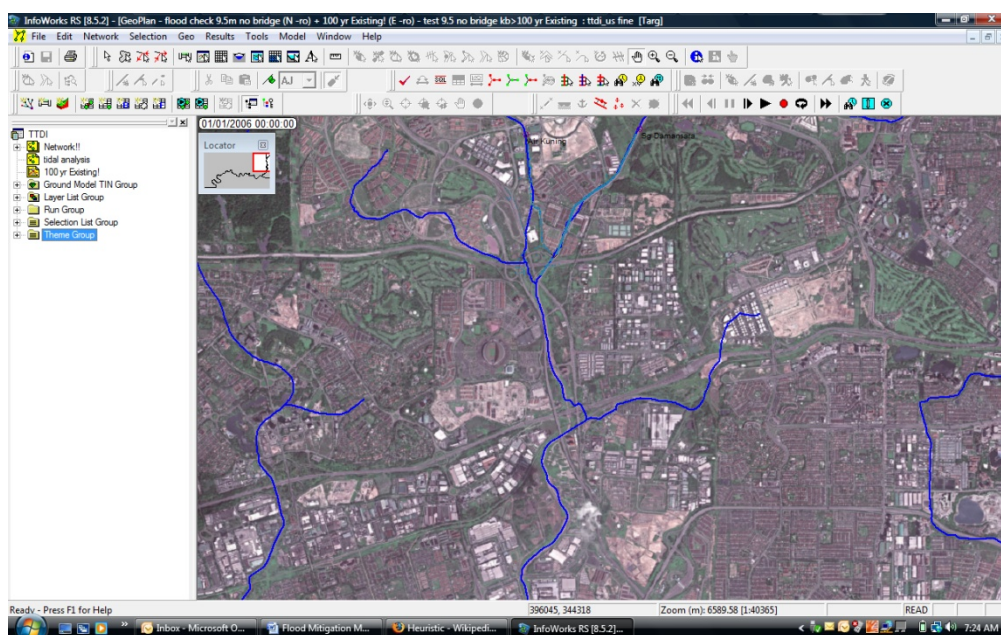


For the above study, the available data for the modelling exercise are:

- Ground data from LIDAR
- Flood Hydrograph from previous study (PREPARATION OF FLOOD MITIGATION MASTER PLAN FOR SUNGAI DAMANSARA CATCHMENT – Jurutera Perunding Zaaba – 2007)
- Bridge information
- River alignment obtained from topographical map
- Satellite images (SPOT5)

Step 1: Built Base Map in Geoplan

As with previous examples, the satellite image and river layer are loaded into a Base Map, shown below:



Step 2: Add Ground Model Data

Since LIDAR data is available, 3D ground data can be generated as shown below.



Digital Terrain Model - TTDI Jaya

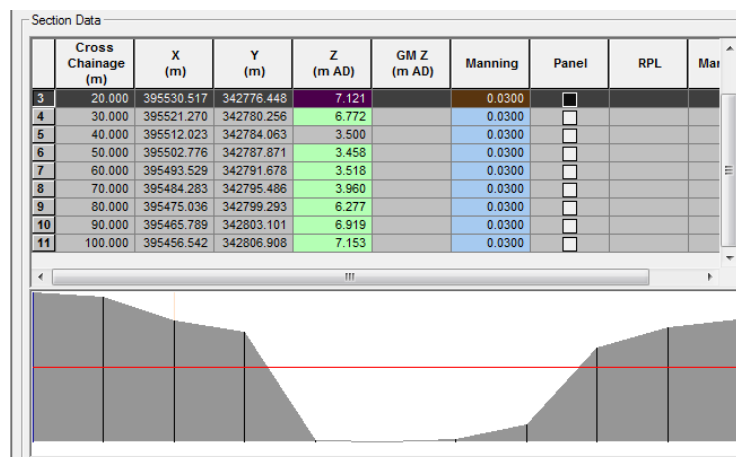


Digital Terrain Model - Kg Kebun Bunga

Step 3: Building River Network

LIDAR data is available at an interval of 1m. This is useful for building a hydrodynamic model.

InfoWorks RS can easily extract the elevations from LIDAR by drawing a line on the map for the cross-section required.



Sample of a river cross section extracted from LIDAR (The chainage is equal spacing)

Create a river cross section at an interval of 100m. For a bridge location, create 2 cross-sections upstream and downstream of the bridge location.

Step 4: Add Bridge Information

Along TTDI Jaya there are 4 bridges to be analysed. The information required includes land survey, abutment position, soffit level and pier.

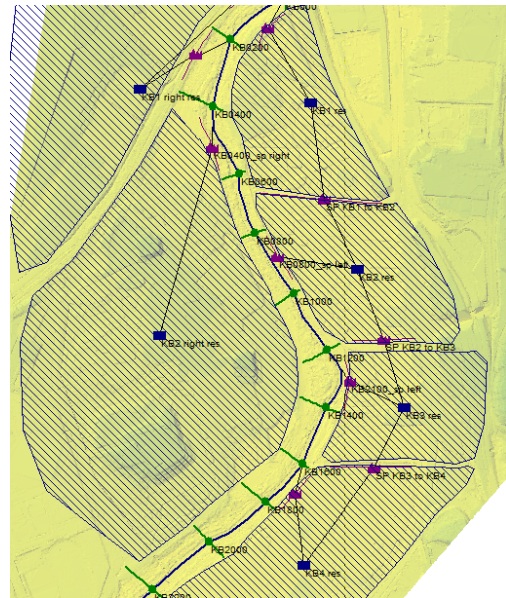


	Cross Chainage (m)	Z (m AD)	Manning	Marker
1	10.000	7.183	0.0250	
2	20.000	6.172	0.0250	
3	30.000	3.500	0.0250	
4	40.000	3.454	0.0250	
5	50.000	3.581	0.0250	
6	55.000	3.400	0.0250	
7	60.000	5.026	0.0250	
8	70.000	6.842	0.0250	

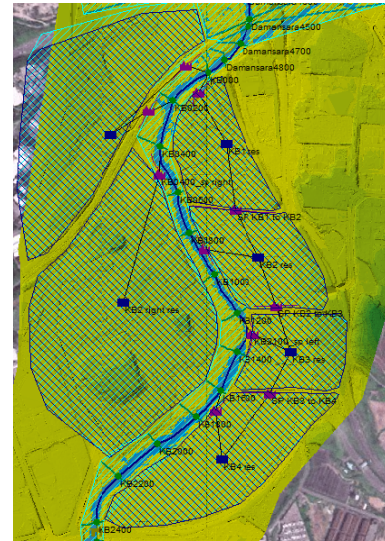
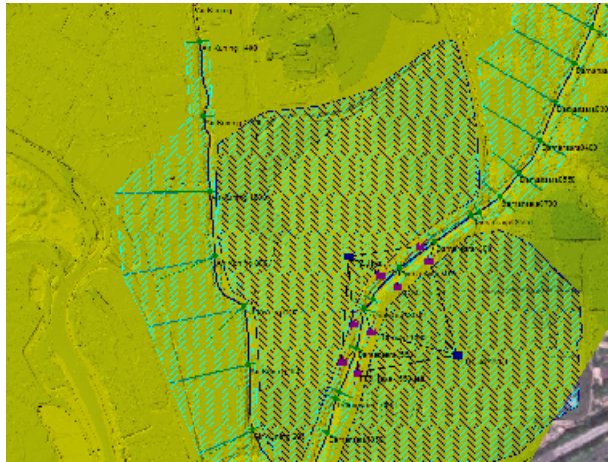
	Left (m)	Right (m)	Soffit Height (m AD)	Spring Height (m AD)
1	20.000	60.000	8.500	7.500

Step 5: Add Flood Plain Information

For 1D model, floodplain can be represented by storage area which is connected to the main river by the spill unit. Concrete wall constructed along the river is used to connect the floodplain with the river.

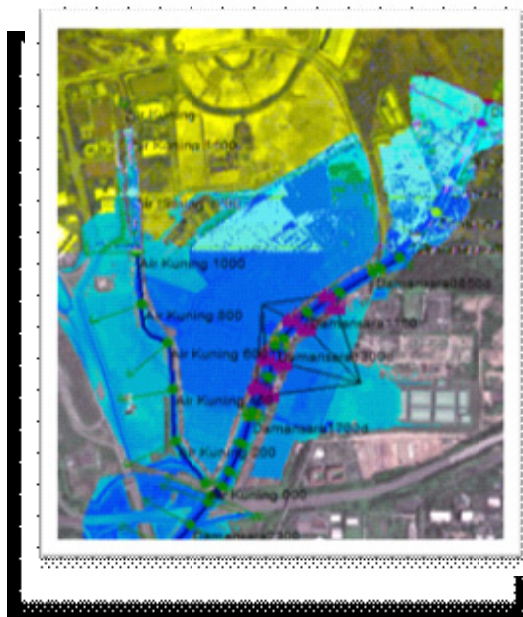


The river and the floodplain (represented by storage area) are linked using the spill link. The top of the wall is used as control level from which floodwater will start to spill into the storage area. The equation applied for flow is a weir equation.

Step 6: Add Flood Plain and Flood Compartment

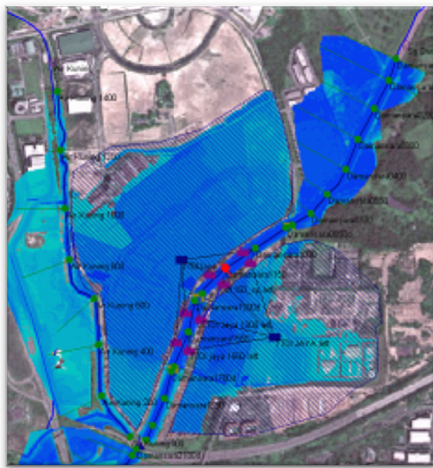
Flood compartment is used in the InfoWorks RS for flood delineation. Water levels in the flood compartment are compared with the ground levels to determine whether any particular area is wet or dry. Depth of water can be determined after completing the simulation.

Final Flood Risk Maps, shown below, are produced from various conditions

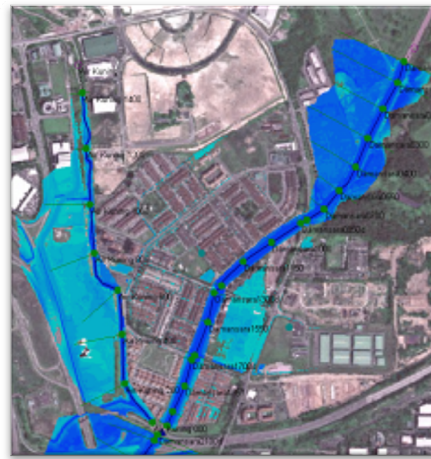


Case I Wall 8.5 m (with the existing bridge)

Case II Wall 8.5 m (with bridge improvements)



Case III Wall 9.5 m (with the existing bridge)



Case IV Wall 9.5 m (with bridge improvements)

Conclusion from the analysis

The analysis provides several useful conclusions. It provides a quantitative evaluation of the impact and performance of the structures (flood wall and bridges) along the river. It also shows the flood pattern that can occur in the TTDI Jaya residential area for various ARI. Various analyses were conducted under various conditions such as the bridges under the existing conditions and after proposed improvements).

Case I: Wall at 8.5m; the existing bridge.

Under the existing condition, the bridge seemed to have significant impact on the flood levels. Floodwater would overtop the wall and flowing into the residential area.

Case II: Wall at 8.5m with bridge improvements

Floodwater would still overtop the wall but the flood extent was slightly less than for Case I. This is an improvement since the floodwater could rise to more than 8.5m.

Case III: Wall at 9.5m and with the existing bridge

Here, the wall was raised by 1 meter to 9.5m level but the bridge remained as in the existing condition. Floodwater will still overtop the wall, flooding the residential area.

Case IV: Wall at 9.5m and with bridge improvements

In this scenario, there is a small chance for the flood not overtopping the wall. This target is achievable only by raising the soffit level of all the bridges. However, raising a bridge deck requires additional land and this is not readily available.

Summary

The example above has demonstrated the versatility offered by hydraulic modelling towards decision making for solving flood problems. It helps in formulating immediate and long-term solutions. For example, the model can also be used to consider constructing flood detention ponds in the future. It can also study the impacts of the proposed solutions on the downstream areas such as at Kebun Bunga.

APPENDIX 11.D

Example 4: Worked Example of Hydraulic Simulation

Various design storms of 2, 5, 50 and 100 year ARI were simulated for various river cross-sections of Sg Skudai, Johor based on the existing land use condition. The river longitudinal sections and selected river cross-sections along Sg. Skudai is shown in Figure 11A.1 and 11A.2. The simulated result from HEC-HMS for the 2, 5, 50 and 100 year ARI design storm serves as input to the hydraulic model HEC-RAS at various locations as shown in Table 11A.1. The river cross-sections are checked based on steady state where only the peak flow will be used to determine the existing conveyance capacity. The detailed cross-sections at various chainages are listed and stored in the file. The results show that overflow begins from Junction 3 until Junction 14. The stretch between Junction 3 and Junction 10 will experience excessive flooding due to 100 year ARI storm under future developed land use condition. Site observation confirmed this finding. Flash flood occurs at all the villages during storm event in December 2006 and January 2007. The rest of figure shows the peak flow at various locations under the existing land use condition for the existing river cross-sections.

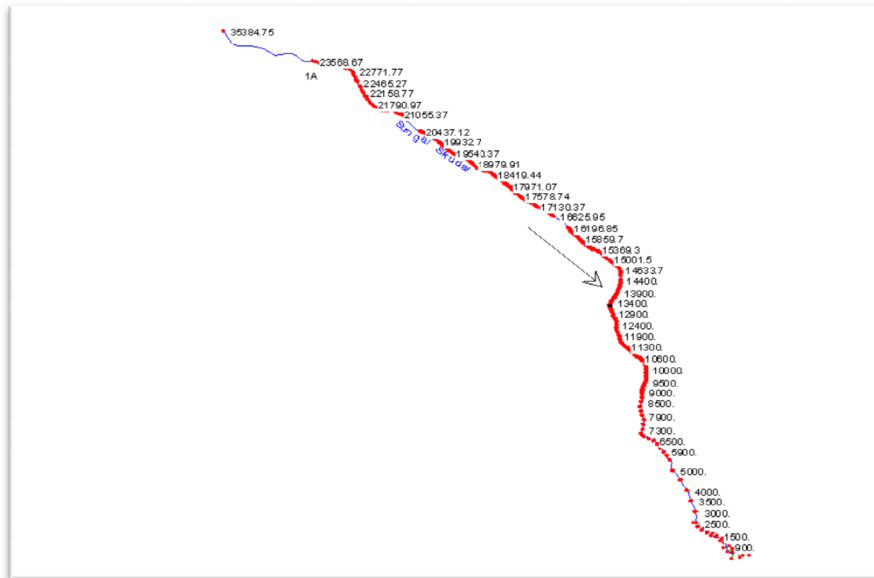


Figure 11A.3 River Cross-Sections along Sg. Skudai

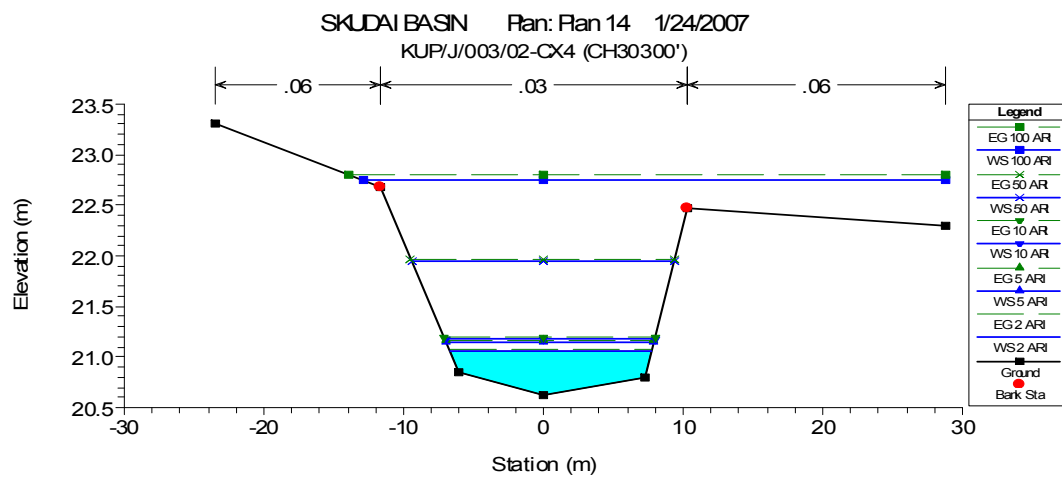
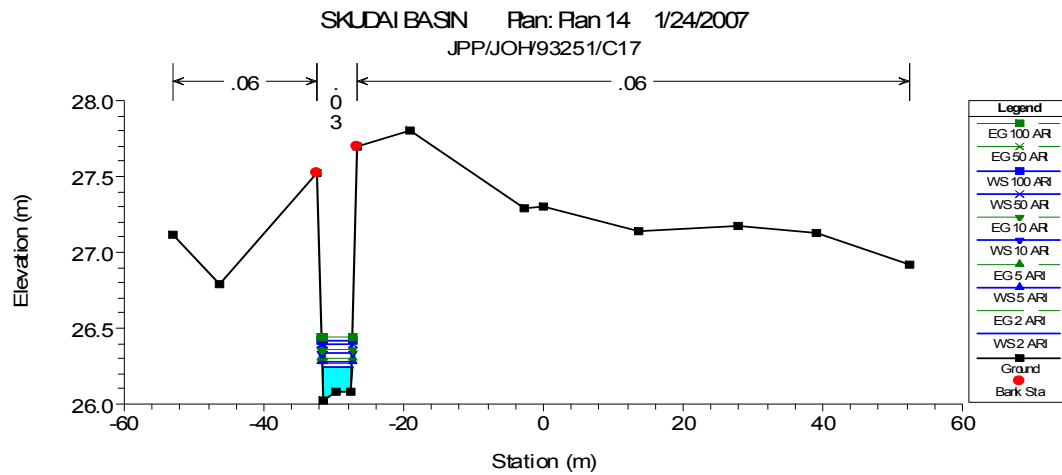


Figure 11A.4 Sample of Existing River Cross-Sections

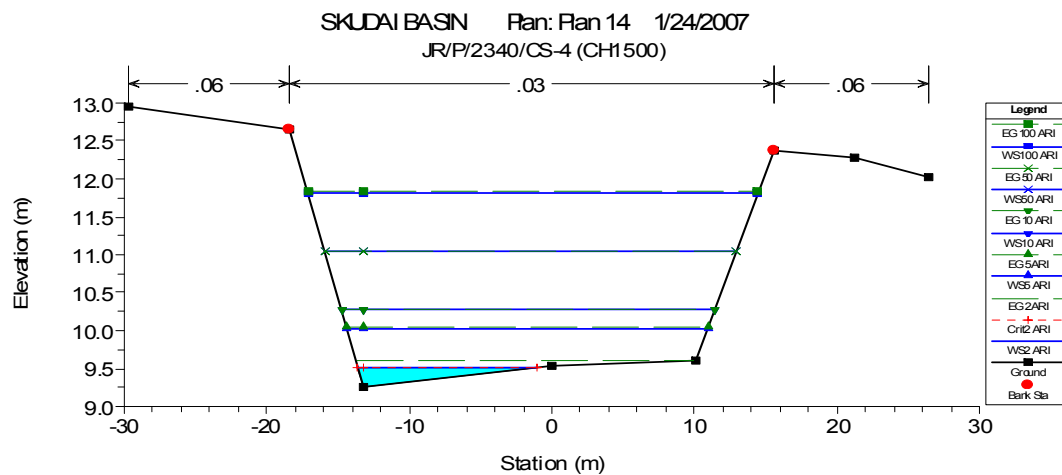
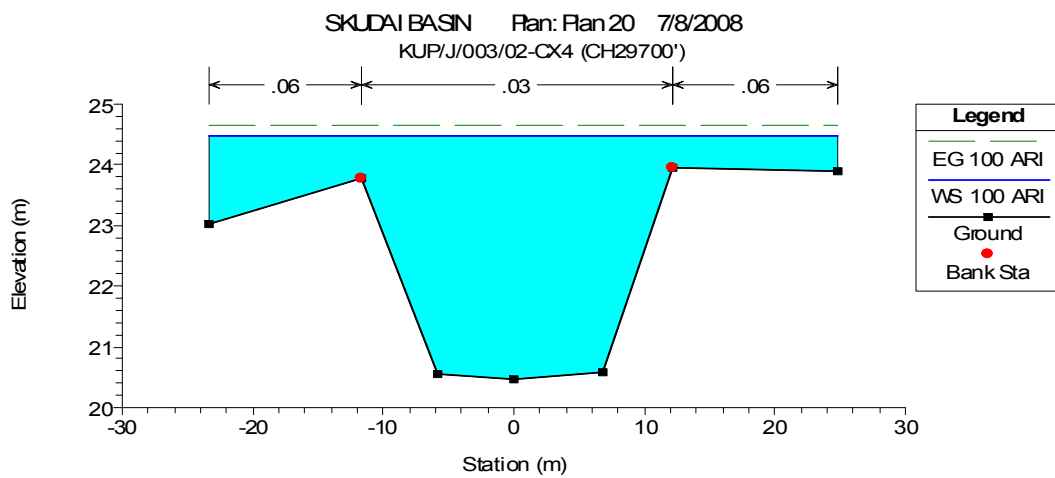
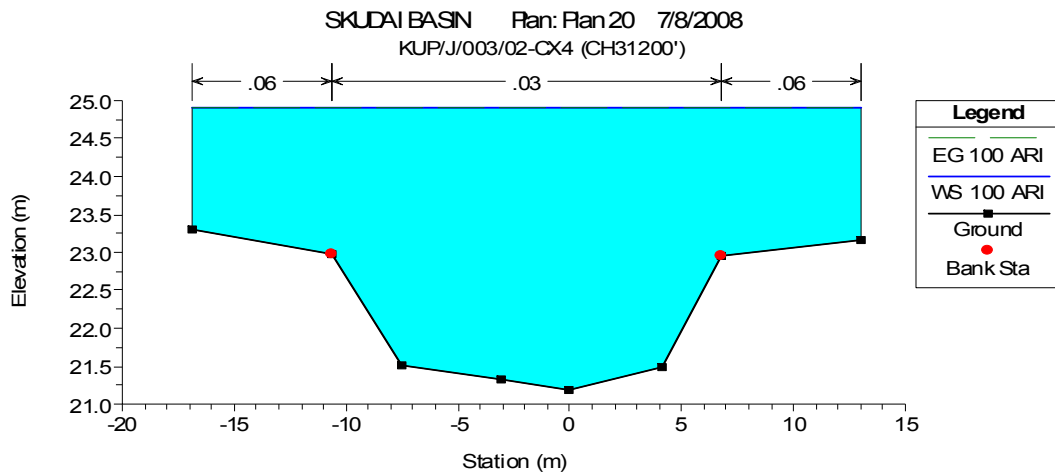
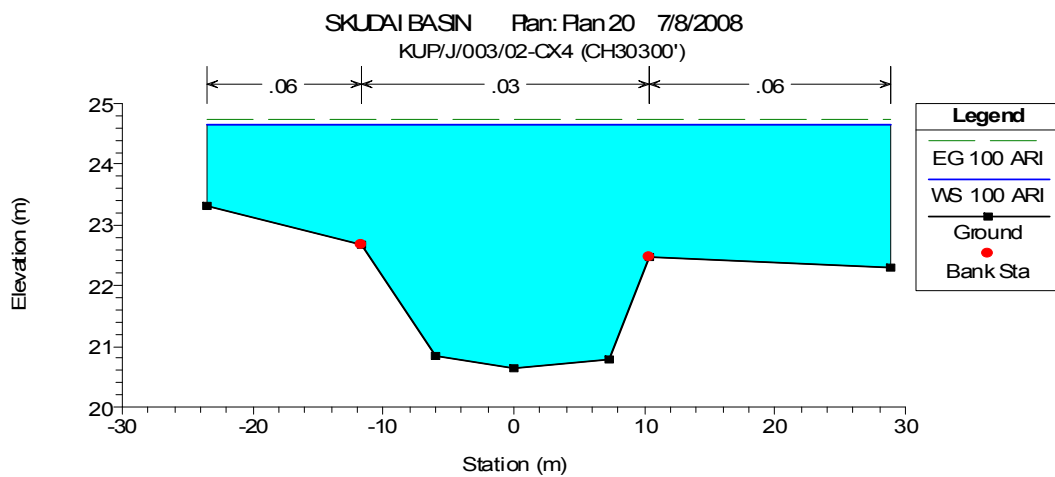
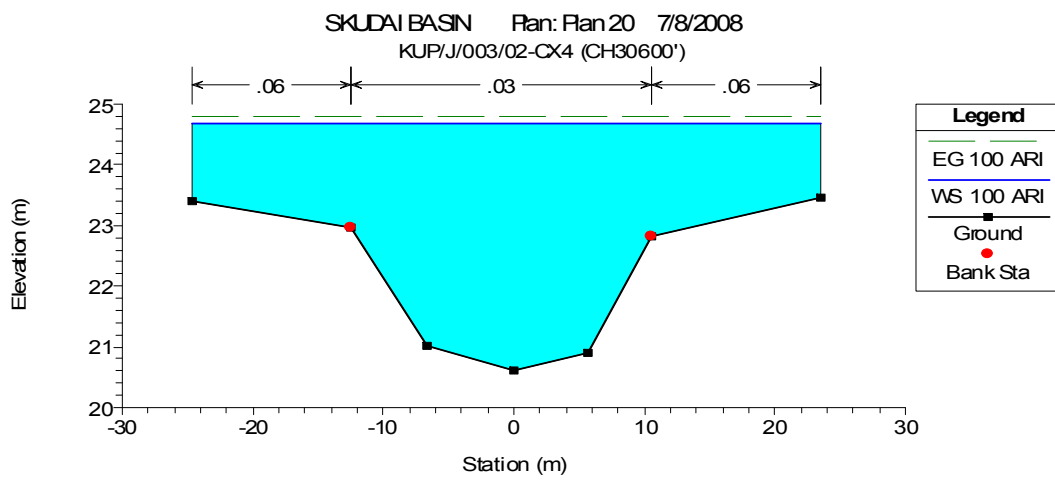
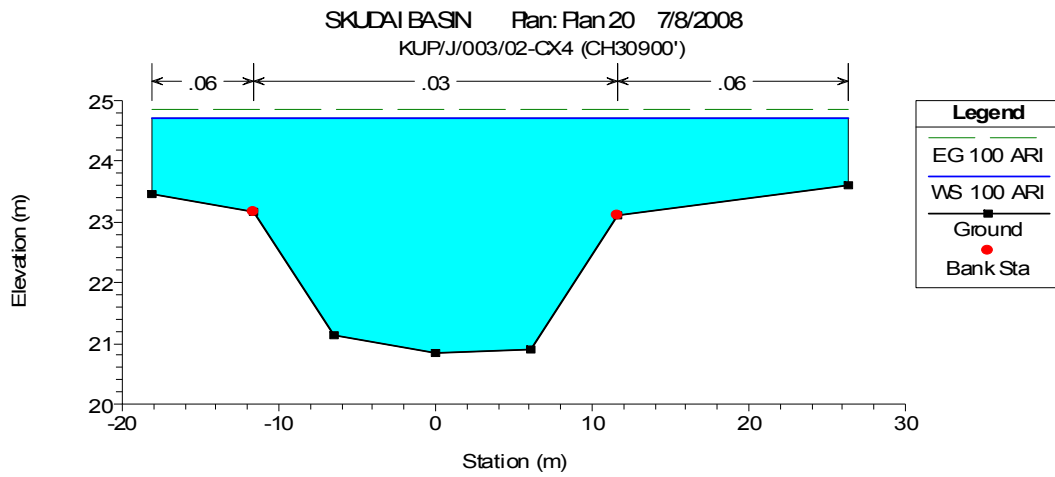
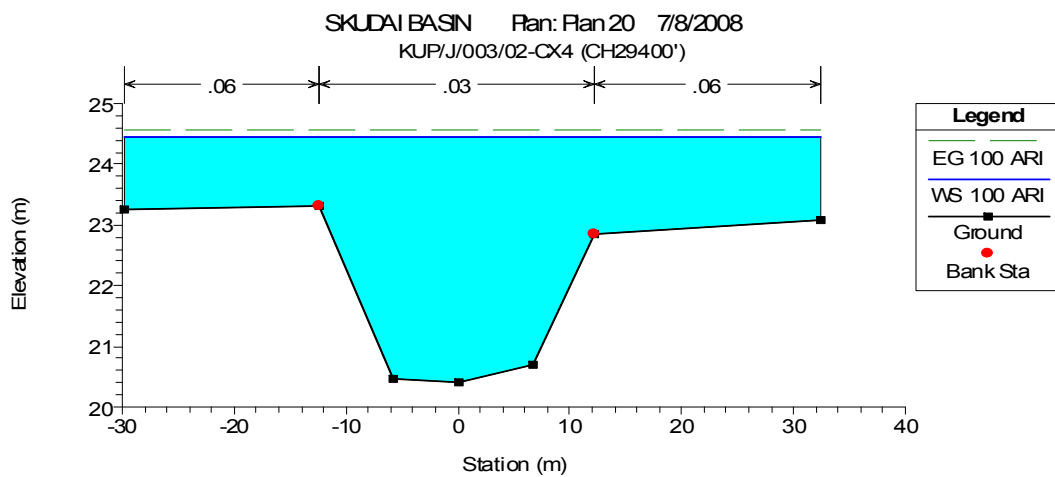
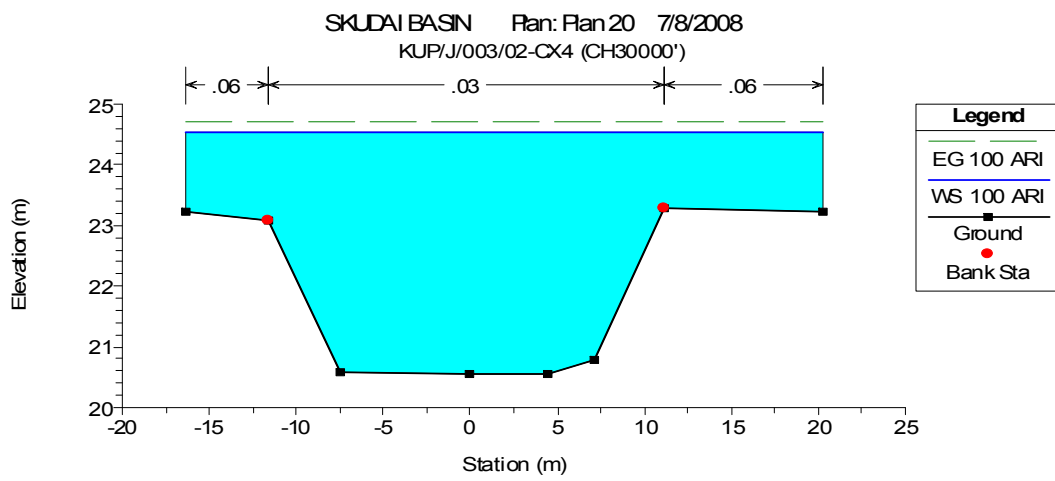
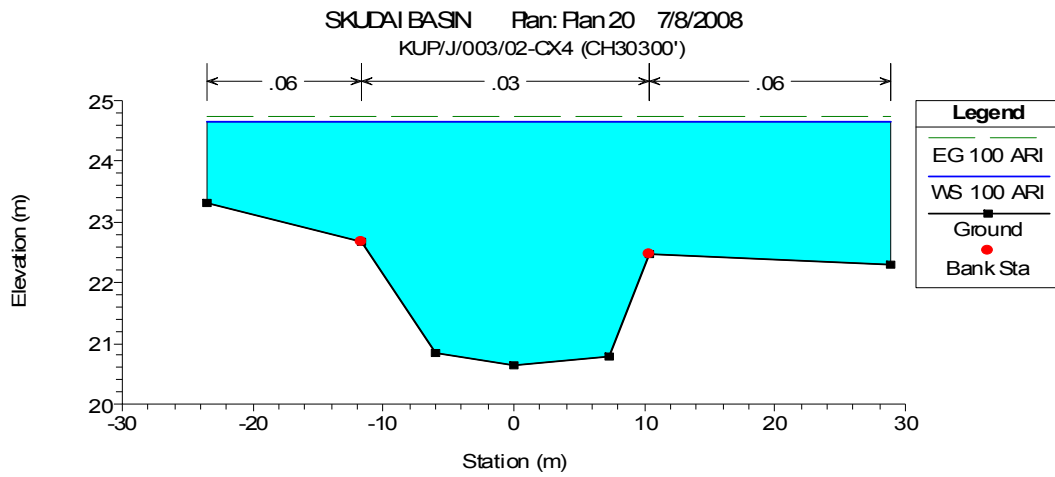


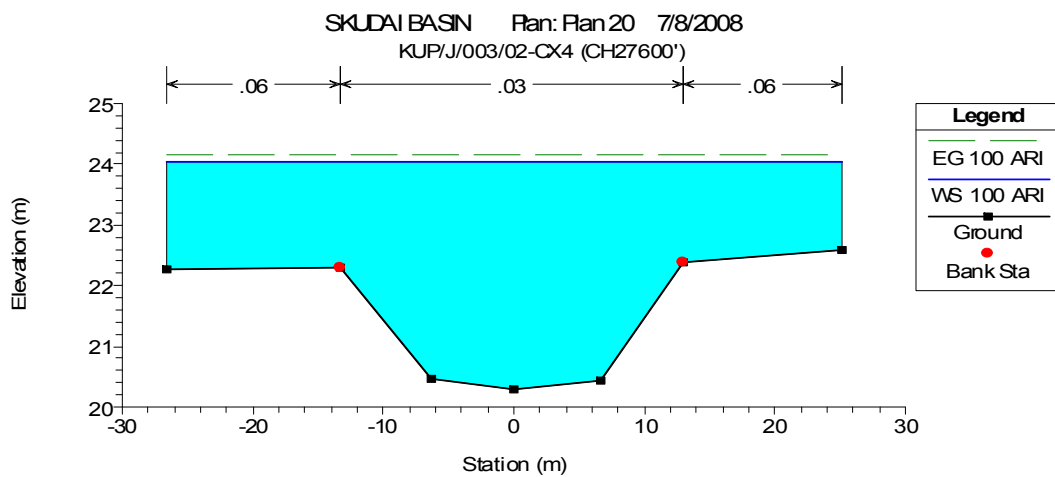
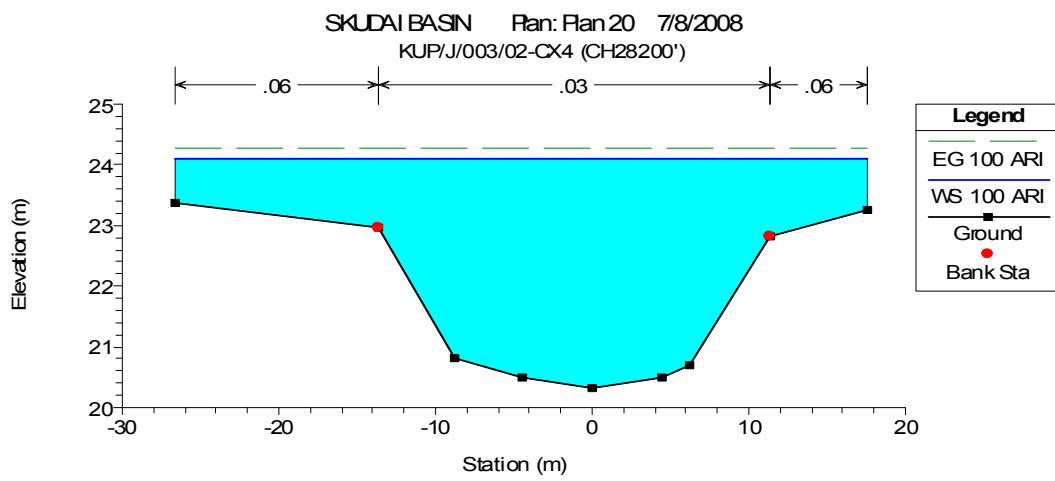
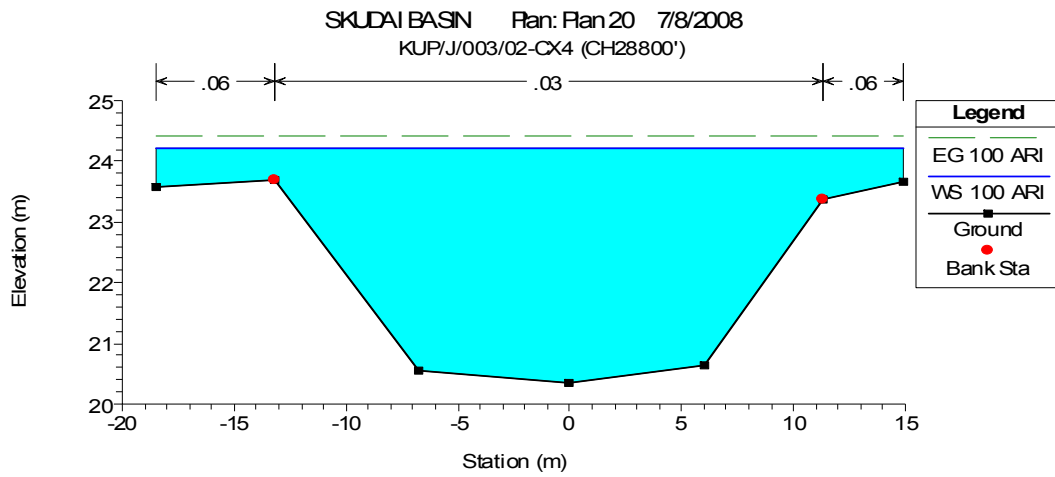
Table 11A.3 Data Input for HEC-RAS

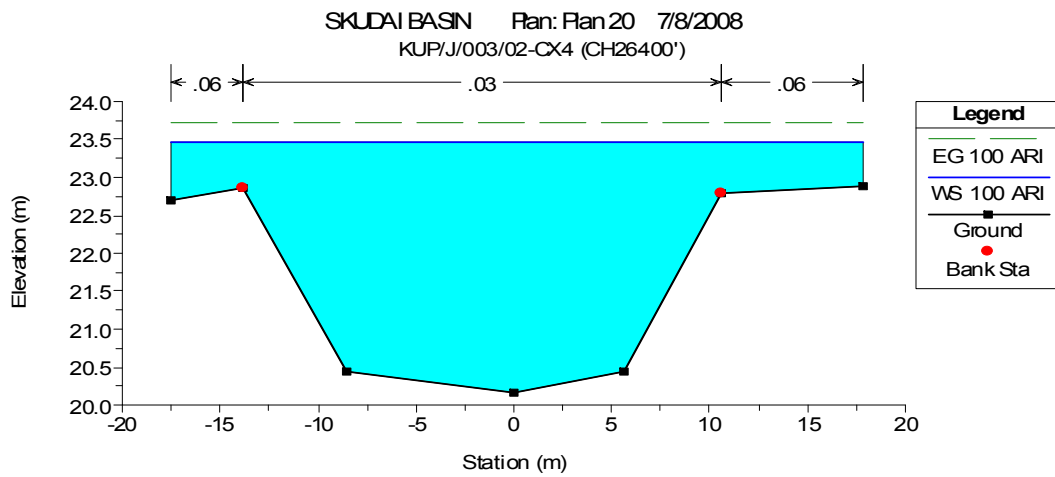
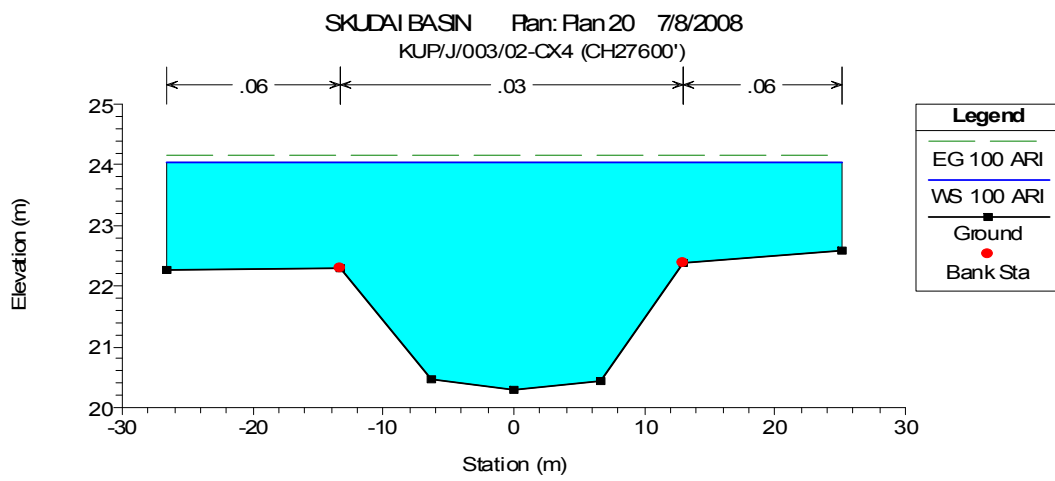
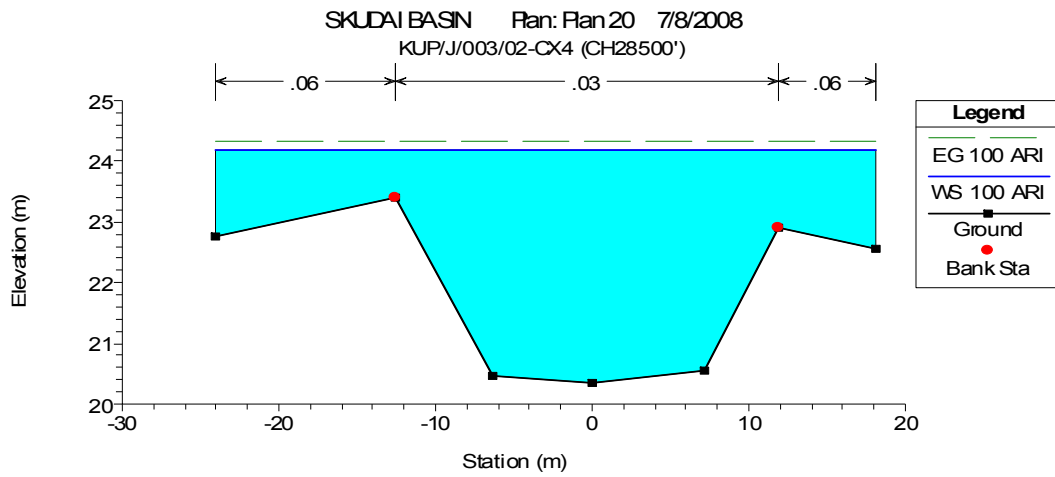
	River	Reach	RS	2 ARI	5 ARI	10 ARI	50 ARI	100 ARI
1	Sungai Skudai	1A	35385	5	10	15	22	30
2	Sungai Skudai	1A	20381	8	15	30	90	150
3	Sungai Skudai	1A	14400	61	98	116	181	350
4	Sungai Skudai	1A	2500	57	100	121	196	550
5	Sungai Skudai	1A	0	70	118	141	224	1200

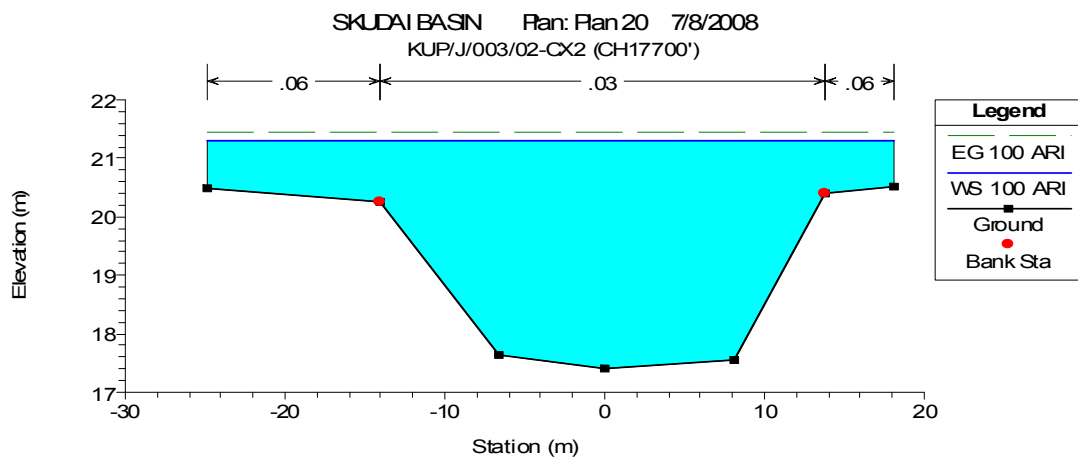
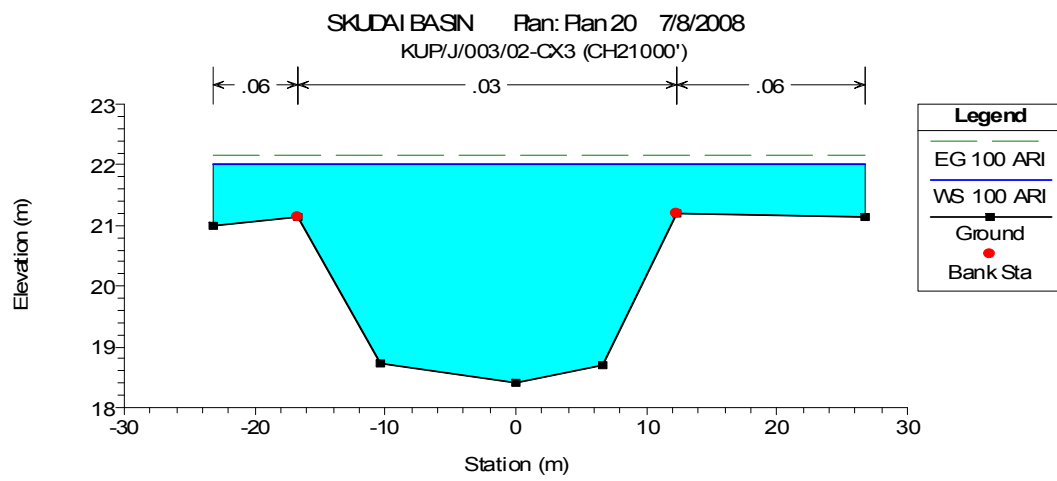
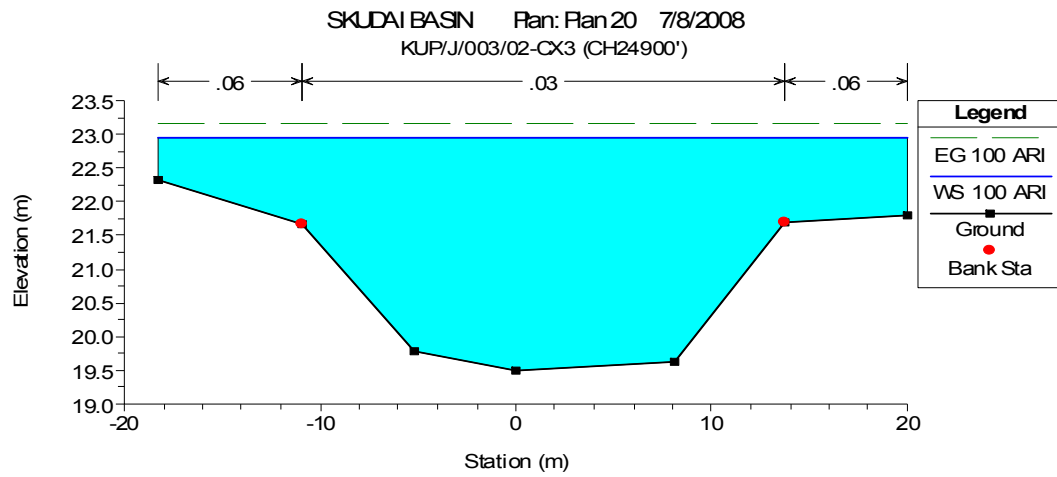


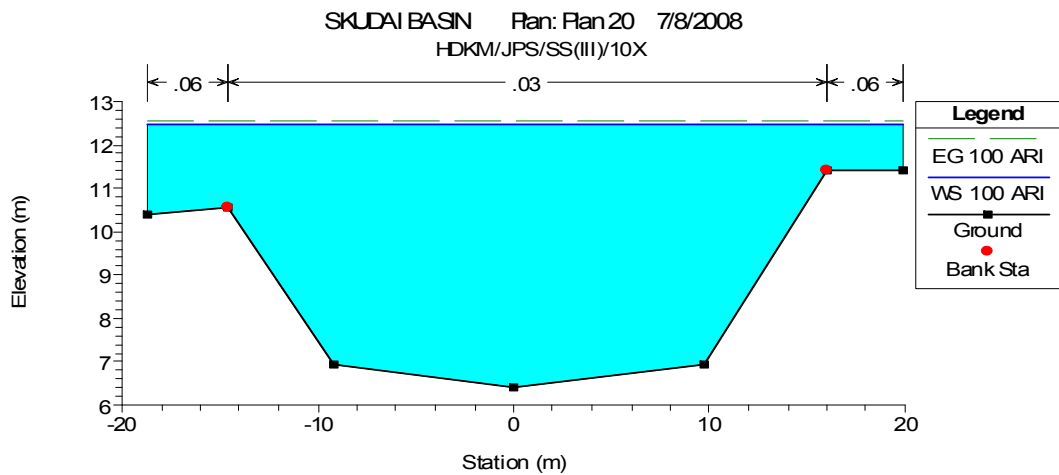
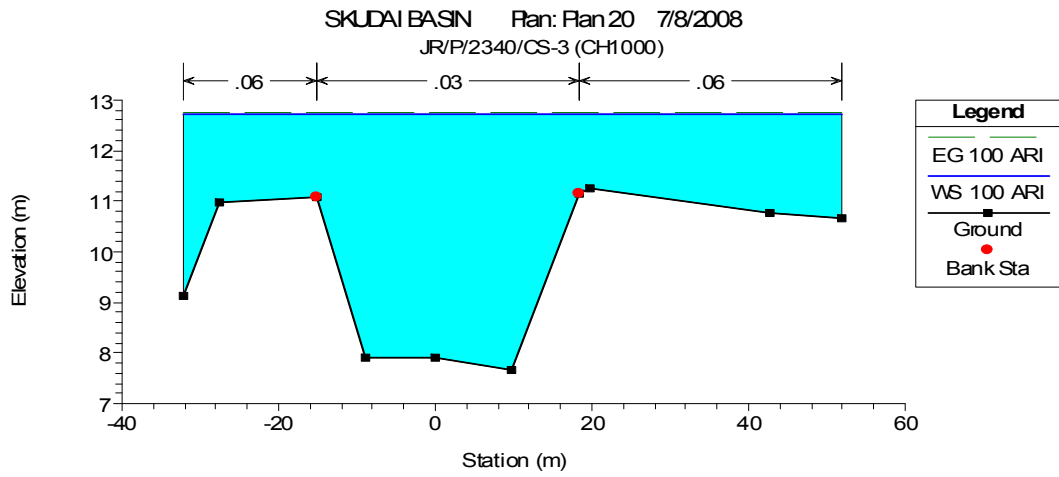
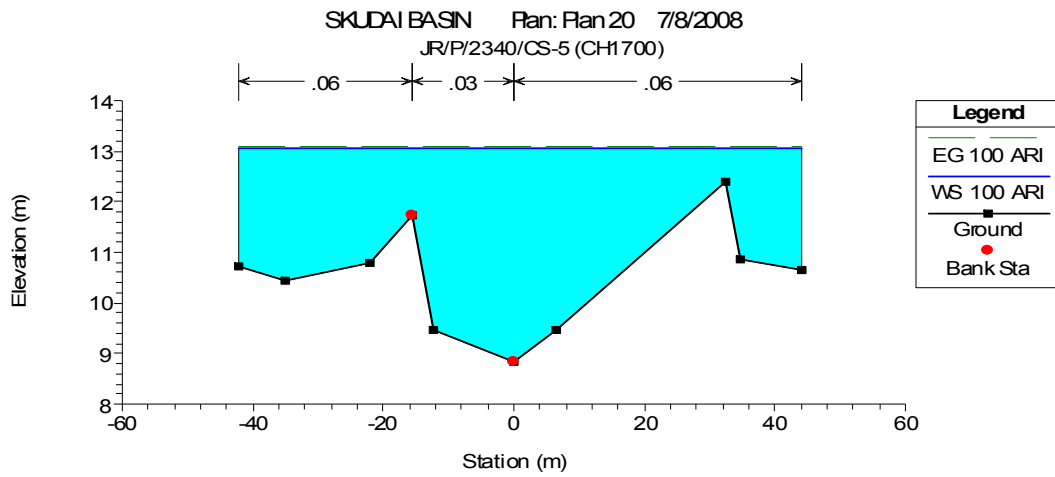


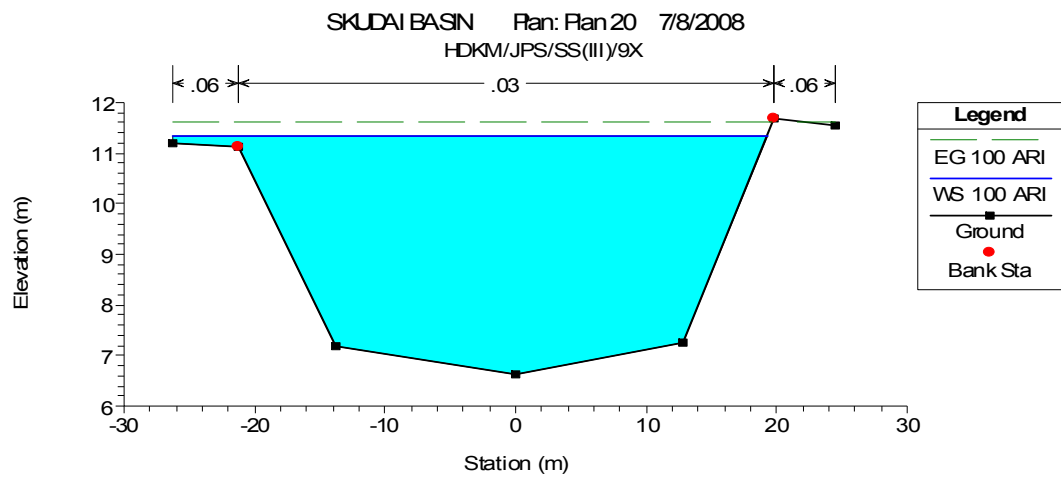












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CHAPTER 12 OPERATION AND MAINTENANCE

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12 OPERATION AND MAINTENANCE

12.1 GENERAL

A proper operation and maintenance (O & M) programme of flood mitigation systems is necessary to maintain the functionality of flood mitigation system as intended by the planners and designers. The purpose of this chapter is to provide general instructions, methods, techniques and data pertinent to the O & M of flood mitigation works. O & M refers to all works and activities required to operate and maintain the installed system and its components.

12.2 BEST MANAGEMENT PRACTICES (BMPs) FOR FLOOD CONTROL

BMPs are associated with the O & M activities in enhancing safety and performance of the flood management system, energy conservation while minimising costs. It encompasses design concepts and parameters, maintenance technique, strategy and control, handover procedure, risk assessment, economic life factors, maintenance audit, condition surveys, health and safety and statutory requirements and training.

O & M management is about determining what needs to be maintained, how and when. This includes identifying problems and diagnosing their causes; monitoring the effects; preparing and analysing records and technical information; initiating the procedure to cope with situations before they arise; and ensuring the techniques adopted achieve the required results. It also covers the human, machinery and equipment and financial resources management.

Maintenance can be broadly categorised as unplanned and planned. In the unplanned maintenance there is no organised arrangement and is performed only to react only when the need arises. Unplanned maintenance suggests that the operator is not responsible for the failure of the structures and the inevitable consequences.

Planned maintenance is organised and controlled in a number of ways such as:

- (a) Preventive maintenance: this is carried out at pre-determined intervals or corresponding to the prescribed criteria, all intended to reduce the probability of failure;
- (b) Corrective maintenance: work is done knowing a fault has occurred to restore mechanically or electrically an installation to normal operation. This approach is subject to prior agreement with the user that this is an acceptable basis for maintenance;
- (c) Immediate maintenance: this is necessitated by unforeseen breakdown or damage and the need to put it right immediately;
- (d) Scheduled maintenance: this is preventive maintenance carried out to pre-determined intervals usually based on the period in operation;
- (e) Opportunity maintenance: work is done as and when possible within the limits of operational demand;
- (f) Design-out maintenance: this is performed when other forms of maintenance are inappropriate. This calls for maintenance that is designed-out to achieve the required level of reliability;
- (g) Condition-based maintenance: this is work initiated by trends highlighted by routine or continuous monitoring of the condition of the mechanical/electrical installation, such as general performance of specific parameters (e.g. bearing vibration and motor-winding temperature); and
- (h) Run-to-failure: this requires that the mechanical/electrical installation be safely and effectively run to destruction without serious loss of their services. Standby units must be available that can automatically operate on failure of the duty unit.

Whichever the type of maintenance plan that is adopted, it would likely comprise of a combination of these methods. It starts with an assessment of what is effective followed by a decision on what is desirable and a consideration of the resources available in terms of labour, materials and facilities; together, these should provide a rational basis for preparing a programme of planned maintenance.

The BMPs for O & M of flood mitigation structures and facilities include setting up the maintenance policy, asset and inventory management, condition review and appraisals, routine inspection, planned preventive maintenance, corrective maintenance, scheduled corrective maintenance, beyond economical repair, quality assurance programme (QAP), maintenance of management information system, and on site library.

12.2.1 Maintenance Policy

During the planning stage of a project, a maintenance policy must be established to ensure the installation is operable and maintainable effectively. The maintenance policy for structures and installation is likely to be unique, but many of the variables are likely to apply generally. The following questions are intended to help in the formulation of a policy.

- (a) Where are the implications of failure?
- (b) How is this installation likely to fail?
- (c) What is the probability of failure?
- (d) Are standby facilities available?
- (e) What level of use is envisaged?
- (f) What type of maintenance is envisaged?
- (g) What level of technical expertise will be available?
- (h) Will spares be available on site?
- (i) Can equipment be purchased or rented locally?
- (j) Can a standard of maintenance be started?
- (k) Will all necessary documentation be provided?
- (l) What financial resources will be available for maintenance?

12.2.2 Asset and Inventory Management

Physical assets have a design life. They are planned and constructed or manufactured, used and managed, and when no longer required, are either disposed or altered for a new use. The life cycle of assets are often known as the asset journey. Assets are owned and managed throughout their life within a framework of economic returns and risks. All asset owners and users expect appropriate returns or benefits from their investment, the minimisation of waste and the matching of their assets with the services they deliver. Conversely, risks brought on by political, financial, operational, workplace health and safety, and environmental factors must be managed by asset owners, managers and users.

Therefore in maintenance management it is important to develop criteria for assets identification such as:

- Locating an area that can be uniquely identified;
- Location code, unique series of alpha-numeric characters used to label, identify and signpost a location;
- Asset, an item owned, maintained or operated by DID that can be uniquely identified;
- Asset Code, a unique series of alpha-numeric characters used to label and identify an asset;
- Inventory services, maintained or operated by DID;
- Inventory Code, a unique series of alpha-numeric characters used to identify a number of similar inventory items; and
- Structures and Equipment Type Code, a unique series of alpha-numeric characters used to code an equipment type.

12.2.3 Condition Review and Appraisals

Assessment of the conditions of structures must be carried out on regular basis. The purpose of the assessment is to recommend for upgrading or replacement of the structures or mechanical and electrical installation of equipment. It involves the preparation of:

- Selective condition appraisal reports for structure, mechanical and electrical installation or equipment;
- Annual selective condition appraisal reports with recommendations for structures, mechanical and electrical installation and equipment;
- Condition appraisal reports as the need arises with recommendations for specific items of structures, mechanical and electrical equipment; and
- Cost estimates for replacement of structures, mechanical and electrical equipment deemed to be "Beyond Economical Repair".

12.2.4 Routine Inspections

Routine inspections involve periodic close observation and assessment of the structures and equipment. It consists of the following activities:

Inspection Checklists and Inspection Frequencies

Every checklist shall bear the following information:

- Asset Name;
- Asset Code ;
- Asset Number;
- Job Code;
- Staff Name;
- Job Intervals;
- Inspection Date;
- Elements of Inspections; and
- Other Remarks.

Inspection Schedule

A calendar chart shall be drawn out by the DID to establish the occasions for the routine inspections. This chart should indicate the projected implementation plan, which shall be generated periodically (annually or quarterly).

The inspection shall be carried out by the DID, contractor or sub-contractors. While executing the task, all necessary care shall be taken to ensure minimal disruption to the operation. Health and safety to staff, public as well as the inspection workers, shall be given prime attention. Such observations shall be carried out to update records on the current conditions of the facilities in terms of the degree of deterioration. Any deviation from statutory requirements and other relevant standards shall also be noted.

Document Inspections

Upon completion of the task, the inspection checklist shall be compiled, analysed, and follow-up actions initiated. The relevant data shall be logged into Management Information System (MIS) for QAP or historical analysis.

12.2.5 Planned Preventive Maintenance (PPM)

Planned preventive maintenance is periodic maintenance on structures, equipment and facilities to minimise the risks of failure and to ensure continued proper operation. These include cleaning, lubricating, adjusting, replacing of certain parts.

Prepare PPM Tasks and Frequencies

Each PPM task shall consist of the following elements:

- A checklist in simple point forms for all the PPM work instructions including the relevant test records;
- A list of work instructions which illustrates the scope of work of the maintenance personnel such as inspection on degree of wear and tear, adjustment or calibration of controls, replenishing of spares and consumables, etc;
- A list of PPM spares and consumables such as spare parts, disposable items and cleaning up materials;
- A list of workforce requirements stating the appropriate skill and estimated man-hour; and
- PPM frequencies i.e. intervals of the PPM tasks.

PPM Schedule

A calendar is necessary for the Planned Preventive Maintenance. This chart should indicate the projected implementation plan that shall be generated periodically (annually or quarterly).

Executing PPM Task

The inspection shall be carried out by the DID, Contractor staff or sub-contractors. While executing the task, all necessary care shall be taken to ensure minimal disruption to the operation.

Document PPM and Submit Reports

Upon completion of the task, the PPM checklist shall be compiled, analysed, and follow-up actions initiated. The relevant data shall be logged into MIS for QAP and historical analysis.

12.2.6 Corrective Maintenance Including Routine Corrective, Breakdown and Emergency Maintenance (CM)

CM is for the purpose of detecting faults in structures, mechanical and electrical installations and equipment and carrying out repairs for restoring the asset to a specified condition when it fails. Corrective Maintenance includes Routine Corrective Maintenance, Breakdown Maintenance and Emergency Maintenance.

Routine Corrective Maintenance

The defects in the operation or usage of an item should be detected by the operator, equipment user or the technical personnel during inspection.

Breakdown Maintenance

Any defects in the operation or usage of an item are to be detected by the operator or staff personnel taking the item out of service. Maintenance work will be carried out by either the on-site in-house staff, regional in-house staff or by the contract-out service providers.

Emergency Maintenance

Emergency maintenance shall be available at all times during and after normal working hours. A clear line of communication must be established. On receiving a request for emergency maintenance, the designated staff shall promptly organize the inspection and repair works.

12.2.7 Scheduled Corrective Maintenance

Scheduled Corrective Maintenance is maintenance that has been pre-determined during the routine inspection of PPM which could not be executed immediately upon detection.

Procedures

Technical staff shall complete a works order form for the defects detected from the following work schedules:

- Daily Inspection Rounds;
- Routine Inspections; and
- Planned Preventive Maintenance

Assessment and planning for the work comprises categories such as:

- If the work request is urgent, then the work shall be performed immediately;
- If the work request is routine, then it should be scheduled; and
- Request and co-ordinate access.

12.2.8 Beyond Economical Repair

This requires development of procedure for recommending "Beyond Economical Repair (BER)" for structures, mechanical and electrical installations and equipment. An item of structures, mechanical and electrical installation or equipment shall be recommended for BER when it has satisfied the BER requirements such as:

Obsolescence

The item of structures, mechanical and electrical installation or equipment is considered as BER when it is obsolete due to any of the following factors:

- A new model of the same equipment has a design change with improved efficiency and increased capacity;
- Increased capacity is required due to expanded operations or less labour intensive requirement;
- Existing concept for the service provided by the equipment is not acceptable to the user;
- New safety requirements renders the equipment unsafe;
- Genuine or approved equivalent spare parts are no longer available; and
- Third party service agents are not available and the equipment cannot be repaired in house.

Reliability

Any item of structures, mechanical and electrical installation or equipment is considered BER when it is:

- No longer dependable for delivering the job in the time available; and
- Un-economical to regain the specified level of reliability.

Statutory Requirements

Non-conformance of the asset within any newly introduced statutory requirement.

12.2.9 Training

User Training

User training is demonstration of proper and safe use of equipment or facility including regular maintenance.

12.2.10 Quality Assurance Programme (QAP)

In order to deliver service of required quality, QAP must be adopted by:

- Developing QA indicators for flood mitigation structures.
- Developing Quality Assurance Programme
- Implementing QAP; and
- Monitoring of QAP

Procedures

- Developing Performance Indicators
- Developing Quality Assurance Programme (QAP)
- Implementing QAP
- Monitoring of QAP
- Providing periodic QAP reports; and
- Carrying out periodic and ad-hoc inspections of QAP.

12.2.11 Maintenance Management Information System

A Maintenance Management Information System is recommended and this shall include:

- Developing a computer based Maintenance Management Information System (MMIS);
- Installing and Implementing MMIS; and
- Accessing Central Host MMIS

12.2.12 On Site Library

This requires providing for on-site personnel with documented O & M instructions by:

- Providing a library facility;
- Obtaining reference material and documentation;
- Compiling and cataloguing reference material and documentation; and
- Accessing the library.

A library is a place at an appropriate site where collection of documents, drawings, manuals, books and materials of similar nature are kept.

12.2.13 As Built Drawings (ABDs)

Upon completion of the flood mitigation construction and installation works, all ABDs shall be properly kept at the on-site library (as hardcopies and softcopies). ABDs could comprise the following drawings:

- Survey drawings;
- Structural drawings;
- Infrastructure drawings;
- Mechanical and electrical drawings;
- Installation and equipment drawings;
- Reference materials;
- Suppliers hand-over documents and reference materials; and
- Operating instruction and maintenance manual.

For reference/documentation purposes, all ADBs shall be compiled, catalogued, filed, and digitised using a modular computerised information system.

12.3 RIVER BUND MAINTENANCE

A properly operated and maintained river bund is crucial in ensuring its reliability and dependability for flood mitigation. River bund maintenance activities include regulation and legislation, control and prevention, inspection and patrolling as well corrective maintenance.

12.3.1 Regulation and Legislation

Any maintenance activities for the flood control works must comply with the relevant regulations and legislations. Among these are Water Supply Act 1998, Fisheries Act 1985, National Forestry Act 1984, Land Conservation Act 1960, Environmental Quality Act 1974, National Parks Act 1980, Protection of Wildlife Act 1972, National Land Code 1965, Occupational Safety and Health Act 1994, Land Ordinance 1930, Conservation of Environment Enactment 1996, Water Resource Enactment 1998, and Environmental Quality Act 1974. Detailed requirements of these legislations are given in Chapter 4 of the Manual.

12.3.2 Control and Prevention

By the legislative requirements, the authorities should control all developments or construction works on, through or in the vicinity of the flood mitigation facilities so that such activities do not reduce the existing standards for flood protection. Any activity outside the river bund right-of-way should be in accordance with the accepted floodplain management practice as established by DID.

12.3.2.1 Excavation

Excavation works adjacent to the river bund, bank protection or other flood protection structures should be discouraged. However, where such excavation is necessary, expert advice should be obtained to ensure the works do not destabilize the existing facilities.

12.3.2.2 Pipes and Cables

Where pipes, cables or other works must pass through or along the river bund, the correct use of seepage collars and compacted backfill materials is mandatory. Rupture resistant pipe, with mechanical or equivalent joints which will not separate under settlement, shall be used where pipe is laid within the design bund section. Material excavated to install the works should be replaced with backfill material of equivalent flood resistant quality and in a manner that will not reduce the standard of protection.

12.3.2.3 Encroachment

Trees or tall shrubs should not be allowed to encroach on the river bund. Structures or other obstructions should not be allowed within the right-of-way or situated in a position that would impede river bund maintenance work or the functioning of designated floodway corridors. Access to

the bund crest, slopes and adjacent bank protection should be maintained to permit inspection, maintenance and repair of the flood mitigation works. Figure 12.1 shows encroachment into a river bund.



Figure 12.1 River Bund Encroachments along Sg. Dungun, Terengganu

12.3.2.4 Proposed Works

Any work or works proposed on or in the immediate vicinity of flood control works (bund, bank protection, structures or internal drainage works) should be reviewed by the relevant authorities.

12.3.2.5 Sediment Removal

Sediment removal from the river channel should not be undertaken in a manner which may jeopardise the river bund. Excavation on the river side should generally be undertaken at a safe distance away from the toe of any riprap as determined by and, as a guide, it should not extend below a 3:1 (3 horizontal metre for each vertical metre) line from the bund crest. If sediment removal is required to be taken out of the river reserve, the Land office shall be referred to for the necessary sediment removal permit and approval. Temporary stockpile of sediments should be located at least 5 metres from the river bank.

12.3.3 Inspection and Patrolling

It is the responsibility of the local DID office to conduct river inspections. However it is good practice to encourage local residents to report any defects and illegal intrusions of the facilities.

12.3.3.1 Routine Annual Inspection

The entire bund system should be inspected at least once a year for routine maintenance. This inspection should be scheduled early enough prior to the flood season to allow adequate time for any required work to be completed before the high water conditions.

The inspector should look for and note any of the following items:

- a) The extent of vegetation growth and the presence of trees.
- b) Any damage to the bund slopes.
- c) Any obvious low spots along the bund crest.
- d) Animal burrows (Figure 12.2).
- e) Any unauthorized excavation or construction in, on or adjacent to the bund. If deemed to be detrimental to the integrity or performance of the flood mitigation works, the inspector may order corrective action; and
- f) Signs of erosion of the river bank or damage to the existing bank protection.

During the inspection attention should be given to:

- Loss of rocks from the existing protective layer;
- Slumping of the slope;
- Erosion or scour of the river bank immediately upstream or downstream of the bank protection, or at the toe of the slope or riprap. In some cases, an underwater survey of the slope may be advisable to determine the degree of any toe scour;
- Weathering or abrasion of rock particles;
- Loss of, or significant changes to, the overbank area which could endanger the bund;
- The condition of the control gates as to the ability to open and close freely and provide a watertight seal when shut;
- Any access obstructions to the river bund and along the crest;
- The condition of all fences, gates and locks and the availability of keys;
- The condition of pumps and pump stations both structurally and functionally;
- Damage to the water level gauges and their legibility; and
- Debris or other problems at intakes (trash racks).

A written report on the results of the inspection should be prepared and submitted to the relevant authority and the necessary work scheduled for completion prior to the next flood period.



Figure 12.2 Animal Burrows at the River Bund

12.3.3.2 Inspections during High Water Events

Additional river bund inspections or patrols should be carried out during high water events to monitor the performance of the flood control works and take corrective action as required.

Prior to flood seasons, the inspector should be consulted for information regarding the predicted runoff volumes. During high water events, local water level gauges should be monitored regularly and the readings recorded for long-term reference. River bund patrol frequency should increase as the water levels approach critical conditions, and should be continuous while the level is within 1 m of the crest. The patrol crews are to observe and report to the relevant authority any occurrences that could signal a weakening of the works, such as:

- a) Seepage - Seepage through the bund and at the landside toe of the bund is to be expected at high flood levels. This seepage is considered to be normal provided flows are not excessive or concentrated in the form of piping or boils. Piping results where fill is transported by the seepage flow; this can be identified either as suspended silts (murky water) or visible grain particles. This process enlarges or progresses toward the river at an increasing rate. Eventually an open path is created and the bund is breached. The piping process is sometimes indicated by boils, small upwelling which can appear at considerable distances inland from the inside toe of the bund, and which are caused by excessive seepage pressure. Close attention should be paid to seepage, as an increase or concentration of seepage flows can threaten the safety of the bund.
- b) Sloughing and/or erosion of the bund slopes (gully).
- c) Settlement of the bund crests and slopes (depressions).
- d) Areas of low freeboard.
- e) Cracking of the bund crest or slopes
 - i. Desiccation cracking: forms in random, honeycomb patterns and is serious only when deep;
 - ii. Transverse cracking: forms perpendicular to the bund alignment and can easily create a seepage path; and
 - iii. Longitudinal cracking: forms parallel to the bund alignment and may indicate the start of a slide or slump. May result from toe erosion, differential settlement or saturation.
 - iv. Erosion of the riverbank adjacent to the bund.
- f) Sloughing and/or erosion of bank protection works. Critical areas should be closely inspected during and after high water events.
- g) Debris accumulation at flood boxes, flap gates and trash racks.
- h) Pumps not operating properly.
- i) Stream blockages or shifts in flow direction due to log and debris, especially near bridges or other constrictions.
- j) Seepage along cables or pipes or box culverts that transverse the bund fill.

A bund inspection log should be kept by the owner to record all inspections.

12.3.4 Corrective Maintenance

12.3.4.1 Bund Corrective Maintenance

The essential bund corrective maintenance activities include the following:

- a) Repair of Bund Slope Damage - Damage to slopes should be repaired as soon as possible by the addition and compaction of appropriate earth fill materials to restore the slope to its original condition.
- b) Trimming of Vegetation Growth - Vegetation on the bund side slopes should ideally consist of closely trimmed grass. The bund slopes should be cut at least once annually. Tree and brush growth should be removed for the following reasons:
 - i. The vegetation attracts burrowing animals whose burrows are detrimental to the bund stability;
 - ii. Tall vegetation obscures signs of seepage or damage to the bund which may thus go undetected and eventually cause bund failure;

- iii. Tree roots, when they decompose, can encourage the development of pipes, and consequent bund failure; and
- iv. Large trees pose an additional threat to bund stability, especially during flood events when the bund structure becomes saturated. High winds and overbank erosion during floods can cause trees to fall resulting in the displacement of bund fill material and possible failure of the bund. In coastal regions especially, these conditions may occur simultaneously.
- c) Restoration of Bund Crest Elevation - Every three to four years the bund crest profile should be surveyed and compared to the design profile. Any low areas should be raised by the addition of crushed gravel surfacing, prior to grading of the whole bund crest as required to maintain a smooth riding surface.
- d) Animal Burrows - If animal holes or burrows are discovered during inspection, they should be excavated and backfilled with compacted material. Trapping of the animals may be advisable in such areas after consultation with local Fish and Wildlife authorities.
- e) Repairing Fences and Gates - It is recommended that access to river bunds be restricted to authorized vehicles only. All fences and gates should be kept in good condition. All locks for the gates should be in good working order, with keys readily available at all times since emergency bund access may be necessary at any time (e.g. for fire-fighting, rescue, etc). There are to be no obstacles placed which prevent access by authorized vehicles.
- f) Water Level Gauges - Water level gauges, if installed, are in key locations. The gauges should be inspected annually, repaired and re-levelled if necessary, so that they can be readily observed by bund inspection personnel at all times. Care should be taken to ensure that the gauges are always maintained to the correct datum. Where a gauge has to be established or re-established or where there is reason to doubt the gauge datum, both the Inspector of river bunds must be informed so that appropriate action can be taken.

12.3.4.2 Bank Protection Maintenance (Repair)

Bank protection usually comprises angular pieces of blasted rock placed over a granular filter layer. The rock gradation and maximum size is determined by the stream velocity and slope of the bank. The bank protection will require varying degrees of maintenance depending upon the degree and frequency of exposure to stream flow or wave action.

Repair should be made by the addition of suitably graded rock riprap. The rock should be placed by backhoe, hydraulic excavator or clamshell to fit tightly together and form a smooth continuous slope.

If a major failure of the bank protection occurs, specialist advice should be obtained prior to undertaking a repair. Approval must be obtained from the Inspector of river bunds before commencing repair work within the wetted perimeter of the channel. Figure 12.3 shows a damaged riverbank bund.



Figure 12.3 River Bund Bank Protection Failure at the riverside of Sg. Dungun

12.3.4.3 Floodbox/Flap Gate Maintenance

The purpose of a floodbox is to allow the gravity discharge of internal drainage water from behind the bund into the main watercourse during times when the external water level is lower than the level behind the bund. A floodbox generally consists of a culvert through the bund with a flap gate at the outlet. Trash racks may be fitted at the inlet and/or the outlet.

Maintenance of a floodbox consists of cleaning the inlet and outlet of any accumulated debris and sediment to ensure water can flow freely through the culvert. The flap gate should be periodically cleaned and lubricated to ensure that it swings freely and closes properly with a good seal. The bund slopes adjacent to the floodbox should be kept clear of trees and brush to allow unimpeded inspection of the inlet and outlet of the floodbox.

All inspections should include a check for signs of sloughing which could block the inlet to the floodbox. Both the inlet and the outlet should be checked for signs of erosion or undermining of the structure. All gates, trash racks and miscellaneous metal should be inspected periodically for excessive wear or deterioration. Metal culvert pipe should be checked internally, where possible, for signs of corrosion and deformation. Corrosion at exposed outlets in proximity of the sea is very common.

Inlet and outlet structures should be inspected for evidence of cracking or spalling. Pipe culverts should be inspected for excessive joint involvement, loss of joint sealant and leaks at joints. Floodboxes should be checked regularly in areas where beavers are present since they can plug culverts or construct dams very quickly. Unusually high water levels are a good indication of beaver activity. Culverts should be cleared immediately before the situation becomes more difficult to rectify.

12.3.4.4 Pump Station Maintenance

During times of high water in the main watercourse when the floodboxes are closed, internal drainage water must be either stored or discharged by pumping. Pump stations generally have operation and maintenance manuals specific to each installation and these should be referred to. During bund inspections the following items at the pump stations should be checked:

- Area adjacent to the pump discharge for signs of erosion or instability;
- Operation of the pump discharge flap gate for signs of possible leakage;
- Accumulation of debris on the trash screen or at the flap gate and the need for removal; and
- Any signs of leakage through the bund on the landside slope at the location where the discharge pipe crosses the bund.

12.3.4.5 Special Maintenance Considerations

The following facilities could require special maintenance:

- Channel bed Erosion or Sedimentation
- Bed Erosion and Design Allowances
- Sedimentation and Design Allowances
- Procedure for Establishing the Need for Sediment/Debris Removal
- Log and Debris Jam Removal.

12.3.5 Emergency Measures

It is advisable to prepare a flood contingency plan in conjunction with the local State Emergency Program Committee. If there is a threat to the safety of a river bund, the DID may carry out any work to prevent failure of the bund or bank protection.

Environmental agencies are available to advise relevant authorities on sound environmental practice. The district DID is responsible to ensure there is adequate personnel, equipment and materials readily available to respond to emergency situations. As the river rises to critical levels, crews should be prepared to undertake emergency repairs as outlined in the following sub-sections.

12.3.5.1 Active Boiling

The simplest and most effective method of treating an active boil (one that is carrying sand and silt) is to construct an impervious ring around it of a sufficient height to stop the transportation of solid material. It should not be built to a height which stops the flow of clear water because of the probability of structures unable to take up an excessive local pressure head, which could cause bund failure or additional boils nearby. Well rings, short pieces of large diameter pipe, earth berms, sheet steel pilings, etc. can all be used, but the most generally accepted method is using sandbag rings.

The recommended method for installing a sandbag containment ring is as follows:

- a) Scarify the base for the ring (internal diameter of which should be at least 1-1/2 times the contemplated height) to provide a watertight bond between the natural ground and the sack ring (a very important step);
- b) Lay sacks in a ring around the boil and surrounding weak ground starting at its outer edge and working towards the centre. Joints are staggered and loose earth is used as a mortar; and
- c) When the proper height is reached (when clear water only is being discharged) a "V"-shaped drain constructed of wood or sheet metal should be inserted near the top of the ring to carry off the water in a more controlled manner in the most desirable direction.

An alternative method of controlling an active boil is by placing a blanket of pea gravel or other free-draining gravel over it. The thickness of the gravel blanket must be increased until the seepage water runs clean. Note that when soil conditions are such that boils occur, it will probably be impossible or imprudent to bring loaded dump trucks into the area, and over the bund crest. First consideration should be given to methods that do not impose heavy loads on the ground adjacent to the boils.

All flowing inactive boils should be flagged and closely monitored throughout the flood period in case they start to transport solids. The flood emergency organization and the DID Office should be alerted under the following situations:

- The active area of boiling is extensive; and
- There is an extensive area of inactive boils and the river level is expected to rise.

12.3.5.2 Seepage and Piping

During high water events the land side slope and toe should be monitored for excessive seepage and possible piping problems. Where seepage on the river bund landside slope leads to soggy unstable conditions, free draining fill berms may be added. Where time permits, expert advice should be obtained, if possible, before taking corrective action.

12.3.5.3 Riverside Erosion

Where river currents are eroding the face of the bund or nearby overbank, additional large rock riprap should be placed with an excavator or end-dumped if the site is accessible to heavy equipment and safe for operation. However, expert advice should, if possible, be obtained.

12.3.5.4 Saturation

If high water levels are sustained for some time and the bunds become thoroughly saturated, it may become necessary to restrict traffic on the crest road.

12.3.5.5 Local Overtopping

As the prediction of flood profiles is uncertain, and because bunds often have varying freeboard, patrols should be advised to pay close attention to lower than average freeboard. Once water flows over the crest, fill is usually washed away creating a breach, which is impossible to close until the water levels equalize and much damage has resulted. It is, therefore, imperative that overtopping be prevented.

Traditionally, sand bags are considered for raising low sections of bund. However, progress is slow and an excessive amount of labour is required. Sand bags should normally only be considered for raising short sections of bund. As an alternative to sandbags, reinforced plastic sheeting can be used to contain loose granular or other fill. Heavy equipment and trucks can be used to raise a bund provided the work is done well in advance of high river levels. No heavy equipment should be allowed on the bund when the water level is near the top of the bund as the vibration might cause a failure.

12.3.5.6 Internal Drainage

Local runoff and drainage will not be released if floodboxes (without permanent pumps installed) are closed in bunded areas. Temporary pumping of local drainage, or interception and diversion of inflow from higher elevations, may be necessary to alleviate this condition. A regularly updated list of potential pump and generator suppliers, together with their required delivery and setup times, should be maintained.

12.3.5.7 Emergency Warning

Should the possibility of uncontrollable bund failure arise, the Disaster Committee at the district level must be alerted immediately. Unless advised otherwise, the Bund Maintenance Team should confine its efforts to preventing flooding while ensuring the safety of its workers. The authority will be responsible for advice to the public. A request for other assistance should be directed to the Disaster Committee who shall coordinate all inter-agency joint action.

12.3.5.8 Special Emergency Measures and Repair Work Considerations

Names and phone numbers of suppliers and construction equipment should be listed and constantly updated for emergency use.

12.3.6 Repairs & Restoration Work

Major repairs and restoration such as bund re-structuring, raising or widening, removal of in-stream sediment aggradations and log and debris blockages, and works that involve breaching of existing bunds such as floodbox replacement, requires expert engineering advice as well as notification to the relevant authorities. Engineering advice should also be obtained regarding permanent repair and restoration work following emergency conditions. All cases of severe damage should, if possible, be recorded with photographs, dates and times of the occurrences.

The mitigation works are designed to provide protection to habitable areas of development up to the design event.

Projections based on routine annual maintenance, emergency response, and an estimated range of projected flood restoration and repair costs (say 5, 20, 50, 100-years) are also checked for a 200-year return event.

12.3.7 Records

The most up-to-date drawings available showing the existing flood mitigation works should be kept available as a reference tool for staff assigned the duty of operating and maintaining the flood mitigation system. Elevations and cross-sectional information are especially useful should repair works become necessary.

Cases of severe damage to flood protection works during high water conditions should be recorded with photographs, and records should be kept of bund inspection logs, gauge readings and high water marks. Also, a detailed record history of all major repair work must be made and kept with as-constructed drawings. Repair records should include dates, stationing and/or location of repairs, dimensions and specifications for materials used, a description of the probable or apparent failure process, and "before" vs. "after" photos of the repairs.

A detailed record of all sediment and log debris jam removal must be kept with the as-built drawings and inspection reports. This must include channel surveys before and after sediment removal, and sediment volumes removed. Annual inspection reports should be sent to the Inspector of river bunds.

12.4 OPERATION AND MAINTENANCE PLAN FOR WATERWAYS AND RIVER CHANNEL

The following sections provide recommendations and requirement for scope of maintenance of various types of waterways and river channels with the purpose of providing health, safety and welfare of citizen, water quality protection, floods conveyance efficiency.

Maintenance of the river channel and natural waterway will involve the followings activities;

- Remove significant debris that is deposited throughout the natural waterways both woody materials and man-made debris.
- When necessary, remove non-native vegetative species to allow for conveyance
- All reasonable precautions to prevent further damage to the stream and its environment to include riverbanks, fishery resources, recreational facilities, undamaged vegetation and tree undergrowths.

Man-made debris includes all non-woody and un-natural materials. Debris that may contain oil, fuel, or other hazardous materials must be handled appropriately following regulations and proper documentation for disposal must be made available.

Natural debris that is in the water shall be pulled from the water placed on the immediate bank for handling:

- Any debris in the water that becomes dislodged because of the operation and floats downstream shall be retrieved for appropriate handling;
- Ground disturbance shall be kept to a minimum;
 - Stop work order may be warranted due to wet conditions to minimize rutting and erosion.
 - All ruts shall be repaired prior to leaving site.

- Most environmentally sensitive and practical treatment of woody and plant can be made on site because:
 - Mulch acts as a cushion, protecting the ground and allows for minimal compaction of soil.
 - More efficient than gathering debris and transporting to a staging area or landfill.
 - Overall cost and time spent on project is substantially lowered.
 - Minimizes trucking and/or disposal cost.

Access Ways

- Placed on higher level adjacent to waterway; and
- Access to pockets of debris can be installed perpendicular to flow of water for 'spot removal' of debris.

Tree Protection

- Viable tree and riparian vegetation removal shall be minimized;
- Trees not damaged by flood or debris are marked and fenced;
- Protection of root zone;
- Take into account riparian practices for vegetation species and population density;
- Land use practices; and
- Damaged tree limb treatment.

Other Considerations

- Property is photographed or video-taped before work begins and after work is complete; and
- After completion, property is returned to pre-maintenance installed condition;
 - Fences replaced.
 - Improved roads repaired.
 - Disturbed ground seeded.

Outside the Scope of river channel maintenance

- Strip clearing of all vegetation and/or undergrowths
 - No formal canalization of natural waterways.
- Remove all woody debris
 - Some is chipped and left for wildlife habitat.
- Silt removal/Relocation
 - Allow for natural sediment Transportation.

The following are some requirements of operation and maintenance program for;

- River Channel/Natural Waterways;
- Lined Waterways; and
- Grassed Waterway.

12.4.1 River Channel/Natural Waterways

12.4.1.1 Removing Debris from Channels

The terms "drift materials" and "debris" can be used interchangeably to describe any floating or submerged materials that are transported by flowing water. Vegetation, sediment, trash, man-made materials and rocks are all considered debris or drift. Vegetation debris and sediment are the primary debris materials that are a maintenance problem.

Many structures have been damaged or have failed as a result of problems caused by debris. The types of damage caused are usually categorized as scour, impact, drag, and miscellaneous.

Scour: Floating debris can catch on structures members, and these obstructions in the stream channel will tend to catch and accumulate additional debris. These accumulations divert and constrict the flow of water, which increases the velocity of the flow and creates turbulence in the flow, both of which increase the potential for bank and bottom erosion (scour) to occur.

Impact: During peak flows, a waterway can carry massive debris such as car bodies, entire trees, superstructure elements of other structures, etc. Debris in fast-moving streams may damage structures and their timber piles. If the water level reaches the superstructure, the beams and bottom chords of trusses may be damaged. Impact damage to solid piers and other structural members is rare but not unknown, especially if barges, floats, or heavy watercraft are swept into them by fast flowing waters.

Drag Forces: Debris caught on the substructure or superstructure members will trap additional debris. Depending upon the size of the debris accumulation and the water velocity, extremely large forces can be applied to the structures. For instance, the massive floods that hurricanes can generate have frequently moved structures superstructures off of their centred position on a pier and have even caused structures spans to collapse.

Miscellaneous Damage: Less common types of damage include fire damage during dry seasons caused by vegetation caught on or accumulated beneath the structures; abrasion damage from sand, gravel, or other suspended particles, especially in streams with high-velocity water flows; and scars on the structures surface caused by debris scratching and marking the substructure and superstructure units.

After heavy storms, structures should be routinely checked to determine the need to remove debris. All structures should be checked at least once per year. If maintenance records indicate that debris accumulation is a common problem, structures should be checked more frequently.

12.4.1.2 Emergency Debris Removal

During peak flows, it may be necessary to have maintenance personnel available for emergency debris removal. This work involves removing floating debris that has lodged against the piers and abutments. This type of work can be hazardous, and when appropriate, workers should be required to wear safety belts, buoyant work vests, hard hats, and other safety gear. A flashlight that will operate when submerged is an excellent safety item for night time work.

12.4.1.3 Routine Debris Removal

Routine debris removal should include removal of all floating debris such as logs, brush, tree limbs, and fallen trees that have lodged against the structures or have been deposited in the immediate vicinity of the structures. Sand or gravel bars and other deposits of debris should be removed on a high-priority basis when it is likely that the deposited material will cause turbulence near the piers or abutments. Otherwise, the material may direct stream flow into the piers or abutments or into the embankments behind the abutments. Trees that have been undercut along a bank should be removed or protected with riprap, preventing them from falling into the stream. Obstructions in the streambed that can trap or catch debris—such as trees, sand bars, or boulders—should be removed. All debris that is removed should be hauled away from the structures and disposed of in a manner that will not allow it to contribute to debris accumulations at downstream structures.

12.4.1.4 Preparation

The methods used for debris removal may depend on environmental regulations. Before performing routine removal tasks, maintenance supervisors should contact appropriate environmental and water resources agencies to ensure clearance for the work required. The agency's maintenance supervision policies should provide guidance to supervisors, assisting them in determining what types of work can be performed in a stream channel without a permit, with a blanket permit that applies to many sites, or with a permit for a specific site.

Environmental restrictions generally apply to those activities that involve major disturbances of a natural streambed. Subdividing debris by sawing or other similar type of equipment processes may be necessary. Schedule variations (e.g., scheduling for fall work rather than summer work) may also be needed. Locations requiring extensive work should be referred to the hydraulic engineering staff as well as conservation and environmental analysts to evaluate the maintenance situation and provide advice on the preferred option.

Maintenance workers should obtain permission from private property owners when it is necessary to remove debris from private property. In some agencies, maintenance personnel handle this task through formal or informal agreements with property owners, while other agencies require that a right-of-way office make arrangements.

12.4.1.5 Methods

A winch or crane is often the most effective type of equipment to remove vegetative debris such as logs and fallen trees that have accumulated near a structure. A crane with a clamshell bucket can remove trees, stumps, and other debris. At structures that span a flood plain, a bulldozer or front-end loader can be used during dry periods to push debris on the flood plain into piles that can be reached by a crane.

When work in the stream channel is required, a crane with a drag line can be used for reshaping and regading. During low flow, it may be possible to reshape or regrade the channel with a bulldozer. The need for regrading and reshaping or other extensive work in the stream channel must conform to environmental regulations and should be evaluated by a professionally qualified hydraulic engineer as well as environmental conservation analysts. An appropriate solution to the problem may require a great deal of coordination, planning, and review before approval to proceed is received. However, if all needed changes are not accomplished, the cause of the problem cannot be corrected.

12.4.1.6 Structure Modifications

Piers that have rounded edges and solid webs reduce debris accumulation. Solid webs can be constructed in multiple-column piers to prevent debris from lodging between the columns. Timber or metal cribs have been installed by some agencies on structures with open pile s. When selecting the cribbing, ensure that it does not increase the problem. Cribbing with large mesh may actually snag and hold debris rather than reduce debris accumulation.

12.4.1.7 Debris Deflectors

Debris deflectors may consist of piles immediately upstream from a pier or fins attached to the upstream end of a pier. The piles and fins are intended to divert and guide debris through the waterway opening of the structures. The effectiveness of deflectors depends upon the direction of water flow. In situations where the flow is not parallel to the pier, deflectors may create hydraulic problems. In such cases, flow control devices, such as spur bunds, may be necessary to allow the deflectors to function properly. Refer to the section on water quality, Volume 2 of the Manual (on river management for types of deflectors).

12.4.1.8 Debris and Sediment Traps

Debris and sediment traps have been effective in forest management projects but are not generally used on structures approaches. Sediment traps and other erosion control measures are commonly used in highway construction projects to reduce the amount of sediment washed into streams when bare earth surfaces are exposed during the construction process. They are not generally considered a permanent installation of the facility. All measures that reduce the sediment load in a stream are helpful to structures maintenance efforts, even if the effect is a secondary one. Figure 12.4 shows sediment clogging problems in locations absent of sediment traps.



Figure 12.4 Sediment Clogging the Waterway

12.4.1.9 Land Use Regulations

Sediment control and land development regulations can be effective means of reducing the amount of vegetative debris and sediment that is washed into streams. In many areas, strict sediment control regulations have been enacted to apply to various types of land use, land development, and construction activities. For example, some agencies limit the square footage of disturbed land area and the amount of time that can elapse before re-establishing ground covers. In some areas, logging operations are required to leave undisturbed buffer strips along streams to catch debris. The utilization of Erosion and Sediment Control Plans becomes necessary to reduce sediment impacts.

12.5 FLOOD DETENTION/RETENTION PONDS

A consistent maintenance program is the best way to ensure a flood detention pond will continue to perform its water quality and/or flood control functions. In general, a maintenance program should contain the following components: regular inspections; review by a licensed Professional Civil Engineer; vegetation management; embankment and outlet stabilization; debris and litter control; and sediment/pollution removal. The remaining sections of this manual focus on describing the maintenance tasks required for proper pond function as well as frequency of various tasks. It is important to keep records of all inspections, maintenance activities, repairs and associated costs. A table has been provided at the back of this manual to assist in documentation (Detention pond Inspection and Maintenance Record).

In general, detention ponds should be inspected after every storm event. The embankment and emergency spillway should also be routinely inspected for structural integrity, especially after major storm events. Embankment failure could result in severe downstream flooding. When any problems are observed during routine inspections, necessary repairs should be made immediately. Failure to correct minor problems may lead to larger and more expensive repairs or even to pond failure. Typically, maintenance includes repairs to the embankment, emergency spillway, inlet, and outlet; removal of sediment; and control of algal growth, insects, and odours. Large vegetation or trees that may weaken the embankment should be removed.

Periodic maintenance may also include the stabilization of the outfall area (e.g. adding rip-rap) to prevent erosive damage to the embankment and the stream bank. In most cases, sediments removed from detention ponds are suitable for landfill.

12.5.1 Regulation

DID is responsible for the maintenance of the flood mitigation ponds or retention/detention ponds at the regional level. On site and community detention/retention ponds are maintained by the respective local authorities. The authority has to ensure that the safety afforded by the flood protection system is not reduced. Certain components such as seepage, outlets structures, sediment, vegetation management, trash removal, and mechanical installation must be regularly maintained to ensure the integrity of the flood protection system. The authority also monitors the performance of ponds and notes any deficiencies in its maintenance program. Operation and maintenance of the ponds should be such that the maximum amount of water is detained in a given time at a reasonable cost.

The designer of the specific project must provide a plan or manual for:

- a) Operation and maintenance activities needed;
- b) Quantitative criteria to determine when each activity should be performed; and
- c) The responsible person for carrying out these activities.

The plan must also outline a step-by-step procedure for restoring a storm water control to its design standard following a failure. The party responsible for each step must be specified in the plan. DID is responsible for approving the operation and maintenance plan.

12.5.2 Routine Maintenance

Pond facilities must be inspected at least once a year to determine whether they are performing as they were designed to. It is also advisable to inspect these facilities after major storms. Records of inspections must be maintained. A sample inspection sheet must be provided for a specific facility.

If the facilities are not performing adequately at the time of inspection, corrective action must be taken. Routine maintenance includes:

12.5.2.1 Inspections

Periodic scheduled inspections should be conducted using a specified checklist and inspections after major rainfall events to check for any obstructions or damage or debris/trash to be removed. They should be inspected on a monthly basis and more frequently if a large storm occurs in between that schedule. During the wetter months inspections shall be conducted monthly. Once the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semi annual basis with additional inspections following the occurrence of a large storm (e.g. approximately 50 mm in 24 hours). Figure 12.5 shows sediment removal activities at a detention pond.



Figure 12.5 Sediment Removals at a Detention Pond

12.5.2.2 Vegetation Management

This requires mowing on a regular basis to prevent erosion or aesthetic problems. Limited use of fertilizers and pesticides in and around the ponds is to minimize entry into the pond and subsequent downstream waters. Access should be provided for vehicles to easily maintain the fore-bay (pre-settling basin) area but not disturb vegetation or sediment any more than is absolutely necessary. Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silt carrying water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass filtration works well with long, narrow, shoulder-type depressions (swales, ditches etc.) where highway runoff flows down a grassy slope between the roadway and the basin.

12.5.2.3 Trash, Debris and Litter Removal

To remove any trash and debris causing obstructions at the inlet, outlet, orifice or trash rack during periodic inspections and especially after every runoff producing rainfall event.

12.5.2.4 Mechanical Equipment Check

To inspect all valves, pumps, fence gates, locks or mechanical components during periodic inspections and appropriate replacement/repair.

12.5.2.5 Structural Component Check

Inspection of the outlet works, inlet, orifice, trash rack, trickle channel on a regular basis for additions to the annual Non-routine Maintenance list

12.5.3 Non-routine Maintenance

Non-routine maintenance comprises the following.

a) Bank Erosion/Stabilization

It is critical to keep effective ground cover on all vegetated areas in order to see the benefits of proper infiltration of runoff, and effective filtering of pollutants. All areas not vegetated should be re-vegetated and stabilized immediately. Maintenance of side slopes is necessary to promote dense turf with extensive root growth, which enhances infiltration through the slope surface, prevents erosion and consequent sedimentation of the basin floor and prevents invasive weed growth.

The use of low-growing grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to the pollution problems, including ground water pollution that the infiltration basin is there to solve. Consult the local agriculture agency for appropriate fertilizer types and application rates. System operation and maintenance of the facilities should be such that the maximum amount of water is recharged in a given time at a reasonable cost. This can be accomplished in several ways depending on the types of surface and subsurface materials in the recharge area and the quantity and quality of the water available for recharge.

b) Sediment Removal

Every six months or so, the accumulated sediment should be removed from the bottom of the outlet structure and the pond depths checked at several points. If the depth of the accumulated sediment is greater than 50% depth of storage zone, sediment should be removed. Sediment removal from non-vegetated river beds is most easily removed when the bed is completely dry and after the silt layer has mud-cracked and separated from the bed. It is recommended that hand raking and removal be done if possible to avoid compaction of the infiltration media by equipment. Large-tracked vehicles should not be used in order to prevent compaction.

Tilling may be necessary to restore the natural infiltration capacity by overcoming the effects of surface compaction and to control weed growth.

Rotary tillers or disc harrows will normally serve this purpose. Light tractors should be employed for these operations. In the event that heavy equipment has caused deeper than normal compaction of the surface, these operations should be preceded by deep ploughing. In its final condition after tilling, the basin floor should be level, smooth and free of ridges and furrows to ease future removal of sediment and minimise the material to be removed during future cleaning operations. A levelling drag, towed behind the equipment on the last pass will accomplish this. To enhance infiltration capacity, tilling should be done. To control vegetative growth, an additional light tillage may be necessary during the growing season.

c) Structural Repair/Filter Media Replacement

Eventually the outlet structure or other structural components like the trickle channel, trash rack or filter media will need repair or be replaced. Both granular filter material, such as sand, and geotextile filter fabric can be used where existing surface materials are not appropriate for the bottom of the recharge pond. Geotextiles can be used on the sloping sides that are to be wetted to prevent wave erosion. Granular filter material used to cover the pond bottom can be removed when recharge rates decline and new material added. With careful maintenance this system should last definitely as long as the media is removed before fine materials pass through the media to the underlying soil. To ensure long life, the granular material should be selected (designed) with care and should consider the size of the fine materials to be trapped.

The type of geotextile filter media to be used must take into account the fine material to be trapped. Information is available from manufacturers on the performance and maintenance of geotextiles under differing conditions. If fabric is used on a ground not free of sharp or angular materials a 150 mm cushion of sand should be provided above and below the fabric to minimise tearing of the fabric. When the recharge rates decline to an unacceptable level, the portion of the sand covering the geotextile filter that has become clogged will have to be removed. Determining when to remove and replace a portion of the sand cover, or the entire cover and the geotextile filter should be the subject of an economic study.

12.5.4 Standard Operating Procedures (SOPs)

SOP shall be prepared for activities that have the potential to impact 'waters of the state. One of the primary goals of these SOPs is to provide time-tested, generally accepted routine procedures that minimize the potential for release of pollutants. Table 12.1 provides an overview of routine maintenance standard operating procedures at a detention pond facility.

Table 12.1 Proposed Routine Maintenance Activities for Pond

Activity	Schedule
Note erosion of pond banks or bottom	Semi-Annual Inspection
Inspect for damage to the embankment	Annual Inspection
Monitor for sediment accumulation in the facility and fore bay.	
Examine to ensure that inlet and outlet devices are free of debris and operational	
Repair undercut or eroded areas	Standard Maintenance
Mow side slopes	
Pesticide/ Nutrient management	
Litter/ Debris Removal	
Seed or sod to restore dead or damaged ground cover.	Annual Maintenance (As needed)
Removal of sediment from the fore bay	3 to 6 months Maintenance
Monitor sediment accumulations, and remove sediment when the depth of pond's storage zone has been reduced by 50%.	3 to 6 months Maintenance

12.5.5 Maintenance Considerations

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. Below outlines some of these practices.

- Inspect inlet and outlet works initially on a monthly basis until the appropriate timing of maintenance is established; prepare a maintenance schedule that assures proper function;
- DO NOT mow detention pond too close to the surface; height should be 100 to 150 mm to maintain healthy grasses;
- Conduct maintenance per schedule, or on an as-needed basis as identified during an annual inspection, or on an as-needed basis after a storm event;
- Keep screen and/or trash rack free from debris using established maintenance schedule or on an as-needed basis after a storm event; notify supervisor if screen or rack is in need of maintenance at a higher level than scheduled; DO NOT clean equipment or conduct maintenance on equipment in the detention pond, or near a storm drain or other storm water conveyance features;
- Report damage/compromise to side slopes, pond banks, inlet pipe, trickle channels, outlet structure; prepare a repair schedule and complete repairs;
- DO NOT leave grass clippings or trimming residue in pond; collect and dispose of in trash;
- Remove vegetation adjacent to outlet works that may interfere with operation; note if noxious weeds present and notify supervisor to schedule treatment/removal;
- DO NOT apply landscaping chemicals in pond area, or in areas where the residue could make it into the pond during a storm event;
- Remove debris/trash from the detention pond and surrounding area and dispose properly;
- DO NOT attempt to clean up any unidentified or possibly hazardous materials found in or around pond during inspections; notify supervisor immediately upon discovery of hazardous materials;
- When mowing, collect grass clippings and all other clippings/trimmings and take offsite for disposal or dispose in trash on site; do not leave in the pond; and
- Notify supervisor any hazardous conditions or materials found during inspection.

12.5.6 Basin Operations of Retention Pond

There are two methods of basin operations namely wet/dry cycle operation and constant head operation.

12.5.6.1 Wet/Dry Cycle Operation

The wet/dry cycle consists of filling the basin and the turning off the inflow. The water in the basin is allowed to infiltrate into the soil and, after a few days, the basin is empty. The bottom of the basin then is allowed to dry and aerate and to reach an aerobic state. This process is then repeated until such time as the time the basin takes to drain by infiltration has lengthened to an unacceptable time. Then the basin will have to be emptied, allowed to dry, and the material that has been deposited on the bottom removed.

12.5.6.2 Constant Head Operation

The constant head method of operation maintains a full basin on a continuous basis. That is, the basin is filled and the rate of flow of influent water is maintained at a rate approximately equal to the rate of recharge from the basin. This operation is continued until the recharge rate lowers to an unacceptable level. Then the basin must be emptied, allowed to dry, and the deposited sediment removed. In some cases, it is possible to empty the basin, let the basin dry out, and restart the recharge operation without removing the deposited sediment. However, the recharge rate will be slightly lower than the original rate. When the basin is kept full of water over an extended period of time, algae and aquatic weed growth may occur.

12.5.6.3 Basin Cleaning

Clogging material on the basin bottom must be removed to restore the facility to its original designed capacity. This clogging material consists of the turbidity filtered from the recharging water and, in some cases, the organic remains of weed and algae growth. Prior to cleaning, the basin should be allowed to dry as much as possible. The basin it should be drained as quickly as possible. Drainage pipes at or near the basin bottom expedite the draining time. For deeper ponds, consideration should be given to the potential for slope failure if water levels are lowered too rapidly. Ponds using grass/soil and media/fabric filters require the use of special cleaning techniques such as special mechanical equipment or hand labour. The pond bottom should be thoroughly dried before cleaning operations are initiated.

In general, less than 150 mm of material must be removed. Cleaning can be costly, considering that the removal of 150 mm of material amount to about 1,500 m³ of material per hectare of basin bottom. Scrapers may be used in such cleaning operations. The self-loading scraper is light-weight equipment and runs on large rubber tires and is used for reducing the compaction of the basin bottom during the cleaning operation. An alternative to using self-loading scrapers is to withdraw the basin bottom material using a motor grader or small bulldozer blade. This withdrawn material can be left on the basin bottom for one or two cleaning periods without any significant adverse effects on infiltration.

The equipment should be operated in a manner that results in the least number of runs over the same area, thus reducing the potential compaction of the basin bottom. Different combinations in size of equipment (load per square meter) and number of passes required should be considered to obtain the least basin bottom compaction. When the cleaning operation is completed, disking or ripping of the pond bottom from 50 to 300 mm deep is sometimes used to overcome the compaction that took place during the cleaning operation. Ripping of the basin bottom must be weighed against the fact that turbidity in the recharge water will filter out in the cracks of the deep ripping, making the bottom seal thicker and requiring greater depths of later removal of pond bottom soil material to restore recharge rates.

A soil sample down to 0.6 m or 1.0 m should be taken to check on the depth of compaction that may have occurred. If compaction is found at these depths it may be advisable to use a tractor and ripper that can reach these depths. After such deep ripping the basin bottom should be smoothed to reduce the potential problem of deep filtration noted previously. As basins are cleaned, they will become deeper because of the necessary removal of some native material during each cleaning.

12.6 Hydraulic Control Structure

12.6.1 AutomatiC gate & SCADA

Tidal Control Gate (TCG) plays an important role in tidal and flood control. Automation of TCG increases the reliability and accuracy of TCG control. Watergate Automation and SCADA System is a system that can control, monitor, analyze, and store data that had been proven to work well. Maintenance needs to be carried out to make sure that the system is always in tip-top condition. The purpose of this section is to ensure the Watergate Automation and SCADA System work well as part of the maintenance schedule. Problems arising during maintenance testing procedure will be corrected and recorded for future reference.

SCADA is the acronym for Supervisory Control and Data Acquisition. SCADA is any system that performs Supervisory Control and Data Acquisition, independent of its size or geographical distribution. SCADA systems are typically used to perform data collection and control at the supervisory level. Some SCADA systems only monitor without doing control, these systems are still referred to as SCADA systems.

The supervisory control system is a system that is placed on top of a real-time control system to control a process that is external to the SCADA system (i.e. a computer, by itself, is not a SCADA system even though it controls its own power consumption and cooling). This implies that the system is not critical to control the process in real-time, as there is a separate or integrated real-time automated control system that can respond quickly enough to compensate for process changes within the time-constants of the process. The process can be industrial, infrastructure or facility.

A SCADA system includes input/output signal hardware, controllers, HMI, networks, communication, database and software. It mainly comes in the branch of Instrumentation Engineering. The term SCADA usually refers to a central system that monitors and controls a complete site or a system spread out over a long distance (km/miles). The bulk of the site control is actually performed automatically by a Remote Terminal Unit (RTU) or by a Programmable Logic Controller (PLC). Host control functions are almost always restricted to basic site over-ride or supervisory level capability. The feedback control loop is closed through the RTU or PLC; the SCADA system monitors the overall performance of that loop

12.6.2 System Function

The system functions of the hydraulic control structure consist of seven components listed as follows:

- Main Power Supply;
- Secondary Power Back-Up;
- Gate Operation (Manual, Auto, Remote, Local and Emergency Stop);
- Water Level and Level Sensor Testing;
- Touch Screen Function;
- Emergency Alert;
- Info Request/Communication Testing;
- SCADA System Validation; and
- Remote Dial-In Monitoring and Control.

These components are displayed in the following sub-sections which contain the maintenance scope and protocol that should be followed to ensure proper functioning of the structures. Sample checklists are in the Appendix 12.A.

12.6.3 Maintenance Scope, Protocols, and Checklist

Maintenance scope, protocols and checklists are as follows:

- a) Main Power Supply
 - i. Carry out the test for verification and maintenance voltage of main supply from TNB to site is ± 415 V.
 - ii. Attach test result and related data for every verification steps.
 - iii. Upon verification finalization, defect acceptance number will be verified and the final result of the test emitted.
 - iv. Any deviation will be recorded in the Deviation Records form.

b) Secondary Power Back-Up

- i. Secondary Power Back up for System during TNB power failed verification.
- ii. Verify that UPS is able to back up the system when TNB power supply fails.
- iii. Verify that UPS is able to wake up after power resumes
- iv. Attach the test result and related data for every verification and maintenance step.
- v. Upon verification finalization, defect acceptance number will be verified and the final result of the test emitted.
- vi. Any deviation will be recorded in the Deviation Records form.

c) Gate Operation (Manual, Auto, Remote, Local and Emergency Stop)

- i. Operation of gate in different mode of control verification.
- ii. Verify that every mode control of the system work well.
- iii. Attach the test result and related data for every verification and maintenance step.
- iv. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- v. Any deviation will be recorded in the Deviation Records form.

d) Water Level and Level Sensor Testing

- i. Verify that sensor reading is correct based on real water level.
- ii. Carry out the following for verification and maintenance:
 - Verify that Ultrasonic sensor work correctly base on actual water level measured from datum.
 - Verify that placement of sensor in 90° horizontal with the sensor bracket.
- iii. Attach the test result and related data for every verification and maintenance step.
- iv. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- v. Any deviation will be recorded following the Deviation Records form.

e) Touch Screen Function

- i. Make sure each function of touch screen works correctly.
- ii. Verify that touch screen function correctly and give the correct information.
- iii. Attach test result and related data for every verification and maintenance step.
- iv. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- v. Any deviation will be recorded in the Deviation Records form.

f) Emergency Alert

- i. Verify that the system will alert the user during emergency event.
- ii. Attach the test result and related data for every verification and maintenance step.
- iii. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- iv. Any deviation will be recorded in the Deviation Records form.

g) Info Request/Communication Testing

- i. Make sure the system will SMS user the gate info whenever user requests through SMS.
- ii. Verify that the system will reply user with gate info whenever requested by user.
- iii. Verify that communication of the system works well
- iv. Attach the test result and related data for every verification and maintenance step.
- v. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- vi. Any deviation will be recorded in the Deviation Records form.

h) SCADA System Validation

- i. Ensure each function of SCADA system works well.
- ii. Verify that each function of SCADA system works in order.
- iii. Attach the test result and related data for every verification and maintenance step.
- iv. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- v. Any deviation will be recorded in the Deviation Records form.

i) Remote Dial-In Monitoring and Control

- i. Ensure the Remote Dial in Monitoring and Control system works well.
 - Verify that Remote Dial in Access system works in order.
 - Verify that remote monitoring and remote control through remote access work well
- ii. Attach test result and related data for every verification and maintenance step.
- iii. Upon verification finalization, defect acceptance number will be verified and the final result of the test will be emitted.
- iv. Any deviation will be recorded in the Deviation Records form.

j) Deviation Records

- i. Description and investigation of deviation.
- ii. Follow-up corrective actions implementation.

k) Final Report

- i. Once all the appropriate verification has been carried out, verification maintenance test is considered complete. A final report will be generated from the verification process, following the format of this protocol. The report should consist of the following sections:
 - Records of all the deviation during testing;
 - Report of all additional information while doing the testing; and
 - Record of the final result whether it is conformance or non-conformance.
- ii. The signature of the report will confirm the acceptance and conclusion of the Operational Qualification.
- iii. The new system will be much more convenient for all personnel involved with the operation and maintenance of the flood control gates.

12.6.4 Flood Gates Operation

This manual is associated with operating the gates, pumping units, and other appurtenant items associated with the flood gates. A general description of each item is provided as well as information regarding aspects associated with the operation of each item. This section provides the information that will be needed by personnel for safely operating the flood gates when a flood is forthcoming. Steps in flood gates closure operation is described in Figure 12.6.

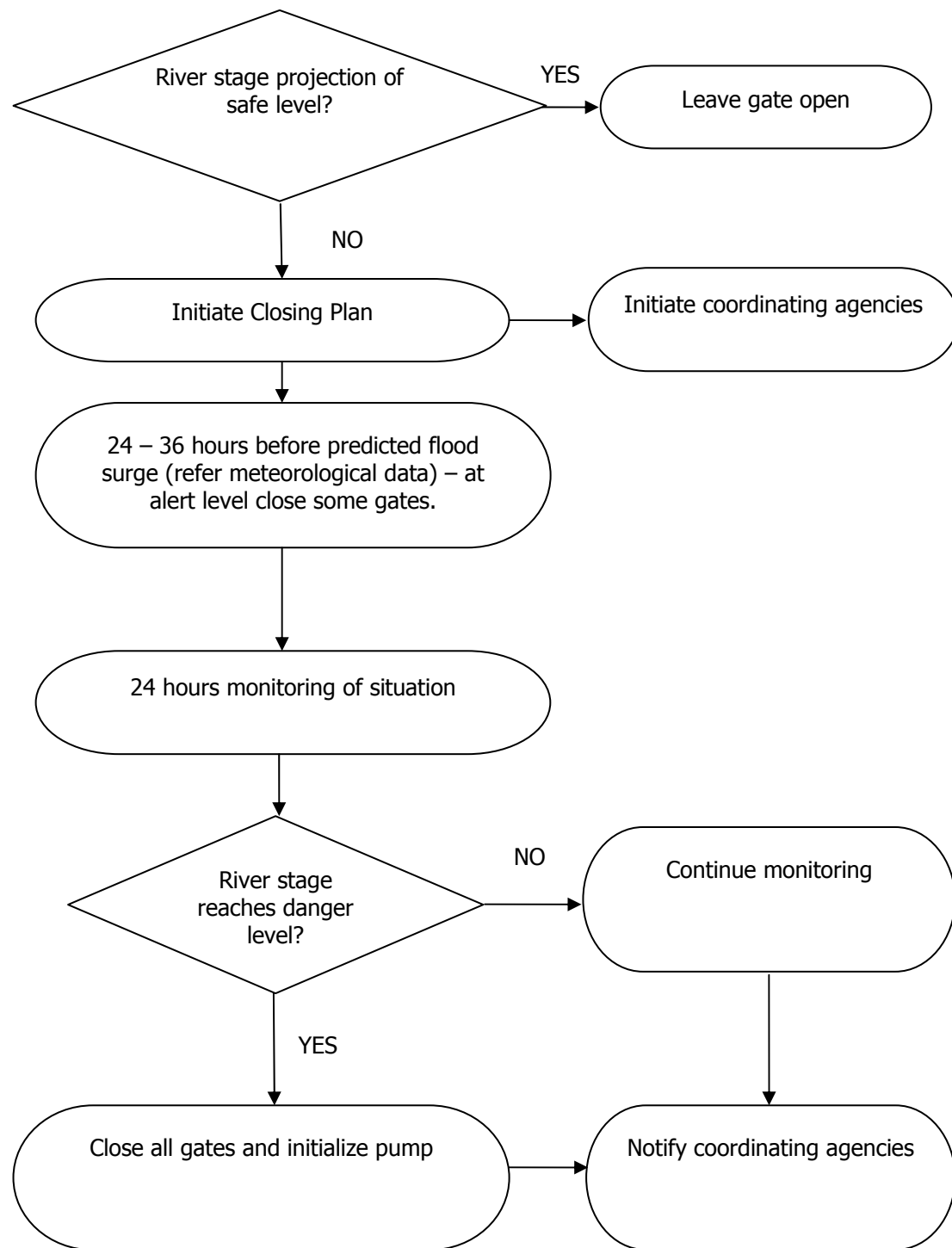


Figure 12.6 Flowchart for Flood Gates Closure

12.6.4.1 Flood Gates

The flood gates permit open flow of the outfall channels during normal meteorological events but will prevent flood surges from the river entering the channels in the event of a flood period. This portion will describe the gates and provide information about use of the gates prior to flood season, during flood season, immediately prior to arrival of a flood, and immediately after a flood hits. It will provide the background about the gates and a procedure to be used for the various different conditions (i.e. prior to flood season, during flood season and other situation.)

12.6.4.2 Preparation for Operation

To ensure that the gates operate properly should a flood threaten the protected area, preparations will need to be performed prior to the start of flood season, during flood season, and when the chances of a flood entering the vicinity areas are first identified. Making the preparations outlined in the paragraphs below will greatly reduce the possibility of problems being encountered when the time for putting the gates into position arrives. While making each of the preparations below the structure, pump engine platform, and facilities should be visually surveyed for any signs of damage, vandalism, or deterioration. Remedial measures should be pursued to address any issues found.

12.6.4.3 Before Flood Season

Prior to the flood season certain activities should be performed with respect to the operation of the gate. The primary concerns are with checking the notches in the sill for obstructions and with ensuring the gate can move unobstructed into the closed position. Details for the activities to be undertaken are described in the following paragraphs and should be completed much earlier so that if a problem is discovered that there is ample time to correct the problem. The check of the notches and the gates should be performed in conjunction with the test of the pumping units.

a) Check Gate Slots in Sill

The notches in the sill structure provide the housing for the bottom of the gates and therefore it is imperative that these notches be free of all foreign material and obstructions. The notches may fill with silt between the end of one flood season and the start of the next. It is also possible that other obstructions, such as tree limbs or trash, will get lodged in these notches. To ensure that the gate will properly seat in the notch, the notch should be checked at each structure by a diver. The diver should go along the entire length of each notch of the structure. A high pressure hose should be available for the diver to use to blow out silt that may have accumulated in the notches. The diver should locate foreign objects that may be in the notches and if they are small enough, he should remove them. If the diver encounters an object that is larger than he is capable of moving the diver should secure the object with cables that will allow it to be removed by a crane.

b) Check Flood Gate Operation

Once the diver has completed inspection and confirmed that all materials have been removed, the operation of each gate should be tested. The gates will be set in the open position throughout most the year and are to be lowered into position. Each gate on each structure should be put into its closed position. The process of putting the gate into the closed position will also ensure that something there are no obstructions in the gate operation. The process of putting the gate into the closed position should be closely observed. If during this process it is observed that as the gate is lowered it does not continue at a constant rate, the top elevation of the gate where the interruption occurred shall be noted and the gate shall go through the operation procedure a second time. If an interruption occurs again at the noted location then an inspection of the guide columns along their full height, as well as the portion of the gate within the guide columns shall be performed to determine the cause the gate to hang up. Any defects found shall be repaired, and the procedure shall be repeated.

12.6.4.4 During Flood Season (General)

Once flood season has started, certain activities should be performed at regular intervals so that issues that could potentially interfere with the operation of the gates can be identified and addressed without the threat of the forthcoming flood. Operation of the gates should be performed every three (3) weeks. Gate operation should be performed in the same manner as described for the check of gate operation prior to the flood season.

12.6.4.5 Forthcoming Flood

When there is a flood season, preparations must be made in anticipation that the flood wave may hit at or around the protected area.

a) Gate Placement

Flood waves may occur several times during the operation. Initially, each gate will be lowered into position to ensure gate notches are clear. If a gate is lowered and the dogging pin can be placed, then the gate can be raised to its stored position. If the dogging pin cannot be placed then divers should be sent to investigate, identify the obstruction, and take measures to remove it. Once all gates have been closed, the crane and all other equipment should be removed from the closure structure bridge to a safe location. The location of the crane and the equipment should be near the closure structure so that during the recovery period they can be deployed quickly. The crane and other equipments should be located on high ground adjacent to the structure so that deployment after the flood will not be impeded by flood waters from a major rain event.

12.6.4.6 After a Flood

The monitoring of flood will continue for a period of time after they have hit the area. Actual data as well as the predictions by the model will be used for the decision-making process regarding the removal of the gates.

a) Removal Conditions

The gates will remain in place until the predetermined conditions are met. The Operation Teams should mobilize and be ready to open the gates as soon as approval is given to open the gates.

b) Required Crew

The crew needed for opening the gates at each closure structure is identical to those required for closing the gates. The Team should return to the closure structure as soon as possible after the flood has passed.

c) Open Gates

Once the required conditions have been met, and approval has been given by the District Engineer, the gates may be raised, starting with the centre gate.

12.6.4.7 Coordination

Coordination will be a key component for successful operation. Close communications between all affected parties will enable the most effective protection against flooding. It is important that the information from the model that results in activating the team.

a) Crew Deployment

The crew required to operate the gate will be the Operations Team. The members of the Operations Team should be familiar with the pumps and the pump operation, since they will be responsible for operating the pumps. During the flood season it is imperative that the points of contact and all crew members notify the individual to whom they report if they will be out of the area and unable to respond to an forthcoming flood. Alternate crew members have been designated in the event a crew member is unavailable.

b) Interaction between Government Agencies

The DID engineers will be monitoring forthcoming storms and conditions and will need to make certain information being gathered is passed along to the local and the agencies of the State Government. The organizational structure and chain-of-command to be used in the event of a forthcoming flood must be followed carefully. Notification will be performed in accordance with the Gate Closure Activities.

c) Initializing Pumps – Stopping Pumps

Initializing the pumps must be done in coordination with phased closing of the gates. Pumps should be initialized after all gates on a channel are closed to ensure adequate water levels for priming. However, pumps should be initialized before or during gate closure if the local pump stations are pumping floodwater into the river at the time of gate closure. Once the gates are closed the pumping system may be activated so that the pumps will start at the predetermined channel level and stop when the water levels in the channels drop at the predetermined level. Under normal circumstances this will be accomplished automatically by the pump control system. The pump control system may be also be overridden by the SCADA remote monitoring and control system and pumps can be started or stopped at any time.

12.6.4.8 Pumping Units

The primary components of the pumping units are the pumps, the hydraulic power units, and the hydraulic lines that connect the pumps to the hydraulic power units. Other manuals which specifically deal with this topic will provide the operating instructions for the pumping units. Should a decision be made to close the gates then the operating instructions should be followed at approximately the same time as the gate closure. Instructions are provided for preliminary, automatic, and manual operation. Information is also provided on stopping the pumps after the flood has passed.

12.6.4.9 Gate General Maintenance (Manual)

All flap gates, slide gates, and other gate systems need to be manually inspected and lubricated at least once a year just before the flood season. If gates are not seated properly, water will flow back through the drainage structure during high water.

During the inspection, all gates should be manually operated, and any debris or obstructions removed. All gate seats should be checked and the frames readjusted if the gate is not seating properly. Cracked or damaged gates need to be replaced. The inlet and outlet channels need to be kept free of debris, trees, brush and other vegetation, and sediment.

Metal grates, hand wheels, and other metalwork should be secure and sound, free from rust, and regularly maintained by cleaning, painting, and greasing. If any pipe or culvert has separated from the inlet/ outlet structure headwall, this needs to be repaired as soon as possible. When high water is predicted, all flap and slide gates should again be inspected and any debris or obstructions should be removed immediately.

12.6.5 Hydraulic Structures (Concrete Structures)

There is no material known which is immune to chemical action and physical deterioration and concrete is no exception to this. Chemical attack on concrete is likely to arise from aggressive compounds in the surrounding water, subsoil or ground water. Over time, concrete surfaces will weather, leaving the rough to the touch, or will hold moisture on the surface. Damage by high velocity water is normally associated with cavitation and abrasion.

Deterioration of hydraulic structures is invariably accompanied by cracking to a greater or lesser degree. The study of crack in concrete structures is a most important factor in the overall repair and strengthening of concrete structures. The cause of the cracking can only be decided by a careful investigation, but its width, position in the member and the degree of exposure can all be easily determined and it will decide whether it is a defect and degree of seriousness. It is important to ascertain the cause of the cracking and to decide whether it is structural or non-structural.

All cracks in the hydraulic structures need to be repaired. Visible cracking, scaling, and spalling are signs of movement and stresses within the structures. Cracks in concrete walls that aren't repaired are subject to damage, which widens the gap and leads to additional spalling of the concrete. When examining any concrete flood control structures, spalling, scaling, or cracking should be very minimal.

Fire and extreme heat can also be very damaging too, and therefore should be discouraged from occurring near structures. Common grass or incidental fires are not typically a great concern, but repeated hot or large fires such as bon fires, camp fires, or brush fires can cause spalling of the concrete. The related spalling, cracking, or other damage would be noted during an inspection and is something that should be taken seriously. Depending on the extent of the damage, the integrity of the structure should be investigated and repairs should be made as soon as possible. Maintenance of the hydraulic structures would involve the following element.

12.6.5.1 Substructure

Maintenance of the substructure should include routine cleaning of the substructure cap. Using a high-pressure pump with sufficient hose length to flush out the substructure cap from every angle is an effective method of cleaning.

Problems often found in structures include deterioration of concrete and corrosion of the reinforcing steel. A horizontal crack along the face of the pile cap, 75 to 100 mm (about 3 to 4 inches) from the top, normally indicates that the reinforcing steel has expanded because of corrosion.

When a superstructure moves beyond the space that is provided for it, pressure is created on the anchor bolts. Occasionally, lateral forces from large chunks of debris hitting the structures during flood flows or high water levels, create large forces on the anchor bolts. The pressure from the anchor bolts is then transmitted to the substructure cap, which can damage the structures seats or cause cracks in other parts of the substructure (such as the columns).

a) Repairing Substructures above water

Repairs to the substructure are usually done with basic materials and processes. Repairs underwater require special considerations, as do pile and pile repairs. Substructure problems include deterioration (especially at the water line), cracking (usually related to settlement), impact damage (associated with traffic under the structures), and shear damage (associated with movement or approach pavement pressure). Since most substructure units are concrete, repairs are often -related processes. If the substructure is exposed to saltwater, either from the surface or from below, problems such as those found in structures surfaces, including corrosion of reinforcing steel and concrete spalling, are likely to have occurred.

Timber substructures can be damaged by decay and vermin attack. Substructure repairs are generally very costly because of the extensive temporary supports needed to carry the superstructure. Thus, preventive maintenance is often a very cost-effective approach to limiting these expensive repairs, especially a program that removes debris and pressure-washes seats, caps, and other substructure surfaces exposed to salt.

b) Repairing Broken or Deteriorated Wing Walls

Portions of an otherwise sound wing wall may be broken off. Weak aggregate in the original concrete mix can also contribute to wing wall deterioration. Losing portions of a wing wall can result in erosion of the fill and further damage to the structures approach. The cause of the wing wall failure must be determined so it can be corrected as part of the wing wall repair process. Forming should be pre-planned and the forming materials cut to size in advance, if possible. Any excavation required to gain sufficient working access and to facilitate removal of defective concrete can be accomplished in advance of the wing wall repair.

Materials and equipment typically needed to make this type of repair vary widely but often include excavating equipment such as a backhoe, an air drill, tie screws or equivalent bolts, wood spacers, reinforcing bars, granular backfill material, hand tools, removal equipment, anchor bolts and anchors, plywood forming, Portland cement, epoxy bonding agent, non-shrink grout, and miscellaneous hardware. Everything needs to be readily available to expedite the repair operation.

- i. Excavate as required to be able to set the dowels and the forms.
- ii. Remove all fractured or deteriorated concrete by chipping and then blast-clean to remove all loosened surface materials.
- iii. Drill and set form anchor bolts and dowels. Typically, dowels 13 mm in diameter (no. 4 bars) are placed a minimum of 225 mm (9 inches) into sound and set with non-shrink grout, 150 mm (18 inches) centre-to-centre, both front and back.
- iv. Cross-laced the 13-mm (no. 4) reinforcing steel bars and set the forms.
- v. Just before placing the cement, apply an epoxy bonding agent to all the existing concrete that will contact the new concrete.
- vi. Before backfilling with granular material, cure the new concrete for a minimum of 7 days or until the concrete has developed sufficient strength to resist the lateral pressures of the backfill.

c) Repairing Abutment Faces

Concrete in abutments may deteriorate from the effects of water or debris impact, any of which can result in portions of the edge or face of the abutment breaking off. Repair is necessary to prevent continued deterioration, especially increased spalling due to moisture reaching the reinforcing steel and causing corrosion. Equipment and materials typically needed include an air compressor, drilling equipment, tie screws (and lag studs), reinforcing steel-wire mesh, forming material, reinforcing steel, Portland cement, epoxy bonding agent, and gravel (stone or riprap also).

- i. Remove deteriorated concrete and loosened face surface materials by chipping and blast-cleaning.
- ii. To support the form work, drill and set the tie screws and lag studs.
- iii. Set reinforcing steel and forms.
- iv. Apply epoxy bonding agent to the concrete surface just before placing the cement.
- v. Place the cement, allow it to cure, and remove the forms.
- vi. Install any needed erosion control materials.

d) Repairing Spread Footing

Deterioration of a concrete spread footing can include breaking off of the footing projections or spalling of the sides. Severe deterioration may be caused by collision of debris against the upstream side of the footing, water penetration resulting in corrosion of reinforcing steel, or initial construction using poor materials. Because the load of the structures was originally designed to be supported by a uniform distribution of pressure on the material under the footing, the area of the footing must not be reduced. Installing a cofferdam, pumping, and dewatering, as needed, will allow the repair to proceed in a "dry" working environment.

- Keep the work area clear of water with diversion channels, cofferdams, sandbags, or sheet piling, as required.
- Chip away the deteriorated concrete until sound is reached. Clean away all loose concrete with air-blasting or other methods.
- Install reinforcing steel, anchors, and rods, as needed.
- Construct forms that adequately restore the footing dimensions of the original design size. Commonly, the footing is extended to cover a large area and the sides of the footing are extended downward if any undermining has occurred.
- Apply any bonding compounds or a neat cement paste for bonding just before placing the new concrete into the forms.
- Mix and place the new concrete, using a strong mix with a low slump. Vibrate the concrete thoroughly to ensure dense placement and a good bond to the existing concrete surface.
- After the new concrete has cured for at least 3 days, remove any cofferdam and restore the stream channel to its proper course. Where shotcrete is used extensively on other parts of the structure, the repairs may be made using shotcrete.

e) Substructure Cracks

A footing may crack transversely because of uneven settlement. This crack is often accompanied by a crack continuing up through the structure. It is advisable to seal the crack, preventing further intrusion of silt, debris, and water that will attack reinforcing steel. If the crack is moving, it should be filled with a flexible material; otherwise, it will open again. If the crack is not moving, it can be bonded back together. Cracks in substructures are generally vertical. Typically, the most effective method of repair is to inject epoxy into the cracks. To get maximum penetration of the epoxy filler, the first injection is made at the bottom of the crack. Starting at the bottom and working up in gradual increments toward the top increases the pressure needed to apply the epoxy and should result in greater crack-filling penetration.

Another repair method that prevents moisture from entering the crack is to chisel a V into the opening and fill it with grout.

- i. Cut a V-shaped groove at the surface along the crack approximately 50 to 75 mm (2 to 3 inches) in width, using a small pneumatic chisel.
- ii. Thoroughly flush and blow out the crack, using water and high-pressure air blasts.
- iii. Secure a retaining form on the face of the footing over the vertical portion of the crack.
- iv. Wet the surfaces of the crack thoroughly by pouring liberal quantities of water into it. Fill the crack with cement (or epoxy) and fine sand grout in a 1 to 2 mix that runs freely.
- v. Clean out the V portion of the surface after the grout has partially set and apply bonding compound or a neat cement base to the surface of the V; then fill the V with a stiff grout mixture.

f) Surface Deterioration

To repair any deteriorated concrete, completely remove all unsound concrete. Clean, sound concrete must be exposed to bond with the new concrete. Air tools are typically the most efficient means of removing the deteriorated concrete. The edge of any area cut out should be undercut enough to allow for deep patches that aid retaining of the new material to the existing concrete.

Effective bonding of the new concrete to the old concrete is usually accomplished with a bonding material and is particularly important when deep cracks need to be filled with a large volume of concrete. A grout of neat cement base can be used as an effective bonding agent. Grout can also be used when the form of the concrete is so inaccessible that an epoxy material cannot be effectively applied to the existing concrete surface. The exposed area can be sloshed liberally with grout just before placing the new concrete. Shotcrete may be used to fill the crack after it has been properly prepared.

Shotcrete is a mortar pneumatically projected at high velocity onto a surface area. Since forms are not generally used for shotcrete, it is particularly effective for an overhead patch on the underside of a surface where a form cannot possibly be used. Shotcrete gives a superior surface bond, provides great strength because of its high density, exhibits low shrinkage, and does not require any formwork; however, it requires lots of space to be applied, demands a high skill level of the application operators, leaves a shoddy appearance, and is costly (especially in small quantities). When shotcrete is used, no bonding agent is necessary if the patch does not exceed a depth of 75 mm (3 inches). For deeper patches, hook anchors are installed in the existing concrete on 300-mm (12-inch) centres, and 50-mm × 50-mm (2-inch × 2-inch) wire mesh is hooked and wired to the anchors. This anchoring system may be repeated for every 75 mm (3 inches) of shotcrete depth applied. Whenever possible, use form and placing rather than shotcrete. Shotcrete tends to waste cement and requires a much higher worker skill level to obtain satisfactory results.

Surface deterioration in reinforced concrete will frequently reach the first layer of reinforcing steel. When this has occurred, the should be removed to a depth of 40 mm (1.5 inches) to 60 mm (2.5 inches) below this layer of reinforcing steel to provide an excellent anchor for the new or shotcrete. If concrete removal is stopped at the surface of the reinforcing steel, a cleavage plane may develop at the interface of the new and the old, reducing the strength of the structure. All rust and other harmful materials should be removed from the exposed reinforcing steel. Where reinforcing steel is exposed, clean both the concrete and the steel by sandblasting the cracks for a good repair.

g) Water Line Deterioration

Deterioration at the water line is unique to abutments or piers in streams or marine environments. A depression or cavity forms in the concrete, extending some distance above and below the average water level. Deterioration at the water line usually occurs on the upstream face or along the sides of the pier. Repair is very similar to any surface deterioration repair, except that it is necessary to control the water flow so the work can be kept dry.

- i. Dewater the abutment or pier.
- ii. Chip away all loose concrete in poor condition.
- iii. Clean the reinforcing steel of scale and loose rust.
- iv. Clean the surface in all areas where new concrete will be placed.
- v. Chip or roughen the surface of the existing concrete, providing a better bond between the old
- vi. and the new concrete.
- vii. Treat the entire area with epoxy or grout before placing the new concrete.
- viii. Construct a form of adequate strength and place concrete in the form.

Since repair of deterioration at the water line can be time consuming and expensive, maintenance supervisors should have the damage situation evaluated by a professionally qualified structural engineer or materials engineer to determine if this work should be done by maintenance personnel or contracted to a firm with special skill and experience in such repairs.

12.6.5.2 Underwater Repair of Substructures

It is presently recognized that failure of structural elements under the water line can lead to structures failures. Agencies now must identify all structures for which underwater inspections are necessary, define an appropriate inspection procedure for each structure, and determine the necessary frequency of underwater inspection, which must not be less than every 5 years. Increased underwater inspection of structures has made agencies more aware of the extent of deterioration below the water line, and consequently, has increased the need to respond with maintenance and repair of such damage.

a) Engineering the Repair

Solutions to underwater problems must be based on sound engineering. When underwater repairs have been necessary, structures maintenance supervisors have tended to think in terms of dewatering the site. Cofferdams are installed and the damaged area is dewatered so that workers can perform the repair work using the same methods that would be used above the water line. The use of conventional above-water methods provides confidence that quality of construction can be controlled. However, dewatering is not always feasible. Additionally, when underwater repairs are undertaken, there is sometimes a tendency to use one of a few commonly available techniques marketed for underwater applications, without considering alternatives that may be superior.

A major concern of underwater repair is that it may only hide a fundamental structural problem while this problem continues to grow worse. Repairing a condition that hides an uncorrected problem may be worse than doing nothing to the existing damage. For example, when contaminated concrete and corroded reinforcing steel are left in place to interface with new, the corrosion process accelerates. Consequently, covering a reinforced- member with a form or jacket that stays in place will not stop or prevent corrosion of the reinforcing steel; the member may look satisfactory while it is deteriorating to an unsafe condition. The repair should address the deterioration process in the structure's environment. If structural members are involved, the repair should be designed to provide the appropriate safety factor and structural redundancy needed. Unless special monitoring can be guaranteed, the repair should provide dependable service within the normal inspection cycle and the normal maintenance that can be reasonably expected from the responsible maintenance agency.

Since most structures engineers are not divers, it is important that they understand the problems and limitations of performing repairs underwater. All repair schemes used above water are not cost effective when performed by divers underwater. The time and cost of labour is more of a consideration for underwater work. For example, it may be less expensive to accept that deterioration will continue and modify the load path by designing the repair to support the total load or by designing a supplemental supporting system than to remove and replace the damage.

b) Protecting Underwater Structures Elements

Cementitious and epoxy coatings have been applied to underwater surfaces to protect concrete against abrasion and to cover cracks and make small repairs. The material is usually a thick mortar that is applied by hand. The cementitious products often include anti-washout admixtures and cure-set accelerators. Cementitious materials are mixed above the water line and delivered to divers in plastic bags. Epoxy resins applied underwater must perform satisfactorily and cure under both wet conditions and low surface temperature conditions.

Underwater cathodic protection (CP) has achieved favourable results in preventing and halting corrosion of reinforcing steel. Cathodic protection can be provided for the reinforcing steel by either a sacrificial anode or an impressed current flow from a rectifier power source. In a marine environment and an underwater application, the sacrificial anode CP is often recommended because of the low-resistivity environment. This system uses a metal (sacrificial) anode higher in galvanic series (metal activity scale) than the reinforcing steel to be protected. Zinc is often used as a sacrificial anode, but magnesium and aluminium are also sufficiently higher in galvanic activity than steel to be effective as sacrificial anodes.

c) Pressure Injection of Underwater Cracks

When cracks expose the reinforcing steel to moisture, the corrosion process may begin. In saltwater environments, corrosion can occur quite rapidly. With the proper selection of a water-compatible adhesive (normally an epoxy resin), dormant cracks (cracks that are not moving) that are saturated with water can be repaired. The procedure can also repair other small voids such as de-laminations or honeycombed areas near the concrete surface. Within limits, pressure injection can be used against the hydraulic head, provided the injection pressure is adjusted upward to counteract the pressure of the hydraulic head. The material must displace the water as it is injected into the crack to ensure that the crack is properly sealed, resulting in a watertight, monolithic structural bond.

Epoxies must have certain characteristics to cure and bond the cracked concrete. Many adverse elements are present inside the concrete crack (e.g., water, contaminants carried by water, dissolved mineral salts, debris from the rusting reinforcing steel, etc.). The typical low surface temperature of concrete underwater makes many repair products unsuitable candidates because of their inability to cure properly. The epoxy injection resins for cracks are formulated for low viscosity, and they do not shrink appreciably. The surface wettability of epoxy resin is a major concern because the resin needs to displace all of the water in the crack, adhere to a wet concrete surface, and then cure in the wet environment. The procedure involves cleaning the crack with a high-pressure water jet system and shaping the surface of the concrete directly above the crack so that it can be sealed with a grout. Using a hydraulic or pneumatic drill, holes are drilled to intersect the crack and then injection ports are installed in the holes. Subsequently, the surface of the crack is sealed with a grout material suitable for underwater use, such as cementitious or epoxy mortar.

The purpose of the grout is to retain the adhesive as it is pumped into the crack. The adhesive is pressure-injected into the crack through the ports that are embedded in the grout at regular intervals. The injection sequence begins at the bottom and advances upward. The injection moves up when the adhesive reaches a port and begins to flow out of it. Epoxy resin is mixed either before or after pumping begins. Cracks varying in width from 0.005 cm (0.002 inch) to 0.6 cm (0.25 inch) have been successfully injected.

Some precautions must be considered before using this repair method.

- Contaminants growing inside the crack, especially those found underwater, can reduce the ability to weld cracks.
- Corrosion debris can reduce the effectiveness of pressure injection.
- Time and patience is required for a successful injection repair.
- An injection repair is a labour-intensive process.
- A diver experienced in the injection process and in the formulation of an epoxy resin is very important for high-quality work.

d) Concrete Removal

The salt-contaminated concrete and rust must be removed from contact with the existing reinforcing steel to ensure that the corrosion damage will not continue. Concrete removal underwater is labour-intensive, difficult, and expensive work to perform. Consequently, structural jackets or auxiliary members should be evaluated as alternatives to removing concrete. Concrete can be removed with high-pressure water jets or with chipping hammers. Construction joints between old and new concrete should be saw cut prior to removing concrete, preventing feather edges at the joint.

Hydraulic or pneumatic-powered concrete saws and chipping hammers may be adapted for use underwater. Mechanical grinders are also available for cleaning concrete surfaces. Surface preparation is required after concrete is removed and before making the repair. High-pressure water jets, abrasive blasting, or mechanical scrubbers can remove all loose and fractured concrete, marine organisms, and silt. Where the water is heavily laden with contaminants, repairs should be made on the day of final surface preparation. This will reduce accumulation of new surface deposits.

e) Forms

Forming materials and forming techniques have been developed specifically for application underwater. Forms are used to encase damaged concrete areas or masonry substructure units. Some pile-jacketing forms are proprietary and marketed as a repair package. The shape, size, and location of the damaged element will often dictate the forming system to be used for the repairs. In work underwater, the cost of the forms is less of an economic factor than the ease of installation and the suitability to the repair. Commonly available polyethylene drainage pipe is also used as a form. In some repairs, it may be more economical and quicker to encase all piling with a jacketing wall in one concrete placement process rather than trying to jacket individual piles. Fabric forms are relatively inexpensive and can be easily handled by a diver. With a fabric form, the final repair may appear irregular in thickness, but shape and texture are not concerns for underwater repairs. Fabric forms are available with zippers for ease of installation, with spouts for pumping the repair material into the form, and with pressure seals to hold the material inside the form.

f) The Concrete Mix

Anti-washout admixtures are used to:

- i. Minimise washing the fine aggregate and the cement out of the concrete while it is in contact with flowing water.
- ii. Prevent segregation of the concrete
- iii. Reduce bleeding
- iv. Decrease migration of moisture within the concrete mix
- v. Inhibit water entrainment as the concrete is placed.

These admixtures tend to make the concrete sticky. A water-reducing agent or a high-range water reducer may be necessary to maintain proper concrete slump. Slump values up to 20 cm (8 inches) are possible. Experience has indicated that concrete mixes containing anti-washout admixtures with either silica fume or fly ash can produce higher quality repairs at equal or lower cost than similar mixes containing higher silica fume content or high cement content but not incorporating anti-washout admixtures.

g) Underwater Placement

When a limited amount of water is needed for cement hydration and for concrete workability, additional water will damage the mix. As the ratio of water to cement increases, the permeability of the concrete increases and the strength decreases. If conventional concrete is dumped into water with no confinement as it falls through the water, it will lose fine particles, become segregated, or be completely dispersed, depending upon the distance of the fall and the velocity of the water current.

Saltwater mixed with the concrete will corrode the reinforcing steel. Special techniques are needed to protect the concrete as it placed underwater.

h) "Bagging"

Concrete placed in bags can be used to repair deteriorated or damaged portions of concrete or masonry substructure elements underwater. Conventional bagged concrete repairs are made with small fabric bags prefilled with dry concrete mix (often only sand and cement is used) and anchored together to form the exterior of the repair. The bags are small enough to be placed in position by hand. The interior portion of the repair is then filled with tremie or dewatered by small crews. This requires minimal skill and equipment. This process is often used when the water is so shallow that special underwater diving equipment is not required.

Bagged concrete application was expanded when it became possible to take advantage of the durability and high strength of synthetic fibres to produce forms for casting underwater. These bags possess sufficient durability to be used in marine environments exposed to cyclic changes (tidal flows) and provide abrasion resistance (to floating debris and to particulates carried in the water flow). The properties of fabric-formed concrete are essentially the same as those expected from cast in conventional rigid forms, with one exception: The water-cement ratio of the concrete can be quite low at the surface since the permeable fabric allows water to bleed through the bags.

i) Pre-packaged Aggregate Concrete

After the repair area is properly prepared and the forms are in place, graded aggregate is placed in the form. A cement-sand grout is then injected into the area containing the aggregate, displacing the water and filling the voids between the aggregate particles. This method is particularly effective for underwater repairs where it would be difficult to place premixed concrete because of forming restrictions. Generally, an expansive grout with a fairly high water-cement ratio is used to provide fluidity. When anti-washout admixtures are added to the grout, the forms do not have to be as watertight as is otherwise needed.

j) Tremie Concrete

Tremie concrete is placed underwater by gravity flow through a pipe called a tremie. The underwater portion of the pipe is kept full of plastic concrete at all times during placement of the total quantity of concrete. Concrete placement starts at the lowest point and displaces the water as it fills the area. A mound of concrete is built up at the beginning of the placement. To seal the tremie, the bottom of the tremie must stay embedded in this mound throughout the placement. The concrete is forced into the occupied area by the force of gravity from the weight of concrete in the tremie. The thickness of the placement is limited to the depth of the mound of concrete. Tremie concrete is best suited for larger volume repairs where the tremie will not need to be relocated frequently or for deep placements where it would be impractical to pump the concrete. The method of placing concrete with a tremie is simple and requires few pieces of equipment, minimizing potential malfunctions. Thus, it is one of the most common methods used to place concrete underwater.

k) Pumped Concrete

Pumped concrete is placed underwater using the same equipment that is used to place concrete above water. The placement process is similar to the process of using a tremie except that the end of the pump line does not need to be in the concrete as with a tremie. A direct transfer of the concrete is provided, and the pump forces the concrete through the supply line. The placement of concrete must start at the bottom of the area and the hose or pipe must stay submerged in the fresh concrete during placement.

However, the pipe does not need to be lifted as much as with a tremie. A handle on the end of the pipe or hose will help the diver position it.

l) Free-Dump Concrete

Anti-washout concrete admixtures have been developed to minimize loss of fine aggregate and reduce segregation when the product is placed underwater. This admixture makes the concrete more cohesive yet sufficiently flowable for placement. However, the concrete mix loses some of its normal self-levelling properties and tends to stick to equipment. It is not clear that free-dumping concrete underwater with admixtures to improve placement quality is as effective as other more controlled methods of placement. Therefore, this method should be used with caution. It may be appropriate when high-quality concrete is not a primary consideration, where there is low water current velocity, and where the free-drop distance is limited to about 1 meter (about 3 feet).

m) Hand-Placed Concrete

Hand-placed concrete is mortar or concrete that the diver places by hand and then packs or rams for consolidation. This method is best suited for isolated repair sites. Use of accelerators, anti-washout admixtures, and a low water-cement ratio is recommended. The method is best suited for deep, narrow cavities. The concrete can be delivered to the diver by a bucket on a rope conveyor assembly. It can also be dropped to him in baseball-sized quantities through a pipe with holes cut in the sides to allow displaced water to escape, easing descent of the concrete. Small quantities needed for patching can also be delivered to the diver in plastic bags.

12.6.5.3 Pile Repair

Most piles require little maintenance because the material into which they are driven protects them or deterioration is not common. Where piles are exposed (whether by design or by scour), there are potential problems. These problems include scaling and spalling of concrete piles, corrosion of metal piles, or decay in timber piles, and buckling in all types if the unsupported length of the pile becomes excessive.

a) Preventive Maintenance

Preventive maintenance of exposed piles is the same as for other substructure elements constructed of the same material. For example, steel should be painted and concrete coated to protect against deterioration and corrosion. Timber piles are often used in substructure to support small structures. New cuts and bolt holes in treated timber should be thoroughly coated with preservative materials to prevent moisture from entering the wood and causing decay. The area around timber pile s and abutments must be scalped, and all weeds and brush removed from the vicinity to limit the fire hazard. Scour of the streambed may expose piling below the flow line to a degree that additional cross bracing may be necessary to maintain structural stability.

b) Jackets for Pile Protection and Repair

Jackets are a common type of pile protection and repair. They are used for protection of all types of piles: concrete, steel, and timber. The jacket can protect against abrasion damage, repair lost cross section, or accomplish both purposes. If the jacket is for protection only, it typically consists of a liner placed around the area to be protected with a cementitious grout or epoxy resin pumped into the annular opening between the existing concrete and the liner. If the jacket is intended to repair structural damage, the liner will provide space for reinforcing steel, and the space between the liner and the old pile will be filled with concrete. The liner (form) is often premoulded fibreglass. However, it could be steel or fabric. Old drain pipes have been used as jacket liners.

Deteriorated reinforced and pre-stressed piles can be encased with a concrete jacket after all unsound has been removed and the surface prepared as for other repairs. Encasement will compensate for the cross-sectional loss and strengthen the pile. Reinforcing steel cages or reinforcing wires are placed around the pile before the forms are placed. The reinforcing steel is usually epoxy coated for protection against corrosion. Standoffs are placed on the reinforcing steel before they are drawn tight to the pile. Forms, either rigid or flexible, are then installed and sealed. It is placed in the form either through a tremie or by pumping underwater. After placing the concrete, the forms are either left in place permanently for further protection of the pile or removed when the concrete is cured.

This method is useful when damage extends above and below the water line. Deteriorated concrete is removed using high-pressure water jets. The jacket extends approximately 600 mm (about 2 feet) beyond the damaged area at each end of the pile to account for any concrete segregation near the bottom or loose materials at the top of the new line. Welded wire fabric or a reinforcing steel cage is wrapped around the repair area. The fibreglass form has a vertical seam so it can be fitted around the pile. Subsequently, top and bottom centring devices and a bottom seal are placed. The form is secured in place with bolted bands and tightened to ensure full enclosure. If the length of the repair exceeds the length of the form, the piles may be repaired in two lifts. If the damage extends below the mud line, trenches are dug at the bottom to extend the repair into the mud zone.

Jacketing of steel piles is basically the same as that described above for concrete piles. Both flexible and rigid forms can be used. Often fibreglass and plastic forms are used because of their ease of installation for underwater applications. Prior to pile jacketing, remove marine growth and corrosion to clean all steel. Next, standoffs are placed on the pile flanges before the forms are installed and the concrete is placed. Welded wire fabric is typically used to reinforce the concrete against cracking. Concrete jackets can cause accelerated corrosion on a steel pile when both concrete and water are in contact with the steel. A corrosion cell will develop either below the bottom or above the top of the jacket. Thus, concrete jackets should be extended well into the mud zone and also well above the high water line.

Special considerations for installing filled pile jackets include:

- i. Using qualified divers for underwater survey and repair work and
- ii. Having pumps available for underwater placement.

The general process to jacket a pile includes the following steps:

- i. Scrape the surface of the pile clean, removing deteriorated concrete or wood.
- ii. Clean the exposed reinforcing steel in concrete piles above the water line. Splice the existing reinforcing steel with new reinforcing steel, if needed. Install a steel mesh reinforcing cage around a timber pile or concrete pile. Use spacers to keep the forming in its proper place.
- iii. Place the forming jacket around the pile and seal the bottom of the form against the pile surface.
- iv. Pump suitable concrete into the form through the opening at the top. Sulphate-resistant concrete should be used in saltwater environments.
- v. Finish the top portion of the repaired area.

Steel piles must be protected with coatings that prevent dissolved oxygen from contacting the steel. Epoxy-coating systems and polyvinyl chloride barriers have been used. While preventive maintenance for piles is thought of most often in terms of marine environments, there are significant concerns about the use in non-marine environments of steel piles driven into soil for foundation support. Although the majority of the manual discussion presented here is directed toward piles in marine environments, the reader should not assume that there are no problems with steel piles in other environments.

c) Pile Replacement

If the necessary equipment is available, either in the agency equipment fleet or through equipment rental shops, it may be easier to replace a damaged pile rather than repair it. Replacement is accomplished by cutting a hole in the surface and driving the pile through the hole. Since the pile is driven from the surface, the surface must be capable of supporting the necessary pile-driving equipment. Maintenance operation planning includes the following steps:

- i. Determine if the structures will support pile-driving equipment. If it will not, an alternative is to drive from a barge or from dry land if conditions permit.
- ii. Make provisions to restrict traffic from the work area.
- iii. Typical equipment needs include pile-driving, wood-cutting, and surface-patching equipment; piles; come-alongs; jacks; flashing; fasteners; cutting torches; and pavement-breaking, sawing, and welding equipment.

The general process includes the following steps:

- i. If the surface is overlaid with asphalt or concrete, locate the centreline of the stringers closest to the pile replacement.
- ii. Cut through the overlay and the surface along the centreline of the stringer. Remove sufficient surface to permit the pile to go through the hole adjacent to the cap.
- iii. If cross bracing is present, remove it from between the piles and on the side of the concrete where the new pile will be driven.
- iv. Set the pile at a slight batter so it will be plumb when it is driven and pulled under the cap. Drive the pile to the specified bearing.
- v. Install U-clamps and blocking around the pile to be replaced. Place a jack on blocking and jack the cap up approximately 13 mm (about 0.5 inch).
- vi. Cut the pile 6 mm (about 0.25 inch) below the cap and pull the pile into position under the cap.
- vii. Positioning the pile can be accomplished by using "come-alongs" to pull against adjacent sheet piles. Place copper sheeting on a timber pile head. On steel, the pile is welded to the cap.
- viii. Lower the jack and strap in place.
- ix. Reconstruct cross bracing on concrete piles.
- x. Close surface holes and restore normal traffic flow.

This process may also be used for strengthening an existing structure.

d) Steel Piles

Steel piles may be damaged, particularly if they are located in waterways where they may be struck by heavy barges or if they are placed near roadway work zones where they may be struck by heavy equipment. The latter scenario is less common. Damage in the form of, torn, or cut flanges may reduce the cross section, and hence the load-bearing capacity, of the pile, requiring repair. More commonly, steel H-piles may become severely corroded in a relatively short section near the main water line in a waterway or as the result of unusual conditions such as broken drains. An otherwise sound steel pile or one that cannot be easily replaced or supplemented because of access or scheduling may be strengthened by repair with bolted channels as a temporary measure.

Maintenance operation planning should include the following actions:

- i. Select appropriate channel size to meet strength and dimensional requirements;
- ii. Determine length of damaged area and secure steel channels of selected size that have been fabricated in appropriate lengths with necessary hardware; and
- iii. Assemble equipment and tools needed (such as equipment to drill bolt holes), protective coating materials, and necessary staging.

The repair process includes the following steps:

- i. Clean the damaged pile.
- ii. Locate the extreme limits of the deteriorated section. The repair channel section should be about 0.5 meter (about 18 inches) longer than the distance between these limits.
- iii. Thoroughly clean the area to which the channel is to be bolted.
- iv. Clamp the channel section in place against the pile.
- v. Locate and drill holes for high-strength bolts through the channel and the pile section.
- vi. Place bolts and secure the channel.
- vii. Remove the clamps.
- viii. If the pile repair is above the water, coat the entire area with a protective coating material.
- ix. For long-term rehabilitation, steel piles should be encased with a concrete jacket.

This procedure can also be used to add a new section of pile above a damaged area.

e) Patch Concrete Pile

Deteriorated concrete in a concrete pile should be removed and replaced with sound concrete. After the deteriorated concrete is removed, the reinforcing steel should then be cleaned of all rust and scale, and the new concrete is placed. Sufficient concrete should be removed so that the thickness of the new concrete placed is a minimum depth of about 50 mm (about 2 inches). After forms are placed, all of the old concrete surfaces that adjoin new concrete should be covered with a bonding material. The new concrete is then placed, or grout-injected dry-packed aggregate is used.

f) Casting Sub-footing to Cap Piles

Badly deteriorated piles that are exposed under a footing must be repaired before the void under the footing is filled. If accessible, timber or steel piles may be spliced. Where there is no room to implement a repair by adding sections, a possible alternate repair process may be used. An alternate process is outlined in the following steps:

- i. Cut out the deteriorated portion of the pile from the footing bottom to the depth of the sound piling material.
- ii. Form and place new concrete from the footing bottom to about 150 mm (about 6 inches) below the new top of the pile.
- iii. When topping out the new concrete, maintain a hydrostatic head at the interface between the fresh concrete and the old footing. Attempt to eliminate voids at the interface. Pumping or pressure grouting may be required after the concrete cures.
- iv. The repair must be phased so that there is always sufficient support to the structure to carry the required load.
- v. Fill all of the voids.

When the void that exposed the piles is caused by erosion, some measures must be taken to prevent its recurrence.

g) Splicing Steel H-Piles under Footings

Deteriorated steel can be repaired by adding sections, if there is sufficient working space to weld or bolt sections in place. To proceed with splicing, loss of cross section should be less than 50%. The web and flanges of the pile should be strengthened by welding steel plates extending far enough above and below the deteriorated area to carry the full load on the pile. Where extreme section loss is present in the pile at the interface with the footing, repairs can be made by welding plates to form an angle with one leg against the footing and the other leg against the pile. Stiffeners should be placed across the angle as needed.

These angle plates should be placed on both flanges. When the welding is completed, all of the exposed piles should be given a heavy, protective coating. Fill should then be placed around the piles up to the bottom of the footing.

h) Pile Shell Repair

Filled shells are cast-in-place concrete piles. A metal shell is driven, the mandrel is withdrawn, and the shell is filled with concrete. Sometimes a problem develops when the shell is corroded as the concrete deteriorates. Temporary support should be erected to carry the load when necessary. Rust and scale must be removed, and the steel primed and painted. When both the shell and the concrete are damaged, the deteriorated portion of the shell must be removed and a collar of sufficient strength and diameter placed around the pile. The collar is extended well above and below the affected area, and a high-quality, low-shrinkage concrete; epoxy mortar; or cementitious grout is pressure-injected inside the collar to fill the voids. The material should be well compacted so that the voids are completely eliminated.

i) Repairing Intermediate

The maintenance repair process varies somewhat depending upon the material used to construct the original structure.

Steel Pile: Corrosion or deterioration in steel piling usually occurs at the water line or ground line where wet and dry conditions alternate. Collision damage may also be a problem where piles are near roadways or navigable waterways. Rust and corrosion should be removed by sandblasting or with pneumatic needle scalers. When possible, damaged areas should be straightened and the deteriorated areas should be strengthened by welding steel plates extending far enough above and below the deteriorated area to restore the full load-carrying capacity of the pile. If deterioration is minor, metal plates may be added by welding. All repaired areas should be cleaned and painted as a preventive maintenance practice.

j) Adding Sections of Timber Pile

Treated timber piles that have decayed or been damaged by fire or impact can be repaired without having to drive into the old pile, if the portion of the pile below the ground is still sound. These steps must be followed:

- i. After the required auxiliary support is in place, the old pile is cut off below the decayed or damaged area.
- ii. A new section of pile is cut about 150 mm (about 6 inches) shorter than the section removed. Plates are put in place on top of the existing pile and on the bottom of the new section of piling.
- iii. A 19-mm (3/4-inch) bolt with a nut is welded to the bottom plate, extending through a hole in the top plate. By adjusting the nut on the bolt, the new section of pile can be raised until it is securely seated against the concrete cap. Care must be taken to raise the new section of piling far enough to cause the concrete cap to lift from the adjacent piling.
- iv. After the new section is in place, 6-mm (1/4-inch) thick angles are welded between the plates at each corner.
- v. Used girder plates or flat stock are then bolted to the timber pile and extended down on the original pile about 300 mm (about 12 inches). Using straps, the top of the pile is secured to the concrete cap.
- vi. A 1 m × 1 m × 0.6 m (3 feet × 3 feet × 2 feet) block of dense concrete is placed around the pile. Any falsework erected may be removed after the concrete has been placed and has cured.

k) Splicing Timber Piles with Steel Columns

Timber pilings that have decayed, have been weakened by insects or marine organisms, or have been structurally damaged by collision or overloading may be replaced with steel columns. Maintenance planning for such repair should (1) evaluate the condition of existing caps and existing piles below the surface; (2) determine any need for a cofferdam to dewater the work area; (3) determine a method of temporary support for the superstructure during repairs; (4) make provisions to restrict traffic from the work area during repairs; and (5) procure necessary equipment and tools such as wood-cutting tools, welding and steel-cutting equipment, light lifting equipment, wrenches, and other small hand tools. The following steps are generally necessary to ensure a satisfactory maintenance process:

- i. Determine all cut-off points on the existing piles and the column length needed for the repair.
- ii. Construct temporary support for the superstructure before beginning the repair.
- iii. Construct a cofferdam (if needed) and dewater the work area.
- iv. Excavate so that the top of the footing will be a minimum of about 225 mm (about 9 inches) below the ground line.
- v. Cut existing piles off so that they will project at least 300 mm (12 inches) into the new footing.
- vi. Separate the old sections of piling from the pier cap.
- vii. Form and place footings over the existing pile stubs.
- viii. Place the anchor bolts in the footing before the initial set of the concrete.
- ix. Cut the steel columns to the proper length and weld on the base plates.
- x. After the pile has reached the required strength, attach the new steel columns to the footings with nuts and washers.
- xi. Attach the top of the new columns to the existing pier caps with lag screws.
- xii. Remove all temporary supports, backfill where necessary, and remove the cofferdam (if one was used).

l) Pile Splice

The timber splice method should not be used when replacing piling in the abutments because it will not provide sufficient resistance to the overturning moment produced by the force of the fill against the back wall. Steps generally included in the maintenance process to repair the top of an abutment pile are as follows:

- i. Place the required falsework.
- ii. Cut the pile off below the decayed or damaged area.
- iii. Split lengthwise and place around the pile a cylindrical steel pile shell, long enough to extend from the bottom of the cap down about 600 mm (about 2 feet) on the remaining pile.
- iv. After the steel pile shell is pulled tight around the pile and welded back together, fill it with concrete.
- v. Remove the falsework after the concrete has cured.

Where it is not practical to repair the piling with this process, a new section of pile can be spliced to the old section, using steel pipe or a band to hold the two butt ends together.

m) Installing Helper

An existing substructure unit that is not capable of supporting its required load may be supplemented with a timber helper. One example is a structure pier in which seat damage is so acute that the bearings are affected and the beams may dislodge. In this case, a timber helper adjacent to the pier would support the load and preclude structures failure if bearing failure did occur.

The timber helper may also be used to reduce the span length and increase the structures load-carrying capacity in a situation where the beams are weakened or were not designed for current legal loads. A professionally qualified structural engineer should determine the size and location of the helper. The engineer must also determine if the structures can support a pile-driving rig or if the equipment can be located off the surface.

A professionally qualified hydraulic engineer should determine if the additional restriction to stream flow that the helper concrete will create is acceptable for hydraulic efficiency. Provisions should also be made to maintain traffic safely away from the work area. Equipment systems that may be needed include pile-driving equipment, lifting equipment, surface-cutting equipment, and perhaps scaffolding. Steps generally included in a maintenance process are as follows:

- i. If the surface is timber with an asphalt or concrete overlay, locate the centreline of the stringers closest to each pile location for the helper concrete. If the surface is reinforced concrete, locate the piles so that the surface beams will not interfere with pile driving.
- ii. Cut holes in only one traffic lane at a time.
- iii. If a timber surface does not have an overlay, cut the timber surfacing at the centreline of the stringer near the centreline of the structures and remove the surfacing across the travelled lane.
- iv. Cut through any overlay and the timber surface along the centreline of the stringer. Remove sufficient amount of the timber surfacing to permit a pile to go through the hole. For a reinforced- surface, remove a sufficient amount of concrete in a square pattern to permit a pile to go through the hole. Cut any reinforcing steel at the centre of the hole and bend it out of the way of the pile to be inserted through the hole.
- v. Set the piling and drive it to the required bearing capacity.
- vi. Cut off the piling approximately 6 mm (about 0.25 inch) above the bottom of the existing cap. If the existing cap has settled, allowance must be made for grade differential.
- vii. Place cover plates over surface holes, open the lane to traffic, move to the adjacent lane, and repeat the process as needed.
- viii. After all piles have been driven and cut off, jack up the superstructure approximately 13 mm (about 0.5 inch), using the existing pile. This may be accomplished with U-clamps and blocking supporting jacks against the beam bottoms.
- ix. Place timber caps over both rows of pilings. For end s, only one row of piles and caps is required.
- x. Lower the superstructure onto the new caps and strap each cap to its piling. Shimming may be required to obtain bearing between the superstructure and the timber caps.
- xi. Remove the surface plates and reconstruct the surface. If the surface is reinforced concrete, splice all reinforcing bars that were cut. Replace the surface one lane at a time. Sections of the surface under repair may be reopened to traffic if protected with steel plates.
- xii. Erect cross bracing on the new pile. For intermediate s, cross bracing between the two new is also required.

An alternative temporary may be constructed with the following procedure:

- i. Set piles and drive to the specified bearing capacity.
- ii. Cut off piles to allow for beams, neoprene pads, and wedge plates.
- iii. Connect 300-mm × 300-mm (12-inch × 12-inch) timber caps to plates with 22-mm (7/8-inch) × 530-mm (1-foot 9-inch) headless drive spikes.
- iv. Connect timber brace to piles.
- v. Set steel beams (such as W21 × 55 or W21 × 62) into position.
- vi. Jack beam from cap to obtain temporary bearing against superstructure.
- vii. Set neoprene pads into position. If necessary, cut them to obtain 225-mm × 225-mm (9-inch × 9-inch) pads.
- viii. Remove jacks and drive lag bolts.

n) Repairing Timber Caps

Repair of timber caps can involve repairing and rotating the cap, replacing the cap, or strengthening the cap.

Rotating Caps: When timber pile abutments are pushed forward by the earthen fill the abutment that is retaining, the pile cap could rotate. Then either the pile stays are broken off or the abutment was constructed without stays. Abutments that are too high can also cause this problem. Generally, the maintenance process to correct this problem includes the following steps:

- i. Remove all earth from behind the abutment. (Excavation behind an abutment may present a high potential for a cave-in. Shoring may be needed)
- ii. Pull the piles and caps back into position.
- iii. Repair or install the pile stays.
- iv. Bury or drive deadmen anchors behind the abutment. Then fasten and tighten the cables to the piles with eyebolts, using the size of cables specified by a professionally qualified engineer.

Replacing Timber Caps: A common maintenance problem with pile caps is decay followed by longitudinal cracks and crushing from the load on the cap. When these problems arise, the pile cap must be replaced. The superstructure is jacked either from the existing columns or from a temporary. The decayed cap is removed and a new cap is secured in position. To avoid future decay, timber pile caps that have deteriorated may be replaced with 300-mm (12-inch) steel beam caps. Stiffeners may be welded between the flanges directly over the piling. The steel cap is secured to the piling with a piece of 75-mm (3-inch) flat stock to encircle the top of the pile and welded to the bottom of the cap.

Strengthening Timber Caps: The need to increase the load capacity of a structure may arise from improper sizes or defects in a particular member. An example is wood pier caps that have developed large lengthwise shrinkage cracks or a large number of splits near bolt fasteners. A structural analysis may indicate such caps rate significantly lower than other members because of these defects. If the original cap is still in good structural condition and no decay is evident, strengthening the cap is often easier and cheaper than replacing it. In some cases, access limitations or other factors may make it very difficult to replace a cap. Thus, strengthening the cap is the most logical maintenance process. Good maintenance planning for cap strengthening should ensure that the existing cap and columns are in good condition, that the new section (as strengthened) will meet the design analysis load conditions, and that the appropriate resources are available (heavy-duty drilling equipment, light lifting equipment, access to the pile cap, wrenches, and small hand tools).

The general process usually conducted to ensure a successful maintenance operation is as follows:

- i. Construct scaffolding, as needed, around existing.
- ii. If the pile diameter is wider than the existing cap, notch the existing piles or columns to accommodate the new timber cap members.
- iii. Snugly place the new members against the existing cap and stringers, and temporarily clamp them in place.
- iv. Drill 21-mm (13/16-inch) holes for 19-mm (3/4-inch) bolts.
- v. Insert the bolts, tighten them down, and remove the clamps.
- vi. Remove scaffolding, if any was used.

o) Installing Deadman Anchorages

The force of earth and stone in the structures approach behind the structures abutment tends to push forward and rotate (tip over) the abutment, especially if the fill behind the abutment is unstable or the abutment is not adequately anchored.

A deadman is a heavy mass (weight)—usually blocks—attached to the abutment with a long steel rod and located in stable earth far behind the abutment. This provides an anchor that prevents overturning of the abutment. Good maintenance planning for installation of a deadman anchorage includes (1) using a professionally qualified engineer to calculate the magnitude of the forces to be resisted by the deadman, to determine the required size of the deadman and the restraining rod, and to determine if piles are required; and (2) providing the necessary resources including excavation equipment, light lifting equipment, drills, miscellaneous hand tools, and any shoring as needed. The general procedure to install a deadman anchorage includes the following steps:

- i. Excavate the area where the deadmen are to be placed and provide a trench for the restraining rods. (Excavation behind an abutment may present a high potential for a cave-in. Shoring may be needed.)
- ii. Drive piles for the deadmen, if required.
- iii. Place formwork and concrete for the deadmen. The side of the deadmen facing the abutment should be cast without forms. No formwork is required if the soil conditions are stable enough for the walls of the excavation to act as earthen forms.
- iv. Drill through the wing walls and place the restraining rods. Wrap and coat them with tar (or provide other means to protect the rods from corrosion).
- v. Bolt the restraining rods at the deadmen.
- vi. Place the waler beams and tighten the rods.
- vii. Grout holes in the wing wall.
- viii. Backfill the excavated area.

12.6.6 Scour Protection and Repair

A wide variety of methods have been developed for scour control and slope protection. Commonly used methods range from routine maintenance activities (e.g., filling and stabilizing washed-out areas) to major construction of extensive slope protection and flow control systems. In extreme cases, modifications such as constructing additional spans to structures may be necessary to provide a larger flow channel.

12.6.6.1 Role of Maintenance Team

Maintenance crews are primarily involved with bank erosion problems that can be corrected by minor or routine types of maintenance. The selection, design, and construction of scour control and slope protection measures for major or chronic problems generally should be conducted under the design and supervision of professionally qualified hydraulic engineers. However, once any major protective measures have been designed and constructed, they become the responsibility of the maintenance division. Thus, maintenance supervisors need to have a basic understanding of the types of devices available, how these devices function, the most likely types of failure, and how the devices should be maintained. Maintenance activity generally falls into the following four areas:

- a) Response to emergency situations.
- b) Maintenance of the protective devices.
- c) Assistance in identifying the need for protective devices.
- d) Provision of input on the selection of alternatives.

Area maintenance personnel should know structures that are susceptible to problems from a major storm. They are generally the first on the scene and the first to know when bank erosion is occurring or when slope protection and flow control measures have been damaged. They should also look for damage to the structures or the structures foundation. Often during major storms, structures are damaged. The need for repairs must be recognized as early as possible. Minor repairs made in a timely manner are likely to reduce the need for major repairs that may result if the problem is left untreated.

Many slope protection and erosion control devices are expected to be damaged by hydraulic forces under severe conditions. This prevents more costly damage to the structures that these devices were designed to protect. Maintenance personnel must be aware of these situations so that needed repairs can be identified and scheduled on a routine basis.

12.6.6.2 Identifying the Need for Scour Countermeasures

Slope protection and scour control devices are usually provided at the time the structures facility is constructed. Natural or man-made changes in the stream channel or drainage basin can change runoff characteristics, the type and amount of sediment carried by the stream, stream alignment, and other stream characteristics. Early identification of potentially severe problems can provide the lead time necessary for analysis, design, and construction of appropriate erosion control and slope protection measures. Sites where problems recur frequently, worsen in spite of frequent maintenance, or where the problems shift to another unprotected location when eroded areas are repaired, should be reported to the engineering division for a hydraulic and geotechnical evaluation.

12.6.6.3 Selection of Alternatives

The selection and design of appropriate slope erosion control and bank protection measures usually involves analysis of complex stream characteristics and can best be accomplished by professionally qualified hydraulic engineers. Several practical matters require input from maintenance personnel. Maintenance personnel are usually the best source of historical data that might pinpoint the cause of the problem, such as when shifts in channel alignment have occurred. Repairs are more likely to be successful when the cause of the damage can be determined.

An important consideration is as to how successful or unsuccessful different treatments have been under similar conditions in the past.

The use of locally available materials will usually reduce construction and maintenance costs. Ease of maintenance should be an important consideration. Access and frequency of maintenance expected are key elements to a good design. The many different methods to control erosion and protect slopes from stream flow, tidal flow, and wave action are generally classified as revetments (slope protection), flow control (stream training), and structure modification or channel modification.

12.6.7 Protective Systems

12.6.7.1 Protecting the Substructure

a) Deterioration at the Water Line

Several deterioration mechanisms act at the water line. Wet or dry and freeze or thaw cycles accelerate substructure deterioration. Material carried by the water can cause an abrasive action that contributes to surface damage at the water line. To protect against these kinds of deterioration, protective coatings and fibreglass liners can be applied at the water line.

b) Settlement

Where serious settlement is present, a professionally qualified soils engineer, structural engineer, or both should be consulted before repairing damage to any abutment or pier. Movement of an abutment or pier should be stabilized before making any repairs, such as by filling cracks or rellevelling structures seats and bearings. Levelling the substructure cap and bearings is required so that when the superstructure load is placed on the bearings there will be no unexpected stress in the structural members. A substructure unit that is resting upon piles may require additional piles to stabilize it. Additional width of a spread footing may have to be constructed to stabilize the footing. In a spread footing, additional support can usually be gained by underpinning.

That is, sectional piles are jacked to bearing under the footing and then a short steel column is inserted and wedged tight after the jacks have been removed. When an abutment has been repaired as a result of settlement of the back wall, it should be checked to ensure that it is not binding on the substructure member. Surface expansion joints and seals should always be checked and adjusted after major repair of a settled substructure unit. When serious settlement occurs in large structures, a professionally qualified engineer should be consulted before any attempt is made to correct the situation.

c) Impact Damage

On navigable waterways, where ships and barges may come in contact with piers and abutments, adequate fenders are necessary to protect against mechanical and impact damage. Steel plates can be installed on the upstream edge of an abutment or pier to reduce the damage caused by flood debris. Any plates installed should be of sufficient thickness to withstand the expected forces and should be well anchored.

d) Salt Damage

Protection against saltwater damage to the substructure is the same as for a structure surface. Coatings can be effective for steel or concrete if applied early in the life of the structure and reapplied as needed to maintain the integrity of the coating. Dense concrete, such as that attained with a pozzolanic additive, can also aid in resisting the damaging effects of saltwater exposure.

e) Pressure from Approach Pavement

Damage caused by pressure from approach pavements can be minimized or even eliminated by installing relief joints in advance of the structures abutment.

12.6.8 Spot Painting to Protect the Superstructure

Spot painting normally involves cleaning the surface, removing corrosion, and replacing the paint system on selected areas of the structures. The replacement paint is selected for colour match (as nearly as possible) and for chemical compatibility with existing paint. Environmental concerns continue to grow with respect to structures painting. The best preventive maintenance approach may be to schedule structures repainting before the condition of the existing paint system deteriorates to the point that paint removal is necessary. If the existing paint contains lead, it can be encapsulated with an environmentally friendly paint such as a zinc-rich or vinyl-based product. Figure 12.7 show the corroded tidal gate spiral steel ladder without paint protection.



Figure 12.7 Tidal Gate Spiral Steel Staircase Badly Corroded Due to Lack of Paint Protection

12.6.8.1 Paint Systems

Paint consists of two basic parts: a pigment made of fine particles to provide colouring, and a vehicle that is the liquid portion carrying the pigment. The paint vehicle generally consists of a binder and thinners. The binders and the embedded pigment remain as the paint coating after the paint has dried (i.e., after the thinners have evaporated). Chemical reactions, in addition to the drying process, cause the binder in some paints to harden when the paint is exposed to air. Rapidly evaporating thinners are sometimes called dryers.

Red lead, titanium oxide, zinc chromate, and silicates are typical pigments. Some pigments, such as zinc chromate, also increase steel resistance to corrosion. Most agencies no longer use lead-based paints because of concerns and restrictions related to worker safety and environmental damage. Binders typically include linseed oil, alkyds, latex, polyurethane, epoxy, or other chemicals. Thinners typically include turpentine, mineral spirits, acetone, water, or other substances. New pigments, binders, and thinners are continually being developed to improve ease of application, quality and durability of the paint surface, and protective qualities of the paint.

The maintenance purpose of painting is to protect the structures from corrosion. Spot painting consists of painting localized areas where the paint has been damaged, has failed, or corrosion has begun. Performing spot painting as soon as defects are noted stops or reduces corrosion before it progresses. This can save time and money before requiring a larger painting effort.

12.6.8.2 Preparation of the Surface

Preparation of the surface before painting is the most important element of the painting process. Surface preparation involves removal of all corrosion, paint, or deposits that may interfere with the adhesion and covering ability of the paint to be applied. Paint should not be applied over loose, scaly, or flaking paint. Mill scale, rust, dirt, oil, and other foreign substances that prevent paint from adhering or covering must be removed. Water and dirt may be removed from the surface by air-blasting and wiping. Grease-like contaminants are most successfully removed by scraping, if the accumulation is large, then wiping or scrubbing with a petroleum-based solvent. Make certain that oily substances are not simply diluted and then spread over a larger area. Vigorous wiping with a clean rag may be desirable to ensure that residues will not interfere with paint adhesion. Paint can be removed by a variety of methods. Each method differs in its cost of implementation, degree of containment required, quality of surface prepared, and amount of debris generated.

12.6.8.3 Cleaning With Solvents

Heavy oil or grease accumulations on a surface must be removed before abrasive blasting or other surface preparation gets underway. Oil and grease may interfere with surface preparation or be spread further by it. In some areas, removal of lighter accumulations may be the only surface preparation required. In other areas, heavy oil or grease deposits and incorporated dirt may have solidified over time so that the material is hard and thick enough to require scraping to remove. Preliminary scraping of the heaviest deposits usually saves time and solvent. The solvents that may be used range from water in combination with special soaps to kerosene to some complex, hazardous chemicals such as di-isobutyl ketone. Properties of solvents that are relevant to their use in surface preparation because of health and fire considerations are as follows:

Relative Evaporation Time: This is the time required for the solvent to completely evaporate, based on a scale value of 1.0 for ethyl ether. The higher the number, the longer the time required for evaporation.

Flash Point: This is the temperature at which the solvent releases sufficient vapour to ignite in the presence of an open flame. The higher the flash point, the safer the solvent.

Explosive Limits (Flammable Limits): This is expressed as a percentage of solvent vapour in a total volume of vapour plus air. Minimum concentrations below this percentage will not ignite. Maximum concentrations above this percentage will not ignite. Concentrations between the minimum and maximum will ignite or explode.

Maximum Allowable Concentration: This is the concentration of solvent vapour in the air that can be tolerated by workers throughout an 8-hour day, expressed in parts per million. The higher the value, the safer the solvent. Common solvents such as carbon tetrachloride and benzol are very toxic and are considered carcinogenic, thus should be handled accordingly.

Paint should not be applied over solvents, so evaporation times should be considered when selecting a solvent. Safety is the first consideration in using solvents because of health and fire hazards. Some general precautions in the use of any solvent include the following:

- Wear goggles, protective clothing, rubber gloves, and barrier cream (petroleum jelly).
- Do not breathe the fumes. (Proper ventilation is always required.)
- Do not use benzene and carbon tetrachloride since they are poisonous.
- Do not use gasoline or solvents with low flash points since they might catch fire or explode.
- Do not smoke or use solvents near fire, flame, or electrical connections.
- In case of skin contact, clean thoroughly with soap and water.
- In case of eye contact, rinse with water immediately and contact a physician.

12.6.8.4 Hand Cleaning

Hand cleaning is laborious and used to remove old paint or corrosion only from small areas. Hand cleaning greatly reduces the amount of material for disposal, and it does not require large or expensive equipment. Hand cleaning is used to prepare areas where the paint is in fairly good condition with only a few bad spots around rivets, welds, and joints; in corners and "blind spots" that other methods do not reach; or on larger areas where traffic does not permit the use of other methods. Hand cleaning can lead to eye injuries from flying debris particles, to cuts from sharp edges, and to falls from slipping. Goggles should be worn at all times. Heavy-duty clothing and leather gloves are also needed. Work must proceed carefully to avoid slips and falls. A minimum of dust is generated by hand cleaning, so hanging a few tarps around the work area can generally satisfy containment requirements. Typical tool requirements include wire brushes, scrapers, chipping hammers, sandpaper, slag hammers, chisels, painters, putty knives, dust brushes, brooms, and sanding blocks.

12.6.8.5 Power Tool Cleaning

Power tool cleaning removes rust, loose paint, and mill scale. As with hand cleaning, productivity is low and the compatibility of the paint system must be assessed. The dust generated by power tools is generally greater than that created by hand tool cleaning, but it is still considerably less than that generated by grit-blast cleaning. Containment consists simply of tarps placed around the work area. Typical tool requirements include impact tools, rushing tools, grinding tools, needle guns, and rotary scarifiers.

12.6.8.6 Power Tool Cleaning With Vacuum Attachments

Power tools can be equipped with vacuum attachments to collect the dust and debris. The degree of dust generated is minimal, but some dust will escape in areas of difficult configuration or where complete seals are difficult to attain. The shrouding can also restrict access in hard-to-reach areas. Debris consists of only the products removed from the steel surface. Productivity is generally lower than for power tools without the vacuum attachments.

12.6.8.7 Chemical Stripping

Chemicals can be applied to the steel surface to soften the paint before scraping or water washing. Chemicals such as sodium hydroxide or methylene chloride are applied to the surface and are allowed to remain in contact with the surface for a few hours or overnight. The stripper and the wash water must be collected for proper disposal. Dust-tight containment is not necessary, but the containment must be capable of capturing the stripper debris and the wash water. The used stripper will be hazardous because of the lead particles in the paint removed, and it may also have a hazardous pH value. Some strippers are classified as hazardous chemicals because of other characteristics. The volume of waste may be increased if the rinse water tests hazardous and it cannot be filtered from the debris. Strippers will not remove rust or mill scale. To properly prepare the surface, blast cleaning may be required after the strippers have been used. If abrasive blast cleaning is needed, some containment will be required for the nuisance dust, even though the stripper has removed the lead paint. Productivity with strippers can be slow, especially if repeated applications are necessary and if additional mechanical surface preparation is required.

12.6.8.8 Overcoating

An alternative to cleaning lead-based paints and repainting steel structures is to overcoat the structures. This process involves applying a surface-tolerant coating over an existing coating containing lead, after minimally preparing the surface. The surface is typically prepared using power water washing to remove dirt, paint chalk, and chlorides. In isolated areas, a combination of hand cleaning and power cleaning may be used. Overcoating eliminates grit blasting in the open air. Prior to overcoating, steel surfaces are spot-painted with a one-component, moisture-curing polyurethane aluminum primer. A polyurethane intermediate coat that meets environmental and safety standards for volatile organic compounds (VOCs) can then be applied to the entire structures surface. The repainting is completed with a light-stable polyurethane topcoat that meets VOC environmental and safety standards.

Painting costs may be reduced 30% to 75% using the overcoat method. Overcoating is generally applicable to structures with a maximum of 25% to 30% surface corrosion. It may also be used if the structures paint has broken down. Important to the success of overcoating is the special surface-wetting, edge-sealing and curing capabilities of the moisture-curing polyurethane spot primer. The low-viscosity primer can penetrate and wet out the old paint, tightly adhering rust. In addition, the primer can penetrate under old paint and can be used for spot-cleaning areas. To cure, the primer scavenges moisture from the rust, the atmosphere, and the existing paint. When determining if a structure is a suitable candidate for overcoating, the following factors should be considered:

- The percentage of the structures surface that is rusted.
- The degree of rusting.
- Structural steel condition.
- Adhesion of the coating.
- Adhesion between the layers of the coating.
- Paint type of the undercoating. (It may be difficult to develop proper adhesion between leafing, pigmented paints and the new coating.)
- Reparability of the coating.
- Compatibility of the existing coating system. (Patch areas may need to be tested.)

12.6.8.9 Spot-Painting Guidelines

Spot painting involves painting damaged, repaired, or corroded members of a structure where less than 35% of the paint on the structures has deteriorated. Generally, if more than 35% of the structures need to be painted, the whole structures should be painted since it will all need to be painted soon. The first consideration is to select a paint type compatible with the existing paint. Paint formulas are constantly changing, and many newer paints will not adhere, cover, or endure if applied over an older formulation. Generally, it is best to spot-paint with the same type of paint already on the structures. When this is not possible, consult the paint manufacturer's technical data to find a compatible paint. Whenever possible, spot painting should be done with a matching colour to enhance the appearance of the structures. Only the part of the structural member that has corroded is cleaned to bare metal, and only that part is given a prime coat, followed by a final coat.

12.6.8.10 Weather Conditions

Weather is an important consideration in producing a high-quality paint job. Painting is best done in warm, dry weather with little or no wind. Avoid painting when the wind velocity exceeds 7 meters per second (15 miles per hour) or when the temperature is below 4°C (40°F) or above 50°C (125°F) unless the paint is specially formulated for more extreme temperatures. Avoid applying paint when the relative humidity exceeds 85%.

12.6.8.11 Thinners

Thinners should be used only when specified or necessary. Too much thinner results in a coating that is not thick enough to protect the steel properly, manufacturer's recommendations should always be followed. If cold weather conditions require increased use of a thinner, extra coats of paint may have to be applied to obtain the necessary coating thickness for proper steel protection. Do not thin lead-based paints. If necessary, they may be heated with hot water or steam radiators.

12.6.8.12 Paint Care and Storage

Proper care and storage of paint is essential for maintaining the quality of the paint and for safety reasons, since many paints are toxic or are a fire hazard. Keeping a reasonable inventory of paints promotes efficiency.

- Store paint at temperatures between 18°C (65°F) to 30°C (85°F) in a dry, well-ventilated area where it will not be exposed to excessive heat or cold, explosive fumes, sparks, flames, or direct sunlight.
- Because of fire hazards, paint and solvents should be stored in a location apart from other combustible materials. If possible, store them in separate structures.
- Store paint neatly. Keep aisles and walkways clear for safety.
- Ensure labels are intact and legible. Re-label containers accurately.
- Containers should remain unopened until required for use.
- Previously opened containers should be used first.
- The oldest paint should be used first.
- If a skin of dried paint has formed on the surface of the paint in a previously opened container, cut the skin out, dispose of it properly, and thoroughly mix the remaining paint.
- Pour partially used containers of paint of the same type and colour into one container to reduce the amount of air space in a container. Air space causes a paint skin to form.
- Ensure that partially used containers are sealed tightly to prevent contamination and drying of the paint.
- Recheck container lids periodically to ensure that the lids are tightly sealed.

- Invert containers in storage each month or two to prevent pigments from settling and caking on the bottom of the container.
- Do not try to salvage improperly stored paint. Return it to the stockroom for disposal and notify the supervisor of the condition and identification of the paint.

12.6.8.13 Inspection of Painting

Painting is not completed until the coating has been inspected and any deficiencies have been corrected. The inspection techniques are designed to reveal defects (e.g., porous areas, pinholes, blisters, unpainted areas, thinly coated areas). A flashlight-equipped magnifying glass can be used to detect and examine surface irregularities. An electric current measuring device can be used to locate thin paint areas and pinholes. A wet-mil gauge can be used to test the thickness of paint before it has set up. A dry-mil gauge can be used to measure the paint thickness after it has set up and before the next coat is applied. Non-destructive dry-mil gauges generally use magnets to test for thickness, while destructive gauges require a scratch through the paint. Before applying successive coats of paint, it is necessary to touch up damaged areas, repaint areas with insufficient thickness, and repair and repaint all unsatisfactory areas.

12.6.8.14 Painting Defects

Some common painting defects and possible repair options are as follows:

Alligatoring: This is a mesh of paint cracks that resembles alligator hide, with the coating pulling away from the surface and causing a rough finish. It is usually caused by not allowing sufficient drying of the paint before recoating, by extreme temperature changes, and by incompatibility between coats of paints (e.g., when vinyl paint is applied over alkyd paint). Remove the finish down through the damaged paint film and refinish the area. Use a solvent recommended by the paint manufacturer. Paint should be mixed thoroughly before applying. Sufficient time for drying should be allowed between coats of paint. Compatible paints should be used.

Blistering: There are many causes of blistering: The topcoat did not adhere to the primer, paint was applied over oil or moisture, too much paint was applied at one time, steam cleaning caused disbonding, fingerprints on the metal, or air was trapped under a very thick coating of paint. Correction requires removing the blisters by sanding with No 400 sandpaper or a ball of screen wire, then refinishing. Products should be properly thinned, and sufficient drying time should be allowed between coats. There should be no water in the air lines when spray-painting.

Lifting: Incompatible coatings may not wrinkle or alligator. Instead, the incompatible coating may cause the coating beneath it to lose its adhesion, resulting in both coats peeling from the surface. This is caused by the solvent in the topcoat acting as a paint remover on the coating beneath it. This is likely to occur when paints containing a strong solvent such as xylene are applied over soft, oil-based paints. Lifting may also occur if an undercoat is not allowed to dry properly before the next coat is applied. Painting over dirty, oily, or greasy surfaces may also cause lifting. Removing the finish down through the damaged paint film and refinishing the area should repair lifting. A solvent recommended by the paint manufacturer should be used. The paint should be mixed thoroughly before applying. Sufficient drying time should be allowed between coats of paint. Compatible paints should be used.

Pinholing (Bubbling, Solvent Pops): These defects are quite common in coatings. Pinholing is often the result of water contamination in the air line of the sprayer or a solvent imbalance (a solvent that is drying too quickly). The coating does not have enough time to flow out before it dries, and little holes are left in the coating. Trapped solvents, settling of pigments and insufficient atomization of the paint may also cause pinholing. If pinholing occurs, it may be necessary to consult a materials laboratory so that the cause can be determined and eliminated.

One successful remedy is to use a considerably thinned tie coat or primer or to thin the topcoat 25% to 50%, sealing the porous surface of a zinc-rich primer. When the use of a tie coat is not acceptable, a mist coating of the topcoat paint should be applied over the surface. A full topcoat should follow this. In extremely severe cases of pinholing, it may be necessary to sand to a smooth surface and refinish. Pinholing can be prevented by keeping water out of the sprayer air lines, by not applying paint too heavily, and by allowing proper evaporation of the solvents. Recommended thinners and sufficient air pressure for proper atomization should be used.

Runs: Runs are rivulets of wet paint film. This defect is caused by over-thinned paint, by slowly evaporating thinners, by improperly cleaned surfaces, or by surfaces being too cold. Holding the spray gun too close to the surface and depositing too much paint on the surface also causes runs in the paint. Repair runs by sanding or washing off the surface and refinishing. The surface should be thoroughly cleaned. Paint should not be applied over an old surface. The paint should be thinned as recommended, using properly specified solvents.

Sags: Sags consist of heavy thicknesses of paint that have slipped and formed curtains on the surface. This is caused by insufficient thinner, insufficient drying time between coats, low air pressure causing insufficient atomization, holding the paint gun too close to the surface, or by a paint gun out of adjustment. Repair sags by sanding and washing the surface, then refinishing it. The paint viscosity should be reduced as recommended by the manufacturer, using a proper thinning solvent. The air pressure and the gun should be adjusted for correct atomization, and the gun should be kept at the correct distance from the surface being painted.

Improper Repair: Holes and cracks that are not properly filled and repaired will allow moisture to get behind the coating and lead to blistering, flaking, and peeling.

Insufficient Coating Application: If too little paint is applied or the paint has been thinned too much, chalking and erosion will soon deteriorate the paint film. Care must be taken to see that there is sufficient paint over the top of the surface roughness to prevent corrosion from starting at the peaks of the surface variations.

Incompatible Paints and Thinners: It is important to use compatible paints and thinners and to remember that inorganics will not stick over organics.

Weathering Steel: Under certain conditions, weathering steel requires maintenance coatings. The corrosion of weathering steel presents certain unique surface preparation problems. The advantage of weathering steel is that the rust that forms on its surface is stabilized by the effect of alloying elements contained in the steel. Thus, the rust layer thereafter inhibits the corrosion of the metal. However, the rust layer does not properly form in environments containing saltwater spray or salt-laden fog. Weathering steel does not perform properly in the vicinity of structures surface joints in climates where de-icing salts are used. The uniqueness of weathering steel creates a significant problem when surface preparation is considered.

- Pits that develop in weathering steel are very deep relative to their diameter, making it difficult to clean the bottom of the pits properly.
- Removal of chlorides from the bottom of the pits is difficult.
- The "green mould" phenomenon is a discoloration that appears shortly after blast cleaning.
- Repeated blast cleaning is often required.

12.6.9 Environmental Aspects

Environmental regulation seems to increase every year. Some of the regulatory acts affecting structures maintenance include the, Environmental Quality Act of 1974, Scheduled Waste Treatment and Disposal 1989, Environmental Quality (Scheduled waste) regulations, 1989 and Environmental Quality (clean air) Regulations, 1978. The agencies need to provide maintenance engineers and maintenance managers with training and education on exactly which regulations apply to specific maintenance activities and what is the appropriate response to the applicable regulatory process.

12.6.9.1 Lead-Based Paint Removal

Removing lead-based paint from deteriorating structures has developed into a major environmental difficulty. The need to provide worker safety and respond to environmental regulation has dramatically increased the cost of repainting structures that were originally coated with lead-based paints. Containment and disposal of the lead-based paint material removed from the structures are two additional factors contributing to the increasing cost.

12.6.9.2 Solid Waste Disposal

Department of Environment (DOE) rules now require that materials classified as hazardous, such as lead-based paint debris, must be subjected to a test procedure to estimate the toxicity of the leachate (TCLP) and not the solid waste itself. The TCLP (i.e., the test procedure) was developed recognizing that landfills are common final resting places of disposed material. Consequently, the leaching characteristic of a hazardous substance can have an impact on the integrity of surface water and groundwater. If the levels exceed those set by the DOE, then the hazardous waste generator must treat the waste to reduce its leachate concentration before disposing of it in a landfill.

The residue produced as a by-product of the lead-based paint removal process must be collected as it is removed from the structure. If the TCLP test indicates that leachable lead levels exceed 5 ppm (parts per million), the waste is considered hazardous. The waste must then be treated to reduce the leachable lead levels to below 5 ppm before it can be disposed of in a landfill. Disposal of the waste, if it is classified as hazardous, must meet DOE requirements, which vary depending upon the amount of waste generated per month.

12.6.9.3 Containment of Residue from Lead-Based Paint Removal

Generally, the working area of the structures is shrouded with tarps during the process of removing lead-based paint to prohibit contaminants from coming in contact with the soil or water. Removing lead-based paint from structures also initiates application of the requirements of Department of Environmental (DOE).

12.6.9.4 Other Environmental Concerns

Lead-based paint removal is a serious and significant environmental concern in structures maintenance. However, a host of other environmental factors can impact structures maintenance. In addition to federal regulations, state environmental agencies and city or county health ordinances may impose environmental restrictions on work done or near structures. Before initiating structures repair activities, maintenance engineers and maintenance managers should confirm if environmental permits are required and review proposed repair methods to ensure that the method is appropriate and environmentally sound, when this is practicable. The following list provides some of the environmental factors that impact structures maintenance in some localities. This list is not comprehensive or current because the number of factors considered continues to grow, and the regulations relating to specific factors continue to change.

However, this list does provide some insight into the degree to which maintenance is being held to an increasing level of environmental sensitivity.

- State or federal list of threatened or endangered species.
- Species of high interest to state or federal agencies.
- Migratory waterfowl habitat.
- Anadromous fish habitat.
- Habitat for birds of prey.
- Wetlands and wetland habitat.
- Riparian habitat.
- Migratory corridors.
- Important wildlife reproductive habitat.
- Public water supplies, including important aquifers.
- Islands and other coastal barriers.
- Hazardous waste sites.
- Regulatory floodways and other flood plain areas.
- Commercial fish and shellfish production areas.
- Important sport fishing areas.
- Highly erodible soils.
- Listed or proposed wild and scenic rivers.
- Navigable waterways.
- Significant historic resources. Natural resource agency holdings or interests (refuges, parks, habitat areas, etc.).

12.6.9.5 Water Quality

The DOE requires that no discharge of a hazardous substance in excess of its Reportable Quantity, RQ into waters. There additional requirements if the water is a source for drinking water or it provides wildlife habitat. Sedimentation and erosion can occur as a result of structures maintenance activities such as removing vegetative cover or construction associated with earthwork. The quality of water in the stream, including its turbidity, can be degraded by maintenance activities, such as placing fill at settled structures approaches. A sediment and erosion control plan is needed if it is anticipated that soil will be disturbed during structures maintenance activities. There may be a requirement for regulatory authority review and certification of acceptance with respect to regulations intended to minimize any impact on water quality and aquatic environments. Construction activities required to accomplish the needed maintenance repair should be designed to minimize effluents from the repair procedure. Watertight cofferdams can help minimize water pollution. The cofferdams themselves should be designed to be environmentally sound and compatible with the stream environment. All materials should be nontoxic, especially if they are to be applied underwater.

When maintenance is required on movable spans with facilities for operators, structures improvements must often include new sanitary facilities that do not discharge pollutants directly into the water, if such facilities were not a part of the existing structures. Incinerator or digester toilets may be an alternative if connecting to an existing sanitary sewer facility is not practicable.

12.7 Worker Safety

Worker safety is traditionally thought of as a personal concern. However, worker safety results from a safe work site; thus, it is logical to categorize it as an environmental concern. Procedures to prevent equipment accidents, falls, and other traumatic injuries are a major part of worker safety, as are safety programs to educate workers about the materials and chemicals used in maintenance operations. As these operations increase in sophistication, the dangers to workers also increase.

Strong safety programs are good financial investments that reduce lost productivity from injuries, increase employee morale, and reduce insurance costs. Safety has to be a priority of maintenance engineers and maintenance managers if it is to be taken seriously by rank-and-file workers. Employees must know the rules, policies, and practices intended to promote a safe work environment if they are to be expected to follow them. Generally, most accidents are preventable if proper safety equipment and safety rules are followed.

12.7.1 Safety at the Work Site (OSHA)

Increase safety at the work site by holding safety meetings; using tools properly, including small hand and small power tools; and storing tools appropriately.

12.7.1.1 Safety Meeting

A five-minute safety discussion at the beginning of each day can pay dividends in terms of reduced accidents and increased efficiency. A daily orientation provides an opportunity for everyone to remind each other what has changed from the previous day, such as modified rigging procedures or different materials that require special caution in handling.

12.7.1.2 Tool Use

Proper use of tools and equipment will accomplish the work assignment in a professional, safe manner. Typical program guidelines include the following items:

- Do not use defective tools or equipment.
- Use the proper tools or equipment for each job.
- Safety procedures should be learned and practiced.
- When in doubt, ask for information.
- To prevent accidents, assume a personal feeling of responsibility.
- Caution to a new worker may prevent an injury.
- Negligence causes accidents.

Small Hand Tools: All tools should be in a safe operating condition. Defective tools should be replaced or repaired immediately.

- When a worker is using an axe, pick, scythe, or similar tool, the worker should always use the proper standing position. The worker should have firm footing and be clear of any obstruction or other workers. The worker should be careful to not strike any objects that could produce flying chips. Even a glancing blow from these types of tools can cause a painful and serious injury.
- Only the proper tools should be used for the job. Crowbars or pry bars should not be used as chisels or punches. A file should never be used as a chisel, a punch, or a pry bar, and a file should never be struck with a hammer since the hardened steel may shatter.
- Sharp-edged tools should always be kept sharp. The cutting edge of a sharp tool should always be carried away from the body. Unguarded sharp-edged tools should never be carried in the pocket. The force of a blow on a sharp-edged tool should always be directed away from the body, never toward the body. A draw knife should be held securely and away from the body. Double-bitted axes should not be permitted in the tool inventory. A single-bit axe should never be used as a striking tool or as a maul. Such action spreads the opening, or eye, of the axe head, causing the handle to loosen. When leaving an axe in a tree or stump, it must be firmly embedded so that it cannot fall out and cause injury. Do not fine dress an axe on emery wheel; instead use sandstone or oil stone. Chisels and punches should be inspected for tempering and cracking. The heads should be kept well dressed and free of burrs.
- Safety shoes and protective helmets (hard hats) should be worn around overhead work or where there is any danger from dropping of heavy or sharp objects. Face, hand, and arm protectors should be worn when work constitutes a hazard to these parts of the body.

Small Power Tools: Most power tools have significant hazards associated with their operation. Electrical shock is always a possibility if the tool is powered by electricity. Malfunctioning of tools powered by compressed air, gasoline, or explosives can cause serious injuries. Most tools are powered to achieve high velocities and penetrate or scrape away wood, metal, or other hard materials. Shielding, insulation, proper inspection, and careful use of these tools are the basic safety measures that should be applied. High-velocity, hand-operated power tools (chain saws, belt sanders, disk sanders, portable grinders, portable circular saws, explosive-powered fastening tools, portable planes, routers, etc.) should be controlled by a deadman switch that shuts the power off if the tool is not properly held. Protective shatterproof goggles or a face shield should be worn when working with these tools, even when protective shields are provided on the equipment itself. Electric power tools should be either double insulated or grounded by a third wire and three-pole connection plug. The plug should be disconnected when the equipment is not in use or when repairs or adjustments to the equipment are made. Tools should be inspected regularly by a mechanic or electrician to ensure that they are in safe operating condition. Operators should note any defects appearing during operation of the tool and correct them immediately. Old materials should be checked carefully for heavy knots or nails before sawing into them with a circular saw to avoid the saw kicking back or severely damaging the blade. Operators of explosive-powered fastening tools should receive special training, and a licensing procedure is recommended to ensure that only properly qualified persons use such equipment.

12.7.1.3 Tool Storage

Adequate tool storage is important. Assembly time is saved when tools have assigned spaces and are readily accessible. Good housekeeping is a natural outgrowth of orderly tool storage and pays dividends because the tools are kept in a better state of repair. When not in use, it is important to return tools to their proper storage places.

12.7.1.4 Shoring and Falsework

The term “falsework” denotes any construction intended for erection use only. In other words, falsework is construction that it is later removed or abandoned. It includes temporary towers, trestles, fixed and floating platforms, staging, runways, ladders, and scaffolding. On major structures, temporary trestles provide quick access to points of construction. Falsework provide temporary supports for erection or superstructure spans. Staging is used to provide working platforms. Ladders should be provided for all towers, and safety should be given full consideration in locating and designing falsework. Whenever practicable, falsework should be built of local materials or materials that can later be used in the permanent structure.

Properly designed and installed shoring is critical to work site safety during placement. Shoring must be able to support all of the installing, forming, and construction loads until the gains sufficient strength to assume the various loads. Formwork must be erected on a proper foundation. General guidelines in the planning and development of shoring and formwork are as follows:

- Instruct workers in proper shoring erection and dismantling, including the importance of strict adherence to the prepared formwork layout.
- Plan the placement sequence to guard against unbalanced loading conditions.
- Do not store reinforcing steel or equipment on erected shoring unless that shoring has been designed for those loads.
- Do not dismantle shoring until the concrete has cured.
- Hydraulic lifting equipment, hydraulic scaffolding, and other power equipment has replaced some of the functions of shoring and falsework. However, often the traditional methods of hand-built works are still more appropriate.

12.7.2 Work Site Safety Review

Every precaution possible should be taken to reduce any unnecessary risks. Some questions that help maintenance engineers and maintenance managers think through the safety issues of structures maintenance work sites are as follows:

- Does the general appearance of the work site demonstrate that tools are used and then replaced, or are tools scattered around the area?
- Are oxygen and acetylene cylinders stored properly in an upright position?
- Are safety glasses, masks, and hearing protection used by workers when appropriate?
- Are proper tools of the correct size available and being used?
- Are tools being used correctly for the purpose for which they were designed?

12.7.3 Toxic Materials

The storage of dangerous toxic and corrosive materials should be given special attention. Materials that are especially dangerous should be stored in separate secure areas and only issued to personnel qualified to use them properly. Manuals or charts that deal with dangerous chemicals and materials that maintenance employees work with should be readily available. Identification, qualities, and precautions should be included as a material safety data sheet. Training courses should emphasize the importance of using the manuals or charts for reference. Safety precautions when handling corrosives or irritants require the presence of an adequate supply of water to flush exposed parts of the body. Clothing that may become saturated should be easily removed, and the use of aprons, protective goggles, shields, gloves, and a respirator should be encouraged.

Acids: The strongest corrosive material that maintenance personnel usually handle in their work is sulphuric acid for use in batteries. Some materials can cause severe irritation through prolonged contact with the skin or can cause extreme pain and possible blindness when accidentally entering the eye.

Herbicides and Insecticides: Herbicides and insecticides (including wood preservatives) can be extremely toxic in concentrated forms. Some are so poisonous that a few drops on the skin can be lethal. Handling and mixing these substances should be regulated in accordance with their rated toxicity. Only qualified personnel wearing rubberized clothing and hoods that ensure complete protection should handle very toxic materials. Workers should be aware of the hazards associated with mishandling such materials.

Lead: Workers must not eat, chew gum, or use tobacco products when working with lead paints. They must not wear lead-contaminated clothing home. A worker can be poisoned in three to four weeks when exposed to high levels of airborne lead. All workers involved with lead paint removal, including containment maintenance, are automatically assumed by OSHA to be exposed to high levels of airborne lead. These workers need to become familiar with their rights and responsibilities under OSHA standards. Workers and supervisors of workers exposed to lead through painting or paint removal processes should take particular note of permissible exposure limits, exposure assessment, methods of compliance with standards and regulations, respirator protection, protective work clothing and equipment, housekeeping requirements, personal hygiene requirements, needed medical surveillance, the possibility of removing a person from the work site for medical protection, required employee training, required work site signing, record keeping for exposure monitoring, the right to observe monitoring, and rights to information.

Other Toxins: Epoxy can cause chemical burns on contact with skin, and a respirator must be worn when applying epoxy materials. Guano (bird droppings) can cause lung cancer, so a dust mask should be worn when performing structures maintenance in areas infested with bird droppings.

12.7.4 Confined Spaces

Special procedures are needed when maintenance work must be performed in a confined space. This situation often occurs during the inspection and maintenance of box beam structures and similar structures.

Training: Before proceeding to the site, personnel should be trained in the hazards of working in confined spaces as well as first-aid procedures, CPR, standard emergency procedures, use of instruments and monitoring equipment, and use and maintenance of protective equipment.

Identify Hazards: When planning for maintenance in a confined space, the following items are generally included to ensure a safe, efficient operation:

- Potential hazards such as oxygen deficiency should be considered.
- Fire safety should be examined when flammable materials are to be used in a confined space.
- Lighting will be required for all confined spaces; hence, an ignition hazard will be present. An oxygen-rich environment can be as dangerous as an oxygen-depleted environment. Use only grounded power equipment.
- Protective equipment and safety procedures for personnel should be outlined.
- Air sampling frequency should be established.
- The type of air testing to be performed should be identified. Usually oxygen, flammable gas, vapour, and toxic gas (carbon dioxide, carbon monoxide, sulphur dioxide, and hydrogen sulphide) tests are performed. Other tests for specific chemicals may be required.
- The type of respirator needed should be selected.
- Sampling equipment should be identified. Calibration will be required as specified by the manufacturer. Before its use, verify that the equipment is functioning properly.
- Test results should be recorded periodically, and alarm conditions should be reported.
- Evaluate the surrounding environment for storage tanks, sewers, chemical spills or bogs that can release poisonous gases or explosive gases; scum, slime, fungus, or decomposing organic matter that can deplete oxygen or release toxic or flammable chemicals; corrosion that can deplete oxygen; and bird droppings that can create a hazard requiring a combination of respirators and ventilation.
- A rescue plan should be developed. The availability of local emergency services must be verified prior to entry. Contact procedures must be included.
- OSHA requires entry permits for confined work spaces. A confined space is characterized as having limited means of entry and egress, having inadequate natural ventilation, or not being safe for continuous human occupation.
- A confined space entry permit is required if the space meets one or more of the following conditions: (1) contains or has the potential to contain a hazardous atmosphere, (2) contains material that has a potential for engulfing an entrant, (3) has an internal configuration that could trap or asphyxiate or a floor that slopes downward and tapers to a smaller cross section, or (4) contains any other recognized serious safety health hazard. If operations are to be performed in a confined space with a possible source of ignition (e.g., riveting, welding, cutting, burning, heating, or any other open flame) a hot-work permit is also required. This permit provides information on fire prevention, protection, and ventilation. The intent of the form is to ensure that all safety precautions are taken.
- Evaluate the work to be done by following these steps: (1) list all tools, equipment, and chemicals required; (2) identify a potentially flammable atmosphere if one can arise in this maintenance activity; (3) locate gasoline- or diesel-powered equipment outside the confined space to be used (not only are exhaust fumes a problem, but noise in a confined space can prevent workers from hearing critical directions or warnings); (4) identify ventilation work that generates dust, fumes, mist, vapour, odour, or smoke; and (5) provide exhaust ventilation for welding or other point sources.

- Identify personnel and ensure that they have received proper training and are medically fit for work in confined spaces. Medical limitations include emphysema (a worker may not be able to breathe adequately against the additional resistance of a respirator), asthma (a worker wearing a respirator would be tempted to remove it during breathing difficulties from an asthma attack), chronic bronchitis, heart disease, anaemia, haemophilia, poor eyesight, hernia (may be aggravated by wearing or carrying respirator protective equipment), evidence of reduced pulmonary function, severe or progressive hypertension, epilepsy (either grand mal or petit mal), diabetes (insipidus or mellitus), punctured eardrum, communication or sinus through upper jaw to oral cavity, claustrophobia or anxiety when wearing a respirator, breathing difficulty when wearing a respirator, lack of use of fingers, scars or hollow temples or prominent cheekbones or deep skin creases or lack of teeth or dentures.

Requirements of Each Entry: Before each entry, personnel shall review the potential hazards, the proper use and maintenance of respirators, blowers, and emergency equipment, the specific entry procedures for that structure, and the emergency procedures. During each entry, the procedure shall include the following steps:

- a) Atmospheric testing equipment will be tested using test gases to ensure the equipment is functioning properly.
- b) The atmosphere shall be tested at the entrance to evaluate for possible hazards.
- c) Be sure to check all spaces where gases can accumulate. Some gases such as propane and butane are heavier than air and will sink to the bottom of a confined space. Light gases such as methane will rise to the top of a confined space.
- d) After testing for explosive gases, test for toxic gases.
- e) At least one worker should remain outside of the confined space to monitor the test equipment and guard against entrapment. The worker outside should have the entry permit in hand and should have radio communication with the workers inside. The worker outside could also have a lifeline attached to all personnel inside the confined space. The worker outside is responsible for contacting any emergency services required.

Workers shall continuously monitor their test instruments for hazardous atmosphere. If an alarm sounds, workers shall perform the following steps:

- a) Evacuate the space immediately.
- b) Record the event and readings that produced the alarm, including work in progress as well as tools and materials used.
- c) Check the instrument for malfunctions.
- d) Determine what caused the alarm.
- e) Correct the problem. Do not enter the space without a mechanical ventilator.
- f) Re-enter the space only when the atmosphere is tested to be within acceptable limits. If the space must be entered and is not within acceptable limits, respirators must be used and escape provisions must be provided. Never re-enter a confined space to rescue a worker before contacting emergency services and determining the cause of the emergency. Over 60% of all confined space fatalities occur to rescuers, not the original entrant.
- g) Evacuate the area if odours are present or if workers experience dizziness or shortness of breath.
- h) The entry team will carry a radio so that radio communications can be maintained between the team and the worker outside the confined space.
- i) Requirements for ventilation, respiratory protection, and standby personnel will be specified.
- j) Work with chemicals, such as paints, solvents, and epoxies, requires ventilation and standby personnel.

12.7.5 Fall Protection, Rigging, Scaffolding, and Hoisting

Occasionally, maintenance work must be performed on parts of the structures that are high above the ground or water. This activity can be safe when it is performed properly. However, carelessness, inattention, or horseplay can lead to serious injury or fatalities. It is important that workers are properly trained in how to erect safe work platforms and how to protect against serious injury from falls. Maintenance planning and preparation for any high structures maintenance activity should include a review of the OSHA safety section and any appropriate department regulations on rigging, scaffolding, ladders, and wire ropes.

Fall Protection: Falls from heights are a routine hazard facing structures maintenance workers. Precautions must always be taken when working from an elevated work surface.

Guardrails: OSHA construction industry standards require guardrails, mid-rails, and toe boards on all work platforms more than 1.8 meters (6 feet) above ground level. Guardrails and toe boards are to be installed on all sides and ends of platforms. Railing should have a vertical height of 1,067 mm (42 inches) from the upper surface of the top rail to the platform. An intermediate rail should be spaced midway between the top rail and the platform floor. The toe board should be at least 4 inches (about 100 mm) in vertical height from its top edge to the platform level. The bottom of the toe board should be no more than 6 mm (1/4 inch) away from the floor. When material is piled on top of the platform and obscures the toe board, screening or panelling should be provided from the platform to the intermediate rail. Vertical posts should be placed at 2.4 meters (8 feet) or less.

Safety Belts, Lines, and Lanyards: In situations where guardrails are not practical or feasible, a secondary means of fall protection must be provided. An alternate system consists of either a harness or safety belt connected by a lanyard to a safety line.

12.8 Operate Mechanical and Electrical Installation

All mechanical and electrical and installation shall operate by competent personnel as the following categories:

Electrical Services

Competent Person who shall visit and inspect an installation shall either be an Electrical Services Engineer, or a Competent Electrical Engineer or an Electrical Supervisor as stated in regulation 67 (1) of the Electricity Regulations 1994 & Rules.

Electrical Chageman means a person who complies the conditions as stated in regulation 49 of the Electricity Regulations 1994 & Rules.

Certificates of Fitness

Certificates of fitness refers to Form A in the Sixth Schedule of the Factory and Machinery (Notification, Certificate of Fitness and Inspection) Regulations, 1970 -- Regulation 10 (2).

Procedures

Maintain Daily Log Sheets

The technical personnel shall on regular basis record the operating parameters of selected mechanical and electrical installation for performance trend analysis. This includes the relevant operating parameters, power or fuel consumption of the mechanical and electrical installation and its output.

Logging shall be limited to the existing available monitoring instrumentation. Installation of additional instrumentation for thorough performance monitoring shall be treated as Reimbursable Works.

Define Required Hours of Operation

Basically, the operating hours shall either be office hours or twenty-four hours. For office-hours areas, the operating hours shall also include the regularly practised overtime hours.

Arrange Authorities Inspections and Certificates of Fitness.

The Factory and Machinery (Notification, Certificate of Fitness and Inspection) Regulations, 1970, Part 2 Clause 10 (1) demands the owner of every steam boiler, unfired pressure vessel or hoisting machine to hold a valid certificate of fitness as long as the machinery remains in service.

The certificate shall remain valid for a period of fifteen months from the date of inspection. To make the necessary arrangement for inspection by the authorities and ensure valid certificates of fitness at all times. This shall only apply for machinery that has been initially registered with the Factory and Machinery Department during installation stage.

Report Breakdowns, Faults and Defects

Personnel who carry out daily logging shall also observe for any abnormality of mechanical and electrical installation performance. He shall take the appropriate remedial action to prevent continuous fault occurrence.

Should the faults lead to equipment breakdown or defects, he shall report promptly for the necessary follow-up action by the maintenance team.

Report Accidents

All staff involved in mechanical and electrical installation operation shall be trained on occupational safety and health requirement as preventive measure against accident.

Safety Representatives shall be appointed at every site. Should any accident occur, the appropriate arrangement for rescue and medical treatment shall be adopted.

Set Policy in Energy Management and Participate in Implementation of Conservation Plan

To set the appropriate policy to ensure effective energy management scheme. The policy shall take into consideration the physical condition and design standard available at each existing site. The policy shall also govern any future upgrading plans and provision for new facilities.

Document Operation, Analysis and Report.

Trend logging of mechanical and electrical installation performance as described, shall be documented. Analyse the mechanical and electrical installation performance parameters by comparing against the appropriate operating limits. Any deviation shall be highlighted and briefly clarified. The report shall also summarise all the deviations, faults and breakdowns. It shall also state the appropriate remedial action that has been carried out.

12.9 Fire Safety

Take all practical measures to prevent fire, maintain all installed automatic and manual fire detection and suppression equipment and to train all staff to take appropriate action in event of fire for all operation, switching and plant rooms.

Fire detection facilities include

- Manual "break glass" fire alarms;
- Automatic thermal fire alarms;
- Automatic smoke detectors; and
- Automatic monitored fire sprinkler systems.

Automatic Fire suppression facilities

Fire suppression facilities include:

- Automatic water type, thermally and smoke activated fire sprinklers; and
- Automatic halogen and carbon dioxide gas flooding systems.

Manual Fire suppression equipment

Fire suppression equipment includes:

- Portable hand held fire extinguishers;
- Fire blankets;
- Dry/wet risers;
- Hose reel;

Procedures

Taking all practical measures to prevent fire.

- To forms a fire safety committee;
- To establishes a fire safety plan;
- During the normal course of work, detecting a significant fire or evacuation hazard. From time to time as the need arises engages BOMBA to perform fire safety audits;
- Assesses fire hazard reports and authorises corrective action as required; and
- Carries out corrective action as directed by BOMBA.

Maintaining all installed automatic and manual fire detection and suppression equipment.

- Identifies all the fire detection and suppression facilities and equipment and records on asset register;
- Maintains and tests all fire detection and suppression facilities and equipment to applicable Manufacturers Guidelines, Fire and Rescue Department (Bomba) and Statutory Standards;
- Records such maintenance and tests in required hard copy record books and on computer based maintenance management and information system; and
- Provides periodic reports on the maintenance of fire detection and suppression facilities and equipment.

Training all staff to take appropriate action in event of fire or evacuation.

- Organises evacuation exercises;
- Plans and schedules fire training sessions;
- Staff attend fire training;
- Conducts fire training in fire prevention and the safe and correct operation of manual fire detection and suppression facilities and equipment;
- Records attendance and notifies DID staff who attended; and
- To provide materials for training.

12.10 OPERATION AND EMERGENCY RESPONSE OF FLOOD

A key component of the flood mitigation scheme is a system normally comprised of bunds, ponds, spillways and floodways designed to protect a particular area from flood of specified sizes such as 20 years, 50 years, 100 years of ARI. It is not practical to use ponds or bund banks to confine all floods. Beyond the specified flood size the system would not be able to confine floods and the spillway which designed to bypass the excess flood water will come into operation. Floods will pass around the natural floodways and submerged the low lying area. In a rapid rise flood this can take as little as 12 hours.

To ensure flood emergency responses can be effectively controlled and coordinated in the event of flooding, the DID has involved in the preparation of a flood emergency plan for the Flood Disaster Committee. To prepare the Plan, it was necessary to have the knowledge of the flood risk and the flood mitigation scheme and this involved direct contribution of DID of the nature of the scheme and how it operates.

The DID also responsible for providing flood forecasting and warning service and has established an Internet-based National Flood Monitoring System known as Infobanjir (<http://infobanjir.water.gov.my>), via which rainfall and water level data can be collected for the whole country. The infrastructures for flood forecasting and warning systems have been installed and maintained by DID including telemetric rainfall stations, telemetric water level stations, manual stick gauges, flood warning boards; flood sirens, real-time flood forecasting and warning systems in nine river basins.

DID also operate, monitor, maintain and provide information on the flood mitigation control structures including:

- Description of each component such as flood gates, ponds and river bunds with all detailing, location, construction type, and the communities protected.
- The heights relative to the relevant flood warning gauge such as;
 - Bund design height
 - Overtopping heights of bund low points
 - Bund Spillway heights
 - Imminent failure height
- Likely locations of bund overtopping and the sequence of overtopping and flooding (these outputs should be presented in a spatial format, accompanied by a description).
- Size of the population; the number of residential and commercial properties; and critical infrastructure affected by bund over-topping or failure. This output should be expressed in relation to a variety of flood magnitudes, including a worst case scenario.
- Scope for additional development in areas protected by bunds, considering the size of available zoned land.
- The height relative to the relevant flood warning gauge that any backwater flooding commences impacting upon urban areas behind each bund and the pattern of inundation.
- Once over-topped the length of time taken to fill the basin area behind each bund and the pattern (evolution) and behaviour of inundation.

- Details of ground profile (topography) inside each bund and the height of potential high points of land relative to the relevant flood warning gauge.
- Location of any parts of each bund which need to be closed other than drains (e.g. gates for roadways and railways) and the height relative to the relevant flood
- warning gauge that action must be completed by.
- Knowledge of any critical issues including structural integrity affecting each bund. Further information regarding DID flood emergency planning is described in

12.10.1 Operation and Response in Flood Situation

The DID operated and coordinated flood mitigation scheme within a district as well as many other areas which were affected by the weather event. The following provides a summary of the operation sequences in which events occurred and what actions were taken by the DID in supporting other emergency services.

12.10.1.1 Prior to Flood Seasons

The DID district office should be ready with information regarding the predicted runoff volumes, type of flood and predicted return period. The entire flood mitigation system should be inspected for need of corrective maintenance. This inspection should be scheduled early enough prior to the flood season to allow adequate time for any required work to be completed prior to high water conditions.

12.10.1.2 Beginning of the Flood Season

For instance, for the east coast area the local water level gauges should be monitored on daily basis in early October where readings recorded at 7 am and 7 pm every day and reported to the district office. District DID may need to revised the operational readiness to control flood operations.

Refer to Volume 4 (hydrology) for detail collection and dissemination process of hydrologic data and information.

12.10.1.3 During flood event

The evacuation of affected area was the largest component of the flood response. The decision to evacuate was made by Disasters and Relief Committee based upon the likely consequences of the predicted flood levels and the subsequent risk to life flooding would have posed. The decision by the committee will be reached in consultation with all committee members especially DID district engineer, Local Council and other emergency services, after considering a range of variables and uncertainties.

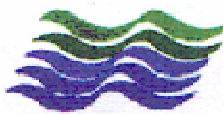
District DID continue monitoring the situation and responsible to ensure there is adequate personnel, equipment and materials readily available to respond to emergency conditions. The crews should be prepared to undertake emergency repairs as outlined in the contingency plan.

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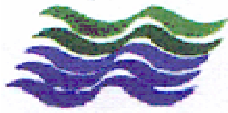
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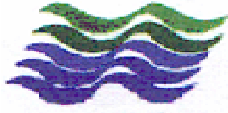
APPENDIX 12.A PROPOSED O&M CHECKLIST

	JABATAN PENGAIRAN DAN SALIRAN BUND MAINTENANCE		
	Asset Type		
	Work Request No.		
	Workgroup		
	Frequency		
	Task No		
Page			

(√) /NA	Work Description	Remark
	Vegetation growth and the presence of trees	
	Damage to the bund slopes	
	Obvious low spots along the bund crest	
	Animal burrows	
	Unauthorized excavation or construction in, on or adjacent to the bund.	
	Signs of erosion of the riverbank or damage to the existing bank protection	
	Loss of rock from the existing protective layer	
	Slumping of the slope	
	Erosion or scour of the riverbank immediately upstream or downstream of the bank protection.	
	Weathering or abrasion of rock particles	
	Loss of, or significant changes to, the overbank area which could endanger the bund	
	The condition of the floodbox flap gates as to the ability to open and close freely and provide a watertight seal when shut	
	Access obstructions to the river bund and along the crest	
	The condition of all fences, gates and locks and the availability of keys	
Open corrective work order if remedial work required		

	JABATAN PENGAIRAN DAN SALIRAN RIVER CHANNEL MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

(√) /NA	Work Description	Remarks
	Inspect significant debris that is deposited throughout the natural waterways	
	-Woody materials	
	-Man-made debris	
	Inspect nonnative vegetative species to allow for conveyance	
	Inspect damage to the stream and its environment to include:	
	-riverbanks	
	-fishery resources	
	-recreational facilities	
	-undamaged vegetation	
	-trees understory	
	- All non-woody, un-natural materials	
	-Man-made debris is to be removed and disposed	
	-Debris that may contain oil, fuel, propane or other hazardous materials (must be handled appropriately following all local, state and federal regulations)	
Open corrective work order if remedial work required.		

	JABATAN PENGAIRAN DAN SALIRAN DETENTION POND MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

(√) /NA	Work Description	Remarks
	Inspect side slopes, berms and spillways for erosion	
	Inspect native vegetation on eroded slopes	
	Inspect 4.5-7.5 meter "no-mow and chemical-free" zone around the pond edge	
	Mow (or burn) the "no-mow" buffer zone.	
	Inspect basin and "no-mow" zone for invasive species.	
	Inspect plant diversity by planting additional vegetation in around the pond	
	Inspect basin for signs of chemicals (solvents, gas, diesel, paint, natural gas). Identify and remove/dispose of properly	
	Inspection obstructions or erosion in vicinity of the pond that could affect performance	
	Inspection pond sides/slopes/bottom show signs of settling, cracking, sloughing or other problems	
	Inspection embankments, emergency spillway (if applicable), or side slopes show any erosion or instability	
	Inspection of animal burrowing or other activity that could contribute to instability or increased erosion?	
	Inspection of encroachment into the pond or improper use of the pond	
	Inspection of vegetated areas and need mowing	
	Inspection areas that need to be re-vegetated	
	Inspection vegetated areas that need thinning, i.e. cattails, willows, trees	
	Inspection accumulation of trash, debris and/or litter that to be removed	
	Inspection of signs of vandalism or other activity that could affect performance of the pond	
	Inspection of permanent pool, any visible pollution	
	Inspection of erosion at high water mark	
	Inspection of abnormally high water level	

Inspection of unusual algae blooms

(May indicate obstruction at orifice, or trash rack;
verify outlet structure operating properly)

(May signal too many nutrients in runoff; identify dog
activity and clippings management; will need
monitoring)

Structural Components:

Inspect the pipes/inlets going into or out of the pond
clogged or obstructed

Inspect the outfall channel from the pond functioning
appropriately

Inspect the inflow trickle channel working properly?

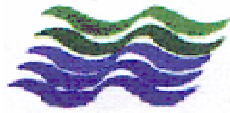
Inspect the orifice and/or trash rack obstructed?

Inspect the outfall channel, trickle channel or other
conveyance in need of repair

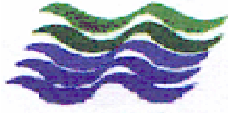
Inspect the manholes, frames, and covers associated
with the outfall channel in appropriate condition?

Inspect any safety features, such as fences, gates or
locks need repair or replacement

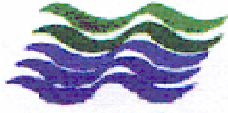
Open corrective work order if remedial work required.

	JABATAN PENGAIRAN DAN SALIRAN LINED CHANNEL MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

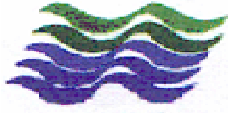
(√) /NA	Work Description	Remarks
	Inspect a vigorous growth of desirable vegetation. This includes reseeding, fertilization and controlled application of herbicides when necessary. Periodic mowing may also be needed to control height.	
	Inspect spalls, cracks and weathered areas in surfaces.	
	Inspect rusted or damaged metal and paint.	
	Inspect weathered or displaced rock riprap to its original grade.	
	Inspect all debris that hinders system operation.	
	Inspect livestock usage to periods and locations that permit grazing without damage.	
	Inspect fences, they shall be maintained to prevent unauthorized human or livestock entry.	
	Inspect all burrowing animals. Immediately repair any damage caused by their activity.	
	Inspect any damage to structures, vegetated areas adjacent to structures or any appurtenances.	
Open corrective work order if remedial work required.		

	JABATAN PENGAIRAN DAN SALIRAN GRASSED WATERWAY		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

(√) /NA	Work Description	Remarks
	Inspect excessive travel on any portion of the diversion or waterway that will damage or destroy the vegetative cover	
	Inspect vigorous growth of desirable vegetation. (Reseeding, fertilization and controlled application of herbicides when necessary. Periodic mowing may also be needed to control height. Mow at least one time per year to control woody vegetation)	
	Inspect fences to control livestock access when adjacent fields are used for pasture. (Limit livestock access to periodic grazing without damage.)	
	Inspect sediment deposits in the channel to maintain design capacity.	
	Inspect all foreign debris that may reduce capacity or hinder system operation.	
	Inspect any obstructions or blockages of spillways, trash racks or pipe inlets.	
	Inspect weathered or displaced rock riprap used for stone center to its original grade.	
	Inspect the earth fill sections for cracks or settlement and repair damage.	
	Inspect all burrowing animals. Immediately repair any damage caused by their activity.	
	Inspect any damage caused by vandalism, vehicular traffic, or livestock access to any earth fills, spillways, outlets or other appurtenances.	
	Inspect woody vegetation from the berm and/or channel to maintain design capacity.	

	JABATAN PENGAIRAN DAN SALIRAN GATE MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

(√) /NA	Work Description	Remarks
	Inspect and lubricate just before the flood season. If gates aren't seated properly, water will flow back through the drainage structure during high water.	
	Inspect all gate seats and the frames readjusted if the gate is not seating properly	
	Inspect all gates that should be operated and any debris or obstructions	
	Inspect cracked or damaged gates need to be replaced	
	Inspect the inlet and outlet channels need to be kept free of debris, trees, brush and other vegetation, and sediment.	
	Inspect metal grates, hand wheels, and other metalwork should be secure and sound, free from rust, and regularly maintained by cleaning, painting, and greasing.	
	Inspect any pipe or culvert has separated from the inlet/ outlet structure headwall, this needs to be repaired as soon as possible	
	Inspect all flap and slide gates and any debris or obstructions that should be removed immediately before high flow.	
Open corrective work order if remedial work required.		

	JABATAN PENGAIRAN DAN SALIRAN PUMP MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

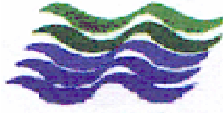
(√) /NA	Work Description	Remarks
	Check pumps condition. Free from leakage, corrosion and damage.	
	1.Check pump gland for leakage. Tighten pump packing, replace if necessary.	
	2.Inspect vibration isolator and holding down bolts of pump and engine for tightness	
	3.Check coupling for alignment and condition of bush.	
	4.Check grease point and greasing as necessary	
	5.Check pipelines and fittings condition. Rectify if necessary.	
	6.Check functionality of all valves and gauges.	
	7.Clean Y - strainers.	
	Diesel Engine	
	1.Check fuel tank and fuel line for damage and leaks.	
	2.Check engine bolts and nuts for tightness.	
	3.Check battery water level and terminal connection.	
	4.Check lubricant oil level in crankcase.	
	5.Check and replace oil filter as necessary	
	6.Check and clean, air filter and level of coolant. Replace as necessary.	
	7.Check fan belting tension (where applicable). Tighten if necessary.	

Starter Panel


Check indicator lights, selector switch and replace any faulty components

Test-run

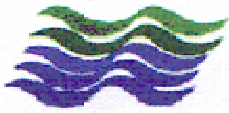
Test run the system for proper function. Observe any abnormal noise.

	JABATAN PENGAIRAN DAN SALIRAN SWITCHBOARD MAINTENANCE		
Asset Type			
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

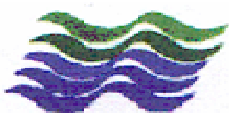
√ /NA	Work Description	Remarks
	Vacuum the interior of LV Sub Main Switchboard.	
	Ensure locks and hinges operate properly. Lubricate if necessary.	
	Check the Ammeter, Voltmeter, Moulded Case Circuit Breakers (MCCBs), Miniature Circuit Breakers (MCBs), Current Transformers (CTs), Voltage Transformers (VTs), switches, indicator lamps, instruments, E/F relays, O/C relays, contactors, timers and push buttons etc. installed on the panel	
	Check tightness of all terminals, connectors, contact blades and bus bar joints. Use torque wrench where necessary.	
	Inspect the busbar and connections for signs of overheating or deterioration of insulation.	
	Inspect for any exposed cables, cable joints, and bus bars.	
	Inspect cable entries, cable conduits, cable pits, ducts and access covers are free from water or any risks.	
	Carry out the manual operation of all out going circuit breakers.	
	Test trip all the out going circuit breakers and relays.	
	Inspect fuse carrier bases and links for fuse switches. Clean if necessary.	
	Ensure that correct fuse wire, cartridges or links are fitted.	
	Inspect the earthing arrangement.	
	Carry out the manual operation of the incoming circuit breaker.	
	Test trips the incoming circuit breaker and re close circuit.	
	Clean and visually inspect all painted surfaces. Touch-up with paint where necessary.	

	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE			
	Asset Type	Main Power Supply		
	Work Request No.			
	Workgroup			
	Frequency			
	Task No			
Page				

Test/Maintenance	Action	Expected Result	Result	
Red Phases Supply Voltage Testing	From power meter on the panel, select the switch to Red-Blue phases. Double confirm by measures with multimeter	Both power meter and multimeter will shown $\pm 415V$ reading	_____ V	
Yellow Phases Supply Voltage Testing	From power meter on the panel, select the switch to Yellow-Blue phases. Double confirm by measures with multimeter	Both power meter and multimeter will shown $\pm 415V$ reading	_____ V	
Blue Phases Supply Voltage Testing	From power meter on the panel, select the switch to Red-Yellow phases. Double confirm by measures with multimeter	Both power meter and multimeter will shown $\pm 415V$ reading	_____ V	
Verification Acceptance Criteria	Comments	Result		
Main Supply from TNB is around 415 V for each phase of supply.		<input type="checkbox"/> C <input type="checkbox"/> NC		
Asset Category	Secondary Power Back-Up	Workgroup	M&E SCADA	
Work Request No.		Frequency	Monthly	

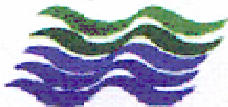
	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE			
	Asset Type	Secondary Power Back-Up		
	Work Request No.			
	Workgroup			
	Frequency			
	Task No			
Page				

Test/Maintenance	Action	Expected Result	Result	
UPS Backup verification	Switch off the main supply of the system	System (Automation system only, power backup for actuator is not included) will continue running with the supply from UPS.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Power resume after power down.	Switch on the main supply	The system (automation system) will automatically switch to TNB supply.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Verification Acceptance Criteria	Comments	Result		
UPS can backup the system (automation system) during power failure.		<input type="checkbox"/> C <input type="checkbox"/> NC		

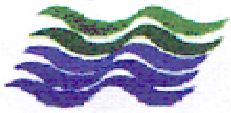
	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE			
	Asset Type	Gate		
	Work Request No.			
	Workgroup			
	Frequency			
	Task No			
Page				

Test/Maintenance	Action	Expected Result	Result
Upstream water level measurement.	Measure upstream water level by using string with weight and measurement tape. (measure 3 times and take the average)	Actual water level of upstream can be recorded.	Upstream water Level = _____ m
Downstream water level measurement.	Measure downstream water level by using string with weight and measurement tape. (measure 3 times and take the average)	Actual water level of downstream can be recorded.	Downstream water Level = _____ m
Verify upstream sensor reading is same as real water level	Compare the upstream sensor reading with measured water level	Both actual water level measurement and sensor reading should be same	<input type="checkbox"/> C <input type="checkbox"/> NC
Verify downstream sensor reading is same as real water level	Compare the downstream sensor reading with measured water level	Both actual water level measurement and sensor reading should be same	<input type="checkbox"/> C <input type="checkbox"/> NC
Verify upstream sensor in 90° horizontal with the sensor bracket	Use the Level measuring to measure the placement of upstream sensor	Upstream sensor is in 90° horizontal with the sensor bracket	<input type="checkbox"/> C <input type="checkbox"/> NC
Verify downstream sensor in 90° horizontal with the sensor bracket	Use the Level measuring to measure the placement of downstream sensor	Downstream sensor is in 90° horizontal with the sensor bracket	<input type="checkbox"/> C <input type="checkbox"/> NC

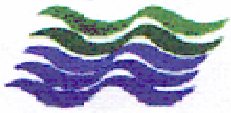
Verification Acceptance Criteria	Comments	Result	
Both upstream and downstream ultrasonic sensor show the same reading with actual water level.		<input type="checkbox"/> C <input type="checkbox"/> NC	
Both upstream and downstream ultrasonic sensor placement are in 90° horizontal with the sensor bracket		<input type="checkbox"/> C <input type="checkbox"/> NC	

	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE		
Asset Type	Water Level and Level Sensor		
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

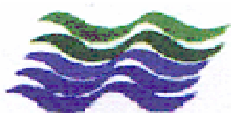
Test/Maintenance	Action	Expected Result	Result	
Different level user login verification.	Login to different user level (operator, engineer and administrator) by using different user name and password.	User can login to different user level with right user name and password combination.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Button function verification.	Test each button on operator login page by press on the button.	User can go to particular page when button of that particular page is pressed.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Gate info page verification.	Compare each reading on gate info page with actual site condition (gate status, mode, water level & etc)	Each info displays the correct site actual condition.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Verification Acceptance Criteria	Comments	Result		
Touch screen functions correctly and display the right information.		<input type="checkbox"/> C <input type="checkbox"/> NC		

	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE			
	Asset Type	Emergency Alert		
	Work Request No.			
	Workgroup			
	Frequency			
	Task No			
	Page			

Test/Maintenance	Action	Expected Result	Result	
Local emergency alert system verification	Generate an emergency event by press on emergency button on control panel.	Siren will sound and revolving light will on.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Emergency SMS alert verification	Generate an emergency event by press on emergency button on control panel.	A SMS will be sent to person in charge for alert purpose.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Verification Acceptance Criteria	Comments	Result		

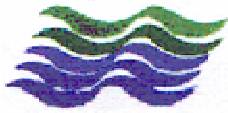
	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE			
	Asset Type	Emergency Alert		
	Work Request No.			
	Workgroup			
	Frequency			
	Task No			
Page				

Test/Maintenance	Action	Expected Result	Result	
Gate info request Testing	Type in K1 using any hand phone and sent to gate info request centre 019xxxxxxx	A list of current gate info will be sent to user through SMS	<input type="checkbox"/> C <input type="checkbox"/> NC	
System Communication Signal Testing	Remote Dial in to the system through any notebook	Remote access from notebook is successful and user can get the real time info from the system	<input type="checkbox"/> C <input type="checkbox"/> NC	
Verification Acceptance Criteria	Comments	Result		
Gate SMS info request system and communication work well		<input type="checkbox"/> C <input type="checkbox"/> NC		

	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE		
Asset Type	Info Request/ Communication		
Work Request No.			
Workgroup			
Frequency			
Task No			
Page			

Test/Maintenance	Action	Expected Result	Result	
Gate view page verification	On the SCADA system and click on Gate View button. Dial up the system to get latest gate info	The system will display latest gate information including gate status, mode and gap of opening	<input type="checkbox"/> C <input type="checkbox"/> NC	
Active alarm page verification	Dial up the system and click on Active alarm	The system will show latest active alarm with time and date	<input type="checkbox"/> C <input type="checkbox"/> NC	
Trending page verification	Click on trending page on SCADA system. Search particular day's trend by click on calendar. Scroll, zoom and analyze the trend. Click on text view button to view the trending in text form. Select on Flow trend to view the flow through out particular gate for that particular day.	System will display selected trend on screen. Trend can be zoomed, and scrolled to view the value of the trend. Text form of trending can also be viewed through text view and flow trend for particular gate will be displayed when selected.	<input type="checkbox"/> C <input type="checkbox"/> NC	
Historical alarm page verification.	Generate an alarm by press on E-Stop. Open historical alarm page by click on alarm button. Click on calendar search machine to find out particular day's alarm	Alarm for particular day will be displayed with related data. Generated E-Stop alarm can also be traced from historical alarm logging.	<input type="checkbox"/> C <input type="checkbox"/> NC	

Test/Maintenance	Action	Expected Result	Result
Historical event page verification	Open historical event page by click on event button. Click on calendar search machine to find out particular day's event	Event for particular day will be displayed with related data.	
Remote setting verification	Dial up the system. Click on remote control and setting button. Upload new setting by click download.	New setting of the system can be remotely changed from the SCADA system.	<input type="checkbox"/> C <input type="checkbox"/> NC
Remote control verification	Dial up the system. Click on remote setting and control page. Click on Open button to open the gate. Click on Stop button to stop the gate and click on Close button to remote close the gate. Click on clear button to set back the system to auto mode.	Remote open, stop and close the gate can be done from SCADA system.	<input type="checkbox"/> C <input type="checkbox"/> NC
Report page verification.	Click on report button on SCADA system to go to report page. Click on search engine to generate report for particular day, week or month.	Report for particular day, week or month will be displayed together with related data. (Refer to attached report below)	<input type="checkbox"/> C <input type="checkbox"/> NC
Verification Acceptance Criteria	Comments	Result	
Each function of SCADA system performs well without any problem.		<input type="checkbox"/> C <input type="checkbox"/> NC	

	JABATAN PENGAIRAN DAN SALIRAN AUTOMATION GATE MAINTENANCE		
	Asset Type	SCADA System Validation	
	Work Request No.		
	Workgroup		
	Frequency		
Task No			
Page			

Test/Maintenance	Action	Expected Result	Result	
Remote dial in from any notebook or PC	Remote access from notebook or by using modem with correct username and password	User can remote log into the Sg Lukut Site Web SCADA system	<input type="checkbox"/> C <input type="checkbox"/> NC	
Gate view page verification	On the Remote access Web SCADA click on Gate View button. Dial up the system to get latest gate info	The system will display latest gate information including gate status, mode and gap of opening	<input type="checkbox"/> C <input type="checkbox"/> NC	
Active alarm page verification	click on Active alarm	The system will show latest active alarm with time and date	<input type="checkbox"/> C <input type="checkbox"/> NC	
Trending page verification	Click on trending page on the Remote access Web SCADA. Search particular day's trend by click on calendar. Scroll, zoom and analyze the trend. Click on text view button to view the trending in text form. Select on Flow trend to view the flow through out particular gate for that particular day. (Only trend for 30 days will be displayed)	System will display selected trend on screen. Trend can be zoomed, and scrolled to view the value of the trend. Text form of trending can also be viewed through text view and flow trend for particular gate will be displayed when selected.	<input type="checkbox"/> C <input type="checkbox"/> NC	

Test/Maintenance	Action	Expected Result	Result
Historical alarm page verification.	Generate an alarm by press on E-Stop. Open historical alarm page by click on alarm button. Click on calendar search machine to find out particular day's alarm	Alarm for particular day will be displayed with related data. Generated E-Stop alarm can also be traced from historical alarm logging.	<input type="checkbox"/> C <input type="checkbox"/> NC
Historical event page verification	Open historical event page by click on event button. Click on calendar search machine to find out particular day's event	Event for particular day will be displayed with related data.	<input type="checkbox"/> C <input type="checkbox"/> NC
Remote setting verification	Click on remote control and setting button. Upload new setting by click download.	New setting of the system can be remotely changed from the Remote access Web SCADA system.	<input type="checkbox"/> C <input type="checkbox"/> NC
Remote control verification	Click on remote setting and control page. Click on Open button to open the gate. Click on Stop button to stop the gate and click on Close button to remote close the gate. Click on clear button to set back the system to auto mode.	Remote open, stop and close the gate can be done from the Remote access Web SCADA	<input type="checkbox"/> C <input type="checkbox"/> NC
Report page verification.	Click on report button on SCADA system to go to report page. Click on search engine to generate report for particular day, week or month.	Report for particular day, week or month will be displayed together with related data. (Refer to attached report below)	<input type="checkbox"/> C <input type="checkbox"/> NC
Verification Acceptance Criteria	Comments	Result	
Remote access from any Notebook or PC with correct username and password is successful		<input type="checkbox"/> C <input type="checkbox"/> NC	
Each function of On the Remote access Web SCADA performs well without any problem.		<input type="checkbox"/> C <input type="checkbox"/> NC	

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CHAPTER 13 FUTURE CONCERNS

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13 FUTURE CONCERNS

13.1 INTRODUCTION

The environment today has degraded dramatically as a result of uncontrolled pollution from urbanisation. Extreme temperature change worldwide makes it either too cold or too hot. Flood and drought devastate without warning in the least expected ways, affecting human life and property, animals and plants, and putting greater pressure on watersheds and floodplains. Cost of insurance and redevelopment escalates exorbitantly into billions. Thus there is need to model or forecast accurately such environmental changes. To say the least, collect relevant data is needed enough to make the models work. Some work extra hard to make this world a safe place to live so people can leave it intact to children and generations to come. It is easy to legislate this or that for a clean environment, but where does this take if there is disregard on waterways for the sake of people habits. To save all living things from more environmental mishaps, alternative way must be find to understand and solve the problems. This would not happen if there is no collaboration on this common goal.

13.2 CLIMATE CHANGE

It is true that human hands actually influence global climate. The foremost concern is increased emission of greenhouse gases, in particular carbon dioxide that induces irreversible changes to the climate. In the very words of the Working Group to the Second Assessment Report of the Intergovernmental Panel on Climate Change (Flood Estimation Handbook, 1999), "the balance of evidence suggests a discernible human influence on global climate". Warming affects water quality, while precipitation patterns affect groundwater aquifers, surface waters, and water quality, causing disease outbreaks, to mention a few. All these can affect human health and lifestyles (Figure 13.1).

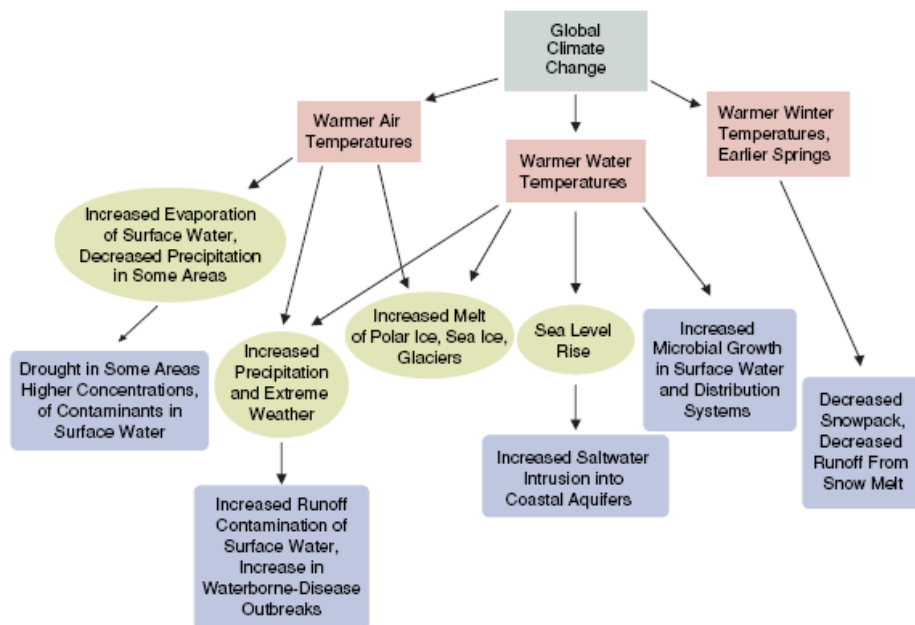


Figure 13.1 Pathways by Which Climate Change Can Alter Health (Paul R. Epstein, 2005)

Modelling global climate change is difficult and subjective, producing controversial results. While modelling has projected that green house emissions affect surface temperatures, worldwide observations give supportive evidence that global climate has warmed since the late 19th century (Figure 13.2).

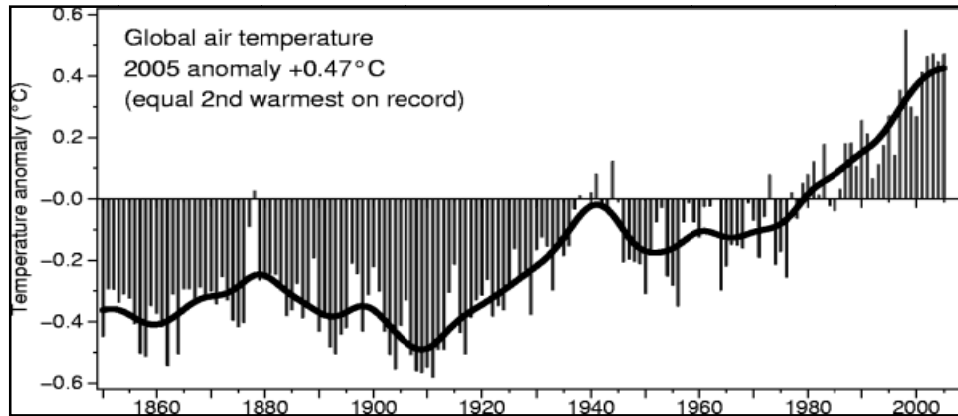


Figure 13.2 Global Air Temperature Anomalies (Flood Estimation Handbook, 1999)

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) presented in December 2007 can be considered a milestone in the commitment of Governments around the world to address the Global Climate Change issues. This report is now generally recognized as the definitive conclusion and confirmation that Global Climate Change is already happening and that some serious action plans must be undertaken to mitigate the impact that this could cause. The report also confirms that this is mostly due to the release of green-house gases (carbon dioxide, nitrous oxide, and methane) as a result of fossil fuel used in modernized activities such as deforestation and agriculture. Efforts to reduce these gases are just beginning and to know their effectiveness will take a long time. In the meantime, the greenhouse effect will continue to change the climate of the world, impacting rainfall patterns and rise in sea levels due to polar ice melting.

13.2.1 Climate Change Implication

The National Hydraulic Research Institute of Malaysia (NAHRIM) has conducted a study on climate change from 2002 to 2006 in collaboration with the California Hydrologic Research Laboratory (CHRL). Climate change was projected for the periods 2025 to 2034 and 2041 to 2050 in an effort to establish a hydro-climate database of rainfall, river flow, air temperature, evapo-transpiration and groundwater storage within the 9 km grid in the Peninsular Malaysia. The database will provide information for future flood mitigation and is accessible at the website www.nahrim.gov.my. In short, the hydro-climate database comprises five modules: precipitation, evapotranspiration, soil water storage, surface temperature and stream flow. In all, there are two sets of data: Simulated Past Data (1984 to 1993) and Simulated Future Data (2025 to 2034 and 2041 to 2050) accessible by single-point or multiple-points methods. The projections obtained from the study that will have direct implications on flood mitigation design and O&M are as follows:

- a) Monthly rainfall increase (maximum 51%) for the east coast states with 32-61% reduction for the rest of the states.
- b) Increase in flood flows (11-43%) for the east coast states.
- c) Reduction (31-93%) in dry weather flow for Selangor and Johor.
- d) Uniform increase (by 1.5 degree Celsius) in monthly temperatures for Peninsular Malaysia.
- e) Seasonal shift by two weeks depending on location.

Globally, the sea level rise is estimated at 1.8 mm/yr (1961-2003) and for Malaysia, this is at 1.3 mm/yr (1986-2006) as recorded at Tanjung Piai. Overall, the apparent rise in the rate of sea level rise at 3.1 mm/yr (1993 to 2003) globally is cause for concern for IPCC.

The above are initial projections; more detailed studies need to be undertaken in the future. However, the data can be used to estimate the impact on flood mitigation and future concerns. In general, it appears that the results of projection for the east coast states have been under estimated whilst those for the rest of the country are over-estimated. Adjustments to the present hydrological procedures will definitely need to be reviewed. This is too early for detailed results but more data are forthcoming with possible adjustments, depending on the economy. Options to the solution of our flood problems are structural and non-structural methods. The former includes construction of new sea defence works or structural adjustments to the existing structures. The latter includes moving people out of the affected areas and attempting on new design methods for the settlements.

A case study by NAHRIM (2006) was to assess flooding for the entire Muda River Basin (4,200 square km) using the data available from the NAHRIM hydro-climate database. Evaluation was made for changes in the flood levels due to projected rainfalls. Frequency analysis was conducted using the Gumbel Extreme Value Type I Method. The Annual Maximum Rainfall (AMR) was projected for the period 2025 to 2050 with rainfall of 24-hour duration and a series of return periods. The projected AMR was compared with the existing design AMR. It was found that projected AMR increases by about 38% on the average, while the design AMR for a 100-year return period falls between the 10-year and 20-year return periods. Flows in the river system were predicted to increase by up to 55% at some locations, as a result of increased rainfall in the river basin. River water levels 0.3 m to 3 m were observed at various key locations. In conclusion, the increase in flood levels predicted is due to the increase in rainfall and this will impact significantly on the design and performance of the existing flood mitigation infrastructures in the entire river basin. Mandatory reviews of the structures need to be carried out for better preparedness to face yet larger catastrophic floods.

13.2.2 Greenhouse Gases (GHG)

Scientists have spent decades figuring out the source of global warming. Natural cycles and events known to influence climate are studied; but this alone cannot explain the magnitude and pattern of warming observed. The only logical way is to study the effect of greenhouse gases (GHG) emitted by humans. Climate change induced by global warming is a result of an excess energy at the earth's surface due to the greenhouse effect.

The greenhouse gases are those gases in the atmosphere which, by absorbing thermal radiation emitted by the earth's surface, have a blanketing effect upon it. The most important of the greenhouse gases is water vapor, but its amount in the atmosphere is not changing directly because of human activities. The concentrations of several greenhouse gases have increased over time. These gasses emanate from sources such as:

- Burning of fossil fuels and deforestation leading to higher carbon dioxide concentrations.
- Livestock and paddy rice farming, land use and wetland changes, and landfill emissions leading to higher methane atmospheric concentrations. (Many of the newer fully vented septic systems that enhance the fermentation process are also major sources of atmospheric methane)
- Use of chlorofluorocarbons (CFCs) in refrigeration systems and halons in fire suppression systems and manufacturing processes.
- Agricultural activities including use of fertilizers leading to higher nitrous oxide concentrations.

Some of the greenhouse gasses also come from the combustion of fossil fuels in cars, factories and electricity production. Different gases have very different heat-trapping abilities. Some of them can even trap more heat than CO₂. A molecule of methane produces more than 20 times the warming of a molecule of CO₂. Other gases, such as CFCs (which have been banned in much of the world because they also degrade the ozone layer), have heat-trapping potential thousands of times greater than CO₂. But because their concentrations are much lower than CO₂, none of these gases adds as much warmth to the atmosphere as does CO₂. Figure 13.3 shows the annual gas emissions by sector that occurred globally.

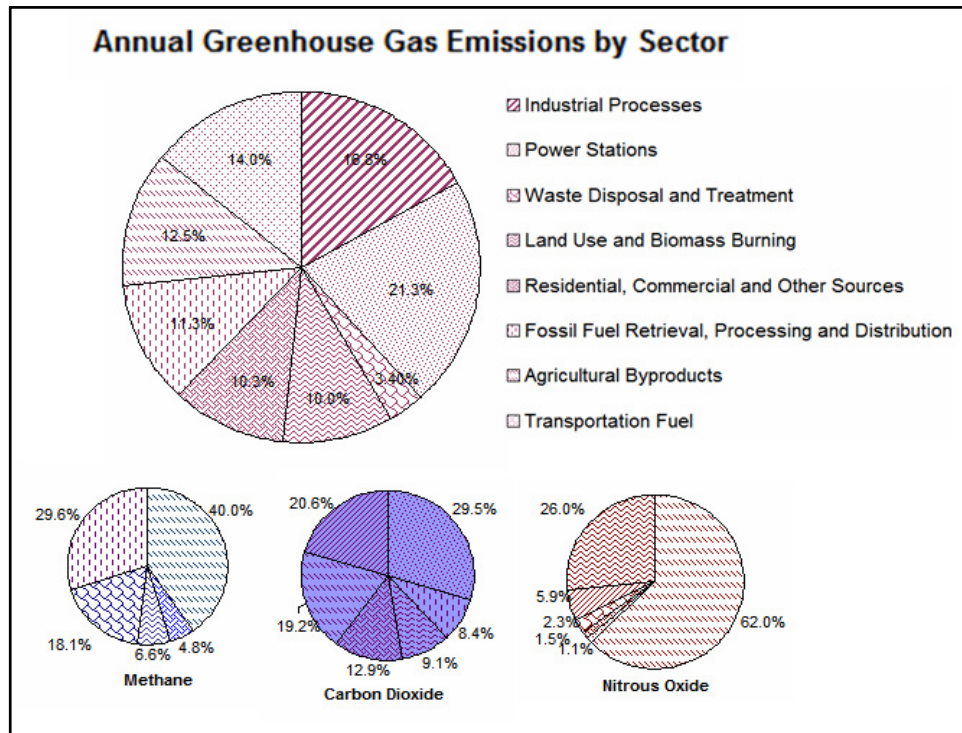


Figure 13.3 Global Anthropogenic Greenhouse Gas Emissions Broken Down Into

Figure 13.3 shows seven sources of CO₂ from fossil fuel combustion. Below are their percentage contributions for the period 2000-2004:

- Solid fuels such as coal : 35%
- Liquid fuels such as petrol : 36%
- Gaseous fuels such as natural gas : 20%
- Flaring gas industrially and at wells : <1%
- Cement production : 3%
- Non-fuel hydrocarbons : <1%
- The "international bunkers" of shipping and air transport not included in national inventories : 4%

Greenhouse gas emissions from industry, transportation and agriculture are very likely the main cause of recently observed global warming. Others include home heating and cooling, electricity consumption and automobiles. Conservation methods include improving home building insulation, use of cellular shades, compact fluorescent lamps, and high miles per gallon vehicles.

13.2.3 Climate Change Impact Assessment

Knowledge of climate change impacts on rainfall and fluvial flood frequency will undoubtedly advance during the life time of this Manual. As a guide to interpreting new findings, some of the language and methods of climate change impact assessment are briefly introduced below.

13.2.3.1 Scenarios

Certain assumptions or hypotheses are needed when using a global climate model to project climate change. Some of the assumptions relate to how a particular process is represented within the Global Climate Model (GCM), while others relate to projections of anthropogenic change. For example, a run of GCM will make particular assumptions about greenhouse gas and aerosol (i.e. microscopic airborne particle) emission rates over the period of the projection, typically, the next 50 to 100 years. This means that the climate impact modeler is presented with several sets of projections. Each is a separate realisation of how the climate will evolve. These are generally referred to as climate change scenario. Sometimes several projections are made using a particular GCM but a key assumption is varied to explore the sensitivity of projections to the particular assumption.

It is impractical to consider all possible scenarios, in which all combinations of assumptions are explored. Thus, the climate impact modeler will generally use a relatively small number of semi-standard scenarios. To an extent, climate change research is divided into two main activities: (i) modelling the global climate and making projections, and (ii) assessing the impact of the projected climate change. Nevertheless, much effort is being given to integration to ensure that feedback effects are better represented.

13.2.3.2 Models on Climate Change

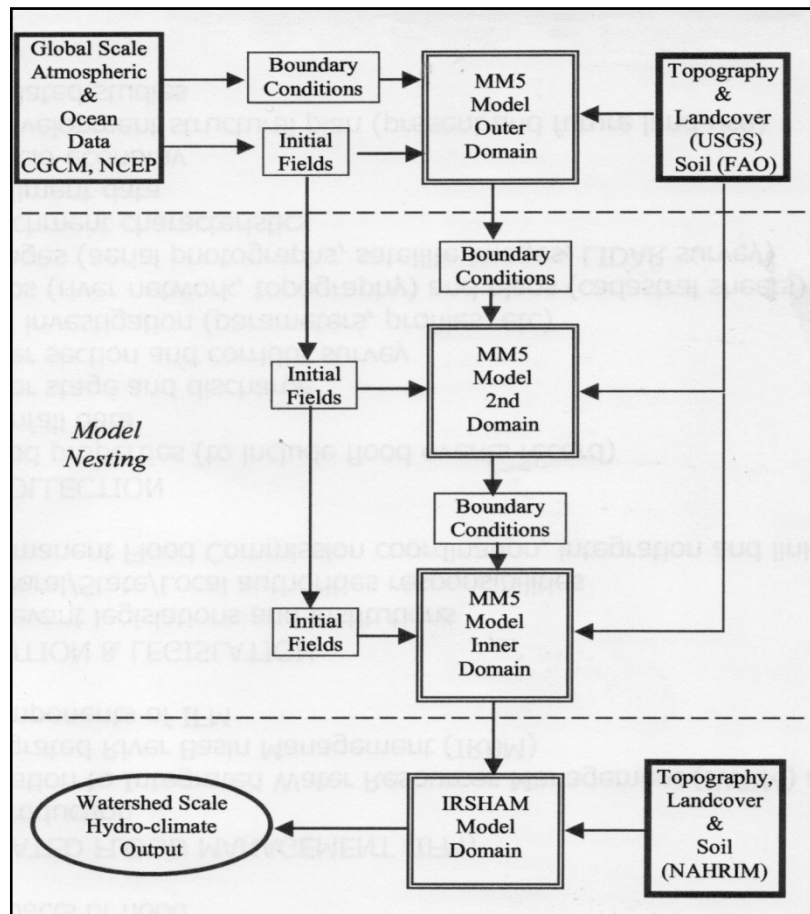
The main approach to assessing climate change impacts is through modelling. GCM is mainly carried out in specialized climate research centres. Many of the developments seek to improve the representation of feedback within the global climate system. Feedback occurs when the effect of a particular change is accentuated or moderated by some consequential effect. For example, a change in global surface temperature affects the prevalence of ice and snow-covered surfaces. These surfaces reflect solar radiation more strongly, being said to have a high albedo. If global warming leads to reduced snow cover, which in turn leads to lower outgoing radiation, the warming is likely to be further enhanced; this is an example of positive feedback. Feedback can also arise from changes in terrestrial ecosystems, notably, vegetation and agricultural practice consequent to climate change.

Ocean currents play an important role in transporting heat around the globe. The most highly developed climate models are atmospheric and oceanic GCM. Sometimes, models of the oceanic and atmospheric circulation are developed separately, and then combined. The upshot is a coupled GCM.

Each climate change scenario leads to a different generated flow series. These are subsequently analyzed as if they were gauged records. Given that river flows are simulated continuously, it is possible to adopt a peaks-over-threshold (POT) approach to flood frequency analysis. The impact of climate change on flood frequency is then inferred by comparing the flood frequency curve resulting from the particular scenario with that for a baseline condition. Often, a period drawn from the observational record will be used as the baseline, e.g. standard period 1961-1990. In other cases, the baseline will itself be a scenario, for example as based on the absence of change in greenhouse gas emissions.

A particular challenge in global climate modeling is to infer changes at the local or district level from climate changes projected at the regional or national level. This is sometimes referred to as the downscaling problem. Wilby et al. (1998) consider several approaches. One possibility is to use atmospheric circulation indices (e.g. Lamb, 1972) as an intermediary variable, as considered by Goodess and Palutikof (1998). A goal might be to establish a link between the frequency distribution of extreme rainfalls (locally) and the frequency of particular airflow circulation patterns (regionally).

The National Hydraulics Research Institute, Malaysia (NAHRIM) under the Ministry of Natural Resources and Environment, Malaysia, has conducted a study on climate change over Peninsular Malaysia. The study evaluated the impact of climate change on the hydrologic regime and water resources using a regional hydro-climate model for Peninsular Malaysia, RegHCM PM (NAHRIM, 2006). The data progression used in the model is shown in Figure 13.4. Data of land use, land cover, elevation contour map and soil survey were provided by NAHRIM. The study has interesting findings, which are discussed further in the following sub-sections of Section 13.4. The study concludes that the water resources must be carefully planned to accommodate the projected changes into the future water balances over Peninsular Malaysia.



- NCEP : United States National Center for Environmental Prediction
 USGS : United States Geological Survey
 FAO : Food and Agriculture Organization of the United Nations
 CGCM : Canadian General Circulation Model
 NAHRIM : National Hydraulics Research Institute of Malaysia

Figure 13.4 Data Flow Chart of RegHCM of Peninsular Malaysia

13.2.3.3 Climate Change Impact

Several hydrological changes are likely to occur as a result of global warming. Some of these will help reduce flooding but others will contribute to worsen the flood problems. The negative effects of global warming on flooding are as follows:

- Highly variable rainfall;
- Increasing incidences of floods and erosion;
- Changes in patterns of surface run-off, groundwater recharge and flow;
- Increased sea levels causing coastal flooding; and
- Contraction of wetlands.

Variable rainfall due to climate change can lessen the accuracy of previous rainfall records because of changing rainfall patterns. More floods induce more erosion because shear force exerted by water on channel bed increases. Changes in patterns of surface run-off, groundwater recharge and flow will affect ground moisture, which in turn affects ground's ability to absorb excess water during floods. Increased sea level constitutes flood threat in low-lying coastal areas. Based on a 20 years tidal record at two pilot sites reported in National Coastal Vulnerability Index, NCVI Study, the rate of the local or relative sea level rise at both sites may be considered to be smaller than the average global low rate of 2-3 mm/year (i.e. Sea Level Rise (SLR) at Tanjung Piai = 0.2 - 1.3 mm/year; SLR at Langkawi = 0.5 - 1.0 mm/year). The increase in flood levels at both sites for the local SLR scenario is not significantly high. Wetlands are important as storage area for water so that contraction of wetlands due to global warming decreases the existing storage for floodwaters.

Besides flooding, climate change will have major impacts on both quantity and quality of freshwaters that will affect natural ecosystems, agriculture and different species around the world. Extreme weather conditions of floods and droughts have become more frequent in many countries in the recent decade and Malaysia is no exception to the phenomena.

13.2.4 Detecting Climate Change

It is sometimes argued that a climate impact cannot be very serious unless this is reflected in the data records. This view is complacent. There are two reasons why detecting underlying trends in flood peaks is difficult. One is the large natural variability of climate, and the other is interference from other effects (notably, changes in land use and measurement practice).

13.2.4.1 Climate Variability

The first obstruction to detecting trend is the large variability of climate on all time-scales. Several types of variation can be distinguished. Yevjevich (1991) notes four categories of temporal behaviour: tendency, intermittency, periodicity and stochasticity. This is broadly the classification used here, that distinguishes the following:

- Progressive change or trend
- Abrupt change or step change
- Quasi-periodic (or cyclical) variation; and
- Quasi-random variation.

It is suggested that the list places the above variations in their order of importance in terms of detecting change impacts (i.e. land-use change impacts) and disrupting flood frequency estimates. When the FEH (Flood Estimation Handbook, 1999) refers to non-stationary, it is primarily referring to trend and step-change effects. The prefix "quasi" pays deference to chaos theory. Computational experiments demonstrate that behaviour that appears regular and random can have a complex deterministic origin.

There is evidence of periodic behavior in some climate variables. However, there is controversy in their origin and practical significance. It is said that behaviour reflects solar disturbances, with effects transported to the earth's atmosphere by the solar wind and that solar particle streams are accompanied by strong magnetic fields emanating from the sun (Lamb, 1972). There is suspicion that some detected cyclic behaviour may be spurious, arising as an artifact of the relatively short records available. Burroughs (1992) suggests that only an 18 to 20-year cycle, possibly corresponding to the 18.6-year solar cycle in gravitational forces, is sufficiently prevalent in climate data to suggest an important effect.

13.2.4.2 Contaminating Effects

The second obstruction to detecting climate change induced effects is that the flood series presented for analysis may be contaminated by other changes such as land use, water use, or measurement practice. Land-use change such as urbanization or forestry is likely to lead to progressive change in flood behaviour. Changes attributable to reservoir construction, drainage diversion, or use of a different flood rating are likely to be abrupt.

13.2.4.3 Methods and Results

The FEH (Flood Estimation Handbook, 1999) recommends that estimates of the 2-year flood, QMED, derived from short records, should be adjusted for climatic variation by reference to long-term records from nearby catchments, ideally from nearby catchments that are hydrologically similar.

These findings can be considered provisional. These are also conditioned as much by the data analyzed as by the methods used. Understanding would be strengthened by the analysis of updated flood peak data sets, by more specific (e.g. regional) studies, and by an auxiliary analysis of trend and variation in rainfall depths.

a) Air Temperature

The mean temperature during the future period for selected watersheds will be higher than during the historical period (Table 13.1). Figure 13.5 shows the whole of Peninsular Malaysia will be warmer by around 2°C in the next 50 years.

Table 13.1 Summary of Monthly Air Temperature During the Historical and Future Periods at Selected Watersheds in Peninsular Malaysia

Region Name	Maximum Monthly Air Temperature ($^{\circ}\text{C}$)		Mean Monthly Air Temperature ($^{\circ}\text{C}$)		Minimum Monthly Air Temperature ($^{\circ}\text{C}$)	
	Historical	Future	Historical	Future	Historical	Future
West Coast	28.9	30.7	27.3	28.6	24.9	26.2
Klang	27.7	29.7	26.5	27.9	24.8	25.5
Selangor	27.7	29.5	26.4	27.8	24.7	25.4
Terengganu	28.2	29.9	25.5	26.8	21.9	23.1
Kelantan	28.0	29.6	25.3	26.5	21.0	22.4
Pahang	28.3	29.9	26.1	27.4	22.8	24.1
Perak	26.1	28.0	24.1	25.4	20.8	22.3
Kedah	28.2	30.3	26.0	27.3	22.3	23.8
Johor	29.4	31.1	27.7	29.1	24.9	26.4
Southern Peninsular	29.3	30.9	27.4	28.8	25.0	26.1
North-East Coast	29.2	31.0	26.4	27.6	22.5	23.7

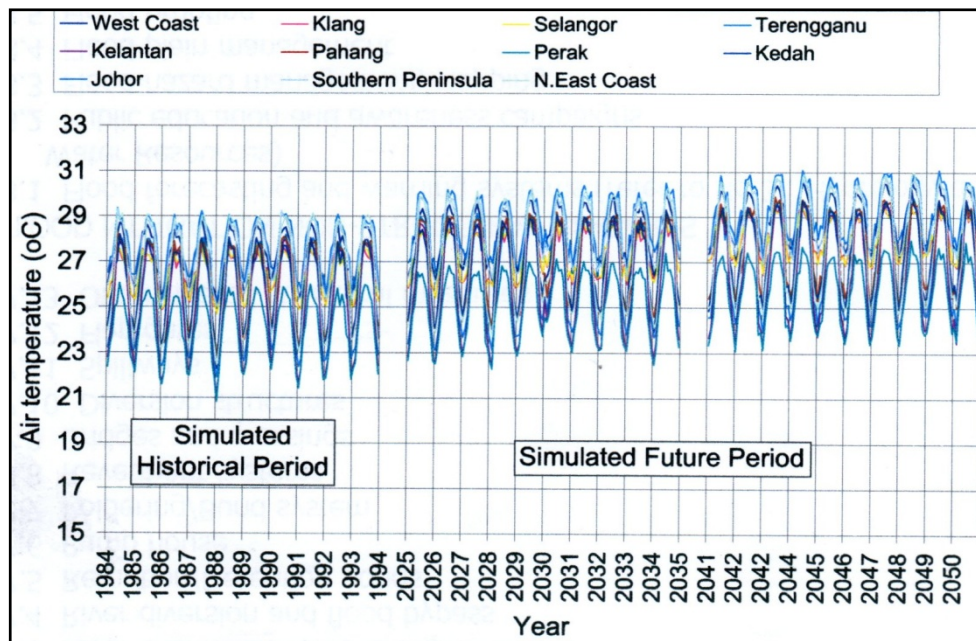


Figure 13.5 Simulated Monthly Mean Air Temperatures at Every Sub-region of Peninsular Malaysia During the Simulated Historical (1984-1993) and Future (2025-2034 & 2041-2050) Periods

b) Precipitation

Table 13.2 shows the summary of simulated monthly precipitation during the historical and future periods at selected watersheds in Peninsular Malaysia. It may be noted that there will be a substantial increase in the mean monthly precipitation over the North-East coastal region and Kelantan. Generally, it can be inferred from Table 13.2 that since higher maximum and lower minimum precipitations are observed in the future for many sub-regions, more extreme hydrological conditions may be expected.

Table 13.2 Summary of Simulated Monthly Precipitation During the Historical and Future Periods at Selected Watersheds in Peninsular Malaysia

Region Name	Maximum Monthly Precipitation (mm)		Mean Monthly Precipitation (mm)		Minimum Monthly Precipitation (mm)	
	Historical	Future	Historical	Future	Historical	Future
West Coast	600.0	560.3	179.2	176.2	12.4	7.9
Klang	436.2	601.3	190.1	182.3	12.8	5.9
Selangor	564.1	525.7	190.2	180.9	12.2	8.3
Terengganu	1271.2	1913.9	289.0	299.0	33.6	14.0
Kelantan	929.7	1128.5	221.8	239.5	15.4	10.9
Pahang	633.6	684.6	198.5	208.4	24.5	16.6
Perak	722.9	767.8	192.9	199.4	9.0	4.1
Kedah	626.7	705.3	173.6	176.6	2.1	1.1
Johor	591.7	538.2	187.3	180.0	13.3	5.2
Southern Peninsular	544.4	608.5	193.7	196.4	18.9	14.4
North-East Coast	1440.9	1573.2	259.5	281.5	19.5	9.9

c) Evapotranspiration

Figure 13.6 shows the simulated annual evapotranspiration at every sub-region in Peninsular Malaysia. As the relationship of evapotranspiration process to various atmospheric conditions such as radiation, air temperature and water availability, is quite complex, no clear trend between historical and future periods can be discerned from Figure 13.6. It is important to note that a fundamental issue of importance in the assessment of the impact of climate change on the water resources of Peninsular Malaysia is the water balance within the framework of water demand and water supply. The most important water demand over a geographical region in Malaysia can be said to be due to irrigation. The actual evapotranspiration estimation is important in determining the irrigation water demand.

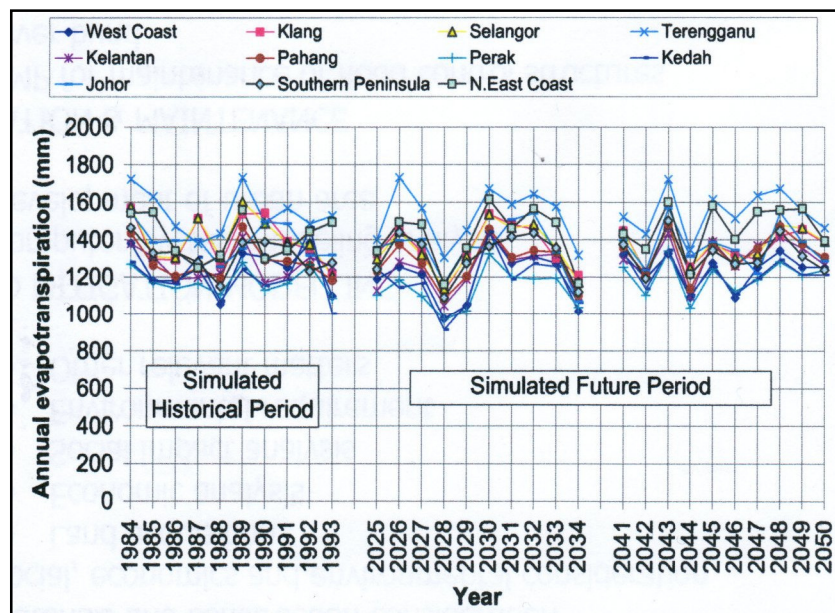


Figure 13.6 Simulated Annual Evapotranspiration at Every Sub-region of Peninsular Malaysia During the Simulated Historical (1984-1993) and Future (2025-2034 & 2041-2050) Periods

d) Soil Water Storage

The monthly soil water storage has seasonal oscillation for all of the sub-regions of Peninsular Malaysia due to the annual periodicity of evapotranspiration as well as precipitation. However, the effect of climate change is not pronounced on soil water storage.

e) River Flow

Table 13.3 summarizes the assessment of simulated historical and future flow conditions over Peninsular Malaysia in terms of maximum, mean and minimum monthly flows at eight selected river stations. From Table 13.3, the mean monthly flows are shown to stay the same in most watersheds except in Kelantan and Pahang where it increases. It may also be inferred that the hydrologic extremes will be magnified significantly in the Kelantan, Terengganu and Pahang watersheds. In the future, minimum monthly flows will be lower and the maximum monthly flows will be significantly higher than their historical counterparts in these watersheds. An increase in the inter-annual and intra-seasonal variability with increased hydrologic extremes (higher high flows, lower low flows) is expected in Kelantan, Pahang, Terengganu and Kedah watersheds in the future.

Table 13.3 Summary of Simulated Flows During the Historical and Future Periods at the Selected Watersheds of Peninsular Malaysia

Region Name	Maximum Monthly Flow (cumecs)		Mean Monthly Flow (cumecs)		Minimum Monthly Flow (cumecs)	
	Historical	Future	Historical	Future	Historical	Future
Klang (Sg. Klang @ Jam. Sulaiman)	31.2	45.8	14.4	13.3	2.6	3.5
Selangor (Sg. Selangor @ Rantau Panjang)	107.9	108.5	40.7	37.5	7.1	0.5
Terengganu (Sg. Terengganu @ Jam. Jerangau, Dungun)	398.4	569.5	93.4	98.3	13.1	10.8
Kelantan (Sg. Kelantan @ Jam. Guillemard)	1535.1	1950.7	535.9	601.7	158.4	125.8
Pahang (Sg. Pahang @ Temerloh)	1697.4	2176.6	669.6	718.1	156.3	122.7
Perak (Sg. Perak @ Jam. Iskandar)	523.7	578.2	286.4	299.7	183.6	139.2
Kedah (Sg. Muda & Jam. Syed Omar)	307.4	340.0	105.6	104.0	25.3	5.3
Johor (Sg. Johor @ Rantau Panjang)	82.7	94.0	32.7	31.8	9.8	6.8

13.3 RESOURCE DEGRADATION

How fast losing of estuaries and wetlands and critical water-based natural resources clearly is indicative of how much effort we need to put in to mitigate floods and manage floodplains. Since 1942, the prevailing notion has been the development, not the preservation, of water resources as there seems to be an abundance of estuaries and riparian areas (Plasencia and Baker, 2007). Conservation and protection of the environmental resources has primarily been about aesthetics, recovery of iconic resources (e.g. orang utans), or control of public health problems. Permit systems are used as the main method of protection against environmental pollution and degradation; in reality however, these are more like a sanctioned degradation of the natural resources.

The perception that there is still large expanse of environmental resources may be true then, but over the years, these natural resources have been gradually used up, altered or degraded. Fisheries of international renown are gone, clean water supply has emerged as a serious problem in many parts of the world and many countries like the United States are increasingly losing their coastlines (Plasencia and Baker, 2007). It should be recognized that flood can both positively and negatively affect the human occupancy of land. A class of adjustment for benefits of the ecosystems and natural resources has to be introduced to ensure their viability in the long run.

13.4 POPULATION

Malaysia's population has grown by about half million per year from 2005 to 2007 (Department of Statistics Malaysia, 2007). If this trend continues, the area of habitable land per person will decrease and eventually, the residential communities will encroach upon food-risk areas, thus increasing the need for more land, and as a result, environmental pollution will escalate, putting greater pressure on our watersheds and floodplains.

Climate change with regard to infectious diseases such as malaria, West Nile virus, Lyme disease and asthma related to extreme weather such as flood and drought. As example the three facets of this case study examine the impacts of flooding on malaria in Mozambique, the indirect impacts of drought on malaria distribution in northeast Brazil and the projected impacts of warming precipitation patterns affecting the potential range of malaria in the highlands of Zimbabwe. These studies serve as examples of how warming and weather extremes can work alone and in combination to influence the prevalence and dynamics of a tropical vector-borne disease and, by extrapolation, how changes may occur in temperate regions at the margins of malaria's current distribution.

13.5 TSUNAMI

Tsunamis, or seismic sea waves, are a series of enormous waves created by an underwater disturbance such as an earthquake, landslide, volcanic eruption or meteorite. A tsunami can move hundreds of miles per hour in the open ocean and smash into land with waves as high as 30 m or more.

From the origin of the tsunami, waves travel outward in all directions. Once approaching the shore, the wave builds up in height. The topography of the coastline and the ocean floor will influence the size of the wave. There may be more than one wave and the succeeding one may be larger than the one before. That is why a small tsunami at one beach can be a giant wave a few miles away.

Earthquake-induced movement of the ocean floor most often generates tsunamis. If a major earthquake or landslide occurs close to shore, the first wave in a series could reach the beach in a few minutes, even before a warning is issued. Areas are at greater risk if they are less than 8 m above sea level and within 1.6 km of the shoreline. Drowning is the most common cause of death associated with a tsunami. Tsunami waves and the receding waters are very destructive to structures in the run-up zone.

13.6 EARTHQUAKES

Earthquake is one of the most devastating natural disasters on earth. The effect of impacts will rise significantly in line with increase in the population of the affected area or existence of structures and infrastructure facilities (Azlan et al, 2007). Flood mitigation structures like dams and revetment systems are particularly sensitive and prone to earthquake damages. Even though preventing an earthquake is impossible, it is possible to mitigate the earthquake effects to reduce the loss of life, injuries and damage to properties.

Figure 13.7 and Figure 13.8 show the Peak Ground Acceleration (PGA) contour map for different probabilities of exceedence (PE) in Peninsular Malaysia while Figure 13.9 and Figure 13.10 show the PGA contour map for different PE in East Malaysia. These maps can be used in flood mitigation planning.

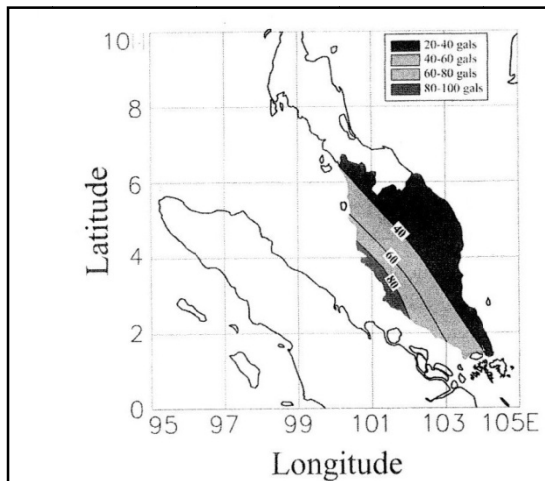


Figure 13.7 PGA Map for 10% PE in 50 Years (P. Malaysia)

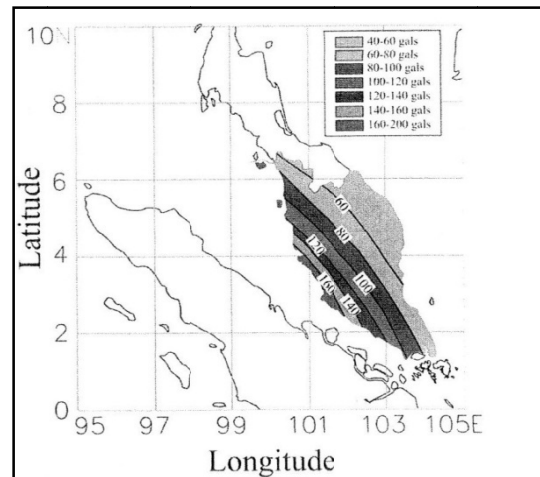


Figure 13.8 PGA Map for 2% PE in 50 Years (P. Malaysia)

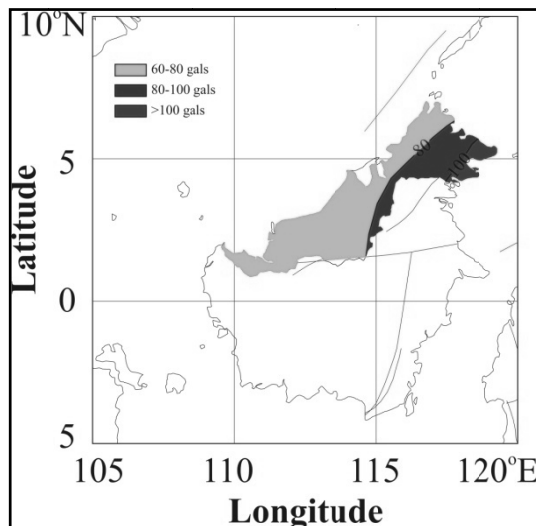


Figure 13.9 PGA Map for 10% PE in 50 Years (E. Malaysia)

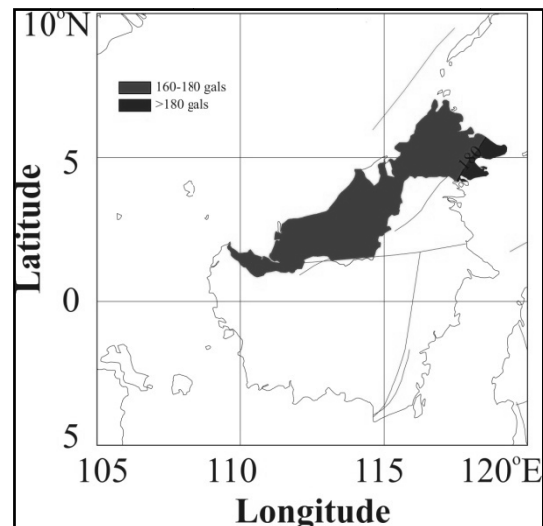


Figure 13.10 PGA Map for 2% PE in 50 Years (E. Malaysia)

13.7 FUTURE LEGISLATION AND GUIDELINES

The legislative framework within which floodplain management is implemented is subject to change. Experience gained while using current manuals and guides may also lead to future updates of this manual as a result of lessons learnt during implementation of various aspects of flood mitigation. Therefore, future legislation and guidelines must be able to accommodate any proposed approach to floodplain management in the future.

13.8 THE DIGITAL REVOLUTION

Society today has become more reliant on the convenience of digital data and transactions. This trend will grow many-folds in the coming future and the flood industry is not spared. Records of major flood events, rainfall and discharge measurements, etc. around the world are stored in all sorts of digital devices. These are priceless data that form the basis for flood estimation and other related analyses.

Digital records are very vulnerable, and once compromised, are gone forever. However, if properly stored and protected, the data can readily be transferred with flexibility and the need for space and access will thus provide a critical component in recovery and continuity (Plasencia and Baker, 2007). This therefore calls for the flood industry to come up with secure and fail-proof ways of keeping these invaluable records intact.

13.9 GEOGRAPHIC CONTINUITY AND INTERDEPENDENCE

Advancement in science and technology has created intricately linked societies, with development in transportation, enhanced communication and the easy transfer of digital data creating convenience not thought of before. Nevertheless, this also creates vulnerabilities as flood damage to a particular industry is no longer an isolated event, the effect can be felt thousands of miles away. This geographic continuity and interdependence must be properly handled for the sake of future flood mitigation efforts.

13.10 PARADIGM SHIFT – CHANGING MINDSETS

Perhaps the most important of all the future concerns is the mindset of the people. Human beings are the only creatures on earth capable of thinking and planning so it is up to us to shoulder the responsibility. A paradigm shift is clearly needed in the mind of the population. Leaving everything to the authorities to handle is not enough. The public must be aware of what is going on, all the efforts that are taken by the authorities to mitigate floods, and how they can contribute to assist in those efforts.

As the public are doing their part, the professionals like engineers and hydrologists that deal with floods must also have a change of mindset. Space must be made for water as channelizing rivers and constructing structural measures to deal with floods alone is no longer sufficient.

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