SECTION 3: STORMWATER MANAGEMENT

3.0 INTRODUCTION

This section covers the design of Stormwater Management facilities including, but not limited to, conveyance systems, storage systems, and treatment.

3.0.1 GENERAL

The overall design principles described in the introduction to these standards are the basis on which all construction is undertaken in the City of Lethbridge. Often, a combination of principles will come into play when designing a particular component of the system.

The purpose of stormwater management is to handle precipitation so it does not become an inconvenience or present a hazard to the community, while also reducing impacts on the environment. Current practice is to use a system of underground pipes, overland flow routes, as well as wet and dry stormwater detention facilities.

Lethbridge would like to take a proactive role in promoting measures to reduce the impacts on the environment due to development. In this respect, these guidelines may be more restrictive than the requirements of Alberta Environmental Protection.

The system must be designed to provide access to components for maintenance. Overland conveyance routes should be designed to limit the potential for erosion. Outfalls and other structures must be as low maintenance as possible.

Stormwater facilities should be designed to be neat and tidy with a minimal amount of maintenance. Wherever possible, stormwater facilities such as wet or dry ponds or major system conveyance should be integrated into a multi-use facility. In combined open space/stormwater facilities the area's primary purpose will be as community green space with the stormwater purpose as a secondary role. The pond's shape, slopes, inlets, and outlets must be designed with safety and aesthetics in mind.

New systems must be designed without exceeding peak flow capacities of the older systems to which they connect; this applies to both overland flow routes and well as underground components of the system.

The designer must take into consideration safety concerns in the design of storm management facilities because rain and runoff events can be sudden and unexpected.

The following safety factors should be considered in the design of stormwater management facilities:

1) Depth, Speed and Extent of Overland Flow and Ponding
2) Preventing Access to the Piped Portion of the System
3) Ability to Escape from Ditches and Ponds
4) Preventing the Formation of Slipping Hazards
5) Access for Emergency Vehicles
6) Prevention of Flooding and Erosion Damage

3.0.2 LEVEL OF SERVICE OBJECTIVES

Level of service for Stormwater Management Systems has traditionally been defined using the return period of the design storms used to size the system. This is described in terms of the Major and Minor systems. The Minor system handles small frequent runoff events and currently consists mainly of underground pipes. The major system handles any runoff which cannot be taken by the minor system and usually consists of overland flow from large infrequent events.

i. The Minor (underground) portion of the system shall be designed with capacity for a one in 5 year storm. The piped system shall convey flows from the one in 5 year storm. Ponding in trapped lows shall not occur for storms up to and including the 1 in 5 year event. Ponding and overland flow must be confined to public property and right of ways. Section 3.3 provides minor system design guidelines.
ii. The Major System storm ponds and overland flow within new developments, shall safely handle a one in 100 year event without causing flooding of private property or erosion damage. Ponding and overland flow shall be confined to public property and right of ways and be limited to no more than 300 mm deep as measured at the gutter of the streets for the 1 in 100 year event. Once collected, Stormwater shall remain on public property. Section 3.5 provides major system design guidelines.
iii. Peak post development flow rates shall not exceed pre-development flows resulting from the one in 5 year event. Where downstream constraints exist, post development flow rates may be restricted to less than the one in 5 year pre-development flow. The allowable release rate shall be maintained for all design storms up to and including the one in 100 year event.
iv. New developments must include measures to improve stormwater quality. Specifically Alberta Environment's MUNICIPAL POLICES AND PROCEDURES MANUAL requires "a minimum of 85% removal of sediments of particles size 75 microns or greater." Erosion and sediment control must be in place as permanent features of development. These include grassed swales and runways to trap silt and ponds designed with dimensions and detention times promoting settling. Higher priority will be placed on environmental considerations along the coulee banks and adjacent to environmental reserves. The City has already taken steps to improve stormwater

quality by implementing a street cleaning program, placing limitations on pesticide use, instituting a doggie bag program and requiring catch basin sumps.

3.0.3 REGULATIONS

The following list is the regulations which have provisions that pertain to stormwater management applicable within the City of Lethbridge:

Provincial Regulations:

1) Water Act
2) Environmental Protection and Enhancement Act

Federal Regulations:

1) Fisheries Act

Designers are encouraged to contact the Provincial and Federal governments with regard to regulations which may apply but are not listed here.

3.1 STORMWATER PLANNING REQUIREMENTS

See Section 2.1 for Infrastructure Planning Requirements.

3.2 ENVIRONMENTAL CONSIDERATIONS AND BEST MANAGEMENT PRACTICES

See Section 2.2 for Environmental Considerations.

3.2.1 EROSION CONTROL AND SEDIMENTATION

i. Erosion protection shall be adequately provided on all permanent surfaces and channels in the development area to resist the one in 100 year event
ii. Concentrated flows over the top of the riverbank, down unprotected slopes, or into unprotected coulees will not be permitted. Sheet flow must occur along the entire top of bank and adequate erosion controls must be implemented to prevent rill erosion and gully formation. In conjunction with erosion protection, slope drains may be used to collect flows and safely convey them to the bottom of the slope.
iii. Catch basins shall be provided with a sump to improve sedimentation.

3.2.2 REDUCING HAZARDOUS CHEMICALS, PETROLEUM PRODUCTS, PESTICIDES AND HERBICIDES

i. Stormwater containment and treatment will be required for developments purposing to use hazardous materials on site. It is recommended that Developers contact the City Engineer at the concept stage when considering these types of facilities.

ii. Stormceptors or other oil and grit separators should be considered for any development with large parking areas or where there is a risk of a petroleum product spill.

iii. Stormceptors or an approved alternate oil and grit separator will be required at all sites containing gas stations. The device shall be installed in an easement or in public property to allow access by City forces for maintenance and cleaning.

iv. Please refer to Section 7.0 Parks and Open Space of this standard with regards to planting designs and methods that are naturally pest and weed resistant.

3.2.3 STORMWATER QUALITY BEST MANAGEMENT PRACTICES

The City of Lethbridge strongly recommends the use of any measures taken in the design which improve stormwater quality, reduce peak flows, and reduce runoff volumes. The following items are suggested for consideration in new developments:

i. Grass swales and runways should be incorporated into pond inlets and green strip conveyance paths. Flow spreaders to encourage sheet flows across grassed areas are highly desirable. Flows across vegetation have been shown to be effective in improving stormwater quality and in reducing volumes.

ii. Appropriately sized trash racks and properly designed transitions from paved to grass areas which will limit the transport of materials off the street into the piped portion of the system.

iii. Constructed wetlands which mimic natural processes for treating stormwater should be considered a viable alternative to either dry-ponds or wet pond features. Constructed wetlands and similar features would be especially appropriate for use in developments adjacent to the river valley provided that safe set back requirements are followed.

iv. Wet and dry ponds with larger length to width ratios are preferred because of their increased sedimentation efficiencies. Target length to width ratios are greater than 5 to 1. Increased flow path lengths can be achieved through the use of interior berms and baffles.

v. Where possible detention times of 24 to 48 hours should be used for ponds to allow greater time for sedimentation.

vi. Sediment fore bays are encouraged at pond entrances. Fore bay designs should include consideration of access for maintenance and sediment removal.

vii. A canal water supply system will be provided for all wet ponds. Systems will be designed to serve all wet ponds with in an Outline plan area.

3.2.4 SERVICE CONNECTIONS

i. All sub-divisions must be built with storm sewers adjacent to all lots. All lots approved shall drain to a sump discharging to the storm sewer system as per the requirements of Section 9.1.4 Foundation Drainage.
ii. Foundation drain collectors shall discharge to the stormwater service. Foundation drains shall not be connected to the sanitary sewer system.
iii. Storm Service connections shall comply with the National Plumbing Code.
iv. Properties zoned for non-residential land uses and for multi-family residential (excluding duplex lots) must retain runoff volumes in excess of the 1 in 5 year return period and up to a 1 in 100 year return period on site. The excess runoff control may take the form of parking lot, rooftop, or underground storage, as well as wet or dry ponds. Infrastructure Services shall approve runoff control designs.
v. Sump pump outlets and roof leaders shall discharge flows no closer than 1.0 m from the property line. Where possible, drainage across property lines shall be spread to encourage sheet flow and reduce concentrated erosive flows.

3.3 ESTIMATION OF PEAK FLOWS, RUNOFF VOLUMES AND HYDROGRAPHS

3.3.1 GENERAL RULES OF THUMB

In order to provide a quick design and review of stormwater management systems the City has created the following rules of thumb:

i. Major overland flow – 200L/sec/Ha
ii. Minor system flow – 90L/sec/Ha
iii. Wet Pond Storage – 1000m3/Ha for 0 release rate situations
iv. Pond size is to be a minimum of 1.5 Ha of normal water level area but larger is preferred

3.3.2 COMPUTER MODEL SIMULATION

The City will not require any computer model simulation of the proposed major and minor systems unless the general rules of thumb mentioned above are unattainable. Computer simulation will be required to assess the impacts of added development on the existing storm water system and to assist in designing detention facilities for optimal release rates and timing. The City establishes allowable release rates based on previously submitted storm water management reports. Where designers can show that capacity is available in the downstream system larger release rates may be allowed.

3.3.2.1 Design Storms

The following storms shall be used to evaluate the stormwater management system behavior:

1) One in 5 year 4 hour duration storm
2) One in 100 year 4 hour duration storm
3) One in 100 year 24 hour duration storm

Additional storm of varying duration and return periods should be used to adequately design stormwater management systems. Though not a requirement, it is suggested that historic long-term precipitation data and data from historical storms be used to evaluate the performance of stormwater management designs.

3.3.2.2 Natural Conditions

Natural conditions refer to the state of the land in the development area prior to its alteration by people. The impacts of the proposed development on peak flows and volumes shall be evaluated based on the following baseline conditions. Table 3.3.2.1 describes the general parameters to be used for the estimation of runoff characteristic resulting from natural conditions. These values represent typical conditions for Lethbridge and are provided as guidelines. Where a designer has more accurate information or actual values, they should be used.

Table 3.3.2.1 General Parameters for Runoff Estimation

Soil Type	Silty-Clay
Porosity	0.48
Effective Porosity	0.42
Hydraulic Conductivity	0.5mm/hr
Soil Suction head	292.2 mm
Cover Type	Short Prairie Grass
Manning's n	0.15
Permeability	100%
Initial Moisture Deficit	0.21-0.26

3.3.2.3 Developed Conditions

i. Developed conditions should reflect the expected zoning of the development. Estimates of percent impervious area should be taken from similar developments within the City. Table 3.3.2.3 Percent Impervious Area may be used as a guide, representing minimum values unless actual values are calculated from similar existing areas.

ii. Guidelines for Manning's "n" can be found in any text on open channel flow. An online resource can be found here: http://www.fhwa.dot.gov/bridge/wsp2339.pdf

iii. Initial Moisture Deficit (IMD) should be estimated conservatively to account for lawn watering in the range 0.10 to 0.30. Alternatively, long-term precipitation data sets are available from Environment Canada to allow better estimates of antecedent moisture conditions however these again may estimate IMD to high because lawn watering is not considered.

iv. Soil characteristics for Topsoil may be used in the analysis for landscaped areas. Typical values are provided in Table 3.3.2.2

Table 3.3.2.2 Topsoil Characteristics

Soil Type	Loam – Topsoil
Porosity	0.46
Effective Porosity	0.43
Hydraulic Conductivity	3.4 mm/hr
Soil Suction Head	88.9 mm

Table 3.3.2.3 Percent Impervious Area

PERCENT IMPERVIOUS AREA	
Land Use or Surface Characteristics	**Percent Impervious**
Undeveloped Farmland/Prairie	0
Commercial Uses	
Mainly Commercial Areas	95
Neighborhood Commercial	70
Residential*	
Single Family	45
Multi-Family	65
Apartments	70
Industrial	
Light Industrial	80
Heavy Industrial	90
Open Spaces:	
Parks/Cemeteries	7
Playgrounds	13
Schools	50
Lawns	0
Streets/Lanes:	
Paved	90
Gravel	15
Aggregated Areas:	
Natural Area/Park/ER	5
Urban Residential	60
Commercial	85
Industrial	95
Note: These values are rough estimates only. Where possible imperviousness of comparable previously built areas should be used.	
Values taken from Storm Water Management Guidelines, Alberta Environment, January, 1999	
* Residential values do not include adjacent streets.	

3.3.2.4 Additional Information

i. Depression storage can be estimated using the following formula.

$$d_p = 0.77 * S^{-0.49}$$

where: d_p is depression storage in millimeters
S is ground slope in %

3.3.3 RATIONAL METHOD

i. The Rational Method can be used for the preliminary design of stormwater conveyance systems to provide initial estimates of peak flows for the first iteration of pipe sizing using a computer model simulation.

3.3.3.1 Rainfall Intensity – Frequency - Duration

i. Rainfall intensities at other times shall be calculated using the following formula and the constants for the various return periods given in the table below.

$$i = \frac{a}{(t+b)^c}$$

Where:

i is the rainfall intensity in millimeters per hour.

t is the time of concentration at the point of design

a b and ***c*** are the constants for the respective design storm return period given in the table below.

Table 3.3.3.1 Rainfall Intensity Constants

Storm Return Period	*a*	*b*	*c*
1 in 5 Year Storm	440.69	0	0.696
1 in 100 Year Storm	1019.20	0	0.731

More detailed information on the above data can be obtained from Environment Canada at: http://climate.weather.gc.ca/prods_servs/engineering_e.html

3.3.3.2 Rational Method Runoff Coefficients

i. The runoff coefficients in the following table are recommended for use in calculations using the Rational Method. The table provides coefficients for the 1 in 5 year event. The coefficients shall be increased by 25% when performing the analysis for the 1 in 100 year event.

Table 3.3.3.2 Runoff Coefficients

Land Use	Runoff Coefficient
Agricultural Land / Natural Prairie	0.15
Parks	0.20
Residential	0.40
Commercial	0.80
Institutional	0.80
Industrial	0.70

3.4 MINOR SYSTEM

3.4.1 TRAPPED LOWS (MINOR SYSTEM STORAGE)

i. New developments shall be designed to limit the number of trapped lows required. The additional storage provided by trapped lows is marginal and the additional maintenance required by the use of Inlet Control Devices makes trapped lows undesirable.

ii. Trapped lows shall be designed so no significant ponding occurs for events up to the one in 5 year event. The maximum depth of ponding in trapped lows shall be 300 mm as measured from the gutter for the 1 in 100 year event. Detailed design drawings shall show the extent of flooded area at trapped lows during a 1 in 100 year rainfall event.

iii. Ponding in trapped lows shall be contained within the road right-of-way or public property.

iv. Overland flow routes out of trapped lows must conform to the requirements of section 3.5.1.

v. Trapped lows shall not be located so they inundate sanitary manholes. Where sanitary manholes must be located within a trapped low, special provisions to limit stormwater inflow to the sanitary sewer must be taken and approved by the City Engineer.

vi. Trapped lows shall be surveyed and the actual extents, spill elevations, and catch basin elevations confirmed on the as-built drawings.

3.4.2 PIPED SYSTEM AND GUTTERS

i. The minimum grade on gutters or paved surfaces shall be 0.6%. Grades 1% or greater are preferred on curved gutters and curb returns.
ii. Minimum grade of lanes shall be 1.5% for a minimum distance of 5 m from the back of concrete along the lane. The minimum grade of lanes shall be 1% at other locations.
iii. The surface of the asphalt in the lane shall be at least 12 mm higher than the concrete where the asphalt meets the back of concrete.
iv. Maximum depth of flow in gutters for the one in 5 year event shall be the lesser of 150 mm or the height of the sidewalk top above the gutter.
v. In the design of pipes a roughness coefficient equivalent to a Manning's n of 0.013 shall be used to account for the degradation of the pipe over time.
vi. The piped system shall be designed so that no surcharging occurs during the 1 in 5 year event.
vii. Back of lot concrete gutter swales (Drawing STR-20) and concrete grade beams shall be used solely for back of lot grade control. Grade of swales and grade beams shall be between 0.6% and 6%.
viii. Back of lot grading shall be designed such that safe depth and velocity requirements for runoff are met for a one in 100 year event.
ix. Runoff shall travel less than 75 m along a back of lot swale or grade beam before reaching a lane, catch basin, open space or back to front swale or grade beam. Runoff shall be prevented from crossing sidewalks.

3.4.3 CATCH BASINS

i. Catch basins which discharge directly to the piped system without passing through a downstream detention facility are required to be installed with flow restriction devices to limit peak flows from the catch basin back to the peak flow from the contributing area to the predevelopment peak runoff for the one in 5 year event.
ii. Catch basins which discharge via storm detention ponds may have flow control devices placed in them to create trapped lows for additional storage. It is preferred that storage be provided through other methods other than trapped lows on the street.
iii. Where they are required low maintenance Inlet Control Devices or designs, which limit clogging, are encouraged.
iv. Catch basins shall not be located in the expected wheel path of vehicles.
v. Catch basins shall not be located in front of driveways, wheelchair ramps, or in entryways.
vi. Catch basins shall be built with a 350 mm deep sedimentation sump.
vii. Catch basins in lanes are discouraged. Where possible, lanes shall drain to a street. Where required, catch basins located in lanes shall be constructed with 10 m of

weeping tile installed below the granular base course down the centerline of the lane each direction from the catch basin.

viii. Catch basin leads to be installed with a minimum 1% grade

3.4.4 CONNECTIONS TO EXISTING PIPED SYSTEMS

i. The designer is required to show that the system downstream from the development has adequate capacity to accommodate changes in peak flows and volumes resulting from the development. The City will provide conservative estimates of downstream system capacities upon request.

ii. In areas where the stormwater system capacity is less than required for the one in 5 year return period, peak flows off the development/redevelopment must not be increased above predevelopment levels. Flows from the development must be retained on site and released so that the length and severity of surcharging in the downstream system is not increased.

3.5 MAJOR SYSTEM

3.5.1 OVERLAND FLOW

i. New developments shall have a continuous route for overland flow from the point of precipitation to a suitable outlet. Continuity of overland flow routes between adjacent developments shall be maintained. The overland flow route will handle runoff from storms that exceed the one in 5 year event.

ii. The route must be adequate to contain the one in 100 year event without causing flooding of private property or erosion damage to existing facilities. Flow and ponding shall be contained within public property and right-of-ways.

iii. Where private property is used to convey runoff from multiple lots:
   a. The means of conveyance shall be designed appropriately.
   b. The full width of flow under the design 100 year rainfall event shall be protected by an easement.

iv. Once overland flow routes have reached public property, they must remain on public property. Providing an escape route for a trapped low via an easement between private residences will not be allowed. Overland flow routes of this type are only allowed along roadways, walkways, and other public properties.

v. The combined conveyance capacity of public right-of-ways downstream of a trapped low shall be equal to or great than the combined conveyance capacity of public right-of-ways upstream.

vi. The following Table 3.5.1.1 provides safe flow velocity – depth relationships. Overland flows shall not exceed these limits for storms up to the one in 100 year event. In locations where these limits cannot be met, measures must be taken to ensure public safety by limiting access and posting appropriate warning signs. Exceptions to these defined limits will be evaluated on a case-by-case basis. Note that the table provides safety limits only and does not address erosion resistance requirements.

Table 3.5.1.1 Maximum Combination of Gutter Flow Depth and Velocity

Water velocity (m/s)	Maximum Permissible Depth (m)
0.50	0.80
1.00	0.32
2.00	0.21
3.00	0.09

vii. Overland flow routes depth and velocity relationships will be determined for critical locations. Critical locations are those points where maximum flow rates are encountered, where high velocity flow is expected, where overland flow may present a danger to the public, and locations where there is particular risk of significant erosion or flooding damage.

viii. Depth and velocity will be calculated using Manning's Equation for open channel flow or an approved alternative method.

3.5.2 USE OF ROADWAYS AS OVERLAND CONVEYANCE

i. Local roadways may be used as part of the Major system conveyance route, provided that the requirements of section 3.5.1 are adhered to for the 1 in 100 year event.

ii. Maximum depth of flow or ponding on local roads shall be 300mm at the gutter of the road in a 1 in 100 year event.

iii. Collector roadways may be used as part of the Major system conveyance route, provided that the requirements of section 3.5.1 are adhered to for the 1 in 100 year event.

iv. Depth of crossing flow or of ponding in trapped lows in Collector roads shall not exceed the lesser of 300 mm at the gutter of the road or 100 mm at the crown of the road in a 1 in 100 year event.

v. Collector roadways should have at least one lane, which is not inundated parallel with the direction of flow.

vi. The travel lanes of Arterial roadways shall not be used as part of the Major system. The City Engineer, on a case-by-case basis, will consider exceptions where it is especially difficult or expensive to prevent flows from entering the arterial road right of way. In cases where Arterial roads must be used, the designer shall show that flow or ponding along the roadway will not adversely impact the operation of the arterial road.

vii. Special permission must be obtained in order to use easements as part of the major overland flow route system.

3.5.3 DRY PONDS

i. Estimation of required storage volumes, peak flows, and drainage times shall be done using an approved computer model.
ii. The pond shall provide sufficient storage so that operation of the emergency overflow does not occur during 1 in 100 year events.
iii. The dry pond shall be graded to properly drain all areas after its operation. The pond bottom shall have a minimum slope of 2.0% (Refer to Section 7.0 Parks and Open Space for details).
iv. Ponds should be designed with organic shapes and undulating edges to provide visual relief. Rectangular ponds or dugout like ponds should be avoided.
v. The maximum one in 100 year high water level shall be 0.45 m below the floor elevation of the building on properties having a common property line with the pond.
vi. An emergency overflow shall be provided on all ponds. The path from the pond overflow to an approved outlet must be identified. Safe depth/velocity relationships cannot be exceeded and adequate erosion protection shall be provided for the emergency overflow and the overland flow routes within the development when operating with peak flows estimated for the 1 in 100 year event.
vii. All inlets and outlet structures associated with dry ponds shall have grates provided over their openings to restrict access and prevent entry into sewers by children or other persons. A maximum clear bar spacing of 100 mm shall be used for gratings.
viii. Grated outlet structures are to be designed with a hydraulic capacity of at least twice the required capacity to allow for possible plugging.
ix. Velocity of flow through gratings on inlets to pipes shall not exceed 1.0 m/s for maximum expected flows during the one in 100 year event.
x. Appropriate means of limiting access to outlets and reducing the danger of falls from headwalls and wing walls shall be taken.
xi. Where possible, dry ponds should be incorporated into parks and open space.
xii. In the design of combined park/dry pond facilities, the park usage of the area shall take precedence over dry pond requirements.
xiii. Dry ponds located in parks shall include special needs access and egress points having slopes of less than 1 vertical to 12 horizontal.
xiv. Design of the area about the high water level is covered in Section 7: Parks.

3.5.4 WET PONDS – PHYSICAL CHARACTERISTICS

i. Estimation of required storage volumes, peak flows, and drainage times shall be made using an approved computer model.
ii. The pond shall provide sufficient active storage so that operation of the emergency overflow does not occur during 1 in 100 year events.
iii. A minimum horizontal distance of 5 meters shall be maintained from any property line to the high water level. Design of the area past the 5m setback is covered in Section 7: Parks.
iv. A silt trap or forebay shall be provided at the inlet of each pond.
v. Access to the pond shall be provided to accommodate expected maintenance traffic including a boat ramp facilitate maintenance for floating or submerged facilities.
vi. The lake bottom and side slopes shall be composed of an impervious material up to the 1 in 100 year level.
vii. The maximum one in 100 year water level shall be 0.45 m below the lowest floor elevation of buildings on properties having a common property line with the pond.
viii. The lowest adjacent manhole invert shall be at or above the normal water level elevation.
ix. The pipe crown at the lowest manhole upstream of the pond shall be above the high water level during a 1 in 5 year storm event to limit back water effects.

3.5.5 WET PONDS – WATER QUALITY

i. Performance Objectives
   a. *AESTHETICS*: (Maintain water clarity, colour and prevent odour)
      i. Keep the pond looking and smelling clean.
   b. *NUTRIENT CONTROL*: (remove nutrients, litter/debris)
      i. Suspended solids – 85% reduction of 75 micron particles and larger by weight.
      ii. Total phosphorus and nitrogen – the pond shall incorporate proven strategies showing removals of these nutrients.
      iii. Litter –the pond shall incorporate strategies that facilitate the trapping and subsequent collection of litter.
ii. Design Considerations
   a. POND CONFIGURATION:
      i. Ponds shall be designed with sufficient area (minimum 1.5 ha), dimensions, and flow characteristics to minimize aquatic weeds and maintain acceptable water quality. Inlets, outlets, pond shape, internal baffles, and aquatic benching will be arranged to prevent stagnant areas and promote circulation. No dead bay areas shall be permitted. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.

   ii. Ponds shall have a power drop location added.
   iii. Wet ponds should be designed with a length to width ratio of at least 3:1 to promote sedimentation. If the length to width ratio is lower, the flow path through the pond should be maximized.

b. *EXTENTS Of AQUATIC BENCHES*: All ponds will include aquatic benches either:
   i. As a continuous ring 2-4 m in width around the perimeter of the permanent pool or,
   ii. Arranged in bands across the flow path covering a minimum of 20% of the open water area as measured at the normal water level. This type of aquatic benching will be arranged as wetland zones at the inlet and outlets from the pond.

c. RIP RAP
   i. Where a vegetated aquatic bench is not provided for shoreline, protection rip rap must be used. Rip rap is to be a minimum of 200mm diameter stones to minimize loss as a result of rip rap being thrown into the lake.

d. AQUATIC BENCH CONFIGURATION:
   i. The aquatic benches will have a maximum depth of 450 mm below the normal water line.
   ii. Organic soils at least 150mm in depth will be used as a planting bed on aquatic benches. Organic soils can serve as a sink for pollutants and generally have high water holding capacities.
   iii. Vegetation will be seeded or planted to initiate the growth of aquatic plants. Robust, non-invasive, perennial plants that establish quickly are ideal. The designer should select species that are tolerant of a range of depths, inundation periods, etc. Monoculture planting should be avoided due to the risk from pests and disease.

e. CIRCULATION / TURN OVER
   i. A source of water is to be provided to all ponds as a make-up water supply and to allow flushing/refreshing of the pond permanent pool during low precipitation and high temperature periods.
   ii. A pond aeration and circulation system is to be provided for all ponds.

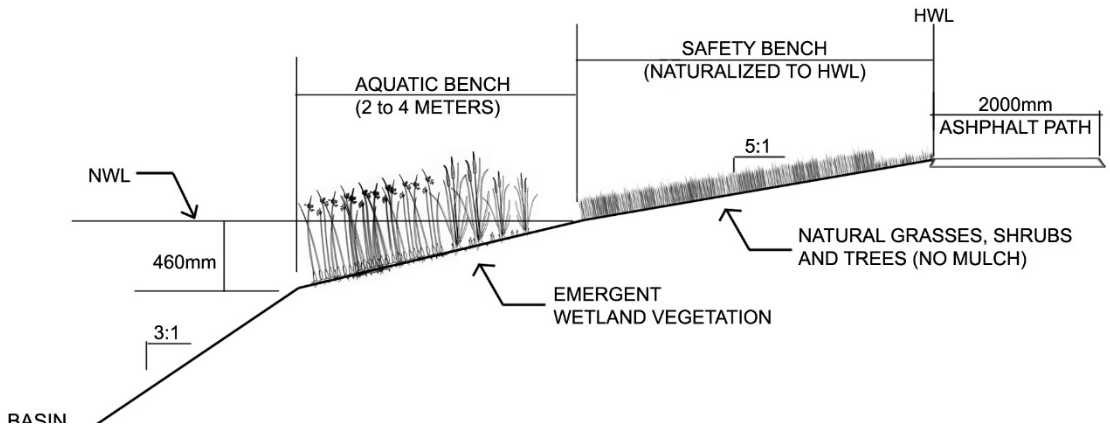
f. LANDSCAPING
   i. Land adjacent to wet pond facilities shall comply with the Parks and Open Space Chapter of this design standard.
   ii. Ponds should be designed with organic shapes and undulating edges to provide visual relief and integrate them into the park and open space. Rectangular ponds or dugout like ponds should be avoided.

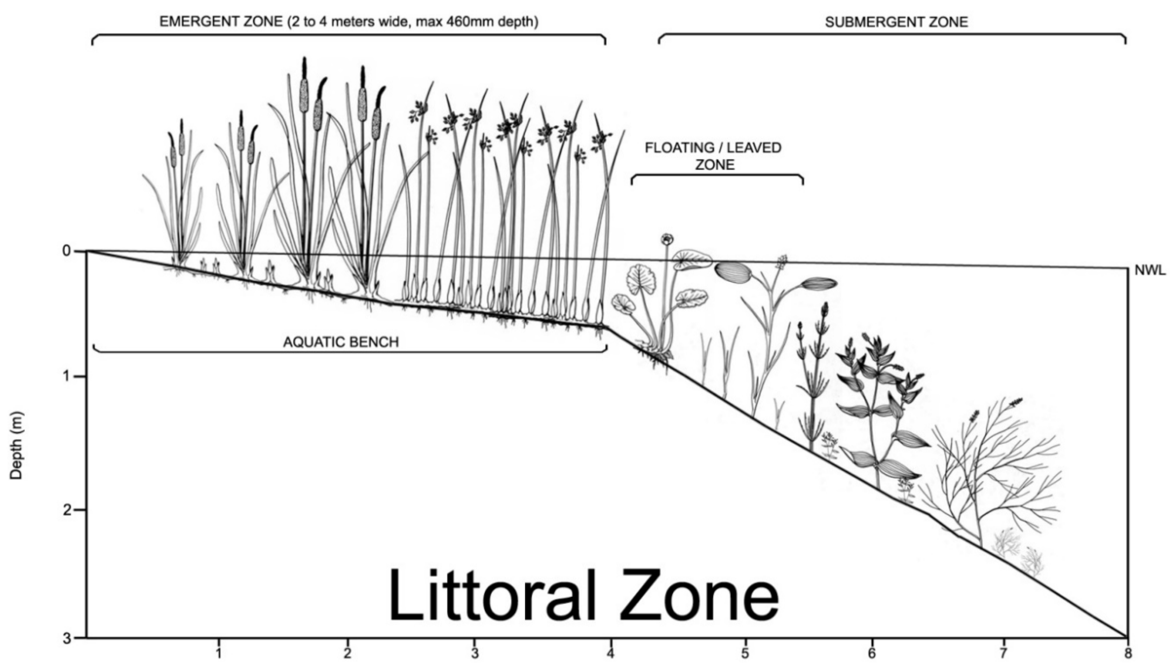
iii. Irrigation systems will not be installed below the High Water Level. Naturalized (native) vegetation is acceptable plant material between the HWL and NWL. All plant material below the HWL will require minimal maintenance.

iv. A physical division will be installed between the un-manicured vegetation below the High Water Level and manicured vegetation above it. This division can take the form of an asphalt pathway or moving strip.

v. When the irrigated areas in the vicinity of a wet pond exceed 2.5 ha, the pond will be provided with a canal water supply and an irrigation pump house.

vi. If the lake is to be considered as a source for irrigation water, then water quality must be modeled to ensure public safety





Littoral Zone - The distribution of different types of macrophytes is largely determined by physical factors such as depth, light, wave action and sediment texture.