Bemidji

Stormwater Design Guide

City of Bemidji

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Bonestroo

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1 STORMWATER DESIGN GUIDE OVERVIEW

The Bemidji Surface Water Management Plan contains goals and policies that define the City's stormwater management program. Bemidji designed its program to minimize the impact urban stormwater has on receiving waters. This Bemidji Design Guide provides detailed discussion on the specific design elements that help the City achieve its stormwater management goals. The Design Guide audience includes developers, engineers, planners and City residents.

2 DESIGN GUIDANCE

2.1 PONDS

Stormwater ponding areas are an essential part of any storm drainage system. Stormwater ponds can reduce peak discharge rates from developments, provide water quality treatment, and provide areas for stormwater infiltration.

The effective use of ponds enables the installation of outflow storm sewers and channels with reduced capacities, since the duration of the design storm is effectively increased over the total time required to fill and empty ponds. Smaller capacity trunk storm sewer and channels provide a cost savings to the City.

The use of ponds to control stormwater runoff rates is a recent phenomenon. Historically, older cities have piped stormwater directly to the nearest large receiving water or river. Continued use of this practice has both cost and regulatory implications. In terms of cost, few cities have the funds necessary to build pipes that provide 100-year protection to properties. In fact, the older cities that have historically piped all their stormwater find that the systems they constructed provide nowhere near the 100-year protection found in newer cities that have used ponds. In terms of the regulatory control, almost all direct discharges (without ponding) to waters of the state are precluded. At present, even direct discharges to wetlands that are not considered waters of the state are regulated through the NPDES construction permit.

Ponds provide water quality treatment by allowing nutrients and sediment carried by runoff to settle before discharge to receiving waters. Ponds designed with relatively flat benches in suitable soils can, when outfitted with restricted outlets, infiltrate runoff to meet Bemidji's volume management standards.

To provide proper protection for adjacent property, the design storm for ponding areas is the maximum flood elevation obtained from analyzing 100-year, 24-hour design event or, in the cases of landlocked basins, back to back 100-year, 24-hour events or the 7.2 inch runoff event.

Runoff determinations for pond design vary from those for storm sewer calculations. The critical storm for storm sewer design is the short, high intensity storm, whereas the critical storm for pond design is often of longer duration, since water is being stored for longer periods of time and released at a slower rate.

2.1.1 PONDS – WATER QUALITY VOLUME SIZING

In cases where infiltration is precluded (whether due to site contamination, high water table, poor soils, etc.) the entire water quality volume for a site will most commonly be provided by a stormwater pond. Alternately known as dead storage or wet volume, a pond's water quality volume is the permanent portion of a pond's volume. As new runoff enters a pond it displaces stored water. When a pond is properly designed, the displaced volume has resided in the pond for a period of time sufficient to allow sedimentation to the pond bottom. The new runoff forces cleaner water out the outlet.

When a pond is the only management practice, the pond water quality volume should be based on the runoff generated by a 2.5-inch rainfall event. Impervious areas and pervious areas should be calculated separately as in the following example:

Development: 25 acre commercial site, 70% imperviousness

Runoff coefficient for impervious = 0.91
Runoff coefficient for pervious = 0.07

70% x 25ac x 0.91 x 2.5in x 1ft/12in	= 3.32 ac-ft = 144,519 ft^3
30% x 25ac x 0.07 x 2.5in x 1ft/12in	= 0.11 ac-ft = 4,764 ft^3
Total	= 3.43 ac-ft = 149,283 ft^3

As can be seen from the example above impervious area is the primary determinant of water quality volume. Consequently, it is not necessary to modify the pervious area runoff coefficient to account for different soil types.

2.1.2 PONDS – EXTENDED DETENTION

The purpose of extended detention is to control post development discharge for smaller rainfalls. Managing small rainfalls through extended detention provides additional water quality treatment and helps prevent downstream erosion. Extended detention also protects lakes, wetlands, and streams from water level fluctuations that might damage shoreline vegetation.

The City of Bemidji's rate control (or flood control) standards consider the 100-year design event. The City's volume management standards and water quality standards focus on average rainfall events that occur frequently in a rainfall season. Extended Detention is the third leg of the stormwater management system, one that overlaps with both the wet volume (water quality) and flood storage requirements of development, redevelopment and linear projects. The purpose of Extended Detention is to control of flow rate for the 1-year rainfall event (2.0 inches in 24 hours).

When Extended Detention occurs, the 1-year rainfall event discharge from a site is slow enough that the extended detention volume is almost as effective as dead storage at settling sediments. Bemidji's extended detention requirement is considered satisfied when the 1-year rainfall discharge rate from a site's stormwater management system provides a 12-hour lag between the center of mass of the inflow hydrograph and that of the outflow hydrograph. Generally, when the peak outflow discharge is 5% or less the inflow discharge, the 12-hour lag is occurring. Table 3.1 provides some guidance on applying the extended detention requirement through comparison of discharge rates.

2.1.3 FLOOD STORAGE AND RATE CONTROL SIZING

The central premise to Bemidji's rate control policy is maintaining existing conditions flow rates to wetlands, lakes and streams. Since predevelopment land use is variable and since it is in the City's interest to have a uniform standard to apply to development projects it is necessary to define existing conditions so the predevelopment baseline is consistent from project to project.

Changes from undeveloped land uses, like agricultural and natural, to more heavily developed land uses like low, medium and high density residential, and commercial have a pronounced affect on hydrology. The increased impervious surface associated with the urban land uses leads to higher runoff peak flows and increased runoff volume. Table 2.1 shows how volume and peak increase for two typical rainfall events.

Table 2.1
Land Use Based Peak and Volume Comparisons
HSG Type B Soils – 2% Slope

Land Use	10-year (3.6") SCS Type II, 24-hour Rainfall		100-year (5.2") SCS Type II, 24-hour Rainfall	
	Runoff Peak	Runoff Volume	Runoff Peak	Runoff Volume
	cfs/ac	inches	cfs/ac	inches
Natural CN=61	0.3	0.53	1.0	1.3
Agricultural (row crop in May and June), CN=81	1.8	1.6	3.3	2.9
Low Density Residential (35% impervious), CN=73	1.2	1.1	2.3	2.2
Commercial (70% impervious)	2.6	2.2	4.2	3.6
Commercial (85% impervious)	2.9	2.6	4.5	4.0

The intent of Bemidji's rate control standard is to reduce the post development peak to a rate more in line with natural conditions, which, according to Table 2.1, allows for 1.0 cfs/ac from development sites.

The 1.0-cfs/ac runoff peak generated on a natural landscape does not always create a discharge to a receiving water. Natural landscapes often have low areas that hold runoff, where captured runoff infiltrates or evaporates. For this reason, the 1.0-cfs/ac natural landscape discharge rate is considered a maximum. To apply this criterion to urban development, the City of Bemidji develops the following rate control guidelines:

1. For zoning categories R1 through R4 and AO, the post development 100-year discharge rate is restricted to 0.5-cfs/ac or existing conditions, whichever is lower.
2. For zoning categories B1 through B4, I1, I2, MO, R4, R5, and U the post development 100-year discharge rate is restricted to 1.0-cfs/ac.

The rate control standards protect the city's lakes, wetlands, and channels from erosion and flooding. The use of volume control is aimed at reducing the post development runoff depth. By reducing the post development runoff depth through abstraction – to something more akin to the depths seen off the natural landscape – lake, wetland and channel protection is further augmented.

2.2 HYDROLOGIC MODELING

Stormwater runoff is defined as that portion of precipitation which flows over the ground surface during, and for a short time after, a storm. The quantity of runoff is dependent on the intensity of the storm, the amount of antecedent rainfall, the length of the storm, the type of surface upon which the rain falls, and the slope of the ground surface.

The intensity of a storm is described by the amount of rainfall that occurs over a given time interval. Storms are typically characterized by their return frequency. A return frequency designates the average time span during which a single storm of a specific magnitude is expected to recur. Thus, the degree of protection afforded by storm sewer facilities is determined by selecting a return frequency for analysis.

For Bemidji the following return frequencies will commonly be used:

- 10-year Rational Method for storm sewer design on state aid streets.
- 5-year Rational Method for storm sewer design other than state aid streets.
- 100-year, 24-hour (Type II distribution) event for overland drainage and pond storage design.

A 100-year, 24-hour frequency event (5.2 inches in 24-hours for Bemidji) has a 1% chance of occurring or being exceeded in any given year. This design rainfall return period is commonly used for flood control throughout Minnesota.

As development occurs in Bemidji, storm sewer design should be a 5-year minimum recurrence for lateral, or local, systems in residential and commercial areas. This implies that no street, parking lot, or backyard ponding would occur for the 5-year design event. An exception can be made for commercial parking lots where some temporary ponding in the lot is desirable to reduce runoff rates. Trunk facilities should be analyzed and designed to accommodate the 100-year ponded discharges plus 5-year rational flows from areas that enter a trunk between ponds.

In general, complete protection against large, infrequent storms with return intervals greater than 100 years is only justified for important flood control projects. For most developing areas like Bemidji, the cost of constructing a large capacity storm drainage system (for events greater than the 100-year) is much greater than the amount of property damage that would result from flooding caused by a larger than 100-year event occurring in a system designed for the 100-year event.

The excess runoff created by storms greater than the 5-year will be accommodated by transient street ponding and overland drainage routes. Providing short-term flooding areas and overland drainage routes reduce flood damage due to larger than design events. Provisions should always be made to provide or preserve overland drainage routes for emergency overflows.

A number of hydrologic and hydraulic modeling methods have been developed to determine the expected maximum rate of runoff from a known area for a specific design storm, given land use and soil moisture conditions. The City of Bemidji's minimum expectation of these calculations is that they be based on a hydrograph method.

Stormwater modeling involves the selection or computation of a time of concentration and a runoff coefficient. The time of concentration is the time required for the runoff from a storm to become established and for the flow from the most remote point (in time, not distance) of the drainage area to reach a pond, BMP or other discharge point. The time of concentration will vary with the type of surface receiving rain and the slope of the surface.

The percentage of rainfall falling on an area that must be collected by a storm sewer facility is dependent on watershed variables such as:

- Soil perviousness
- Ground slope
- Vegetation
- Surface depressions
- Development type
- Antecedent rainfall

These factors are taken into account when selecting a runoff coefficient (C) in the Rational Method or a runoff Curve Number (CN) for use in hydrograph routing methods, including modern computer programs.

In the Rational Method, the runoff coefficient for urban areas varies from 0.2 for parks to 0.95 for asphalt and concrete surfaces, while in hydrograph routing methods (or more correctly, the SCS methodology which these are based upon), the CN varies from 58 for parks to 98 for asphalt and concrete surfaces. CN values depend on the type of soil, cover type and hydrologic condition. Under fully developed conditions, the values of CN will rise with:

1. increases in impervious area caused by pavements and buildings
2. compaction of soils due to grading and construction activity.

Table 2.2 provides CN values and runoff coefficients for HSG Type B soils in Bemidji. To ensure consistency with the SWMP, future analyses (whether they be for development proposals or other city projects) should use the values contained within Table 2.2. For other types of land use not identified in the table, SCS Technical Release 55 (TR-55) curve numbers should be used.

The Table 2.1 values assume HSG Type B soils. To the extent that soils fall into the C or D categories the curve numbers should be modified accordingly. For HSG A there is no adjustment. Though HSG A soils have a higher "native" infiltration capacity than HSG B, development grading and construction compacts these soils and reduces their infiltration capacity. The CN values also reflect Antecedent Moisture Condition II (AMC II), which is a typical assumption in hydrologic analyses. AMC II simply implies that average soil moisture conditions apply prior to simulation of the design event.

Table 2.2
Runoff Coefficients

Land Use Type	Average Runoff Coefficient C for Rational Method			CN Value
	5-Year	10-Year	100-Year	
Park/Open Space	0.16	0.25	0.30	60
Low Density Residential (30% impervious)	0.33	0.45	0.50	72
Medium Density Residential (65% impervious)	0.59	0.63	0.72	85
High Density Residential (72% impervious)	0.66	0.70	0.77	88
Commercial/Industrial (85% impervious)	0.76	0.79	0.85	92
Ponds	1	1	1	99

Source: National Engineering Handbook

3 DESIGN STANDARDS

3.1 SUBMITTAL REQUIREMENTS

All grading, erosion control, and site restoration work should be done in accordance with the most recent additions of the Mn/DOT Standard Specifications for Highway Construction and two Minnesota Pollution Control Agency publications: Protecting Water Quality in Urban Areas and the Minnesota Stormwater Manual.

For site development and construction activities over one acre in size (that require a NPDES permit) the project submittals – be they design plans, project memoranda, stormwater management plans, etc. – must demonstrate stormwater management and erosion and sediment control techniques that meet the City's standards as outlined here. The following describe the City of Bemidji's expectations for these submittals:

1. The project proposer shall obtain all regulatory agency permits and approvals necessary for the proposed construction (i.e., DNR, Army Corp. of Engineers, MPCA, etc.).
2. Contact information for the engineering firm, developer, and owner.
3. Date of submittal.
4. Legal description of property.
5. Show City of Bemidji project number on the Plan, if applicable.
6. Signature of company responsible for erosion and sediment control plan preparation, implementation and maintenance.
7. Show all erosion control measures.
8. Note on the plans that all erosion control measures to be installed by the contractor should be inspected by the City prior to any site work.
9. A location map indicating the vicinity of the site.
10. Two-foot contour information extending a minimum of 200 feet beyond the property boundary that shows features such as buildings, structures, walls, trees, fences etc. and any hydrologic features such as wetlands, ponds, lakes, and streams that are wholly or partially encompassed by the project perimeter.
11. Two-foot contour information shall include the following:
    a. Existing contours
    b. Proposed contours
    c. Contour labeling
12. Directional arrows to indicate the site and lot drainage directions.
13. Details on existing wetlands, lakes, streams, etc.
    a. Normal Water elevation (NWL) and 100-year design storm High Water Level (HWL).
    b. Ordinary high water level, if available, for wetlands within the site.
    c. Whether waterbodies are DNR protected.
    d. Wetland delineations for wetlands on the site.

14. Information on individual lots including:
    a. Type of structure (i.e., walkout or rambler).
    b. Lowest ground elevation adjacent to building, first floor, basement walkout and lookout window threshold elevations.
    c. Existing and proposed lot corner spot elevations.
    d. Proposed mid-point side lot spot elevations.
    e. Proposed spot elevations at any high points or drainage breaks.
    f. Proposed spot elevations where drainage swales intersect lot lines.
    g. Proposed spot elevations where drainage and utility easements intersect with lot lines.
    h. The benchmark utilized for elevation determination.
15. All easements and outlots existing and proposed.
16. All adjacent plats, parcels, property lines, section lines, streets, existing storm drains and appurtenances, and underground utilities (public and private).
17. Grading and clearing limits; details of topsoil removal, topsoil stockpiling and topsoil respreading.
18. Delineation of existing vegetative cover.
19. Description of types of vegetation that will be removed and installed with the project.
20. Existing and proposed shoreline buffer strips.
21. Quantification of amount of excavation within shore impact zone and outside shore impact zone.
22. Quantification of existing and proposed impervious surfaces.
23. Drawings showing existing and proposed drainage boundaries, including watersheds contributing runoff from off-site.
24. Emergency Overflow (EOF) elevations and directions of flow for all street and rear yard catch basins, parking areas, ponds, wetlands, lakes, streams, swales, etc.
25. Maintenance access for stormwater ponds and other BMPs that will require periodic inspection and maintenance by City staff. Show or define access routes for maintenance purposes to all inlets or outlets at ponding areas.
26. Identify aquatic bench and maintenance bench as defined in the design guidance.
27. Existing and proposed storm sewer, catch basins, manholes, and pumping stations with invert, slope and ground elevations noted.
28. Existing and proposed BMPs including volume management, water quality, and water quantity BMPs.
29. Soils map or boring reports to verify assumptions regarding infiltration capacity.
30. Hydrologic and hydraulic calculations for the 1-year, 10-year, and 100-year 24-hour (Type II distribution) rainfall events.
31. In the case of landlocked basins hydrologic and hydraulic calculations should also include back to back 100-year, 24-hour rainfalls, and the 7.2-inch runoff event.
32. Drainage calculations to verify the sizing of pipe, ponds, emergency overflow spillways, and catch basin spacing.
33. Calculations or plan notes that indicate proposed pond wet volumes, extended detention volumes, and flood storage volumes.
34. Calculations showing infiltration sizing and credits sought.

35. The project proposer, upon the completion of the construction of a designated ponding area, is required to submit an as-built record plan certifying that the pond constructed meets all design parameters as set forth in the reviewed and approved pond plans.

3.2 DESIGN REQUIREMENTS

Storm Sewer:

1. Manhole spacing should not exceed 400 feet.
2. Where more than one pipe enters a structure, a catch basin/manhole should be used.
3. Storm sewer pipe should match top of pipe to top of pipe unless grade constraints prevent this.
4. Storm water pipes shall be designed utilizing the rational method or hydrograph method (based on sound hydrologic theory) for pipe. Channel design shall be hydrograph method only. All methods are subject to the City Engineer's approval.
5. Lateral systems should be designed for the 5-year rainfall using the rational method or some other comparable technique. State Aid roadway storm sewer should be designed for the 10-year event.
6. Trunk storm sewer should be designed to carry 100-year pond discharge in addition to the 5-year design flow for direct tributary areas.
7. For storms greater than the 5-year event, and in the case of plugged inlets, transient street ponding will occur. For safety reasons, the maximum depth should not exceed 2 feet at the deepest point and the lowest ground at adjacent building elevation should be at least 1.5 feet above the elevation to which water could rise before overflowing through adjacent overland routes.
8. To promote efficient hydraulics within manholes, manhole benching shall be provided to ½ diameter of the largest pipe entering or leaving the manhole.
9. Vaned grate catch basin castings shall be used on all streets. At low points alternate casting can be used with the approval of the City Engineer.
10. Sanitary sewer manholes that could be subject to temporary inundation, due to their proximity to ponds, channels, or roadway low points, should be equipped with watertight castings. Precautions should be taken during construction to prevent the entrance of stormwater into the sanitary sewer. When access is required at all times, sanitary manholes located near ponding areas should be raised above the 100-year high water level. If access is not required, water tight castings should be installed. Future storm drainage construction should include provisions for improving the water tightness of nearby sanitary sewer manholes. All newly constructed sanitary manholes in the vicinity of ponding areas and open channels should be waterproof.

Outlet and Inlet Pipes:

1. Inlet and outlet pipes of stormwater ponds should be extended to the pond normal water level whenever possible.
2. Outfalls with velocities greater than 4 feet per second (fps) into channels where the angle of the outfall to the channel flow direction is greater than 30 degrees require energy dissipation or stilling basins.
3. Outfalls with velocities of less than 4 fps that project flows downstream into a channel in a direction 30 degrees or less from the channel flow direction generally do not require energy dissipators or stilling basins, but do require rip rap protection.

4. In the case of discharge to channels, rip rap should be provided on all outlets to an adequate depth below the channel grade and to a height above the outfall or channel bottom. Rip rap should be placed over a suitably graded filter material and filter fabric to ensure that soil particles do not migrate through the rip rap and reduce its stability. Rip rap should be placed to a thickness at least 2.5 times the mean rock diameter so as to ensure that it will not be undermined or rendered ineffective by displacement. If rip rap is used as protection for overland drainage routes, grouting may be recommended.
5. Discharge velocity into a pond at NWL shall be 6 fps or less.
6. Where outlet velocities to ponds exceed 6 fps, the design should be based on the unique site conditions present. Submergence of the outlet or installation of a stilling basin approved by the City is required when excessive outlet velocities are experienced.

Channels and Overland Drainage:

1. Overland drainage routes where velocities exceed 6 fps should be reviewed by the City Engineer and approved only when suitable stabilization measures are proposed.
2. Open channels and swales are recommended where flows and small grade differences prohibit the economical construction of an underground conduit. Open channels and swales can provide infiltration and filtration benefits not provided by pipe.
3. Whenever possible, a minimum slope of 2% should be maintained in unlined open channels and overland drainage routes. Slopes less than 2% and greater than 1% are difficult to construct and maintain and may require an underdrain system. Slopes less than 1% are not allowed for lot drainage and channels designed primarily for conveyance.
4. Minimum grade for lot drainage swales and lot grading shall be 2% or greater.
5. Maximum length for drainage swales shall be 300 feet, or as approved by the City Engineer.
6. Channel side slopes should be a maximum of 4:1 (horizontal to vertical) with gentler slopes being desirable. Where space permits, slopes should be cut back to match existing grade.
7. Rock rip rap should be provided at all points of juncture between two open channels and where storm sewer pipes discharge into a channel.
8. The design velocity of an open channel should be sufficiently low to prevent erosion of the bottom. Rip rap or concrete liners should be provided in areas where high velocities cannot be avoided.
9. Periodic cleaning of an open channel is required to ensure that the design capacity is maintained. Therefore, all channels should be designed to allow easy access for equipment.

Ponds:

1. Storm water detention facilities constructed in the City of Bemidji shall be designed according to the standards reflected in the MPCA publication Protecting Water Quality in Urban Areas and the design criteria from the Minnesota Stormwater Manual. Water quality treatment will be designed and constructed to provide a water quality volume equivalent to the runoff from a 2.5-inch rainfall event, or the requirements of the NPDES construction site permit, whichever leads to higher treatment capacity. This runoff depth can be reduced by the amount of infiltration depth obtained from the site. For instance, if the runoff from the 2.5-inch event totals 1.25 inches and the 0.75-inch infiltration depth is met then the water quality volume needed becomes 0.5 inches.

2. Maximum allowed pond slopes are 4:1.
3. All constructed ponds and wetland mitigation areas shall have an aquatic of safety bench around their entire perimeter. The aquatic bench is defined as follows:
    a. Cross slope no steeper than 10:1
    b. Minimum width 10 feet
    c. Located from pond NWL to one foot below pond NWL
4. All constructed ponds shall be provided a maintenance access from an adjacent roadway. The maintenance access shall be provided in the form of an easement no narrower than 20 feet. The maintenance access shall have a longitudinal slope no steeper than 6:1 and minimal cross slope. Maintenance access routes, due to their extra width, also serve well as emergency overflow (EOF) routes.
5. All constructed ponds and wetland mitigation areas shall have a maintenance access bench around sufficient perimeter to provide access to all inlets and outlets. At a minimum the maintenance bench should extend around 50% of the basin perimeter. The maintenance bench should extend from NWL to 1 foot above NWL and its cross slope should be no steeper than 10:1. The maintenance bench shall connect to the maintenance access.
6. Elevation separations of buildings with respect to ponds, lakes, streams, and storm water features shall be designed as follows:
    a. The lowest ground elevation adjacent to homes and buildings must be a minimum of 2 feet above the calculated 100-yr HWL or 1.5 feet above the EOF, whichever criteria leads to the higher elevation.
    b. Landlocked lakes and wetlands require either 1) a five-foot separation between basin HWL and lowest ground elevation adjacent to building or 2) a three-foot separation between basin HWL for back to back 100-year storms and the lowest ground elevation adjacent to building or 3) 2-foot separation between the highest known or recorded basin elevation in the case of large wetlands and lakes and lowest ground elevation adjacent to building. Whichever of the three methods yields the highest allowable ground at building elevation should be the one used.
    c. Drainage easements for ponds, lakes, wetlands, streams etc. shall encompass an area to 1 foot (vertical) above the calculated 100-year HWL.
7. Maximum pond wet volume depth is 6 feet; minimum wet volume depth is 3 feet.
8. In airport runway clear zones maximum wet volume depth is 3 feet. In these areas other BMPs may be necessary to obtain the City’s required water quality performance.
9. Mean depth for water quality ponds should be 3 to 5 feet in areas outside airport runway clear zones. Mean depth is defined as the area at NWL divided by the wet volume.
10. Flood bounce is defined as the vertical difference between pond NWL and pond HWL. Flood bounce shall not exceed 6 feet except in the case of regional basins, as defined by the City Engineer.
11. All ponds shall have outlet skimming for up to the 2-year, 24-hour event.
12. All ponds shall be graded to 1 foot below design bottom elevation. This “hold down” allows sediment storage until such time as site restoration is complete.
13. The top berm elevation of ponds shall be a minimum of 1.5 feet above the 100-year pond HWL.
14. Grading shall not block or raise emergency overflows from adjoining properties unless some provision has been made for the runoff that may be blocked behind such an embankment.

15. Utilization of existing wetlands for storm water management is subject to review by the appropriate regulatory agency in accordance with the "Wetlands Conservation Act".
16. Restrict clearing and grading within 20 feet of an existing wetland boundary to provide for a protective buffer strip of natural vegetation.
17. Seeding around ponds shall be a native mix, as approved by the City Engineer.

3.3 PERFORMANCE MEASURES

Volume Management:

1. For development projects, the performance benchmark for runoff volume reduction is 0.75 inches off all new impervious surfaces. Allowable BMPs include:
   a. Infiltration benches adjacent to constructed ponds
   b. Rainwater gardens or infiltration areas separate from ponds such as depressed medians or grassed areas adjacent to parking lots and buildings
   c. Pervious pavement or pavers
   d. Vegetated swales
   e. Constructed wetlands
   f. Underground storage with infiltration
   g. Underground storage with water recycling for irrigation
   h. Green roofs
2. For redevelopment projects outside the Flexibility Area, volume management standards shall apply only to newly created impervious surfaces. Project proposers are encouraged to retrofit volume management BMPs for existing impervious surfaces.
3. For linear projects these standards shall apply only to newly created impervious surfaces.
4. For all infiltration calculations the following infiltration rates shall be assumed:
   Type A soils: 0.80 in/hr (sand, loamy sand, or sand loam)
   Type B soils: 0.30 in/hr (silt loam or loam)
   Type C soils: 0.20 in/hr (sandy clay loam)
   Higher infiltration rates from Minnesota Stormwater Manual table 12.INF.9 may be used if corresponding soil classifications can be demonstrated by borings or other soil testing.
5. Infiltration areas shall be designed to infiltrate water in 48 hours.
6. Infiltration areas shall not be constructed in karst or fractured bedrock areas, nor should they be constructed adjacent to steep slopes.
7. The volume management standard may be waived for small redevelopment projects where previous use has compacted the soil.
8. The volume management standard is waived in areas of known soil contamination or for developments where the potential for spills makes infiltration inadvisable.
9. Infiltration areas shall not have a 100-year design storm flood bounce that exceeds 3 feet.
10. Pretreatment, in the form of forebays or filter strips, shall be provided for all infiltration areas.
11. For infiltration benches adjacent to ponds the following standards apply:
    a. Benches shall have slopes no steeper than 6:1 over the proposed infiltration zone. A slope of 10:1 is preferred.
    b. Benches may be excavated and backfilled with sand or sandy topsoil to provide additional storage volume for infiltration without violating the 3 foot flood bounce requirement.

12. Porous pavement or pavers shall be considered pervious surface for the purposes of infiltration calculations.
13. Porous pavement or pavers are considered sufficient to infiltrate water off impermeable surfaces at a ratio of 5:1 (impermeable surface area to porous pavement area).

Rate Control:

1. Post development runoff rates shall not exceed 0.5 cfs/ac for the 100-year design event for residential development or 1.0 cfs/ac for high density residential or commercial development. In no case shall post development discharge rates exceed existing.
2. For linear projects post development runoff rates shall not exceed existing conditions.
3. For redevelopment projects in the Flexibility Area post development runoff rates shall not exceed existing. In redevelopment projects, project proposers must consider the feasibility of retrofitting some rate control to the redevelopment site.
4. For development projects less than 5 acres is size, the 0.5-cfs/ac residential rate control standard may sometimes be infeasible. In these instances the rate control target is at the discretion of the City Engineer but should not exceed existing conditions.

Water Quality:

1. The required water quality volume is the runoff generated by a 2.5-inch rainfall.
2. The amount of infiltration obtained is subtracted from the water quality volume.
3. Newly constructed ponds shall include an outlet design allowing for extended detention of the 1 year rainfall event. The hydrograph duration for pond discharge should extend a minimum of 12 hours for the 1 year event, as defined below.
4. The extended detention release rate is defined as that providing a 12-hour lag between the center of mass of the inflow hydrograph and that of the outflow hydrograph, for the 1-year rainfall (2.0 inches in 24-hours for the Bemidji area). Generally, when the peak outflow discharge is 5% of the peak inflow discharge this will be achieved. The following table provides some general guidance on allowable rates based on these discharge criteria.

Table 3.1
Extended Detention Discharge Rate

Land Use	1-year (2.0") SCS Type II, 24-hour Rainfall	
	Inflow Runoff Peak	Outflow Runoff Peak
	cfs/ac	cfs/ac
Low Density (35% impervious)	0.3	0.015
Commercial (70% impervious)	1.4	0.07

As a practical matter the extended detention discharge rate cannot be obtained on residential developments less than 25 acres unless some volume management is included.

4 CALCULATION EXAMPLES

Example 1

Proposed 25 acre commercial development on HSG Type D soils with 70% impervious surface. No volume management BMPs are proposed due to the poor soils. Volume management can also be precluded due to soil contamination, the potential for soil contamination, or excessive soil compaction due to previous uses on the site.

STEP 1: VOLUME MANAGEMENT CALCULATIONS

No volume management proposed.

STEP 2: INFILTRATION AREA SIZING

No volume management proposed.

STEP 3: WATER QUALITY VOLUME

The City requires a water quality volume equal to the runoff from the 2.5-inch event. Since volume management or infiltration is not proposed, it is assumed that all the water quality volume will occur in a pond through dead storage.

Runoff coefficient for impervious = 0.91
Runoff coefficient for pervious = 0.07

70% x 25ac x 0.91 x 2.5in x 1ft/12in	= 3.32 ac-ft = 144,519 ft^3
30% x 25ac x 0.07 x 2.5in x 1ft/12in	= 0.11 ac-ft = 4,764 ft^3
Total	= 3.43 ac-ft = 149,283 ft^3

STEP 4: EXTENDED DETENTION

To meet Bemidji's extended detention requirement, the 1-year rainfall outflow discharge rate should be 5% the inflow rate. The following HydroCAD pond sizing example demonstrates a design that accomplishes this for the 2.0-inch, 24-hour rainfall, which is considered the 1-year rainfall for Bemidji.

Summary for Pond 2P: Pond Area Example 1

```
Inflow Area =     25.000 ac,  Inflow Depth =  1.31"
Inflow      =     36.15 cfs @  12.12 hrs,  Volume=       2.739 af
Outflow     =      1.78 cfs @  14.18 hrs,  Volume=       2.738 af,  Atten= 95%,  Lag= 123.1 min
Primary     =      1.78 cfs @  14.18 hrs,  Volume=       2.738 af

Routing by Stor-Ind method, Time Span= 5.00-200.00 hrs, dt= 0.05 hrs
Starting Elev= 5.00'   Surf.Area= 0.500 ac   Storage= 2.000 af
Peak Elev= 8.00' @ 14.18 hrs   Surf.Area= 0.680 ac   Storage= 3.770 af   (1.770 af above start)
Plug-Flow detention time= 2,100.5 min calculated for 0.738 af (27% of inflow)
Center-of-Mass det. time= 881.4 min ( 1,701.4 - 820.0 )
```

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	6.150 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
0.00	0.300	0.000	0.000
5.00	0.500	2.000	2.000
10.00	0.800	3.250	5.250
11.00	1.000	0.900	6.150

Device	Routing	Invert	Outlet Devices
#1	Primary	4.00'	**21.0" x 100.0' long Culvert** Ke= 0.500 Outlet Invert= 3.00' S= 0.0100 '/' Cc= 0.900 n= 0.013
#2	Device 1	5.00'	**5.0" Vert. Orifice/Grate** C= 0.600
#3	Device 1	7.85'	**4.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=1.75 cfs @ 14.18 hrs HW=8.00' (Free Discharge)
↑—**1=Culvert** (Passes 1.75 cfs of 20.13 cfs potential flow)
  ↑—**2=Orifice/Grate** (Orifice Controls 1.10 cfs @ 8.0 fps)
  └—**3=Broad-Crested Rectangular Weir** (Weir Controls 0.65 cfs @ 1.1 fps)

Note that the inflow rate to the pond is 36.15 cfs and that the pond outflow rate is 1.78 cfs, or 4.9% the inflow rate, which is less than the 5% required and thus meets the extended detention requirement. Rate control for the 2.0-inch rainfall is accomplished by a 5-inch orifice.

The pond NWL = 5.00 feet in this example and $HWL_{2.0\ inches}$ = 8.00 feet. This elevation range is the extended detention volume. Note also that the center of mass detention time is 881 minutes which exceeds the desired 12 hours, or 720 minutes, so the 5% rule works for extended detention in this example.

Step 5: Rate Control Sizing

For commercial sites, Bemidji's rate control sizing requires that post development rate meet the natural or predevelopment conditions rate of 1.0 cfs/acre. The following HydroCAD pond sizing example shows detail on how this can be accomplished.

Summary for Pond 2P: Pond Area Example 1

[82] Warning: Early inflow requires earlier time span

Inflow Area = 25.000 ac, Inflow Depth > 4.10"
Inflow = 114.72 cfs @ 12.12 hrs, Volume= 8.551 af
Outflow = 19.80 cfs @ 12.63 hrs, Volume= 6.559 af, Atten= 83%, Lag= 30.9 min
Primary = 19.80 cfs @ 12.63 hrs, Volume= 6.559 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Starting Elev= 5.00' Surf.Area= 0.500 ac Storage= 2.000 af
Peak Elev= 10.99' @ 12.63 hrs Surf.Area= 1.148 ac Storage= 6.812 af (4.812 af above start)
Plug-Flow detention time= 230.7 min calculated for 4.543 af (53% of inflow)
Center-of-Mass det. time= 98.6 min (853.7 - 755.1)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	8.050 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
0.00	0.300	0.000	0.000
5.00	0.500	2.000	2.000
10.00	1.000	3.750	5.750
12.00	1.300	2.300	8.050

Device	Routing	Invert	Outlet Devices
#1	Primary	4.00'	**18.0" x 100.0' long Culvert** Ke= 0.500 Outlet Invert= 3.00' S= 0.0100 '/' Cc= 0.900 n= 0.013
#2	Device 1	5.00'	**5.0" Vert. Orifice/Grate** C= 0.600
#3	Device 1	7.85'	**4.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=19.80 cfs @ 12.63 hrs HW=10.99' (Free Discharge)
└─**1=Culvert** (Barrel Controls 19.80 cfs @ 11.2 fps)
  ├─**2=Orifice/Grate** (Passes < 1.58 cfs potential flow)
  └─**3=Broad-Crested Rectangular Weir** (Passes < 73.82 cfs potential flow)

The 19.8 cfs discharge equates to 0.8 cfs/ac, which meets the requirement that 100-year discharge be below 1.0 cfs/ac for commercial sites. The pond area at the 100-year HWL is 1.148 ac or 4.6% the total 25 acre site. Pond bounce, or the elevation difference between NWL and the 100-year HWL, is 5.99 feet.

Example 2

Proposed 25 acre residential development on HSG Type D soils. The assumed imperviousness is 35% (approximately 1/3 acre lots). No volume management BMPs are proposed due to the poor soils.

STEP 1: VOLUME MANAGEMENT CALCULATIONS

No volume management proposed.

STEP 2: INFILTRATION AREA SIZING

No volume management proposed.

STEP 3: WATER QUALITY VOLUME

The City requires a water quality volume equal to the runoff from the 2.5-inch event. Since volume management or infiltration is not proposed, it is assumed that all the water quality volume will occur in a pond through dead storage.

Runoff coefficient for impervious = 0.91
Runoff coefficient for pervious = 0.07

35% x 25ac x 0.91 x 2.5in x 1ft/12in	= 1.66 ac-ft = 72,260 ft^3
65% x 25ac x 0.07 x 2.5in x 1ft/12in	= 0.24 ac-ft = 10,323 ft^3
Total	= 1.90 ac-ft = 82,583 ft^3

STEP 4: EXTENDED DETENTION

To meet Bemidji's extended detention requirement, the 1-year rainfall outflow discharge rate should be 5% the inflow rate. The following HydroCAD pond sizing example demonstrates a design that accomplishes this for the 2.0-inch, 24-hour rainfall, which is considered the 1-year rainfall for Bemidji.

Summary for Pond 2P: Pond Area Example 2

```
Inflow Area =     25.000 ac,  Inflow Depth =  0.32"
Inflow      =      6.44 cfs @  12.17 hrs,  Volume=        0.667 af
Outflow     =      0.26 cfs @  22.51 hrs,  Volume=        0.667 af,  Atten= 96%,  Lag= 620.1 min
Primary     =      0.26 cfs @  22.51 hrs,  Volume=        0.667 af

Routing by Stor-Ind method, Time Span= 5.00-200.00 hrs, dt= 0.05 hrs
Starting Elev= 5.00'   Surf.Area= 0.270 ac   Storage= 1.100 af
Peak Elev= 6.34' @ 22.51 hrs   Surf.Area= 0.359 ac   Storage= 1.521 af   (0.421 af above start)
Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= 968.7 min ( 1,885.1 - 916.4 )
```

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	3.275 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
0.00	0.170	0.000	0.000
5.00	0.270	1.100	1.100
10.00	0.600	2.175	3.275

Device	Routing	Invert	Outlet Devices
#1	Primary	4.00'	**12.0" x 100.0' long Culvert** Ke= 0.500 Outlet Invert= 3.00' S= 0.0100 '/' Cc= 0.900 n= 0.013
#2	Device 1	5.00'	**3.0" Vert. Orifice/Grate** C= 0.600
#3	Device 1	6.50'	**4.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=0.26 cfs @ 22.51 hrs HW=6.34' (Free Discharge)
└─**1=Culvert** (Passes 0.26 cfs of 4.48 cfs potential flow)
  ├─**2=Orifice/Grate** (Orifice Controls 0.26 cfs @ 5.3 fps)
  └─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

The inflow rate to the pond is 6.44 cfs and that the pond outflow rate is 0.26 cfs, or 4.0% the inflow rate, which is less than the 5% required and thus meets the extended detention requirement. Rate control for the 2.0-inch rainfall is accomplished by a 3-inch orifice.

The pond NWL = 5.00 feet in this example and the $HWL_{2.0\ inches}$ = 6.34 feet. The volume between these elevations is by definition the extended detention volume.

Note also that the center of mass detention time is 968.7 minutes which exceeds the desired 12 hours, or 720 minutes, so extended detention is accomplished by this design by using the 5% rule as guidance.

STEP 5: RATE CONTROL SIZING

For residential sites, Bemidji's rate control sizing requires that post development rate meet the natural or predevelopment conditions rate of 0.5 cfs/acre. The following HydroCAD pond sizing example shows detail on how this can be accomplished.

Summary for Pond 2P: Pond Area Example 2

Inflow Area = 25.000 ac, Inflow Depth > 2.23"
Inflow = 67.00 cfs @ 12.13 hrs, Volume= 4.638 af
Outflow = 12.02 cfs @ 12.69 hrs, Volume= 4.073 af, Atten= 82%, Lag= 33.3 min
Primary = 12.02 cfs @ 12.69 hrs, Volume= 4.073 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Starting Elev= 5.00' Surf.Area= 0.270 ac Storage= 1.100 af
Peak Elev= 9.96' @ 12.69 hrs Surf.Area= 0.597 ac Storage= 3.249 af (2.149 af above start)
Plug-Flow detention time= 184.4 min calculated for 2.963 af (64% of inflow)
Center-of-Mass det. time= 68.3 min (870.5 - 802.1)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	3.275 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
0.00	0.170	0.000	0.000
5.00	0.270	1.100	1.100
10.00	0.600	2.175	3.275

Device	Routing	Invert	Outlet Devices
#1	Primary	4.00'	**15.0" x 100.0' long Culvert** Ke= 0.500 Outlet Invert= 3.00' S= 0.0100 '/' Cc= 0.900 n= 0.013
#2	Device 1	5.00'	**3.0" Vert. Orifice/Grate** C= 0.600
#3	Device 1	6.50'	**4.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=12.02 cfs @ 12.69 hrs HW=9.96' (Free Discharge)
└1=**Culvert** (Barrel Controls 12.02 cfs @ 9.8 fps)
 ├2=**Orifice/Grate** (Passes < 0.52 cfs potential flow)
 └3=**Broad-Crested Rectangular Weir** (Passes < 85.30 cfs potential flow)

The 12.0 cfs discharge equates to 0.5 cfs/ac, which meets the requirement that 100-year discharge be below 0.5 cfs/ac for residential sites. The pond area at the 100-year HWL is 0.597 ac or 2.4% the total 25 acre site. Pond bounce, or the elevation difference between NWL and the 100-year HWL, is 4.96 feet.

Example 3

Proposed 25 acre commercial development on HSG Type B soils with 70% impervious surface. Volume management requirements apply since the site's soils are suitable for infiltration.

STEP 1: VOLUME MANAGEMENT CALCULATIONS

Volume management calculations are based on the abstraction volume (Av) calculated as follows:

Av = 0.75 in x 0.70 x 25 ac = 13.1 ac-in

STEP 2: INFILTRATION AREA SIZING

Type B soils: 0.30 in/hr
Runoff must be infiltrated in 48 hours

For all impervious:
(13.1 ac-in)/(0.30 in/hr x 48 hr) = 0.91 ac infiltration area

The infiltration area for the roof and parking impervious must have 13.1 ac-in volume over a 0.91 ac footprint. Average depth is approximately 1 foot. If depth to groundwater allows some of the 13.1 ac-in volume could be obtained within the pore spaces of an infiltration trench backfilled with sand.

STEP 3: WATER QUALITY VOLUME

Per the performance criteria for water quality volume, when the City's infiltration standard is met the water quality volume requirement is reduced by the infiltration depth obtained – in this example 0.75 inches. For this example we will assume the balance of the water quality volume is obtained through dead storage in a traditional stormwater pond.

Runoff coefficient for impervious = 0.91
Runoff coefficient for pervious = 0.07

70% x 0.91 x 2.5in = 1.59 inches
30% x 0.07 x 2.5in = 0.05 inches
Total = 1.64 inches

Less Infiltration Volume = 0.75 inches
= Net Water Quality Volume = 0.89 inches

0.89 IN X 25AC X 1FT/12IN = 1.85 AC-FT = 80,768 FT^3

The 1.85 ac-ft of water quality volume beyond what is provided for in infiltration design can occur in a couple ways. If a centralized infiltration area is used the water quality volume would be the dead storage in a water quality pond upstream of the infiltration area. In a disperse infiltration area the water quality volume can occur in forebays upstream of these infiltration areas or in filtration strips around or within the infiltration practice. A pubic domain water quality model such as P8 can be used to relate filtration to the water quality volume through calculation of TSS removal. Additionally, infiltration in excess of the 0.75-inch requirement may be used in lieu of water quality volume obtained through dead storage as long as the infiltration areas are protected by filter strips of vegetation.

STEP 4: EXTENDED DETENTION

To accomplish Bemidji's Extended Detention requirement, the outflow discharge rate should be 5% the inflow rate. The following HydroCAD pond sizing example demonstrates a design that accomplishes this for the 2.0-inch, 24-hour rainfall, which is considered the 1-year rainfall for Bemidji. In this example we conceive a three-cell stormwater management pond with a dead storage pond discharging to an infiltration area. For flood events both the dead storage pond and the infiltration area discharge to a rate control cell. For the extended detention portion of this example just the infiltration area and rate control portion of the pond are used. The discharge rate is determined in two steps 1) from the infiltration area to the rate control pond and 2) from the rate control pond through its outlet.

1. Infiltration Area to the Rate Control Pond

Summary for Pond 3P: Infiltration Area

Inflow Area = 25.000 ac, Inflow Depth = 1.31"
Inflow = 36.15 cfs @ 12.12 hrs, Volume= 2.739 af
Outflow = 5.16 cfs @ 12.74 hrs, Volume= 2.739 af, Atten= 86%, Lag= 37.2 min
Discarded = 0.18 cfs @ 9.10 hrs, Volume= 1.487 af
Primary = 4.98 cfs @ 12.74 hrs, Volume= 1.251 af

Routing by Stor-Ind method, Time Span= 5.00-200.00 hrs, dt= 0.05 hrs
Peak Elev= 9.25' @ 12.74 hrs Surf.Area= 1.210 ac Storage= 1.510 af
Plug-Flow detention time= 1,476.4 min calculated for 2.738 af (100% of inflow)
Center-of-Mass det. time= 1,477.4 min (2,297.3 - 820.0)

Volume	Invert	Avail.Storage	Storage Description
#1	8.00'	2.420 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
8.00	1.210	0.000	0.000
10.00	1.210	2.420	2.420

Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**0.150 in/hr Exfiltration over Surface area**
#2	Primary	9.00'	**15.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Discarded OutFlow Max=0.18 cfs @ 9.10 hrs HW=8.02' (Free Discharge)
└**1=Exfiltration** (Exfiltration Controls 0.18 cfs)

Primary OutFlow Max=4.97 cfs @ 12.74 hrs HW=9.25' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 4.97 cfs @ 1.3 fps)

2. From Rate Control Pond Through Its Outlet

Summary for Pond 2P: Pond Area Example 3

```
Inflow Area =      25.000 ac,  Inflow Depth =   0.60"
Inflow      =       4.98 cfs @   12.74 hrs,  Volume=          1.251 af
Outflow     =       1.52 cfs @   15.27 hrs,  Volume=          1.251 af,  Atten= 69%,  Lag= 151.5 min
Primary     =       1.52 cfs @   15.27 hrs,  Volume=          1.251 af

Routing by Stor-Ind method, Time Span= 5.00-200.00 hrs, dt= 0.05 hrs
Starting Elev= 5.00'   Surf.Area= 0.500 ac   Storage= 2.000 af
Peak Elev= 5.89' @ 15.27 hrs   Surf.Area= 0.553 ac   Storage= 2.468 af   (0.468 af above start)
Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= 303.3 min ( 1,250.5 - 947.2 )
```

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	6.150 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
0.00	0.300	0.000	0.000
5.00	0.500	2.000	2.000
10.00	0.800	3.250	5.250
11.00	1.000	0.900	6.150

Device	Routing	Invert	Outlet Devices
#1	Primary	4.00'	**21.0" x 100.0' long Culvert** Ke= 0.500 Outlet Invert= 3.00' S= 0.0100 '/' Cc= 0.900 n= 0.013
#2	Device 1	5.00'	**9.0" Vert. Orifice/Grate** C= 0.600
#3	Device 1	7.85'	**4.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=1.52 cfs @ 15.27 hrs HW=5.89' (Free Discharge)
└─**1=Culvert** (Passes 1.52 cfs of 11.66 cfs potential flow)
  ├─**2=Orifice/Grate** (Orifice Controls 1.52 cfs @ 3.4 fps)
  └─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Note that the inflow rate to the pond is 36.15 cfs and that the pond outflow rate is 1.52 cfs, or 4.2% the inflow rate, which is less than the 5% required and thus follows the extended detention sizing guidance. Rate control for the 2.0-inch rainfall is accomplished by a 9-inch orifice. The extended detention volume extends from a NWL = 5.00 feet to a $HWL_{2.0inches}$ = 5.89 feet.

STEP 5: RATE CONTROL SIZING

For commercial sites, Bemidji's rate control sizing requires that post development rate meet the natural or predevelopment conditions rate of 1.0 cfs/acre. The following HydroCAD pond sizing example shows detail on how this can be accomplished.

Summary for Pond 2P: Pond Area Example 3

```
Inflow Area =      25.000 ac,  Inflow Depth >  3.60"
Inflow     =    104.43 cfs @  12.12 hrs,  Volume=         7.505 af
Outflow    =     24.77 cfs @  12.53 hrs,  Volume=         6.939 af,  Atten= 76%,  Lag= 24.7 min
Primary    =     24.77 cfs @  12.53 hrs,  Volume=         6.939 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 9.67' @ 12.53 hrs   Surf.Area= 1.914 ac   Storage= 3.281 af
Plug-Flow detention time= 87.6 min calculated for 6.915 af (92% of inflow)
Center-of-Mass det. time= 61.0 min ( 830.4 - 769.4 )

Volume      Invert    Avail.Storage   Storage Description
  #1         5.00'        4.000 af    Custom Stage Data (Prismatic) Listed below (Recalc)

 Elevation      Surf.Area        Inc.Store       Cum.Store
   (feet)         (acres)      (acre-feet)     (acre-feet)
     5.00          0.500           0.000           0.000
     9.00          0.700           2.400           2.400
    10.00          2.500           1.600           4.000

Device   Routing       Invert   Outlet Devices
  #1     Primary        4.00'   21.0"  x 100.0' long Culvert   Ke= 0.500
                                Outlet Invert= 3.00'  S= 0.0100 '/'  Cc= 0.900  n= 0.013
  #2     Device 1       5.00'   9.0" Vert. Orifice/Grate   C= 0.600
  #3     Device 1       6.00'   4.0' long  x 0.5' breadth Broad-Crested Rectangular Weir
                                Head (feet)  0.20  0.40  0.60  0.80  1.00
                                Coef. (English)  2.80  2.92  3.08  3.30  3.32

Primary OutFlow  Max=24.77 cfs @ 12.53 hrs  HW=9.67'   (Free Discharge)
└─1=Culvert  (Barrel Controls 24.77 cfs @ 10.3 fps)
   ├─2=Orifice/Grate  (Passes < 4.41 cfs potential flow)
   └─3=Broad-Crested Rectangular Weir  (Passes < 93.50 cfs potential flow)
```

The 24.77 cfs discharge equates to 1.0 cfs/ac, which meets the requirement that 100-year discharge be below 1.0 cfs/ac for commercial sites. The pond area at the 100-year HWL is 1.914 acres and conceptually this includes the infiltration area and dead storage pretreatment upstream of the infiltration area. For the same site without infiltration a 1.148 acre footprint was calculated (4.6% the total 25 acre site). The 1.914 acre footprint here is 7.6% the development site. With berming between the three pond cells total area dedicated to stormwater management becomes 2.5 acres, or 10% of the site. Pond bounce, or the elevation difference between NWL and the 100-year HWL, is 4.67 feet.

Bemidji

Stormwater Guidelines for Land Development

City of Bemidji

January 2008

Project Number: 001908-06001-0

Bonestroo

DESIGN STANDARDS

SUBMITTAL REQUIREMENTS

All grading, erosion control, and site restoration work should be done in accordance with the most recent additions of the Mn/DOT Standard Specifications for Highway Construction and two Minnesota Pollution Control Agency publications: Protecting Water Quality in Urban Areas and the Minnesota Stormwater Manual.

For site development and construction activities over one acre in size (that require a NPDES permit) the project submittals – be they design plans, project memoranda, stormwater management plans, etc. – must demonstrate stormwater management and erosion and sediment control techniques that meet the City's standards as outlined here. The following describe the City of Bemidji's expectations for these submittals:

1. The project proposer shall obtain all regulatory agency permits and approvals necessary for the proposed construction (i.e., DNR, Army Corp. of Engineers, MPCA, etc.).
2. Contact information for the engineering firm, developer, and owner.
3. Date of submittal.
4. Legal description of property.
5. Show City of Bemidji project number on the Plan, if applicable.
6. Signature of company responsible for erosion and sediment control plan preparation, implementation and maintenance.
7. Show all erosion control measures.
8. Note on the plans that all erosion control measures to be installed by the contractor should be inspected by the City prior to any site work.
9. A location map indicating the vicinity of the site.
10. Two-foot contour information extending a minimum of 200 feet beyond the property boundary that shows features such as buildings, structures, walls, trees, fences etc. and any hydrologic features such as wetlands, ponds, lakes, and streams that are wholly or partially encompassed by the project perimeter.
11. Two-foot contour information shall include the following:
    a. Existing contours
    b. Proposed contours
    c. Contour labeling
12. Directional arrows to indicate the site and lot drainage directions.
13. Details on existing wetlands, lakes, streams, etc.
    a. Normal Water elevation (NWL) and 100-year design storm High Water Level (HWL).
    b. Ordinary high water level, if available, for wetlands within the site.
    c. Whether waterbodies are DNR protected.
    d. Wetland delineations for wetlands on the site.

14. Information on individual lots including:
    a. Type of structure (i.e., walkout or rambler).
    b. Lowest ground elevation adjacent to building, first floor, basement walkout and lookout window threshold elevations.
    c. Existing and proposed lot corner spot elevations.
    d. Proposed mid-point side lot spot elevations.
    e. Proposed spot elevations at any high points or drainage breaks.
    f. Proposed spot elevations where drainage swales intersect lot lines.
    g. Proposed spot elevations where drainage and utility easements intersect with lot lines.
    h. The benchmark utilized for elevation determination.
15. All easements and outlots existing and proposed.
16. All adjacent plats, parcels, property lines, section lines, streets, existing storm drains and appurtenances, and underground utilities (public and private).
17. Grading and clearing limits; details of topsoil removal, topsoil stockpiling and topsoil respreading.
18. Delineation of existing vegetative cover.
19. Description of types of vegetation that will be removed and installed with the project.
20. Existing and proposed shoreline buffer strips.
21. Quantification of amount of excavation within shore impact zone and outside shore impact zone.
22. Quantification of existing and proposed impervious surfaces.
23. Drawings showing existing and proposed drainage boundaries, including watersheds contributing runoff from off-site.
24. Emergency Overflow (EOF) elevations and directions of flow for all street and rear yard catch basins, parking areas, ponds, wetlands, lakes, streams, swales, etc.
25. Maintenance access for stormwater ponds and other BMPs that will require periodic inspection and maintenance by City staff. Show or define access routes for maintenance purposes to all inlets or outlets at ponding areas.
26. Identify aquatic bench and maintenance bench as defined in the design guidance.
27. Existing and proposed storm sewer, catch basins, manholes, and pumping stations with invert, slope and ground elevations noted.
28. Existing and proposed BMPs including volume management, water quality, and water quantity BMPs.
29. Soils map or boring reports to verify assumptions regarding infiltration capacity.
30. Hydrologic and hydraulic calculations for the 1-year, 10-year, and 100-year 24-hour (Type II distribution) rainfall events.
31. In the case of landlocked basins hydrologic and hydraulic calculations should also include back to back 100-year, 24-hour rainfalls, and the 7.2-inch runoff event.
32. Drainage calculations to verify the sizing of pipe, ponds, emergency overflow spillways, and catch basin spacing.
33. Calculations or plan notes that indicate proposed pond wet volumes, extended detention volumes, and flood storage volumes.
34. Calculations showing infiltration sizing and credits sought.

35. The project proposer, upon the completion of the construction of a designated ponding area, is required to submit an as-built record plan certifying that the pond constructed meets all design parameters as set forth in the reviewed and approved pond plans.

DESIGN REQUIREMENTS

Storm Sewer:

1. Manhole spacing should not exceed 400 feet.
2. Where more than one pipe enters a structure, a catch basin/manhole should be used.
3. Storm sewer pipe should match top of pipe to top of pipe unless grade constraints prevent this.
4. Storm water pipes shall be designed utilizing the rational method or hydrograph method (based on sound hydrologic theory) for pipe. Channel design shall be hydrograph method only. All methods are subject to the City Engineer's approval.
5. Lateral systems should be designed for the 5-year rainfall using the rational method or some other comparable technique. State Aid roadway storm sewer should be designed for the 10-year event.
6. Trunk storm sewer should be designed to carry 100-year pond discharge in addition to the 5-year design flow for directly tributary areas.
7. For storms greater than the 5-year event, and in the case of plugged inlets, transient street ponding will occur. For safety reasons, the maximum depth should not exceed two feet at the deepest point and the lowest ground at adjacent building elevation should be at least 1.5 feet above the elevation to which water could rise before overflowing through adjacent overland routes.
8. To promote efficient hydraulics within manholes, manhole benching shall be provided to ½ diameter of the largest pipe entering or leaving the manhole.
9. Vaned grate catch basin castings shall be used on all streets. At low points alternate casting can be used with the approval of the City Engineer.
10. Sanitary sewer manholes that could be subject to temporary inundation, due to their proximity to ponds, channels, or roadway low points, should be equipped with watertight castings. Precautions should be taken during construction to prevent the entrance of stormwater into the sanitary sewer. When access is required at all times, sanitary manholes located near ponding areas should be raised above the 100-year high water level. If access is not required, water tight castings should be installed. Future storm drainage construction should include provisions for improving the water tightness of nearby sanitary sewer manholes. All newly constructed sanitary manholes in the vicinity of ponding areas and open channels should be waterproof.

Outlet and Inlet Pipes:

1. Inlet and outlet pipes of stormwater ponds should be extended to the pond normal water level whenever possible.
2. Outfalls with velocities greater than 4 feet per second (fps) into channels where the angle of the outfall to the channel flow direction is greater than 30 degrees require energy dissipation or stilling basins.
3. Outfalls with velocities of less than 4 fps that project flows downstream into a channel in a direction 30 degrees or less from the channel flow direction generally do not require energy dissipators or stilling basins, but do require rip rap protection.

4. In the case of discharge to channels, rip rap should be provided on all outlets to an adequate depth below the channel grade and to a height above the outfall or channel bottom. Rip rap should be placed over a suitably graded filter material and filter fabric to ensure that soil particles do not migrate through the rip rap and reduce its stability. Rip rap should be placed to a thickness at least 2.5 times the mean rock diameter so as to ensure that it will not be undermined or rendered ineffective by displacement. If rip rap is used as protection for overland drainage routes, grouting may be recommended.
5. Discharge velocity into a pond at NWL shall be 6 fps or less.
6. Where outlet velocities to ponds exceed 6 fps, the design should be based on the unique site conditions present. Submergence of the outlet or installation of a stilling basin approved by the City is required when excessive outlet velocities are experienced.

Channels and Overland Drainage:

1. Overland drainage routes where velocities exceed 6 fps should be reviewed by the City Engineer and approved only when suitable stabilization measures are proposed.
2. Open channels and swales are recommended where flows and small grade differences prohibit the economical construction of an underground conduit. Open channels and swales can provide infiltration and filtration benefits not provided by pipe.
3. Whenever possible, a minimum slope of 2% should be maintained in unlined open channels and overland drainage routes. Slopes less than 2% and greater than 1% are difficult to construct and maintain and may require an underdrain system. Slopes less than 1% are not allowed for lot drainage and channels designed primarily for conveyance.
4. Minimum grade for lot drainage swales and lot grading shall be 2% or greater.
5. Maximum length for drainage swales shall be 300 feet, or as approved by the City Engineer.
6. Channel side slopes should be a maximum of 4:1 (horizontal to vertical) with gentler slopes being desirable. Where space permits, slopes should be cut back to match existing grade.
7. Rock rip rap should be provided at all points of juncture between two open channels and where storm sewer pipes discharge into a channel.
8. The design velocity of an open channel should be sufficiently low to prevent erosion of the bottom. Rip rap or concrete liners should be provided in areas where high velocities cannot be avoided.
9. Periodic cleaning of an open channel is required to ensure that the design capacity is maintained. Therefore, all channels should be designed to allow easy access for equipment.

Ponds:

1. Storm water detention facilities constructed in the City of Bemidji shall be designed according to the standards reflected in the MPCA publication Protecting Water Quality in Urban Areas and the design criteria from the Minnesota Stormwater Manual. Water quality treatment will be designed and constructed to provide a water quality volume equivalent to the runoff from a 2.5-inch rainfall event, or the requirements of the NPDES construction site permit, whichever leads to higher treatment capacity. This runoff depth can be reduced by the amount of infiltration depth obtained from the site. For instance, if the runoff from the 2.5-inch event totals 1.25 inches and the 0.75-inch infiltration depth is met then the water quality volume needed becomes 0.5 inches.

2. Maximum allowed pond slopes are 4:1.
3. All constructed ponds and wetland mitigation areas shall have an aquatic of safety bench around their entire perimeter. The aquatic bench is defined as follows:
   a. Cross slope no steeper than 10:1
   b. Minimum width 10 feet
   c. Located from pond NWL to one foot below pond NWL
4. All constructed ponds shall be provided a maintenance access from an adjacent roadway. The maintenance access shall be provided in the form of an easement no narrower than 20 feet. The maintenance access shall have a longitudinal slope no steeper than 6:1 and minimal cross slope. Maintenance access routes, due to their extra width, also serve well as emergency overflow (EOF) routes.
5. All constructed ponds and wetland mitigation areas shall have a maintenance access bench around sufficient perimeter to provide access to all inlets and outlets. At a minimum the maintenance bench should extend around 50% of the basin perimeter. The maintenance bench should extend from NWL to 1 foot above NWL and its cross slope should be no steeper than 10:1. The maintenance bench shall connect to the maintenance access.
6. Elevation separations of buildings with respect to ponds, lakes, streams, and storm water features shall be designed as follows:
   a. The lowest ground elevation adjacent to homes and buildings must be a minimum of two feet above the calculated 100-yr HWL or 1.5 feet above the EOF, whichever criteria leads to the higher elevation.
   b. Landlocked lakes and wetlands require either 1) a five-foot separation between basin HWL and lowest ground elevation adjacent to building or 2) a three-foot separation between basin HWL for back to back 100-year storms and the lowest ground elevation adjacent to building or 3) two-foot separation between the highest known or recorded basin elevation in the case of large wetlands and lakes and lowest ground elevation adjacent to building. Whichever of the three methods yields the highest allowable ground at building elevation should be the one used.
   c. Drainage easements for ponds, lakes, wetlands, streams etc. shall encompass an area to one foot (vertical) above the calculated 100-year HWL.
7. Maximum pond wet volume depth is 6 feet, minimum wet volume depth is 3 feet.
8. In airport runway clear zones maximum wet volume depth is 3 feet. In these areas other BMPs may be necessary to obtain the City's required water quality performance.
9. Mean depth for water quality ponds should be 3 to 5 feet in areas outside airport runway clear zones. Mean depth is defined as the area at NWL divided by the wet volume.
10. Flood bounce is defined as the vertical difference between pond NWL and pond HWL. Flood bounce shall not exceed 6 feet except in the case of regional basins, as defined by the City Engineer.
11. All ponds shall have outlet skimming for up to the 2-year, 24-hour event.
12. All ponds shall be graded to one-foot below design bottom elevation. This "hold down" allows sediment storage until such time as site restoration is complete.
13. The top berm elevation of ponds shall be a minimum of 1.5 feet above the 100-year pond HWL.
14. Grading shall not block or raise emergency overflows from adjoining properties unless some provision has been made for the runoff that may be blocked behind such an embankment.

15. Utilization of existing wetlands for storm water management is subject to review by the appropriate regulatory agency in accordance with the "Wetlands Conservation Act".
16. Restrict clearing and grading within 20 feet of an existing wetland boundary to provide for a protective buffer strip of natural vegetation.
17. Seeding around ponds shall be a native mix, as approved by the City Engineer.

PERFORMANCE MEASURES

Volume Management:

1. For development projects, the performance benchmark for runoff volume reduction is 0.75 inches off all new impervious surfaces. Allowable BMPs include:
    a. Infiltration benches adjacent to constructed ponds
    b. Rainwater gardens or infiltration areas separate from ponds such as depressed medians or grassed areas adjacent to parking lots and buildings
    c. Pervious pavement or pavers
    d. Vegetated swales
    e. Constructed wetlands
    f. Underground storage with infiltration
    g. Underground storage with water recycling for irrigation
    h. Green roofs
2. For redevelopment projects outside the Flexibility Area, volume management standards shall apply only to newly created impervious surfaces. Project proposers are encouraged to retrofit volume management BMPs for existing impervious surfaces.
3. For linear projects these standards shall apply only to newly created impervious surfaces.
4. For all infiltration calculations the following infiltration rates shall be assumed:
   Type A soils: 0.80 in/hr (sand, loamy sand, or sand loam)
   Type B soils: 0.30 in/hr (silt loam or loam)
   Type C soils: 0.20 in/hr (sandy clay loam)
   Higher infiltration rates from Minnesota Stormwater Manual table 12.INF.9 may be used if corresponding soil classifications can be demonstrated by borings or other soil testing.
5. Infiltration areas shall be designed to infiltrate water in 48 hours.
6. Infiltration areas shall not be constructed in karst or fractured bedrock areas, nor should they be constructed adjacent to steep slopes.
7. The volume management standard may be waived for small redevelopment projects where previous use has compacted the soil.
8. The volume management standard is waived in areas of known soil contamination or for developments where the potential for spills makes infiltration inadvisable.
9. Infiltration areas shall not have a 100-year design storm flood bounce that exceeds 3 feet.
10. Pretreatment, in the form of forebays or filter strips, shall be provided for all infiltration areas.
11. For infiltration benches adjacent to ponds the following standards apply:
    a. Benches shall have slopes no steeper than 6:1 over the proposed infiltration zone. A slope of 10:1 is preferred.
    b. Benches may be excavated and backfilled with sand or sandy topsoil to provide additional storage volume for infiltration without violating the 3 foot flood bounce requirement.

12. Porous pavement or pavers shall be considered pervious surface for the purposes of infiltration calculations.
13. Porous pavement or pavers are considered sufficient to infiltrate water off impermeable surfaces at a ratio of 5:1 (impermeable surface area to porous pavement area).

Rate Control:

1. Post development runoff rates shall not exceed 0.5 cfs/ac for the 100-year design event for residential development or 1.0 cfs/ac for high density residential or commercial development. In no case shall post development discharge rates exceed existing.
2. For linear projects post development runoff rates shall not exceed existing conditions.
3. For redevelopment projects in the Flexibility Area post development runoff rates shall not exceed existing. In redevelopment projects, project proposers must consider the feasibility of retrofitting some rate control to the redevelopment site.
4. For development projects less than 5 acres is size, the 0.5-cfs/ac residential rate control standard may sometimes be infeasible. In these instances the rate control target is at the discretion of the City Engineer but should not exceed existing conditions.

Water Quality:

1. The required water quality volume is the runoff generated by a 2.5-inch rainfall.
2. The amount of infiltration obtained is subtracted from the water quality volume.
3. Newly constructed ponds shall include an outlet design allowing for extended detention of the 1 year rainfall event. The hydrograph duration for pond discharge should extend a minimum of 12 hours for the 1 year event, as defined below.
4. The extended detention release rate is defined as that providing a 12-hour lag between the center of mass of the inflow hydrograph and that of the outflow hydrograph, for the 1-year rainfall (2.0 inches in 24-hours for the Bemidji area). Generally, when the peak outflow discharge is 5% of the peak inflow discharge this will be achieved. The following table provides some general guidance on allowable rates based on these discharge criteria.

Extended Detention Discharge Rate

Land Use	1-year (2.0”) SCS Type II, 24-hour Rainfall	
	Inflow Runoff Peak	Outflow Runoff Peak
	cfs/ac	cfs/ac
Low Density (35% impervious)	0.3	0.015
Commercial (70% impervious)	1.4	0.07

As a practical matter the extended detention discharge rate cannot be obtained on residential developments less than 25 acres unless some volume management is included.