Sewer Rehabilitation

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Reduction of inflow and infiltration (I/I) of sanitary sewer by repair or replacement. Reduction of private connections to storm sewers by rehabilitation. Opportunity to install new storm conveyance system elements during storm sewer rehabilitation.

Replacement of sewer infrastructure

Related WWFMPs: Inflow and infiltration controls for sanitary sewers including downspout disconnection and foundation drain disconnection. For storm sewers, exfiltration system, downspout disconnection, oil/grit separators as inlet or conveyance system controls, and catch basin controls. Cross connection evaluation and control methods also apply here. Basement flood control methods. Sewer and catch basin cleaning and maintenance programs. Sewer flushing.

Description: Repair or replacement of sewer infrastructure to improve function or retain structural integrity. Generally practised for sanitary sewers to control inflow and infiltration to reduce flow to the sewage treatment plant and/or control basement flooding. Inflow refers to water flowing into the sanitary sewer during wet weather through direct connections to downspouts or surface connections through manhole covers. Infiltration flows generally occur after rain events are over and are basically groundwater. Rainfall induced infiltration can occur where surface drainage gains access to foundation drains connected to the sewer.

The first step in an evaluation program is to identify inflow and infiltration problems through examination of flow records at sewage treatment plants and in major sewer interceptors. Next individual sewers should be examined by visual inspection either manually or with television cameras to locate cracked and broken pipes and private connections. Basement flooding records can locate areas where I/I problems may exist (however, the source of the inflows may be far removed from the flooding areas).

Sewer rehabilitation methods include complete sewer replacement to replacing or repairing catch basins, manhole repair, and replacement of manhole covers. Many technologies are available for relining sewers and repairing and replacing sewers without digging up the street (trenchless technologies). Storm sewer rehabilitation is carried out often in conjunction with road repair and replacement. The need for storm sewer rehabilitation is often identified through surface flooding problems or structural deficiencies discovered by visual examination of the sewer.

Application Requirements: For sanitary sewers, the methods would be applied based on the existence of excessive wet weather flows at the sewage treatment plant, structural integrity problems or basement flooding. Municipalities have a duty to maintain infrastructure in good operating condition. Due diligence through active inspection programs and sewer rehabilitation will avoid problems caused by collapsed sewers such as flooding and sewer back-ups.

Proven Effectiveness / Experience Elsewhere: All municipalities rehabilitate sewers based on need.

Cost Considerations: The report "Existing Sewer Evaluation and Rehabilitation (1983, ASCE Manual 62, WPCF MOP FD-6) describes a cost curve for determining the degree to which sanitary sewers should be rehabilitated. This is based on establishing the savings from sewage treatment and conveyance (pumping) of excess I/I flows, compared to the cost for rehabilitation.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	X
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	X

Opportunities Considerations:

- Sanitary sewer rehabilitation options for addressing basement flooding problems will be extensively reviewed and quantitatively analyzed. Generally, the extent of I/I problems will be established by review of flow records at Toronto sewage treatment plants. I/I controls through sewer rehabilitation will be evaluated through program review.
- Storm sewer rehabilitation opportunities will be established through program review, with the assessment of performance based on combined quantitative assessment and program review.

References:

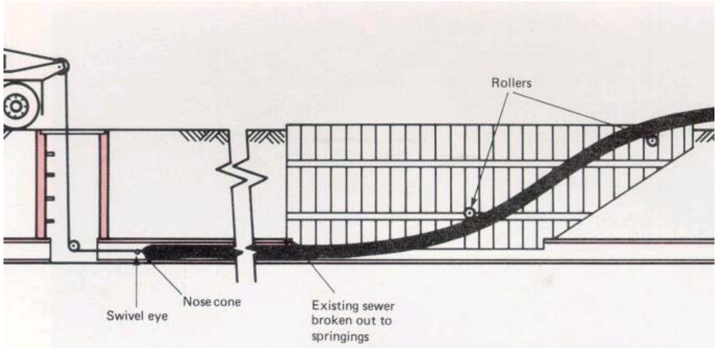
- Existing Sewer Evaluation & Rehabilitation. ASCE Manual of Practice No. 62 and WEF Manual of Practice FD-6, 1983.
- Handbook-Sewer System Infrastructure Analysis and Rehabilitation, EPA/625/6-91/030, 1991.

Sewer Rehabilitation – Lining Technologies

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Reduce Infiltration

Related WWFMPs: All other sewer rehabilitation methods



Continuous sliplining

Description: *Cured-in-Place Pipe*
The cured-in-place pipe (CIPP) lining process is a completely trenchless sewer rehabilitation technique. A flexible resin-coated fabric lining is inserted through an existing manhole, and inverted under water pressure. Circulating hot water then cures the lining, and it forms a tight seal with the existing pipe. Once the lining is completely cured, side sewers, service connections and laterals are easily located and reopened.

Swagelining/Rolldown Deformed Pipe
These are two very similar processes in which the diameter of a polyethylene (PE) liner pipe is reduced prior to insertion into the damaged host pipe. The processes use rollers and a swagelining machine, respectively, and reduce the diameter by 10-15%. Both processes use high pressure to expand the liner pipe once installed, forming a tight fit between it and the host pipe. After the liner is installed and expanded, side sewers, service connections and laterals are easily located and reopened.

Fold-and form Pipe
The fold-and-form process uses high-density polyethylene (HDPE) or polyvinyl chloride (PVC) pipes folded into a “U”-shape for easy insertion into the damaged sewer. The liner pipe can either be extruded in a folded form, or extruded in circular form and folded using a thermomechanical process. Once inserted, steam or hot water heats and pressurizes the liner, expanding it until it fits against the existing host pipe. After the liner is installed and expanded, side sewers, service connections and laterals are easily located and reopened.

Continuous Sliplining
Sliplining is a well-established method of trenchless rehabilitation. The process involves inserting a new pipe (of smaller diameter) inside the damaged pipe, and grouting the annular area between the pipes to prevent leakage and provide structural integrity.

High-Density Polyethylene (HDPE), polybutylene (PB) and fibreglass-reinforced polyester (FRP) pipes are normally used for continuous-pipe sliplining. The pipe sections are welded together, and the continuous pipe is drawn through the damaged sewer, with a nose cone attached to the leading end of the pipe. The nose cone serves as a point of attachment for the winch cable that pulls the pipe, and also to prevent snagging during the installation process. Small-diameter pipes (less than approximately 600mm) can be welded together on the surface and inserted through a lead-in trench. Larger diameter pipes and deep installations usually require the welding to take place in the bottom of the insertion trench, which requires more excavation. Once the new pipe is installed, side sewers, service connections and laterals are reconnected.

One disadvantage of these technologies is the reduced cross-sectional area of the new pipe, which usually means that capacity is reduced. In some cases, however, this loss in area of flow is offset by the decreased roughness coefficient of the new pipe.

Application Requirements:

Cured-in-Place Pipe

- This process can be used in pipes of diameter ranging from 100mm to 2400mm.
- Depending on size, 900m of CIPP can easily be installed from a single insertion, though curing can be difficult and lengthy for long pipe sections.
- Installing a CIPP liner requires absolutely no excavation.
- CIPP liners can be manufactured to suit many sewer shapes.
- CIPP liners can accommodate small deformations (up to approximately 10%), and can easily follow bends in the sewer.
- Flow bypass or diversion is required for this operation, and sufficient time must be allowed for the curing process.

Swagelining/Rolldown Deformed Pipe

- This process can be used in pipes of diameter ranging from 50mm to 600mm.
- Continuous sections of up to 300m can be installed.
- An insertion trench is required. These are therefore not completely trenchless technologies, but the amount of excavation required is considerably less than traditional dig-and-replace method. These techniques are therefore generally much less expensive than complete replacement.
- Flow bypass or diversion is required for this operation.

Fold-and form Pipe

- This process can be used in pipes of diameter ranging from 50mm to 450mm.
- Depending on the diameter, continuous sections of up to 1500m can be installed.
- Installing a fold-and-form liner requires absolutely no excavation.
- Flow bypass or diversion is required for this operation.

Continuous Sliplining

- This process can be used in pipes of diameter ranging from 100mm to 1600mm, although it is not well suited for small-diameter pipes.
- The maximum installation length is 300m.
- The flexibility of the materials used for this operation allows negotiation of large-radius bends in the sewer.
- Flow bypass pumping may be required for this operation, however the speed of the installation process mitigates this cost. The annular space between the host pipe and the new pipe can be used to convey low levels of flow during the sliplining process, but care should be taken to prevent rags and solids from lodging in the annulus, which would be detrimental to the grouting process.
- Insertion trenches are required since manholes are not large enough to pass the new pipe down into the existing sewer. Sliplining is therefore not a completely trenchless technology, but the amount of excavation required is considerably less than traditional dig-and-replace method. Sliplining is therefore generally much less expensive than complete replacement.

Proven Effectiveness/Experience Elsewhere: Municipalities across North America have used the lining technologies as part of their sewer rehabilitation projects, and have been successful in reducing I/I typically between 50-80%. I/I removal rates will vary depending on the material and condition of the pipe, local soil type, groundwater flow, and other site-specific conditions.

Cost Considerations: There are many factors that will ultimately affect the overall cost of lining technologies. Among them are: sewer length, sewer diameter, flow diversion costs, traffic diversion costs, number of connections, amount of excavation required, and sewer preparation.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunity identification is typically based upon structural and service condition ratings, determined through closed-circuit television (CCTV) inspection of sewer lines.
- Opportunities can also be identified through I/I quantity assessments, based upon flow monitoring data.
- The age of a sewer installation *may be* an initial indicator of pipe condition.

References:

- O'Brien and Gere Companies, Website: "WhitePaper: Trenchless (http://www.obg.com/InfoCentre)".
- United States Environmental Protection Agency (USEPA), Collection Systems O&M Fact Sheet: "Trenchless Sewer Rehabilitation", USEPA, 1999.
- Water Environment Federation (WEF) and American Society of Civil Engineers(ASCE), "Existing Sewer Evaluation and Rehabilitation" (Second Edition), WEF/ASCE, 1994.
- Water Research Centre (WRc), "Sewerage Rehabilitation Manual" (Second Edition), WRc, 1990.

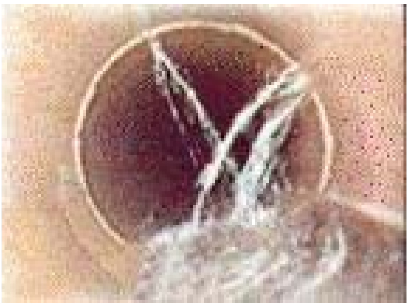
Sewer Rehabilitation – Internal Grouting

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Reduce Infiltration

Related WWFMPs: All other sewer rehabilitation methods

Description: Internal (chemical) grouting is the most popular rehabilitation method for structurally sound pipe networks. It is usually performed in conjunction with root removal in order to decrease infiltration and restore sewer capacity. Typically, the grout is pressure-injected through small joints and cracks in the pipe into the surrounding soil where it cures.



Pipe before internal grouting

While grouting can be the least expensive rehabilitation method initially, it is not considered a long-term repair. Also, depending on temperature and soil conditions, the grout may shrink and become ineffective.

Pipe after internal grouting

Application Requirements:
- This process can be used in pipes of all sizes (person-entry is not a requirement).
- Flow bypass pumping or diversion is required for this operation.
- Offset joints and longitudinal cracks cannot be grouted.
- Grouting does not restore the structural strength of the sewer pipe.

Proven Effectiveness/Experience Elsewhere: Municipalities across North America have used internal grouting as part of their sewer rehabilitation projects, and have been successful in reducing I/I typically between 50-80%. I/I removal rates will vary depending on the material and condition of the pipe, local soil type, groundwater flow, and other site-specific conditions.

Cost Considerations: The costs involved with grouting are highly variable, and depend primarily on the structural condition of the sewer. Length and width of cracks are not the only factors, however, since the grout is injected under pressure into the surrounding soil. If infiltration has been occurring for a long time, more soil will have been eroded and washed into the sewer, which will require a greater volume of grout to fill the void.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification is typically based upon structural and service condition ratings, determined through closed-circuit television (CCTV) inspection of sewer lines.
- Opportunities can also be identified through I/I quantity assessments, based upon flow monitoring data.
- The age of a sewer installation *may be* an initial indicator of pipe condition.

References:

- O'Brien and Gere Companies, Website: "WhitePaper: Trenchless (http://www.obg.com/InfoCentre)".
- Water Environment Federation (WEF) and American Society of Civil Engineers(ASCE), "Existing Sewer Evaluation and Rehabilitation" (Second Edition), WEF/ASCE, 1994.
- Water Research Centre (WRc), "Sewerage Rehabilitation Manual" (Second Edition), WRc, 1990.

Manhole Rehabilitation – Non-Structural

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Reduce Infiltration

Related WWFMPs: Sewer Rehabilitation Technologies

Manhole Rehabilitation

Description: Defective manholes can contribute a significant portion of inflow and infiltration (I/I) in sewer systems. It is therefore important to properly maintain manholes in order to keep this to a minimum. The rehabilitation methods presented here do not provided structural reinforcement, and therefore should not be used for badly deteriorated or structurally unsound manholes.

Spot repairs, which are not a long-term solution, are quick to perform and are relatively inexpensive. They are effective in eliminating infiltration without excavation. A variety of chemical grouts and mortar products are available for these applications.

Cementitious coatings (portland cement by-products or calcium aluminates) can also be used to prevent leaks, but they too will degrade over time, especially in corrosive environments. These coatings can be sprayed or trowelled onto the entire interior surface of the manholes. Some product mixtures can be applied using radial spray guns, meaning that workers need not even enter the manholes.

In highly corrosive environments, another option is a chemical coating like epoxies or polyureas. These coatings provide an infiltration barrier that is more resistant to corrosion than cementitious coatings. They can be used alone, or as a corrosion-resistant topcoat to a cementitious coating.

Application Requirements: These processes can generally be used in all manholes, though some are better suited than others based on soil type, groundwater conditions, and corrosion potential.

Proven Effectiveness/Experience Elsewhere: Municipalities across North America undertaken manhole rehabilitation as part of I/I reduction strategies, as manholes commonly account for 25-30% of system-wide infiltration. I/I removal rates will vary depending on the material and condition of the manhole, local soil type, groundwater flow, and other site-specific conditions.

Cost Considerations: The costs involved with spot repairs and grouting are highly variable, and depend primarily on the degree of degradation in the manhole. Length and width of cracks are not the only factors, however, since the grout is injected under pressure into the surrounding soil. If infiltration has been occurring for a long time, more soil will have been eroded and washed into the sewer, which will require a greater volume of grout to fill the void.

Chemical coating is typically 20% more expensive than cementitious coating.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification is typically based upon structural and service condition ratings, determined through visual inspection of manholes and appurtenances.
- Opportunities can also be identified through I/I quantity assessments, based upon flow monitoring data.
- The age of a sewer installation *may be* an initial indicator of the condition of the manholes.

References:

- O'Brien and Gere Companies, Website: "WhitePaper: Trenchless (http://www.obg.com/InfoCentre)".
- Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE), "Existing Sewer Evaluation and Rehabilitation" (Second Edition), WEF/ASCE, 1994.
- Water Research Centre (WRc), "Sewerage Rehabilitation Manual" (Second Edition), WRc, 1990.

Sewer Replacement

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanisms: Reduce Infiltration. Increase Capacity

Related WWFMPs: Capacity increase

Description: *Pipe Bursting* (or in-line expansion) is a form of trenchless sewer replacement. This process can be used to replace damaged sewer pipes with new ones of equal or slightly greater diameter. The process involves fracturing the existing pipe, pushing the fractured pipe into the surrounding soil, and then inserting the new pipe (using a jack or a winch) into the enlarged hole.

Open cut sewer replacement

Open Cut
Complete sewer upgrading using the traditional "dig-and-replace" method is perhaps the most common method of upgrading existing sewer systems. It is a relatively simple operation and has very few limitations, but it is quite expensive and highly disruptive in downtown areas.

Application Requirements:
Pipe Bursting

- This process can be used in pipes of diameter ranging from 100mm to 600mm.
- The maximum installation length is 250m.
- Flow bypass pumping is required for this operation.
- Lateral connections should be excavated and disconnected prior to the bursting step.
- Working pits are required at each end of the operation. Pipe bursting is therefore not a completely trenchless technology, but the amount of excavation required is considerably less than traditional dig-and-replace method.
- Pipe bursting is a suitable method for replacing pipes made from brittle materials such as vitrified clay, unreinforced concrete, asbestos cement, some PVC, and cast iron.
- This method is not suitable for all soil types, as ground movement is possible during the bursting step.

Open Cut

- This process can be used in pipes of all sizes, and the installation length is unlimited.
- Flow bypass pumping is required for this operation.
- Dewatering is required where the groundwater table is above the pipe invert.

Proven Effectiveness/Experience Elsewhere: The pipe bursting method was developed in England in 1980, and has since become a well-recognized method of trenchless sewer replacement. When used to control I/I, pipe bursting is typically successful in reducing these levels by 50-80%. I/I removal rates will vary depending on the material and condition of the pipe, local soil type, groundwater flow, and other site-specific conditions.

Open cut sewer replacement is commonly performed in areas where the existing sewers are collapsed.

Cost Considerations: There are many factors that will ultimately affect the overall cost of installing a pipe-bursting project. Among them are; sewer length, sewer diameter, flow diversion costs, traffic diversion costs, number of connections, and the required depth of working pits.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:

- I/I Reduction:
    - Opportunity identification is typically based upon structural and service condition ratings, determined through closed-circuit television (CCTV) inspection of sewer lines.
    - Opportunities can also be identified through I/I quantity assessments, based upon flow monitoring data.
    - The age of a sewer installation *may be* an initial indicator of pipe condition.

- Capacity Increase:
    - Opportunity identification is typically based upon known hydraulic deficiencies, such as flooding.

References:

- O'Brien and Gere Companies, Website: "WhitePaper: Trenchless (http://www.obg.com/InfoCentre)".
- United States Environmental Protection Agency (USEPA), "Collection Systems O&M Fact Sheet: Trenchless Sewer Rehabilitation", USEPA, 1999.
- Water Environment Federation (WEF) and American Society of Civil Engineers(ASCE), "Existing Sewer Evaluation and Rehabilitation" (Second Edition), WEF/ASCE, 1994.
- Water Research Centre (WRc), "Sewerage Rehabilitation Manual" (Second Edition), WRc, 1990.

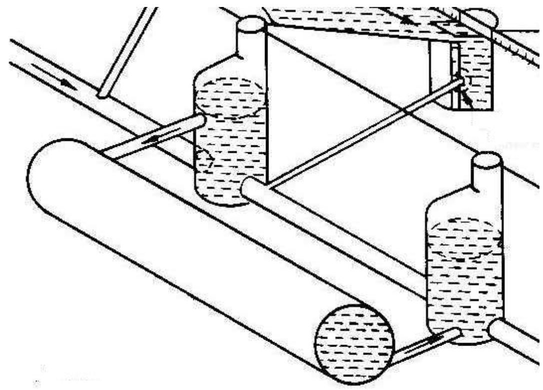
In-Line / Off-Line Storage

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanisms: Provide storage. Increase total conveyance capacity

Related WWFMPs: Sewer replacement

Description: In-line and off-line storage projects are often undertaken to regulate and moderate peak flows in locations where the capacity of a sewer is inadequate during high-flow events. These systems are generally installed as an alternative to upgrading an entire sewer system. Both the in-line and off-line systems incorporate a flow regulator and a large storage capacity, which serves to make optimal use of the downstream sewers.



Underground storage tank fills when system storage is full

The in-line storage unit is typically a large-diameter pipe (1500mm and above), which is installed into an existing sewer system. All flow through the system enters the device at its upstream end, and flows towards the regulator at the downstream end. Typically, this regulator is a simple orifice that is sized depending on the available pipe capacity downstream. Flow above this level is retained in the device until the after peak has passed, at which point the device begins to drain and flow in the sewer system returns to normal.

The off-line storage system uses a regulator to divert excessive flow out of the sewer system and into an off-line tank. The flow to the downstream pipe capacity proceeds undiverted up to a pre-determined rate, and flow above this rate passes through a regulator and into the tank. The tank provides storage until the flow rates in the sewer are below the downstream capacity, at which point the stored volume is slowly released back into the sewer. The outlet from the tank requires a slightly more sophisticated control device than the simple orifice used in in-line storage. An effective option is a flap gate, for example, which could be set to open as flow depth in the sewer drops. A superpipe is a type of in-line/off-line storage device specific to source control.

Application Requirements:

In-line Storage:

- Flow bypass pumping or diversion is required during installation of the device.
- The existing sewer must be deep enough that the obvert of the device remains below basement elevations while still allowing the device to drain by gravity. Proximity to an existing drop manhole provides an excellent opportunity for this application.
- This process is only viable where sufficient space exits for the large-diameter pipes. Installation under existing roads is not always possible due to the presence of other utilities.

Off-line Storage:

- Flow bypass pumping is not required when installing this system.

- Sufficient open space is needed near the sewer for installation of the underground tank. Parks and parking lots are ideal locations.

Proven Effectiveness/Experience Elsewhere: Both in-line storage and off-line storage have been used extensively across North America, as they are proven technologies. Locally, in-line storage has been used extensively in the former City of North York (Winston Park Boulevard and Neames Crescent are two examples of many projects that have been completed) and off-line storage tanks have been installed in former City of York.

Cost Considerations: Costs can vary significantly depending primarily on sewer depth and the presence of bedrock. Flow and traffic diversion costs also need to be considered.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunity identification for both in-line and off-line storage is typically based upon known hydraulic deficiencies, such as flooding. In-line storage can be applied where space exits for the large-diameter pipes. Land requirement can limit the application of off-line storage facilities, since they are typically constructed underground.

References:

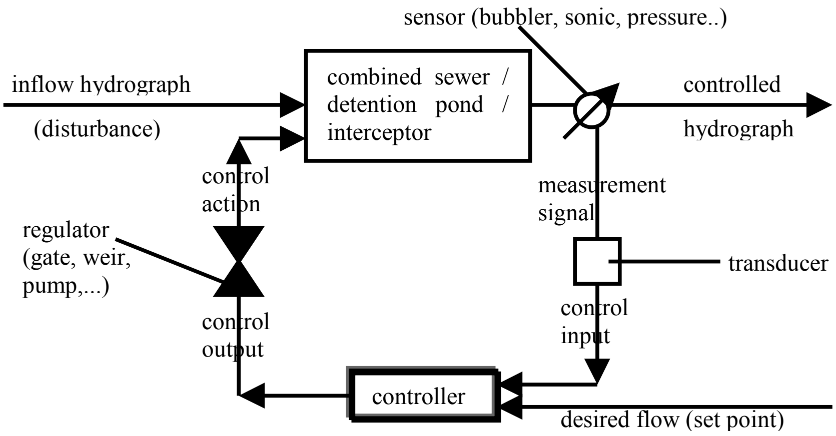
- United States Environmental Protection Agency (USEPA), “Combined Sewer Overflow Technology Fact Sheet: Retention Basins”, USEPA, 1999.
- WPCF, Combined Sewer Overflow Pollution Abatement, Manual of Practice No. FD-17, 1989.

Real Time Control

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Better utilization of existing collection system facilities

Related WWFMPs: Conveyance system capacity increase, in-line storage capacity increase.



Typical control loop in a combined sewer system

Description: The concept of Real Time Control (RTC) of sewer systems is based on the fact that most sewer systems are designed for a specific load which, in reality, rarely occurs. Instead, due to rainfall temporal and spatial variability, parts of the system remain under-utilized during a storm event, while some other parts may be overloaded and overflow. This static approach towards operation of sewer networks doesn't take advantage of the in-line storage that may exist. Under a RTC scenario, control structures are put in place, and flows are stored in, or diverted to parts of the sewer system where capacity is available during a rainfall event. Thus, the performance of the sewer system can be significantly improved by introducing on-line control.

Two modes of control that can be exercised over the behaviour of the sewer system: reactive and predictive (or anticipatory). In a reactive mode, the system is operated in response to its state as the storm progresses over the catchment. In predictive mode, the system is operated in response to the anticipated state of the system prior to the occurrence of rainfall event and in response to both the predicted and the actual state of the system once the event has started. In addition, two types of control can be distinguished: local and global. The local control relates to a single control point, where a regulator is controlled to maintain a certain set point. The global control relates to the total sewer system or the integrated system (sewer system, treatment plant and receiving water), where the set points of local regulators are found from a global control strategy and communicated to the local controllers. Modelling of the sewer system is required regardless of which type or mode of control is utilized.

Continuous models are most often employed in evaluating the set points under local type of control. The simulations are conducted under different set points, with an objective such as minimization of the number and/or volume of overflows, reduction of the "first flush" effect, maximization of storage utilization, equalization of inflows to the treatment plant and minimization of operation and maintenance costs. Under global control, the performance of the sewer system can be optimized mathematically with respect to certain control strategies. In order to do that, hydrologic/hydraulic models are most often used, along with the optimization models that typically include a simplified representation of the sewer system. The time in which the flows and water levels within the system can be predicted and the optimal strategy determined has to be relatively short, therefore allowing sufficient time for the required changes to the system to take place.

Application Requirements:
Both the potential and the limitations of RTC depend on catchment characteristics, sewer system configuration, available storage and loading variability. Large temporal and spatial variations of surface runoff and pollutant concentrations, low catchment slope, large storage volume (in-pipe and tanks), long flow times, existence of movable regulators, under-utilization of storage during overflows and significant operating costs are all indicators that RTC can potentially be used to solve operational problems. Small catchments with shallow sewers, drainage networks with high slope and little or no storage and, a small number of diversion points are all unfavorable for application of RTC.

Proven Effectiveness/Experience Elsewhere:
RTC has been applied successfully to numerous urban drainage systems throughout Europe and North America. Significant reductions in overflow frequency and volume have been reported for the existing applications of RTC, ranging from 20% to 75%.

Cost Considerations:
- Existing movable regulators can be retrofitted for local RTC applications without a major investment.

- A global RTC system requires a threshold investment for data transmission and a control center, and beyond that depends largely on the complexity of application (number of storage elements and control points).
- A predictive RTC system also requires rainfall prediction capabilities, which can add significant cost to the application.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:
- Factors that favour the use of RTC include: high spatial and temporal variation in surface runoff volume and quality, low catchment slope, existing control devices in the collection system, under-utilized storage during wet weather and significant pumping costs
- Reduction in overflows approximately equal to 1/8 of the existing storage volume (per event) can be expected with the use of RTC, based on existing applications

References:

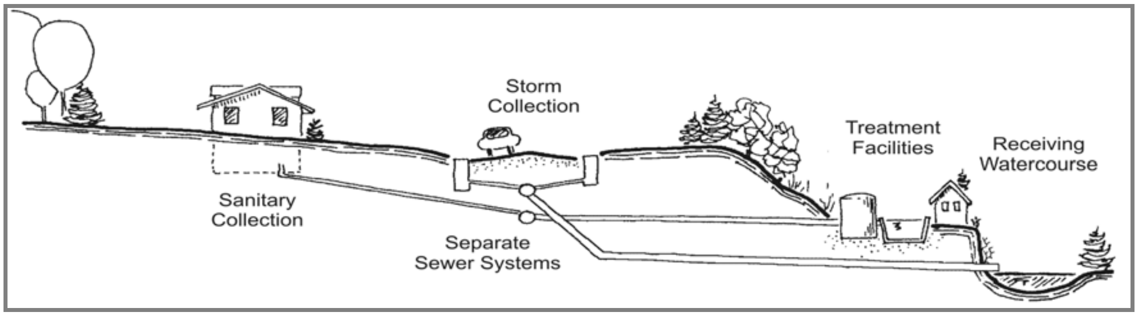
- Schilling, W. “Potential and Limitations of Real Time Control”, NATO Advanced Study Institute: Hydroinformatics Tools for Planning, Design, Operation and Rehabilitation of Sewer Systems, Harrachov, Czech Republic, 1996.

Sewer Separation

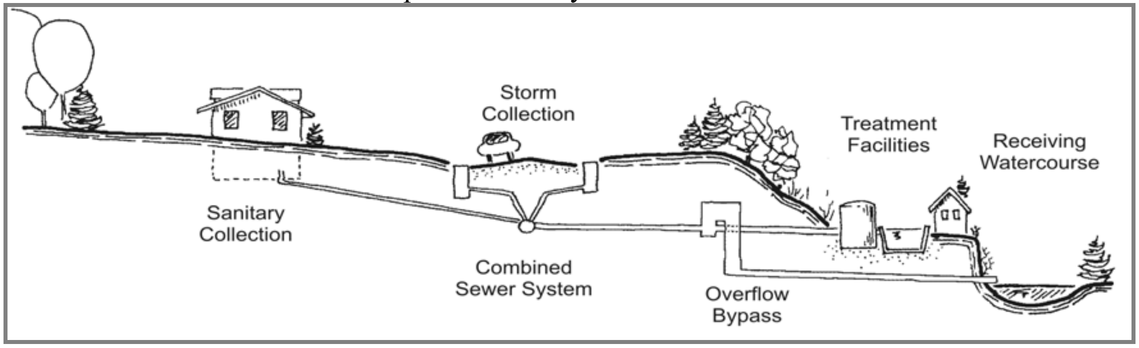
Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Separation of wet weather flows

Related WWFMPs: Partial sewer separation, full sewer separation



Separate sewer system schematic



Combined sewer system schematic

Description: Sewer systems that convey both sanitary sewage and storm water through a single pipe are referred to as combined sewer systems (CSSs). Generally, the CSS is able to convey all flows to the wastewater treatment facility. During periods of heavy rainfall, however, the capacity of the CSS is often exceeded, causing untreated combined sewage and storm water to back up into basements and to overflow onto streets. To prevent these occurrences, CSS outfalls are designed to discharge directly into receiving waters during combined sewer overflows (CSOs). However, CSOs cause problems in receiving waters with untreated domestic, industrial and commercial wastes, as well as storm water runoff. To alleviate the problems resulting from CSS the practice of sewer separation is widely applied not only to new drainage systems but also to existing combined sewers.

Sewer separation is the practice of separating the combined, single-pipe system into separate sewers for sanitary and storm water flows. The frequency and magnitude of sewer backup and overflow conditions are improved, but neither is completely eliminated. Furthermore, problems are routinely encountered with private connections and storm sewer pollution. The advantages of separation are that it can control basement flooding and sewer overflows, and it reduces treatment and conveyance requirements. However, it is capital cost-intensive and produces a high level of disruption during construction. Private connections and leaky sanitary sewers may leave significant wet weather problems from extraneous flows.

Partial Sewer Separation
A partially separated sewer system is defined as a system of sewers collecting wastewater and storm water from an area where some portion, but not all, of the storm water runoff is collected in a system of separate storm sewers. A partially separated sewer system is often the result of separating an existing combined system, or adding separated sewer areas to an existing combined system. Partial separation usually involves the construction of street storm sewers to take surface runoff with roof and foundation drains often left connected to the original combined sewers. There is a level of cost saving with sewer separation since the new storm sewer is installed at a shallow depth compared with a combined sewer, resulting in reduced excavation costs.

Full Sewer Separation
By definition, a separate system carries sanitary wastes and storm water runoff in separate conduits. A separate sanitary sewer may also carry minor quantities of ground, storm and surface water that are not admitted intentionally. Modern suburban development in most municipalities involves the installation of separate sewer systems for sanitary flow and storm water. In fact, combined sewers have not been installed in Ontario since 1956. There was a shift in the mid-1980s away from sewer separation as the only solution for solving flooding and overflow problems. However, sewer separation is still regarded as an important part of most storm water management plans. Unlike partial sewer separation, where some storm runoff is directed into the sanitary sewer (often the old combined sewer), with full separation all storm runoff is directed into the storm sewer system. For example, roof leaders and foundations drains that may have been connected to the combined system would instead be connected to the storm system. In some cases, roof leaders would be disconnected entirely and the storm water allowed to run off onto the property in the hope that some of it would infiltrate without ever reaching the storm sewer.

Application Requirements: Sewer separation can be considered wherever a combined sewer system exists. Past experience has indicated that sewer separation if often an appropriate technology in areas where one or more of the following conditions exist (EPA Office of Water, 1999):

- Most sewers are already separated
- Siting constraints and costs prohibit the use of other structural measures
- Uses and the assimilative capacities of receiving waters prohibit other CSO controls
- Other CSO strategies are not publicly acceptable
- Additional infrastructure improvements, such as road repaving, are also required
- The combined system is undersized
- Elimination of CSO is desired
- Other CSO measures are not able to achieve the community's goals

Proven Effectiveness/Experience Elsewhere: In general, very few combined sewers have been built in Ontario since 1950, and then only as extensions to existing combined systems. Sewer separation is an accepted means of reducing storm water management problems (e.g., basement flooding, inflow/infiltration, overflows, area flooding) in urban areas, although it by no means eliminates these problems. Modern suburban development in most municipalities involves the installation of separate sewer systems for sanitary flow and storm water.

In the 1960s the City of Toronto embarked on a 25-year sewer separation program. Existing combined sewers were converted to sanitary sewers and the newly installed pipes became the storm sewer system. In this case, only the surface drainage reaching the street gutters is conveyed to the new storm sewer system. Foundation drains and some roof downspouts previously connected to the combined sewer remained combined with the sanitary flows. Thus the newly created sanitary sewer system remains liable to storm water flows and therefore to overflows. Both the frequency and magnitude of sewer backup and sewer overflow conditions have improved, but have not been completely eliminated.

In 1970, an EPA-sponsored study recommended the discontinuance of sewer separation, in favour of developing pollution abatement programs related to the specific needs of individual combined and separate sewer areas. Sewer separation is still applied throughout the province, but the main thrust of storm water management strategies today is towards alternative technologies that address the specific requirements of particular drainage areas. The disfavour of sewer separation is partly due to the high cost and long time span for implementation and community disruption. Additionally, it has become apparent that separation in itself does not necessarily solve water quality problems associated with storm water overflows.

Sewer separation reduces and often eliminates untreated sanitary discharges from discharging into receiving water bodies, and therefore positively impacts receiving water quality. On the other hand, sewer separation increases untreated storm water discharges to the receiving water body. The performance achieved with sewer separation will depend on the existing storm water pollutant loading and the existing sanitary pollutant loading. A study performed for North Dorchester Bay, MA, estimated that the overall fecal coliform removal potentially achieved by sewer separation was only 45 percent. Actual fecal coliform removal rates have been determined for several sites where sewer separation has been implemented. For example, water quality monitoring in St. Paul and Minneapolis from 1976 to 1996 indicated a fecal coliform reduction of 70 percent. Another benefit of sewer separation is the return of wildlife to an area where it had been driven out.

Cost Considerations: The costs associated with sewer separation vary considerably due to the location and layout of existing sewers, the location of other utilities that will have to be avoided during construction, other infrastructure work that may be required, land uses and costs, and the construction method used. Simultaneous upgrading of infrastructure components can result in a much lower cost relative to upgrading them independently.

The cost of operation and maintenance (O&M) of the separated sewer system is difficult to predict. Factors contributing to the O&M costs include the age and the condition of the previously combined sewer, the length and diameter of the sewers, the frequency and the amount of sand and grit removed, and the size of the drainage areas. Sewer separation can reduce treatment and O&M costs at the receiving treatment plant by potentially eliminating storm water flows to the plant. Energy costs for transporting flows to the treatment plant could also be reduced due to the reduced flow volume.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic processes	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	X
12. Reduce sanitary sewer inflow and infiltration	X
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunities identification for this technology are based on the requirements of an existing combined or partially combined sewer system and the presence of foundation drains and downspouts connected to the combined system. Opportunities are also assessed by the condition of the roads and existing sewer pipes. Where road or sewer reconstruction is imminent, sewer separation is considered an attractive option. Finally, sewer separation should be seriously considered in areas where surface and/or basement flooding has occurred as a result of sewer surcharge.

References:

- Adams, B.J. and F. Papa. Urban Stormwater Management Planning. Toronto: Wiley, 2000.
- EPA Office of Water. “Combined Sewer Overflow Management Fact Sheet: Sewer Separation.” USEPA, 1999. Available: http://www.epa.gov/owm/mtb/sepa.pdf.

Stream Corridor Measures

WWFMP Type: Conveyance Control

Primary Mechanism: Limit Supply of Nutrients, Sediment; Stream Shading; Attenuate Stream Flow; Contribute to Instream Habitat Diversity and Food Supply

Vegetative plantings in the riparian corridor

Related WWFMPs: Erosion and sediment control, tree plantings, bank protection, stream corridor measures, grassed swales, channel reconstruction, retention ponds.

Description: *Stream Corridor Measures* are applied adjacent to the stream within its riparian zone, floodplain, valley slope or crest. They include *native vegetation plantings* (trees, shrubs, grasses and groundcovers), *access controls* (means to limit encroachment on the stream by livestock, vehicles, people), buffer treatments (grassed buffers, cover crops,) and *management practices* (use of "no spray" and "no mow" practices). These measures restore or mimic key functions of riparian corridors, and their success is directly related to the width and length of stream corridor that is successfully restored. A healthy, naturally vegetated stream corridor provides stream shading; controls the overland movement of water (hydrologic attenuation) and associated sediments, nutrients, contaminants; adds nutrients (from leaf litter) and woody debris to the stream providing food sources and habitat; helps to stabilize stream banks. In addition, stream corridors provide wildlife habitat and, depending on the width of the corridor, offer important linkages between other natural features (woodlands, wetlands) that promote dispersion/migration of plant and animal communities.

Application Requirements: To be applied primarily within the stream corridor. Has broad application, since measures have incremental benefits directly related to width and length of corridor protected. Implementation is very easy and can be accomplished through volunteers (has strong public appeal)

Natural Vegetation Plantings:
- Agricultural, parkland, new or redevelopment areas
- Requires limitations on other uses (i.e. active recreation, crop production)
- Published equations exist to estimate the water temperature decreases as a result of decreasing solar inputs due to plantings

Access Controls:
- Agricultural, parkland, new or redevelopment areas
- Depends on public education to be effective
- This alternative is not generally modelled

Buffer Treatments:
- Most applicable to agricultural areas
- Reduces the amount of land available for agricultural activities

- Typically modeled indirectly by reducing the concentration of water quality contaminants in surface runoff to reflect the pollutant removal characteristic of the buffer treatment

Management Practices:
- Agricultural, parkland, new or redevelopment areas;
- Depends on public education to be effective
- some conflicts with park users (noxious weeds, difficult access to stream edge)
- Typically modeled indirectly by reducing the concentration of water quality contaminants in surface runoff to reflect the pollutant removal characteristic of the management practice

Proven Effectiveness/Experience Elsewhere: Widespread acceptance that implementation is an effective means of restoring stream functions, however, performance difficult to measure directly. Performance depends on other characteristics of the stream corridor (slope, topography, soil types, water table, etc).

Natural Vegetative Plantings:
- Percent canopy / stream cover values to support a variety of aquatic resources (e.g. cold water fishery) have been determined
- Increasing natural vegetation plantings is in widespread use to benefit aquatic resources and monitoring indicates that it is effective

Access Controls:
- Restricting livestock access is generally viewed as effective at reducing sediment and bacteria loadings to streams. Performance data not generally available.
- Widespread use throughout Ontario

Buffer Treatments:
- Proven to reduce total suspended solids loading from agricultural areas from approximately 40 to 90 percent depending on the width of the buffer strip
- Widespread use throughout Ontario

Management Practices:
- Proven to reduce total suspended solids loading from agricultural
    - Widespread use throughout Ontario

Cost Considerations:
- Does not result in a loss of developable land because these techniques are applied within hazard lands and are protected by policies (e.g. Public Health and Safety, Policy 3.1, Stream and Valley Protection Policy).
- Cost of plant materials is relatively low, depending on size, labour costs can be supplement by volunteers
- In many instances can represent cost savings in terms of reducing normal maintenance activities
- Generally has high aesthetic value

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	X
5. Re-establish natural features	X
6. Virtual elimination of toxic contaminants using pollution prevention at source	X
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunities identification based on:
  - New development or redevelopment areas;
  - Physical implementation criteria;

- Matrix-type Opportunities Considerations by watershed (Step 3B in Assessment Process)

References:

- Brookes, Andrew and F. D. Shields (Editors), 1996, River Channel Restoration: Guiding Principles for Sustainable Projects, 433 p., John Wiley & Sons Ltd, West Sussex, England.
- Federal Interagency Stream Restoration Working Group, 1998, Stream Corridor Restoration: Principles, Processes, and Practices, U.S.D.A.
- Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado.

Channel Modification

WWFMP Type: Conveyance Control

Primary Mechanism: Modification of river behaviour through changes in channel/valley form

Related WWFMPs: System rehabilitation, softer engineering approach, vegetative buffer strips, tree plantings/urban forests, constructed wetlands, bank protection, stream corridor measures.

Examples: Natural channel restoration, stream meander restoration, slope re-grading, low flow channel restoration, floodplain restoration, valley wall protection, and maintenance of hydraulic connections.

Stream meander restoration

Description: *Channel Modification* here refers to changing channel and/or valley form by direct intervention to eliminate a disturbance that is causing stream instability. Modifications include changing the course of a river (i.e. *planform modification*), the channel dimensions (i.e. *channel and valley cross-section modification*), or the character of the channel (e.g. *roughness or thalweg modification*). *Planform modifications* can create a more stable channel in cases where the channel has been straightened or in cases that involve a change in upstream inputs (e.g. urbanization, deforestation). *Channel and valley cross-section modifications* can be engineered to increase stream stability. Floodplains can be created to relieve stress on the channel during flood flows for channels that have cut into their floodplain. This can be accomplished by infilling the bed of the incised channel or excavating a terrace into the floodplain. Channel *roughness* can be used to speed up or slow down flow within a channel and manage the flow characteristics. This involves changing the size and quantity of the rock and woody debris in the channel. In cases where the stream is very unstable or instream creation projects, all three measures may be required (i.e. planform, cross section, roughness). For sites where the disturbed state is not as advanced, only one or two of these measures may be required.

Application Requirements: To be applied primarily within the stream corridor. Difficult to apply where urban encroachment has occurred on the floodplain/valley. The alternatives are not generally modeled during watershed / subwatershed planning.

Planform modifications:
- Agricultural, parkland, new or redevelopment areas;
- Requires available land;
- Requires detailed modeling and geomorphic assessment;
- May require additional land.

Channel and valley cross-section modification:
- Must consider flood prone zone;
- Requires detailed modeling and geomorphic assessment;
- Must assess impacts to downstream reach;

Roughness and thalweg modifications:

- Requires detailed modeling and geomorphic assessment;
- Highly dependent on desired effect but principles of natural channel design to be followed;

All alternatives are in widespread use throughout Ontario. Channel modifications have been implemented on the Don River, Highland Creek and Humber River.

Proven Effectiveness/Experience Elsewhere:

Planform modifications:

- Effectiveness depends on the level of understanding of the system and degree of modification;
- Generally effective in restoring a self maintaining stable channel;
- Mostly applied to meandering channel systems (e.g. slopes < 2%)

Channel and valley cross-section modification:

- Effective in reducing the rate of channel activity;
- Failures typically occur if bankfull is set too low and frequent overtopping occurs;
- Failures in bed raising occur if the bed material is undersized;

Roughness and thalweg modifications:

- Modification of roughness by adding rock is a proven practice;
- Modification of roughness by adding woody debris practices but with more varied results;
- Pool:riffle and meander sequencing add flow resistance.

Cost Considerations:

- Cost is proportional to the amount of excavation and degree of contamination of the excavate;
- Costs can be minimal in restoration projects and large in creation projects;
- Typically does not result in a loss of developable land because the zones of application for these techniques exists within hazard lands and are protected by policies (e.g. Public Health and Safety, Policy 3.1, Stream and Valley Protection Policy).

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic process	X
5. Re-establish natural features	X
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
  - Land and space requirements;
  - Fisheries objectives;
  - Physical implementation criteria;

- Matrix-type Opportunities Considerations by watershed (Step 3B in Assessment Process)

References:

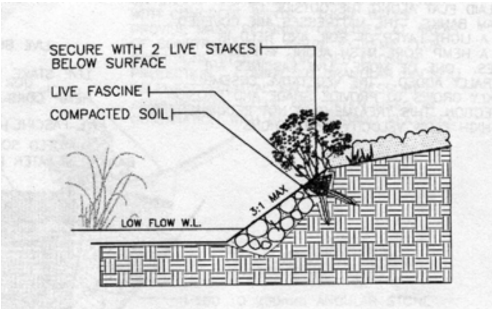
- Brookes, Andrew and F. D. Shields (Editors), 1996, River Channel Restoration: Guiding Principles for Sustainable Projects, 433 p., John Wiley & Sons Ltd, West Sussex, England.
- Federal Interagency Stream Restoration Working Group, 1998, Stream Corridor Restoration: Principles, Processes, and Practices, U.S.D.A.
- Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado.

Bank Protection

WWFMP Type: Conveyance Controls

Primary Mechanism: Modification of river behaviour through changes in bank character

Related WWFMPs: System rehabilitation, softer engineering approach, vegetative buffer strips, tree plantings/urban forests, constructed wetlands, bank protection, stream corridor measures.



Live fascine bank protection

Examples: Bank shaping and planting, branch packing, brush mattresses, coconut fibre roll, dormant post plantings, vegetated gabions, joint plantings, live cribwalls, live stakes, live fascines, log, rootwad, and boulder revetments, riprap, stone toe protection, tree revetments, vegetated geogrids.

Armourstone bank protection

Description: *Bank Protection* methods are used to slow down or arrest the movement of a stream to provide temporary or more permanent control. *Hard* bank protection measures tend to arrest stream movement and provide more permanent control. *Soft* bank protection measures permit stream movement, have less permanence, but strive for self-maintenance. Materials used in bank protection works include rock, brush, wood, and vegetation. *Soft* methods primarily use vegetation but *hard* methods use more rock, brush and wood.

Hard bank protection works may be required where site constraints do not allow movement of the stream or where this is the natural condition to be mimicked. Softer bank protection works may be applied where stream energy is lower and channel wandering is accepted.

Bank stabilization techniques include *Anchored Cutting Systems (bioengineering)*, *Geotextile Systems*, and *Integrated Systems*. Anchored cutting systems use large numbers of cuttings arranged in layers or bundles that are anchored to the stream bank. Geotextiles are used to retain soils and protect from direct erosion by water. *Geotextile systems* refers to the use of both fabrics and plantings to provide extra support. Biodegradable geotextiles are often used in softer, self maintaining designs. *Integrated systems* use numerous bank protection techniques together to achieve bank stability. Bank toe protection can include logs (natural or coir) and/or rock. Upper banks can be protected by a combination of Anchored Cuttings, and Geotextiles.

Application Requirements: To be applied within the stream corridor.
A site investigation and analyses of bank failure mechanism, flow and soils are required to determine the type of bank protection method to apply (e.g. soft – hard). Small low energy streams can be controlled by vegetation but large river systems require integration of rock, wood, brush and fabrics to provide adequate levels of control.

Consideration must be given to access, maintenance, urgency and availability of materials. Since these are prone to aggravating problems downstream, they require careful planning and design. Hydraulic modeling generally undertaken during design to ensure proposed design minimizes downstream impacts.

Proven Effectiveness/Experience Elsewhere: The degree of effectiveness of the technique is assessed by how well it achieves the project goals. The suitability and adequacy of the technique to provide the level of protection sought after depends largely on appropriate selection. Failure of bank protection measures typically occurs where the strength of the protection does not match the forces of the attack by the stream. This often results when attempts are made to contain flows that should dissipate on the floodplain, within the channel. Failure also often results because of undermining of the toe of bank. There are many cases where stream bank protection methods have provided long term protection and/or the stability required for ecological recovery.

Bank protection works are in widespread use throughout Ontario to protect property and / or to reduce instream erosion levels.

Cost Considerations:

- Cost is dependent on the type of system, availability of materials and amount of excavation required;
- Typically does not result in a loss of developable land because the zone of application for these techniques exists within hazard lands and are protected by policies (e.g. Public Health and Safety, Policy 3.1, Stream and Valley Protection Policy).

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic process	
5. Re-establish natural features	X
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:
- Opportunities identification based on:
  - Land and space requirements;
  - Fisheries objectives;
  - Physical implementation criteria;
- Matrix-type Opportunities Considerations by watershed (Step 3B in Assessment Process)

References:

- Brookes, Andrew and F. D. Shields (Editors), 1996, River Channel Restoration: Guiding Principles for Sustainable Projects, 433 p., John Wiley & Sons Ltd, West Sussex, England.
- Federal Interagency Stream Restoration Working Group, 1998, Stream Corridor Restoration: Principles, Processes, and Practices, U.S.D.A.
- Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado.

Roadside Ditches

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Infiltration

Related WWFMPs: Grassed swales, infiltration trenches

Roadside ditch to replace the traditional curb and gutter system

Description: Traditionally, road and lot drainage systems have been designed to convey storm runoff away as quickly as possible to reduce localized ponding. This approach to urban storm water drainage, using curb-gutter-sewer systems, has led to downstream flooding, erosion, water quality degradation, reduced groundwater recharge and stream basement, and aquatic habitat destruction. In many cases, alternative stormwater management practices are being considered to replace the traditional curb and gutter system. One alternative to the curb-gutter-sewer system is the roadside ditch.

Roadside ditches are channels, usually along both sides of a roadway, constructed to a design cross-section and grade. They are designed to convey runoff from impervious services and adjacent slopes and dispose of this concentrated surface runoff without damage from erosion, deposition or flooding. Roadside ditches are also designed to prevent the lengthy accumulation of standing water. There are three basic cross-section designs utilized with roadside ditches: parabolic, trapezoidal and v-shaped.

Ditches are visually similar to grassed swales, although they are not designed to promote infiltration. Instead, ditches are primarily used to convey storm water. For this reason, ditches are applicable in many areas that swales are not, such as where soil conditions do not promote infiltration. Another difference between the roadside ditches and grassed swales is that the ditches are deeper to permit the drainage of the road sub-grade.

Application Requirements:
Roadside ditches are most effectively applied where:

- Concentrated runoff will cause erosion damage
- Slopes are greater than two percent
- Continuous or prolonged flows occur
- Soils are erodible and soil properties are not suitable for handling concentrated flows
- Space is available for the channel cross-section

By comparison, the curb-gutter-sewer system can be applied in a wide variety of site conditions, although installation may not be as simple as for a roadside ditch.

Proven Effectiveness/Experience Elsewhere: Municipalities have a wide experience with curb-gutter-sewer systems. These systems are the drainage practice of choice for most situations. They do accomplish the main objectives of a storm water drainage system but they also create a number of environmental and economic problems.

Public perceptions vary regarding roadside ditches. Some urban residents view ditches as an eyesore, urging municipalities to replace them with a curb and gutter system. Other communities like the rural character of streets with roadside ditches and argue to maintain them when road reconstruction projects are undertaken.

Roadside ditches are very effective in reducing the peak flows during a storm runoff event, so that a smaller fraction of the storm water is allowed to enter the receiving body without treatment.

Cost Considerations: Capital costs and the frequency of various maintenance activities can vary from one municipality to another.

By comparison, the construction cost of a curb-gutter-sewer system is much greater than that of an open ditch. The cost of this type of drainage system is often transferred to the price of the lots, effectively burdening the individual home buyers with the cost of the drainage system. A recent study in Etobicoke found that the annual maintenance cost per unit length of curb-gutter-sewer roads was higher than that of ditch roads. Environmental damage caused by curb-gutter-sewer systems also requires substantial cleanup and other associated costs to the taxpayers. Furthermore, maintenance of curb and gutter systems can be difficult, costly and disruptive to local residents.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic processes	X
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunities identification for this technology are based on the presence of certain surface features, such as the type of land use (residential), the type of soil (erodable and not suitable for handling concentrated flows), ground topography (slopes greater than two percent), and the availability of space for the channel cross-section. In other words, a significant right-of-way on either side of a roadway is required for a roadside ditch. Opportunities are also identified by the condition of the roads and existing sewer pipes in an area. If roads and/or pipes are considered to require reconstruction in the next five years, retrofitting a street or subdivision with roadside ditches could be desirable.

References:

- J.F. Sabourin and Associates. “.Evaluation of Roadside Ditches and Other Related Stormwater Management Practices.” The Toronto and Region Conservation Authority, 1998.

Grassed Swales

WWFMP Type: Conveyance Control

Primary Mechanism: Infiltration or filtration

Related WWFMPs: Roadside ditches, backyard swales, roof-leader disconnection, reduced lot grading, soak-away pits, vegetative filter strips, lot level depressions.

Grass swale for water conveyance and treatment

Description: The curb-gutter-sewer system is the drainage and conveyance system currently favoured by many municipalities. It has long been used in urban centres, but more recently it has been gaining acceptance in newer residential subdivisions, industrial parks and other low-density developments in more rural municipalities in southern Ontario. These are areas where alternative technologies, which tend to utilize more land, could be used.

It is well known that the standard curb and gutter system effectively achieves the main functions of a road drainage system; namely, the efficient conveyance of storm water away from the surface and the prevention of the lengthy accumulation of standing water. However, the system's efficiency also contributes to a variety of environmental and economic problems, including a lack of pretreatment, reduction of groundwater recharge, soil erosion, safety hazards and operational problems, and high capital and maintenance costs. Generally, if a curb and gutter system is to be considered as a storm water conveyance control, it should be used in tandem with other storm water control technologies. An example of an alternative storm water technology is grassed swales.

Grassed swales are broad, shallow channels with dense of vegetation covering the side slopes and bottom. Swales can be natural or man-made, and are design to trap particulate pollutants, promote infiltration, and reduce the flow velocity of storm water runoff. The flow depths are often below the height of the grass that grows within them. Some infiltration occurs through the underlying soil cover, but that is not the primary mode of treatment. Suspended solids are primarily removed by filtering through the vegetation and through settling. Dissolved constituents may also be removed through chemical or biological mechanisms mediated by the vegetation and the soil. Swales are also designed to reduce flow velocity of storm water runoff. Grassed swales are not effective and may even erode when flow volumes and velocities are high. Many local municipalities prohibit grassed swales if peak discharges exceed 140 L/s or if flow velocities are greater than 1 m/s. In these cases, alternative technologies should be considered.

In areas where the soils do not support good infiltration, grassed swales act as filters, removing coarse particulate and providing pre-treatment for downstream controls. As filters they do not contribute significantly to the hydrologic balance or to erosion control. Swales that rely on filtering rather than infiltration are generally much less effective as a pollutant removal control. Generally, filtration-only grassed swales are not recommended. Other storm water management practices should be considered. The main difference between grassed swales and roadside ditches is that swales are designed to promote infiltration while roadside ditches are simply designed to convey storm water.

The application of grassed swales is most useful when they are designed into the development form. In such designs, the grassed swale can be combined with easements for walkways, lanes or storm sewer infrastructure. Application in retro-fit and infill situations is typically not recommended because of the problems with existing drainage patterns, fencelines and the potential for communal disputes. In general, related options such as soak-away pits or lot level depressions (where the measure is confined to a single lot) are recommended in these situations.

Application Requirements: Grassed swales are primarily applicable for new or re-development residential areas with appropriate physical conditions. They are problematic for retro-fitting situations and infill because of land requirements and existing grading.

Infiltration:
- New or re-development area with pervious soils (minimum infiltration rate of 15 mm/hr)
- Bedrock and water table greater than one metre below bottom of swale
- Slope between 0.5 and 5 percent, ideally between 1 and 2 percent in the direction of flow

Filtration:
- New or re-development area with impervious soils (maximum infiltration rate of 15 mm/hr)
- Bedrock and water table greater than one metre below bottom of swale
- Slope between 0.5 and 5 percent, ideally between 1 and 2 percent in the direction of flow

Proven Effectiveness/Experience Elsewhere: Grassed swales have historically been associated with rural drainage and have been constructed primarily for stormwater conveyance. Stormwater management objectives are changing and grassed swales are now being promoted to filter and detain stormwater runoff. Swale drainage can be a useful technique in areas of low grade, so long as the distance flow is to be conveyed is not great.
- Most effective when they are wide and shallow, with a channel slope between one and two percent and a bottom width of at least 0.75 metre
- Slope of up to four percent can be used for water quality purposes, but effectiveness decreases as velocity increases
- Grass should be allowed to grow to 75 mm to enhance filtration of suspended solids
- Largely ineffective from December to March

According to a report by the Washington Council of Governments, grassed swales have an overall removal capability rated as low. Low gradient swales with check dams have slightly higher removal rates than high slope swales without check dams, but removal rates of common pollutants are rarely more than 40 percent. For high slope swales without check dams the removal rates for common pollutants (e.g., suspended sediment, total phosphorous, total nitrogen, oxygen demand, trace metals and bacteria) are generally in the range of 0 to 20 percent. For low gradient swales with check dams removal rates are generally in the range of 20 to 40 percent.

Cost Considerations: Grassed swales typically cost less to construct than curbs and gutters or underground storm sewers. Construction costs depend on specific site considerations and local costs for labour and materials. However, grassed swales are not considered to be a standalone control option and are generally employed as part of a multi-component approach that uses a series of controls.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic processes	X
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunities identification for this technology are based on a new development or redevelopment area with suitable soil conditions (sandy with good infiltration potential), the depth of bedrock and the water table (greater than one metre), the roof to lot area ratio (less than 0.5), the ground topology (slopes between 0.5 and 5 percent), the type of land use (residential), and the availability of land adjacent to roadways. Opportunities are also identified by the size of the drainage area (less than 15 acres) and the condition of roads and existing sewer pipes in the area. If roads and/or pipes are considered to require reconstruction in the next five years, retrofitting a street or subdivision with grassed swales could be desirable.

References:

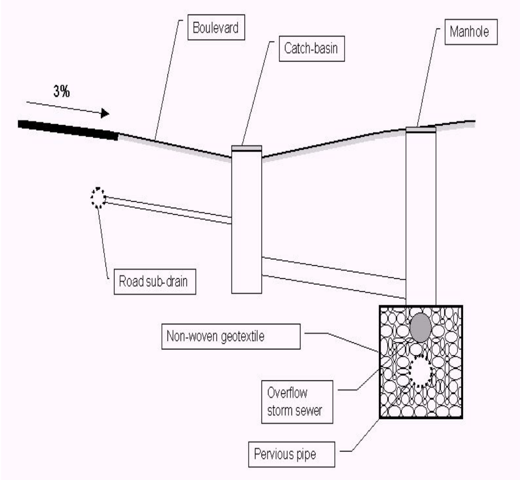
- EPA Office of Water. "Stormwater Technology Fact Sheet: Flow Diversion." USEPA, 1999. Available: http://www.epa.gov/owm/mtb/fl.pdf.
- EPA Office of Water. "Stormwater Technology Fact Sheet: Vegetated Swales." USEPA, 1999. Available: http://www.epa.gov/owm/mtb/vegswale.pdf.
- Li, J., R. Orlando and T. Hogenbirk. "Environmental road and lot drainage designs: alternatives to the curb-gutter-sewer system." Can. J. Civ. Eng. Vol. 25, 1998.

Pervious Technologies - Pervious Pipe Systems

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Exfiltration or infiltration

Related WWFMPs: Catch basins, swales, buffer strips, porous pavement, infiltration trenches, pervious catch basins.



Pervious pipe exfiltration system

Description: Pervious pipe systems are designed to exfiltrate storm water into the surrounding soil as it is conveyed downstream, reducing runoff volumes and providing pollutant removal. However, their effectiveness is dependent on soil characteristics, the suspended solids characteristics of the storm water and maintenance practices. A pervious pipe is similar to that used for tile drainage on agricultural lands and is available with either a smooth-walled or corrugated interior. A schematic of a typical pervious pipe system is shown. Due to the fact that pervious pipe systems have a contaminating potential, they are not suitable for use in areas where storm water has a high contaminant loading.

The exfiltration system is best suited in areas with pervious soils. A variation on the system uses filtration rather than exfiltration and is applicable to areas with tighter soils. In this variation, flow from the catch-basin is discharged to a length of perforated pipe within a gravel-filled trench (in which the conventional storm sewer is also bedded). The runoff filters down through the trench and is collected by a second perforated pipe at the bottom of the trench. The second pipe conveys flow to the next downstream manhole and into the conventional sewer system. If the trench volume or catch-basin capacity is exceeded, a second, higher level outlet in the catch-basin allows flow to be conveyed to the conventional storm sewer.

Application Requirements:

- Small drainage area (less than 15 acres)
- Not suitable in locations that receive a large sediment load that could clog the pre-treatment system
- Pre-treatment of road runoff by conveying storm water from road to a low grass boulevard, which is graded towards catch-basins connected to the pervious pipe system
- New or re-development area with pervious soils (minimum infiltration rate of 15 mm/hr)
- Bedrock and water table greater than one metre below bottom of drainage media
- Slope between 0.5 and 5 percent, ideally between 1 and 2 percent in the direction of flow
- Minimum setback from building foundations: 3 metres downgradient, 30 metres upgradient

Proven Effectiveness/Experience Elsewhere: A few municipalities in Ontario (e.g., City of Nepean, former City of Etobicoke) have implemented pervious pipe systems for stormwater drainage. These

systems are experimental in nature and problems have been experienced in the past. In areas where they have been implemented and monitored, some systems were noted to have clogged after several years. The Regional Municipality of Ottawa-Carleton, however, has reported success with pervious pipe systems.
The former City of Etobicoke has implemented a double pipe system (regular storm sewer above a perforated pipe) in a retrofit situation on a local road not subject to heavy salting or sanding. A monitoring program for the Etobicoke systems has been completed. Two exfiltration systems (serving about 13 and 30 hectares) and a filtration system (serving 2.4 hectares) were monitored. The systems each work very well and may in fact be overdesigned. The design basis for the systems was the runoff from a 15-mm AES storm and exfiltration to saturated media. There have been no reported overflows and it has been hypothesized that much higher rates of exfiltration are occurring because the media is not saturated. Since there were no outflows from the system, contaminant discharge was eliminated over the period of monitoring.

Cost Considerations: The system installed in Etobicoke is relatively expensive if applied in a "new development" situation, but does provide a means for implementing water quality controls on a retrofit basis, in areas of existing development which are undergoing storm sewer rehabilitation or upgrading.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	X
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic processes	X
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunities identification for this technology are based on the presence of certain surface features, such as the type of land use (residential), the type of soil (sandy with good infiltration potential), the depth of bedrock and the water table (greater than one metre), the roof to lot area ratio (less than 0.5), and the type of roads (two or fewer lanes). Opportunities are also identified by the condition of the roads and existing sewer pipes in an area. If roads and/or pipes are considered to require reconstruction in the next five years, retrofitting a street or subdivision with a pervious pipe system could be desirable. Also, where surface features and soil conditions permit, pervious pipe systems are suitable in new development or redevelopment areas.

References:

- Environment Canada. "Stormwater Management and Combined Sewer Overflow Control Series: Etobicoke's Stormwater Exfiltration Project." Great Lakes Cleanup Fund, 1995.

- Li, J., R. Orlando and T. Hogenbirk. "Environmental road and lot drainage designs: alternatives to the curb-gutter-sewer system." Can. J. Civ. Eng. Vol. 25, 1998.

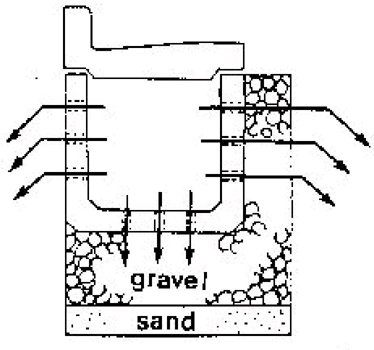
Pervious Technologies - Pervious Curb and Gutter System

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Infiltration and inflow

Related WWFMPs: Infiltration trenches, porous pavement, curb-gutter-sewer system

Description: In many cases the increased land requirement for many storm water management practices makes them impractical in many situations. Cities in Japan, which are at the forefront of alternative drainage practices, have implemented a number of innovative drainage systems to alleviate flooding, which is a serious problem in many parts of Japan. One such system is the infiltration LU curb, which is intended to replace traditional storm sewers of small to medium-sized diameter.



LU pervious curb and gutter system

Infiltration LU curbs consist of an L-shaped gutter above a U-shaped drain, installed on both sides of a street. The L-shaped gutter collects the storm water from the road surface and passes it into the U-shaped drain. Gutter inlets are arranged at intervals, and storm water connections from adjoining lots can be connected directly to the U-shaped drain. In many cases both elements of the drainage system are constructed of porous concrete to promote infiltration of storm water into the ground. However, porous concrete is not strong enough to take the weight of large vehicles and so often the L-curbs are made of ordinary concrete while the U-curbs are made of perforated or porous concrete. The U-curbs are installed in gravel that surrounds the bottom and side walls of the curb. Collected storm water is distributed and infiltrated through the gravel to infiltration inlets.

To properly operate and maintain LU drains, periodical cleaning and future rehabilitation is required. In particular, sedimentation of soil and sand is the biggest single problem from the standpoint of operation and maintenance, since the LU drains also function as gutter inlets. To alleviate sediment loading, sediment traps 15 cm in depth should be installed at 20-metre intervals. The cleaning/dredging frequency is considered to be approximately every four years, although the exact frequency for an area would largely depend on the specific surrounding conditions.

Application Requirements:
- Low to moderate runoff flows (i.e., used to replace small to medium-sized storm sewers)
- Not suitable in locations that receive a large sediment load that could clog the gutter and drain
- Pervious soils (minimum infiltration rate of 15 mm/hr)
- Bedrock and water table greater than one metre below bottom of drainage media
- Slope between 0.5 and 5 percent, ideally between 1 and 2 percent in the direction of flow

Proven Effectiveness/Experience Elsewhere: An LU curb system is easier to install than a traditional curb-gutter-sewer system because it does not require excavation on the sides of the street, which can be difficult due to the presence of fences, sidewalks and buildings. Furthermore, downstream storm sewers do not have to be buried as deep due to the shallow depth of the LU curbs, and the requirement for lateral sewers is also reduced.

From April 1983 to March 1989 a total of 145 km of infiltration curb was installed in Tokyo, Japan where the L-shaped gutter and U-shaped drain are readily available on the market (Fujita, Proc. 6th Intl. Conf. on Urban Storm Drainage, 1993). Their experience with LU curbs has been that road excavation widths are reduced by 55 percent for a 4-metre wide road. The Tokyo area is suitable for infiltrating storm water due to the large infiltration capacity of the soil. The infiltration LU-curb, in tandem with other infiltration technologies, has been employed in a number of Japanese cities other than Tokyo.

Cost Considerations: Since this technology has not been widely applied, little information regarding costs is available. However, the experience of some Japanese cities with LU curbs indicates that they have reduced excavation costs over traditional storm sewer systems due to the shallow depth of excavation. Furthermore, construction is simple, land requirements are small, disturbance of existing underground utilities is reduced, and maintenance work (e.g., inspection, cleaning) is easier to perform, all of which promote reduced costs. According to Nakama, Nomura and Yamazaki (Proc. 6th Intl. Conf. on Urban Storm Drainage, 1993) construction expenditures were reduced by 32 percent compared to a conventional curb-gutter-sewer system.

Objectives Addressed:

Technical Objectives	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	X
3. Reduce erosion impacts	X
4. Re-establish natural hydrologic processes	X
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunities identification for this technology are based on the presence of surface features such as the type of land use (residential), the type of soil (sandy with good infiltration potential), the depth of bedrock and the water table (greater than one metre), the roof to lot area ratio (less than 0.5), and the type of roads (two or fewer lanes). Opportunities are also identified by the magnitude of the expected flows (low to moderate flows in small to medium-sized sewers) and the condition of the roads and existing sewer pipes in the area. If roads and/or pipes are considered to require reconstruction in the next five years, retrofitting a street or subdivision with a pervious curb and gutter system could be desirable. Finally, but perhaps most importantly, the shallow depth at which pervious curbs and gutters are installed may cause problems in colder climates where freezing of storm runoff during winter months could create the potential for serious flooding. For this reason, the climate of the study area may not be suitable for this type of storm water management technology.

References:

- EPA Office of Water. "Stormwater Technology Fact Sheet: Porous Pavement." USEPA, 1999. Available: http://www.epa.gov/owm/mtb/porouspa.pdf.
- Fujita, S. "Infiltration in Congested Urban Areas of Tokyo." Proc. 6^{th} Intl. Conf. on Urban Storm Drainage, Vol. I, 1993.

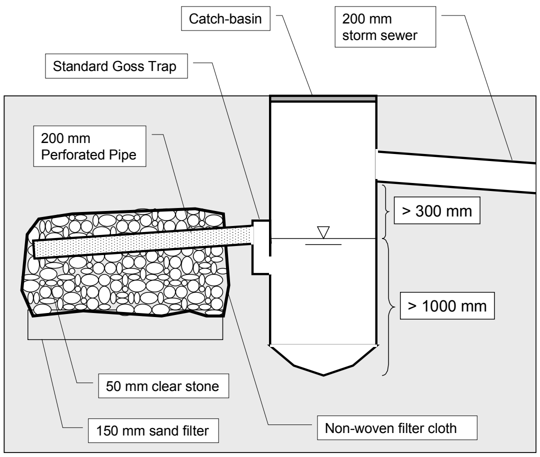
Pervious Technologies - Pervious Catch-basins

Wet Weather Flow Management Practice (WWFMP) Type: Conveyance Control

Primary Mechanism: Infiltration or filtration

Related WWFMPs: Pervious pipe systems, swales, buffer strips, infiltration trenches, porous pavement.

Description: A pervious catch-basin is simply a normal catch-basin with a large sump which is physically connected to exfiltration storage media. In some designs the storage media is located directly beneath the catch-basin via a series of holes in the catch-basin floor. Although this design is convenient and conserves land, it is more susceptible to clogging and compaction as a result of the lack of pre-treatment and the weight of water in the catch-basin. Some manufacturers offer catch-basin filters as pre-treatment media in this type of design. These filters are expensive, however, and must be replaced frequently. An alternate design uses the catch-basin sump for pre-treatment of runoff and discharges low flows through the wall of the catch-basin to the exfiltration storage media located beside the catch-basin. A schematic of a typical pervious catch basin is shown below.



Pervious catch-basin

As with pervious pipe systems, the exfiltration of road runoff is a contentious issue due to the elevated levels of pollutants. The MOE "Reasonable Use" guideline may apply where pervious catch-basin designs are proposed. Application of the "Reasonable Use" guideline is usually site specific and dependent on the potential for exfiltrated stormwater to contaminate a deep groundwater aquifer system, or a shallow system if it is being used for drinking water. If there is reasonable certainty that the exfiltrated water will only enter a shallow groundwater system that discharges to a nearby surface stream, the "Reasonable Use" guideline generally does not apply.

Long term clogging as a result of a lack of pre-treatment and catch-basin maintenance is the major drawback of this stormwater conveyance control. Frequent catch-basin cleaning is required to ensure its longevity. Eventually, the exfiltration storage media will become clogged and will need to be replaced.

Application Requirements:

- Small drainage area (less than 15 acres)
- Not suitable in locations that receive a large sediment load that could clog the pre-treatment system
- Pre-treatment of road runoff by conveying storm water from road to a low grass boulevard, which is graded towards catch-basins connected to the pervious pipe system
- New or re-development area with pervious soils (minimum infiltration rate of 15 mm/hr)
- Bedrock and water table greater than one metre below bottom of drainage media

Proven Effectiveness/Experience Elsewhere: Pervious catch-basins have been used previously in the Cambridge and Ottawa areas. As with pervious pipe systems, varying results have been reported. The Regional Municipality of Ottawa-Carleton has reported success with pervious catch-basins. Where difficulties have been observed, they have usually been due to poor design (storage media, filter cloth, lack of pre-treatment), poor construction practices, inadequate stabilization of development before construction (construction timing) or poor site physical conditions (e.g., soils, water table, bedrock depth). One of the benefits of pervious catch-basins located off-line is that they can be plugged until construction has finished and the development has stabilized. This measure helps to prolong the life of the exfiltration storage media.

Cost Considerations: Construction costs include clearing, excavation, placement of filter fabric and stone, installation of the monitoring well, and establishment of a vegetated buffer strip. Additional costs include planning, geotechnical evaluation, engineering and permitting. The necessity to periodically replace the exfiltration storage media makes this technology more expensive. Maintenance costs also include buffer strip maintenance and catch basin inspection and rehabilitation.

Objectives Addressed:

Technical Objectives		Measure Addresses
1.	Achieve healthy aquatic communities	X
2.	Reduce fish consumption advisories	X
3.	Reduce erosion impacts	X
4.	Re-establish natural hydrologic processes	X
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	X
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9.	Improve body contact recreation in rivers and reduce beach closures	
10.	Eliminate aesthetic nuisances	X
11.	Reduce basement flooding	X
12.	Reduce sanitary sewer inflow and infiltration	
13.	Protect life and property from flooding	

Opportunities Considerations:

- Opportunities identification for this technology are based on the presence of certain surface features, such as the type of land use (residential), the type of soil (sandy with good infiltration potential), the depth of bedrock and the water table (greater than one metre), the roof to lot area ratio (less than 0.5), and the type of roads (two or fewer lanes). Opportunities are also identified by the size of the drainage area (less than 15 ha) and the condition of the roads and existing sewer pipes in an area. If roads and/or pipes are considered to require reconstruction in the next five years, retrofitting a street or subdivision with a pervious catch basin system could be desirable. Also, where surface features and soil conditions permit, pervious catch basin systems are suitable in new development or redevelopment areas.

References:

- EPA Office of Water. "Stormwater Technology Fact Sheet: Infiltration Trenches." USEPA, 1999. Available: http://www.epa.gov/owm/mtb/infltrenc.pdf.