# Sanitary Sewer Design, Installation and Inspection in Small Rural Community

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## Declaration of Sole Authorship

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## Abstract

Access to a safe, reliable and efficient municipal water and wastewater servicing system is an integral component of a strong local economy.  In rural Ontario there are many small communities serviced with on-site sewage systems (primarily septic systems) and a combination of onsite septic holding tanks.  These small communities may be faced with problems of failing systems, including saturated leaching beds, foul odours, and ponding of effluent. In order to develop a solution the governing municipality may consider the design and installation of a local municipal wastewater collection and treatment system.  Designing and constructing a new wastewater collection and treatment system in an existing rural community has its challenges from the initial design to the final connection.  It is evident that a municipality can be successful when faced with the construction and operation of a new municipally owned wastewater system to fulfill Ministry, population growth and economic  development requirements.

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## 1.0 INTRODUCTION

This report describes the process followed and conclusions reached for the design, installation and inspection of a municipal sanitary (wastewater) collection system for a small rural community within a larger municipality in Ontario. A municipality with rural communities having populations less than 1500 people, which consist primarily of residential developments with small urban cores and small outlying industrial areas, represents the municipality upon which this report is based. These rural communities have little to no existing municipal infrastructure. Pollution surveys and studies performed by Ministry and Health Unit agencies indicate that the existing private septic systems have adverse effects on the local environment; the communities are thus in need of a solution for ongoing environmental and community safety concerns.

The information presented will be centred on the design and construction of a gravity feed collection system in compliance with applicable standards for the Province of Ontario. For the purpose of this report, the design of the end of pipe treatment facility will not be considered. However, the end of pipe invert will be designed to a point which will accommodate a sufficient grade to satisfy the requirements of a treatment facility.

This report will focus on the background to the problem, the reasons why a municipal system is considered for this situation, design considerations, the types of construction materials and methods available, and the inspection, tendering and contract administration processes involved with this type of construction.

## 2.0 METHODOLOGY AND DISCUSSION

### 2.1 Solution Alternatives

An effective solution should address the existing environmental problems and health hazards in the community, provide a technically suitable sanitary servicing strategy that meets current regulations, provide sanitary servicing that minimizes environmental impacts and provide a cost effective and financially sustainable sanitary servicing strategy for existing and future growth that will not result in economic hardship to the residents of the community.

Given the above criteria, solution alternatives are as follows:

a) Do Nothing: This alternative essentially maintains the existing sanitary treatment 'as is', hence using the existing private septic systems without any improvements.

b) Upgrade Individual On-Site Septic Systems: This alternative involves assessing and rating each individual sewage system in the area and upgrading the substandard systems to comply with the governing regulations, most likely the current requirements of the Ontario Building Code (OBC). These upgrades involve insuring proper separation between on-site sewage systems, existing wells, property lines and structures.

c) Gravity Main: Gravity sanitary lines are constructed within the road right-of-way throughout the community. Each lot is provided with a lateral service connection to the main line. Sewer mains are constructed at various depths to allow for proper flows and pumping stations are constructed in areas which warrant them.

d) Connect to Existing Municipal System: This option involves constructing a collections system from the community similar to option 'c' however the raw sewage flow would be directed via a forcemain to a nearby community with an existing treatment facility.

## 2.2 Evaluation of Solutions

The next step towards a methodical solution is to evaluate the different alternatives and select the most appropriate for the situation. This process involves listing the advantages and disadvantages of each solution alternative.

a) Do Nothing: As indicated previously, this alternative would involve maintaining the existing septic systems 'as is'. This option should not be considered but rather used as a basis for improvement. Since reports have indicated that the problem is derived from the existing conditions it is known that this is the area that needs to be improved upon.

b) Upgrade Individual On-Site Septic Systems: This alternative may be seen as a 'quick fix' solution in that it may ultimately result in continued environmental concerns. It is very unlikely that given the existing structures on-site septic systems would be able to meet the setback requirements sought by the current OBC (Ontario Ministry of Municipal Affairs and Housing, 2006). Further investigation should be done before deciding in favour of this option; soil type, water table elevations, and setbacks are all considerations that will weigh in on this decision.

c) Gravity Main: This option involves decommissioning individual on-site systems and installing a municipal system to a local municipal wastewater treatment plant with. The most cost-effective solution would be a shallow gravity sewer, with wastewater conveyed to a single wastewater treatment facility.

d) Connect to Existing Municipal System: This option is only feasible if there happens to be an existing wastewater treatment facility in a nearby community which would be close enough to feasibly direct wastewater flows via a forcemain, or gravity fed system with high lift pumps as required.

Alternative ‘c’ is the best solution for a small rural community situated within a larger municipality.

## 2.3 Preliminary Design Criteria

In order to provide a sustainable, safe and environmentally responsible urban footprint consideration must be given to the way we collect, treat and dispose of our wastewater. The purpose of a sanitary sewer collection system is to collect and convey industrial and domestic wastewater from all points at which it is generated in a specific catchment area, and deliver it to a wastewater treatment facility where it can be cleaned and released back into the watershed free of contaminants (Water Environment Federation,1996). Refer to Drawing 1 in Appendix A for an example of an identified catchment area in a small rural community.

There are certain overall considerations that must be addressed when designing a sanitary system. A topographical survey of the area to be serviced is a key component and will set the foundation for the sewer design. The survey should include as much detail as possible, and should include all existing features within the area. The survey will show the existing layout of the community, from the location of trees and structures, to the elevation and layout of the road network.

When designing gravity fed sanitary collection systems to service existing communities there are several design constraints which must be taken into consideration prior to implementing a final design. Since, in this situation, the collection system will be servicing existing structures the elevation of the finished floor must be considered. This is an integral component which will be heavily relied upon during the final or detailed design period. It is important that this information be collected during the topographic survey of the serviced area. This is vital information since the grade and depth of the sanitary main must be deep enough to ensure the minimum slopes can be met when these structures are required to connect to the system.

### 2.4 Final Design Criteria

Sanitary sewers must be designed to handle flows from existing residential, commercial and industrial establishments. A well-designed system will also take into consideration the future growth and population of the community. In most cases existing zoning and land use designations is defined by the municipality and aids in forecasting future land use and ultimately the anticipated wastewater flows. Since the wastewater flows are directly related to population, an important design consideration is to know what the existing and future population will be. Existing population records can be gathered from various sources and should be readily available. As an example, the Township of Perth East uses a population factor of 2.7

people per residential unit (R.J Burnside and Associates, 2006). As far as future populations, there are several methods used to predict these densities; population comparisons, graphical extensions, and mathematical extrapolation are all examples (R.J Burnside and Associates, 2006). Most municipalities have a policy on calculating future and existing populations which they require designers to follow. The following table depicts the average number of persons per area of future development based on the type of zoning.

| Zoning Type | Persons Per Hectare |
| --- | --- |
| Single Family | 8-14 |
| Semi-Detached | 12-20 |
| Multi-Family | 24-40 |
| Apartments | 160-240 |
| Commercial | 8-12 |

Table 1: Populations Densities (Municipal Engineers Association, 1984)

This table represents a generalization only; it is very common for municipalities to have predetermined sewage flows.

One of the first steps in designing the wastewater flows is to determine a design period. For example, in the Township of Perth East, the urban design standard for municipal servicing is a 20-year design period. Sanitary systems should be designed for the density of population expected for the given design period. The next step is to determine the peak sewage flows during a given day. This can be accomplished by using the existing population plus the future population growth expected over the design period.

Once the population density has been determined, the peaking factor (M) can be calculated. This is achieved by using the Harmon Formula (Stantec Consulting Ltd, 2001):

$$M = 1 + (14.0/(4+ p)) \text{ where } p = \text{population in 1000's}$$

Figure 1 in Appendix A uses this formula to calculate the peaking factor for a sewer system in a small rural community.

In addition to population density and peaking factor, the design of sanitary sewers must also consider groundwater infiltration (extraneous flows) into the system. Although it is a closed system, there may be a way for groundwater to leach into the system and this volume must be accounted for. This factor is typically calculated based on applying a constant value on the area of the watershed. Common values used for the design of gravity sewer systems, based on area, range from 0.25 to 0.30 litres per second per hectares for infiltration (R.J Burnside and Associates, 2006).

Peak domestic sewage flows (Q)(d) can be calculated using the following formula (Stantec Consulting Ltd, 2001):

$$Q(d) = PqM + IA$$

where:

Q(d) = Peak domestic sewage flows (including extraneous flows in Us)
p = Design population in thousands
q = Average daily per capita domestic flow in Llcap/day
(exclusive of extraneous flows)
M = Peaking factor = Unit of peak extraneous flows in Uha/s
A = Gross tributary area in hectares

Sample calculations using this formula to determine peak flows for a rural community with existing lots are available in Figure 2 in Appendix A.

Now that the peak sanitary flow has been calculated, pipe sizing and grade can be determined. Since this design will be constructed under existing conditions, the depth and grade of a gravity sewer will be greatly influenced by the grade of the existing conditions and as previously mentioned, the elevation of the existing structures. Sewer grades must be design with proper velocity in order to carry organic solids, provide self-cleansing of the pipe and to prevent settling out of solids, this is usually achieved by establishing a minimum grade of 0.5% (Ontario Municipal Water Association, 2010).

To improve maintenance and prevent blockage the minimum pipe size for a sanitary main is 200mm for the Province of Ontario (Ontario Municipal Water Association, 2010). Typical minimum and maximum velocities are 0.7m/s and 3.0m/s respectably and are directly related to the size and grade of sewer pipe. (R.J Burnside and Associates, 2006)

A sample spreadsheet showing the typical layout, and calculations using the methods and formulas discussed is available in Table 1 of Appendix A. Due to the low population of small rural communities peak flows can expect to be low. In order to maintain minimum pipe size and achieve the desired velocity the grade of the sewer pipe may need to be adjusted.

## 2.5 Analysis of Pipe Material

Once the pipe sizing and grade have been determined the type of pipe material is selected. Factors which influence the selection of pipe material include the depth at which the pipe will be located and the type of soil it will be placed in; the number of connections to the pipe, the installation methods expected during construction, cost and product availability.

*Concrete Pipe*

Many sanitary sewer designs are configured around the use of concrete pipe. This type of pipe material can be manufactured to withstand high structural loading which is typically sought during deep installations where the amount of soil loading is considered to be higher than average. Reinforcing steel can be added to the pipe during the time of manufacturing to achieve the desired structural loading capabilities (Municipal Engineers Association, 1984). Concrete pipe is most commonly used in larger diameter sewer situations and typically would not be required for smaller rural communities with low flow rates. Concrete pipe is also not recommended for applications where it may be exposed to high acidic concentrations, such conditions may be found in an industrial application or certain soil conditions.

*Polyvinyl Chloride Pipe*

Polyvinyl chloride pipe (PVC) is a common and economical type of pipe which is widely used for this type of application. PVC pipe is typically manufactured by hot extrusion of bulk plastic material. This process results in a tight, precise pipe which allows for good quality joints, virtually eliminating infiltration or leakage. This type of pipe material is a good candidate for sewer installation projects where flows are relatively low and pipe diameter is generally less than 500mm. PVC pipe is subject to deflection if the installation and bedding is insufficient (Water Environment Federation, 2007).

*High Density Polyethylene Pipe*

High Density Polyethylene Pipe (HOPE) is a flexible pipe which is typically only used during sanitary sewer applications when directional drilling is required. HOPE pipe segments are joined by heat fusion in the field which creates a very strong bond if prepared correctly (Water Environment Federation, 2007). This type of pipe is subject to deflection if not installed properly. Although not recommended for open trench installation because of its flexible nature, this is an ideal candidate for trenchless methods. HOPE pipe will likely be part of a sanitary sewer project when trenchless methods are desired, as would be the case for this type of scenario. Since pipe grade is a major component of an effective sanitary collection system, trenchless methods should be used only when absolutely required (Ontario Ministry of Transportation OPSS 410, 2008).

## 2.6 Installation Methods

Typically, there are two common methods used when installing sanitary sewer pipe: open cut and trenchless. When considering the design of a new gravity feed collection system intended to service an existing community it is important to design around the conditions which currently exist within the community. These factors will weigh heavily on the type of installation methods chosen.

*Open Cut*

The standard open cut method is the most common and widely used way to install sewer pipe. This technique is used for most situations where there is ample room for construction equipment and proper sloping of the excavated trench. The maximum unsupported vertical wall height of a trench where a sewer pipe is to be laid is 1.2 meters with a 1:1 (horizontal to vertical) side slope above the trench wall. In situations where loose soil conditions exist the side slopes must even out to as shallow as a 3:1slope with the toe of the slop running to the bottom of the excavation (Ontario Ministry of Labour, 2011).

Depending on the depth of the installation, these conditions may cause a larger than desired excavation and will directly influence the overall cost of the project and the amount of restoration required. However, in a most cases this method will be the ideal candidate for installation as it is generally the most cost effective installation method.

If loose soil conditions present difficulties for stabilizing the trench wall during an open cut installation there are construction techniques available to support the excavation. The most common of these techniques will utilize the availability of a trench liner or 'trench box'. The trench liner open cut method can be used to support unstable soil or when an excavation reaches depths where the 1:1 slope will become excessively wide at the surface. A steel trench liner will be lowered into the excavation and the sewer installation will occur within the confine of this box, the trench liner will be pulled along as the installation of the pipe proceeds. Existing underground utilities may have to be temporarily disconnected to allow the trench liner to be pulled ahead. Another method used to stabilize a trench wall is the use of shoring and sheeting. Similar to a trench liner, the sheeting and shoring is used to brace the trench wall by providing horizontal pressure to counteract the trenches tendency to cave-in. Although effective, sheeting and shoring is more expensive and time consuming than trench lining (Water Environment Federation, 2007).

*Trenchless*

There are a few different types of trenchless installation methods. Boring and directional drilling are the most common methods that will most likely be considered when an open cut installation is not permissible. When constructing a sanitary collection system to service an area which is already populated there will be many obstacles which will restrict from installing pipe by means of the traditional open cut method. Limited space in relation to existing buildings and structures, road, railway, and watercourse crossings are typical situations which will be encountered during this type of project and trenchless installation is a solution to the problem.

Boring is generally used for short distances such as road and watercourse crossings. An excavation is created adjacent to the area to be bored and an auger is placed and aligned at the base of the excavation in the location intended to be bored. The auger will bore a path underneath the obstruction and the sewer pipe will then be reamed through the same path. This is typically used for situations where a smaller pipe diameter is required.

Directional drilling is a very common trenchless method in the construction industry. Directional drilling is relatively simple and little space is required for the install. A cutting head is reamed through the soil by a flexible drill rod from a surface-mounted drill rig. Drilling fluid is used to remove the cuttings and lubricate the hole as the drill advances. Directional drilling is able to achieve sweeping bends and grade changes without the need to excavate the soil. Once the drill head reaches the desired location, the head is removed and the sewer pipe is pulled back through the hole. The benefit of directional drilling is that the restoration work is minimal and installation can occur in areas where open cut methods are not permissible. When directionally drilling for gravity feed sanitary sewer purposes care must be taken to ensure a proper grade is maintained during the installation process.

## 2.7 Pipe Bedding and Alignment

*Pipe Bedding*

Pipe bedding, which is place prior to backfilling, is the aggregate material immediately surrounding sewer pipe (Ontario Ontario Ministry of Transportation OPSS 401, 2008). The bedding provides support to enable the pipe and soil to work together to meet the design load requirements of the sewer. Bedding increases the load-carrying capacity of a pipe, and the ability of the bedding to do this is measured by a term called the load factor. There are four classes of bedding commonly used and each class has a different load factor.

Class A is the highest class of bedding with a load factor of 3.0 and is usually only used in poor soil or at extreme depths where the pipe walls are insufficient to withstand the earth pressures (R.J Burnside and Associates, 2006). Class A bedding consists of a concrete encasement partially or fully around from the pipe to the bottom and walls of the trench, this class of bedding will not likely be required for this type of gravity feed supplication; a cost effective design will prevent excess depth of pipe.

Class B is the most commonly used class of bedding with a load factor of 1.9. It consists of a well-compacted and well-graded granular material cradle extending all the way up to the spring line of the pipe and out to the walls of the trench (R.J Burnside and Associates, 2006). The granular material should be a maximum of 19mm in size and should be a well graded material.

Class C is a class of bedding with a load factor of 1.5. It consists of simply shaping the bottom of the trench to receive the bottom of the pipe (R.J Burnside and Associates, 2006).

Class D is the lowest and rarely used class of bedding with a load factor of 1.1(R.J Burnside and Associates, 2006). It consists of burying the pipe with no preparation of the trench bottom. The appropriate class of bedding to be used in a project is based on loads on the pipe, which are derived from the pipe material and diameter, the trench width and condition, the soil type and the depth of backfill above the pipe (Ontario Ministry of Transportation OPSS 514, 2008).

*Pipe Alignment*

Another important aspect of a gravity feed sanitary sewer design is the pipe alignment. In order to achieve uniform loading on the system each pipe section should be bedded and compacted equally along its entire length, this will result in continuous quality of the system. There should be no high or low points on the bottom of the trench for the entire length; this could result in breaks and backups along the pipe and poor pipe alignment (Ontario Ministry of Transportation OPSS 514, 2005).

### 2.8 Construction Layout

Construction surveys provide the horizontal and vertical control for every key component of a construction project, in effect transferring the project design from paper to the ground. Experienced technologists familiar with both the project design and the appropriate construction techniques should set the line and grade for sewer pipes being installed. Knowledge of the design and construction techniques is essential to interpret the contract drawings effectively for layout purposes, and to ensure that the layout is accurate for line and grade control. In this case sanitary sewer flow efficiency depends on gravity. Therefore, it is essential that the construction grades be given precisely.

## 2.9 Inspection

The role of the site inspector is to administer the contract and to protect the interest of the municipality. The inspector should ensure that construction is preceding in accordance with the contract documents. In the case of a sewer pipe installation it is important that the inspector ensures that the contactor is using the appropriate pipe materials and class of bedding as outlined in the contract documents and that installation is in compliance with the municipal and/or provincial standards. Other duties of the inspector should include the following:

- Checking site conditions
- Addressing public concerns
- Checking specifications
- Checking alignment and grade
- Maintaining a works diary
- Recording as constructed information
- Measuring quantities for payment
- Administering changes in the work

If changes or necessary additions to the work are identified the contract administrator may issue a "Notice of Change" to the contractor and when agreed upon, issue a "Change Order" to cover extra work or a changed condition. It's also important that the inspector ensure proper care and due diligence is expressed during inspection and administrating progress payments to the contractor. Typically the contract administrator's authority is set out in the general conditions of the contract.

## 2.10 Tendering and Contract Documentation

Prior to advertising a construction project for bidding the contract documentation must be prepared. Construction drawings, specifications and a form of tender will make up the contract documents. Project specifications should include any special considerations related to the project such as utility relocations, property acquisitions, legal surveys and ministry approvals. Tender documents for a construction project which relies heavily on excavation and trenching in the vicinity of existing structures should include a pre-condition survey. A pre-condition survey will make note of all existing conditions within the construction area. A survey of private property prior to commencement of any construction will record any deficiencies and will aid in settling any conflicts which may arise post construction. All available information should be provided to the bidders in great detail to avoid any confusion and reduce the risk to the bidder or municipality. The contract should clearly define the rights and obligations of the parties involved, as well as provide a complete description of the work to be performed.

## 3.0 CONCLUSIONS

Based on the foregoing report on the proper design, installation and inspection of sanitary sewers, the following conclusions can be made:

- Municipalities with small rural communities that require new sanitary systems to replace existing systems can achieve the desired results if they are diligent and methodical during their approach towards selecting the most appropriate solution to the problem they are faced with.
- Designing and constructing a new gravity feed wastewater collection system in an existing community will have its challenges. However, if proper engineering practices are implement during the design and construction phases a municipality can be left with a low maintenance, effective, safe and reliable collection system.

## 4.0 RECOMMENDATIONS

The following recommendations are made with respect to the construction of a gravity feed sanitary collection system in a small rural community which is experiencing failure of the existing private on-site septic treatment systems:

- Systematically evaluate all options available to resolve the challenge facing a municipality;
- Screen and select the most appropriate solution based on solving the environmental and safety concerns, long term service life, financial sustainability, and the ability to service both the current and future populations;
- Consider all existing conditions, including the existing structures to be serviced as part of the design solution;
- Design a sound sanitary system capable of handling the current and future wastewater and infiltration flows;
- Select the appropriate pipe material and installation method for the construction situation;
- Execute diligent inspection practices to ensure proper techniques are used;
- Insure tender and contract documentation is precise, specific and include a pre- condition survey of all existing private and public structures.

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# APPENDIX A

TABLES, DRAWINGS AND SAMPLE CALCULATIONS
[not included in sample report]