APPENDIX I
STORMWATER MANAGEMENT PRACTICES – DESIGN EXAMPLES*

* *Note: Examples showcase real world projects that were developed in the 1990s and are based on the 1994 Manual. The 2003 Manual has updated many concepts. Therefore, designers must refer to the 2003 Manual to ensure that future projects are designed in accordance with current standards.*

I.1 Introduction

Users of the *Stormwater Management Practices Planning and Design Manual* (1994) indicated that design examples would be useful to show the level of detail required in stormwater design submissions and supporting documents for applications to approval agencies. The examples provided in this Appendix are typical of submissions made in the 1990s in various Ontario municipalities. The following points should be noted when reviewing the design examples:

i) While the majority of the requirements are similar across different geographical locations, there may be standards specific to individual municipalities and districts. Designers should obtain specific municipal and other approval agency guidelines in order to incorporate these requirements into their design and obtain the necessary approvals.

ii) The *Stormwater Planning and Design Manual* promotes an integrated planning and design process based on the "treatment train" approach to the control of stormwater (lot level controls, conveyance controls, and end-of-pipe stormwater management facilities). Lot level controls (e.g., flatter grading of rear yards to promote infiltration) are generally incorporated in the overall grading design for the development. Generally, there are no specific drawings or details submitted for approval beyond the usual detailed grading plans. This is not to downplay the importance of lot level controls, but simply reflects the way in which they are normally incorporated in the stormwater management design.

iii) The SWMP facility should be designed so that it is an integrated component of the area serviced. For example, overland flow routes must be carefully designed to ensure that flows reach end-of-pipe facilities that provide major system flood control. Similarly, the effect of peak water levels in an end-of-pipe facility on the hydraulic grade line in the storm sewers must be carefully considered to avoid surcharging and possible basement flooding problems.

iv) At the detailed design stage, drawings for stormwater management facilities are frequently submitted for approval as part of an overall subdivision design package including: grading plans, drainage plans, detailed plans and profiles of storm and sanitary sewers, water mains, other utilities, road profiles, etc. This appendix does not contain examples of all these drawings. Also, in order to avoid duplication, only selected items from the complete design package have been included to illustrate a specific type of SWMP. A complete submission in such cases would be more extensive than shown.

I.2 Design Example 1 – End-of-Pipe Extended Detention Facility (Quantity and Quality Control)

A two-cell facility which separates water quality and erosion control from quantity control will be discussed in this example. However, single-cell facilities for all types of control are more commonly used. Single-cell ponds are similar to Design Example 2 (see Section I.3) with quantity control storage being provided above the erosion control storage level.

The facility is located within a new primarily single-family residential community and provides quantity and quality control for 66 hectares of storm runoff (Figure I.1). The quality control cell was designed as an artificial wetland, and the quantity control cell was designed as a dry detention area to receive flows only when the quality pond filled.

The “Stormwater Servicing Plan” (SSP) (essentially a simplified subwatershed plan) design criteria for the facility were developed in consultation with the Town, the Conservation Authority and the District Office of the Ministry of Natural Resources. Approval was obtained from the Ministry of the Environment through the delegated authority of the Region.

The SSP design criteria were:

Flood Control
Post-development peak flows to be controlled to pre-development levels for the lands draining to the facility for 2 to 100 year design storm events. In addition, supplementary flood control storage was incorporated to ensure peak flows further downstream in the subwatershed remained at pre-development levels.

Erosion Control
Twenty-four hour detention for the runoff from a 40 mm storm was incorporated.

Water Quality
Storage was based on the 1994 SWMP Manual requirements for Level 1 protection **[Editor’s Note: now referred to as enhanced protection]** including 40 m^3/ha of active storage. This active storage was in addition to that provided for flood and erosion control.

The following design drawings were included and are illustrated in this chapter:

- Plan view (Figure I.1) at a scale of 1:500 (reduced copy of the plan – Figure I.2);
- Example of detail sheet showing the design of inlet and outlet structures (Figure I.3); and
- Two detailed planting plans at a scale of 1:500 showing the design of the artificial wetland and plantings around the border of the facility (Figures I.4 and I.5, respectively).

These drawings were accompanied by a “Stormwater Management Report” for the community which updated information contained in the “Stormwater Servicing Plan” and included a description of the functional design of the facility referred to as the South Pond. It is somewhat more extensive than a design brief which would typically accompany the design drawings. A more typical example is included in association with Design Example 2 (Section I.3).

Figure I.1: Plan View

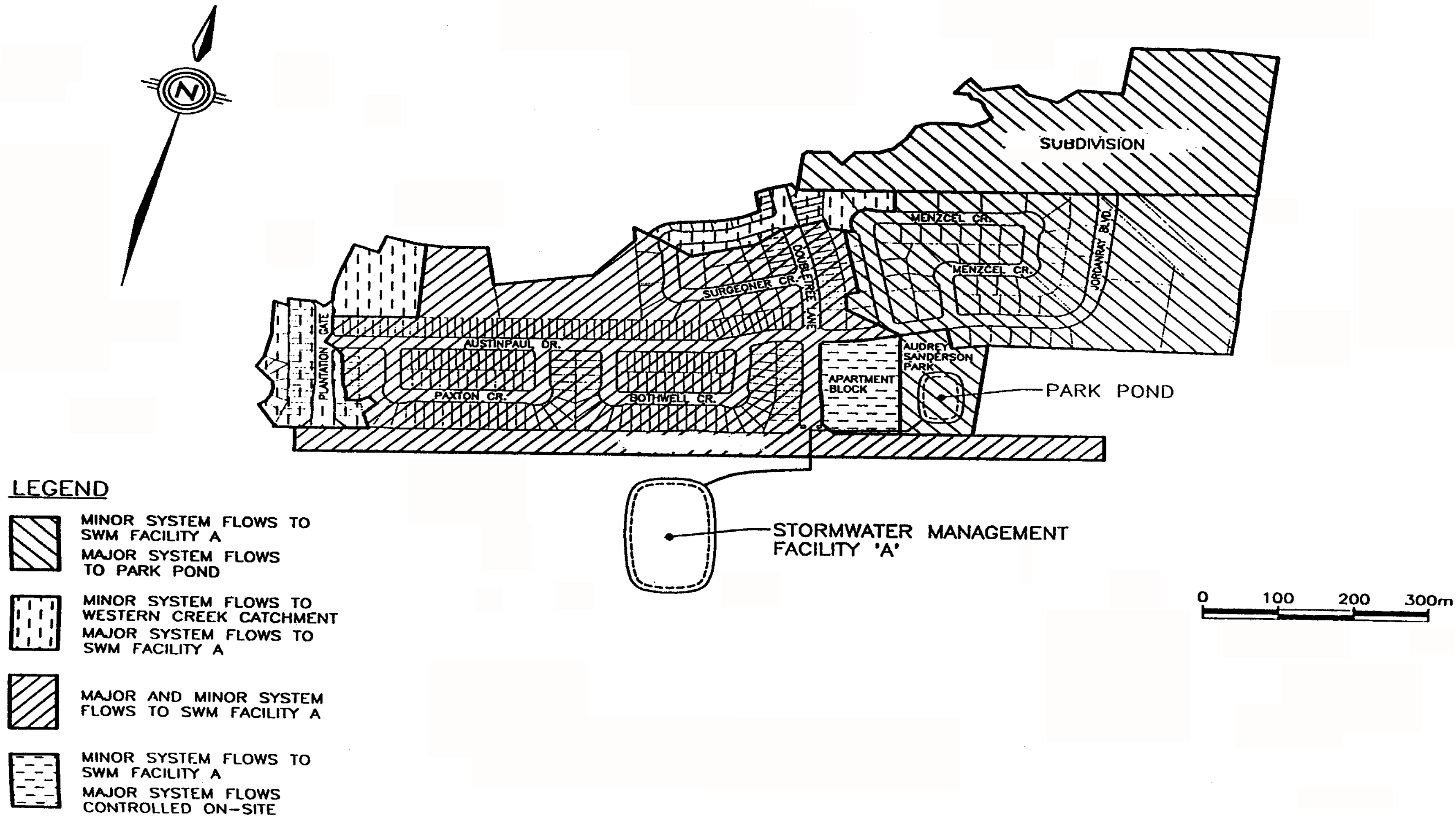


Figure I.2: Plan View (reduced copy)

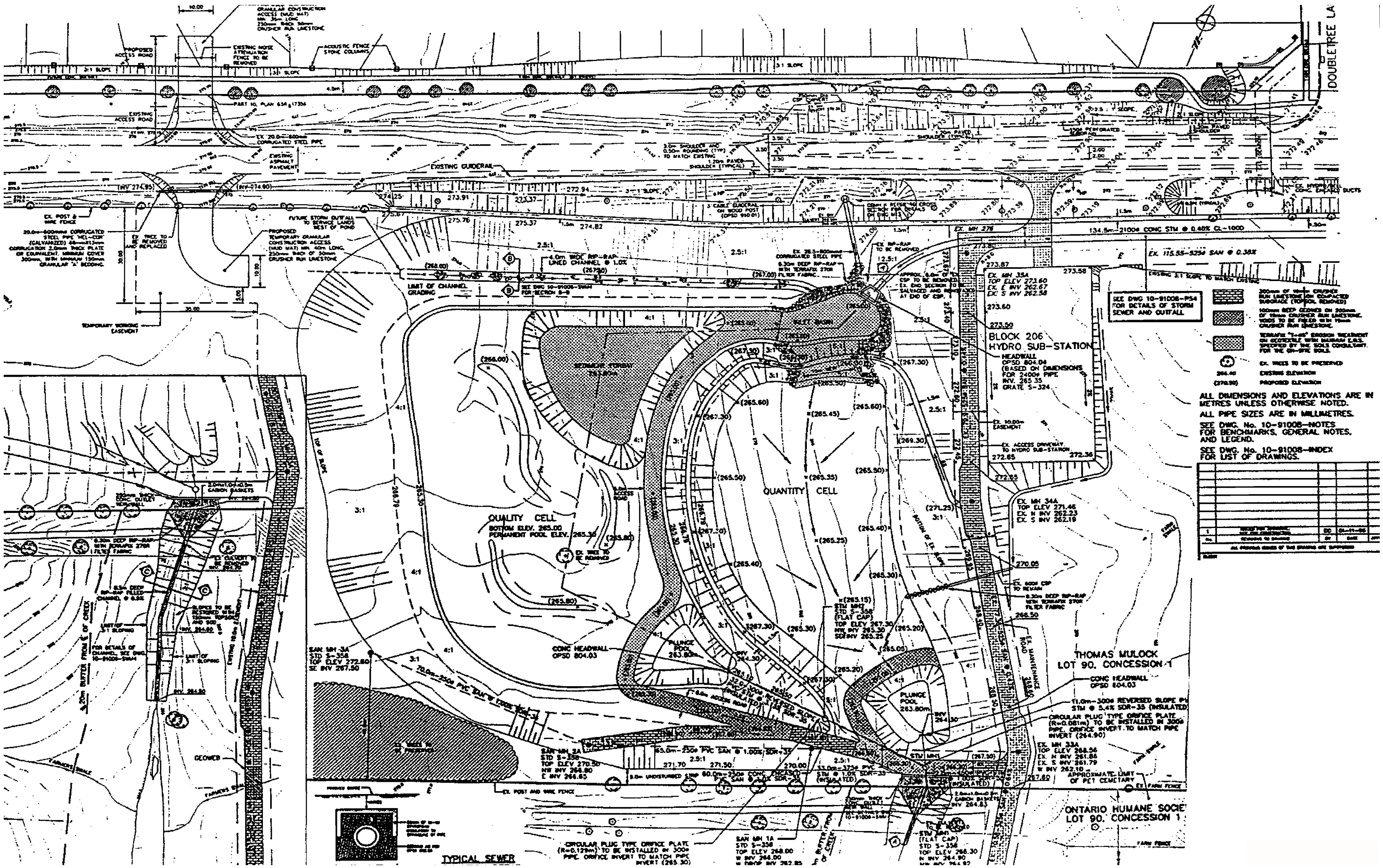


Figure I.3: Detail Sheet showing the Design of Inlet and Outlet Structures

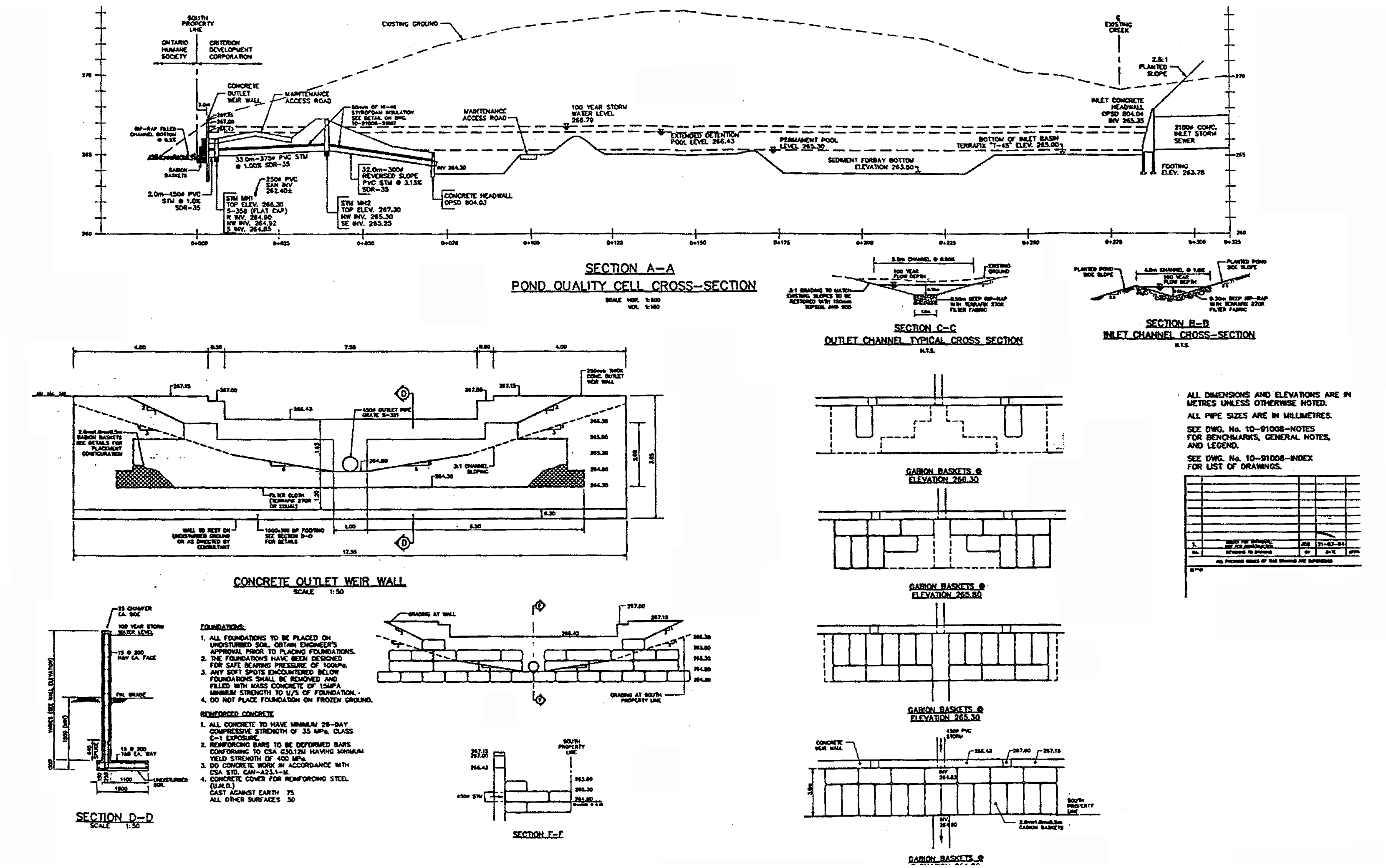


Figure I.4: Planting Plan showing the Design of the Artificial Wetland

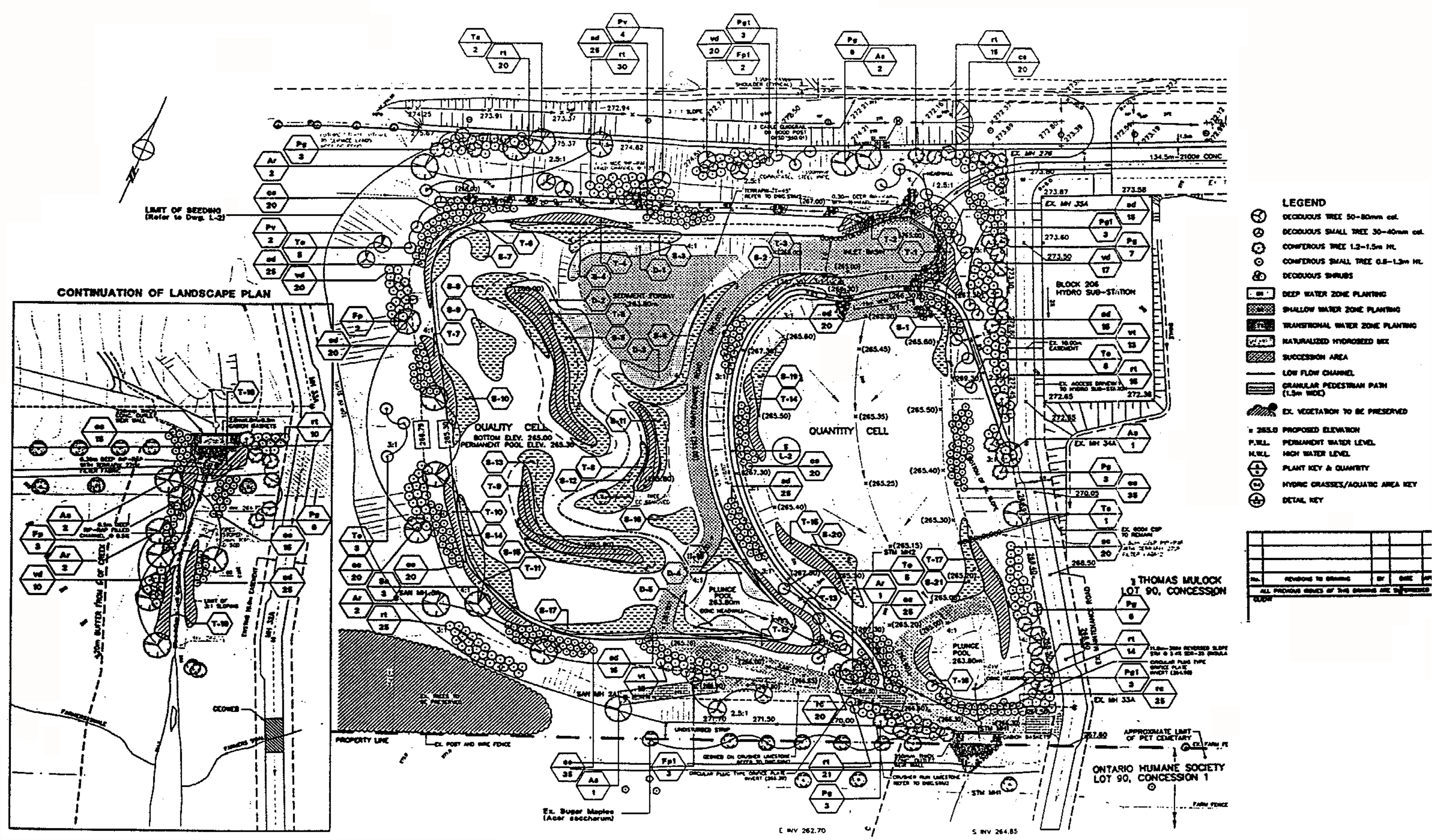
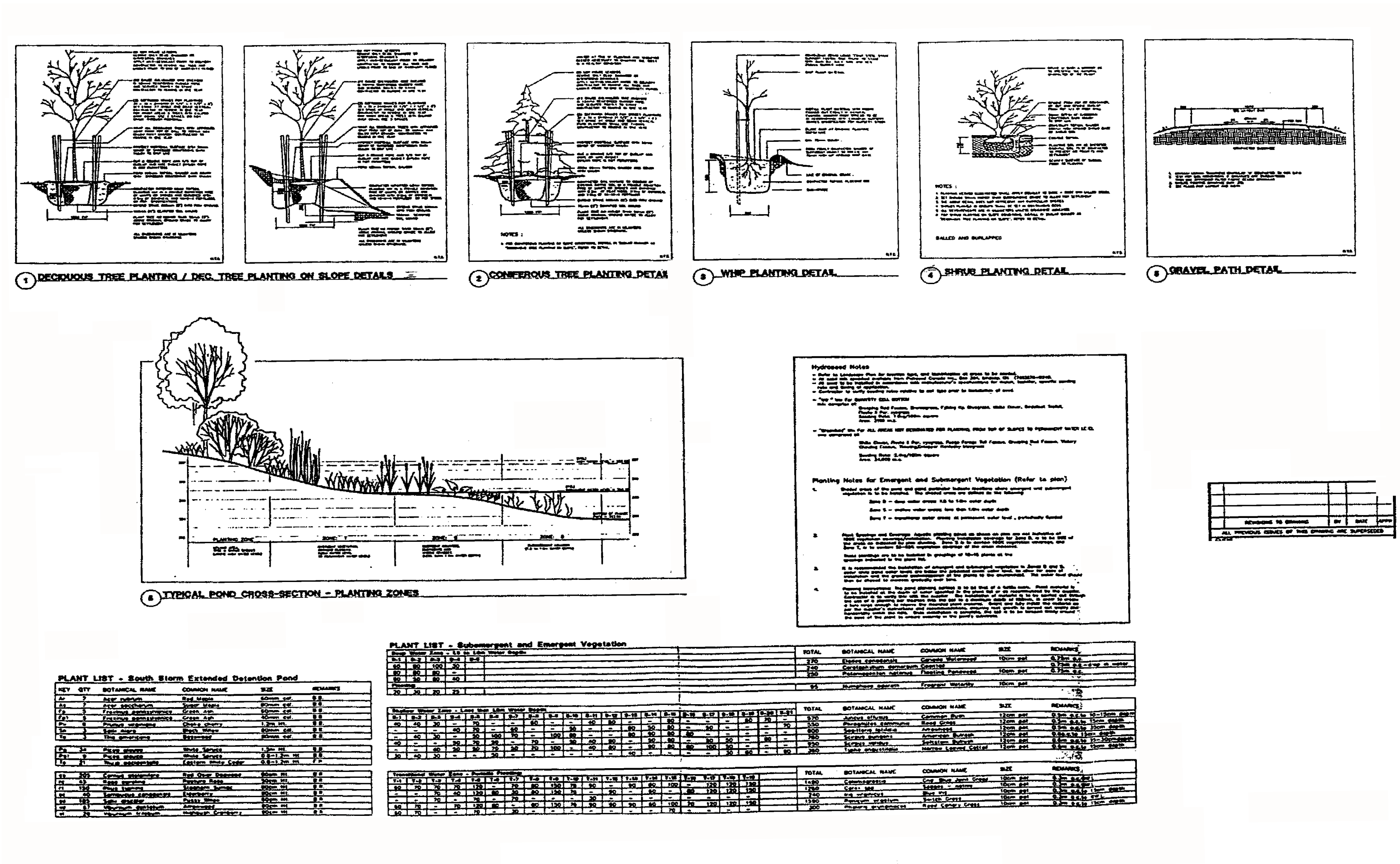


Figure I.5: Planting Plan showing Plantings around the Border of the Facility



I.3 Design Example 2 – End-of-Pipe Extended Detention Facility (Quality and Erosion Control Only)

The single-cell facility discussed in this section was designed to provide water quality and erosion control. The design can be extended to include quantity control by providing additional storage above the erosion storage.

The facility is located within a new retirement residential community (detached homes on relatively small lots) surrounded by a 9 hole golf course. The stormwater pond provides water quality control for storm runoff for about 10 hectares and was designed to be part of the golf course. The pond was designed to implement one of the recommendations of the "Stormwater Management (SWM) Plan." SWM Plan design criteria were developed in consultation with the Town, the Conservation Authority, and the District Office of the Ministry of Natural Resources. Approval was also obtained from the Ministry of Environment and Energy.

The design criteria for the SWM Plan were:

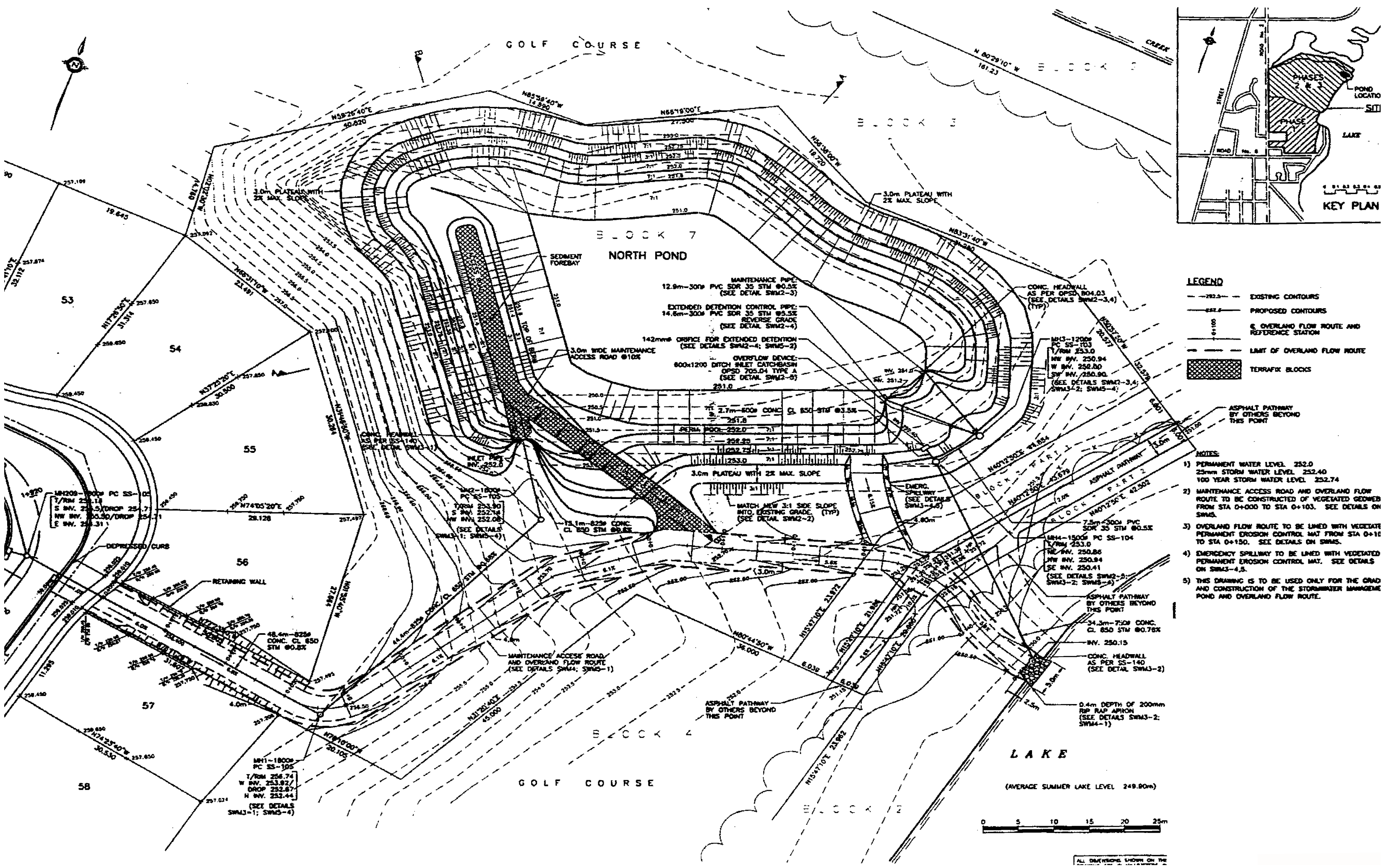
> **Flood Control**
> Since the pond drains directly into a sizeable lake, there was no requirement to control post-development peak flows to pre-development levels.
>
> **Erosion Control**
> Twenty-four hour detention for the runoff from a 25 mm storm was incorporated.
>
> **Water Quality**
> Permanent pool storage based upon the 1994 SWMP Manual requirements for Level 1 protection was incorporated **[Editor's Note: now referred to as enhanced protection]**. The active storage requirement of 40 m^3/ha for water quality control was taken as part of the 25 mm (erosion) detention storage.

The facility was designed as a single-cell extended detention pond with wetland plantings incorporated in certain areas. The inflow to the pond is restricted to 5 year flows from the storm sewer system. The major system flows are diverted around the facility via an overland flow route directly to the lake.

The design drawings included:

- Plan view at a scale of 1:500 **[Editor's Note: not included]** (reduced copy of the plan – Figure I.6);
- Four detail sheets showing the design of inlet/outlet structures and overland flow routes **[Editor's Note: not included]**; and
- Detailed planting plans prepared by a landscape consultant showing the wetland plantings around the border of the facility **[Editor's Note: not included]**.

Figure I.6: Plan View (reduced copy)



These drawings were accompanied by a “Functional Design Report” describing the design criteria, final hydrologic modelling of the facility, storage calculations, inlet and outlet design, maintenance and access features, and the overland flow route design. Excerpts from this report are provided in the following sections to indicate the level of detail typically included in such a document.

I.3.1 Functional Design Report Example

Introduction

Proponent X is developing a residential subdivision and golf course in Township X. It is located on the shores of Lake XXXX, east of Road Number 2 and north of Road Number 8. As illustrated in Figure 1, the development is scheduled to proceed in three phases **[Editor’s Note: Figure 1 has not been included]**. Construction of Phase 1 and its associated services has commenced. The primary stormwater management practice that has been implemented for this portion of the development is an extended detention quality control facility located adjacent to Lake X. This facility, a wet pond, has been named the South Water Quality Pond. It is proposed that an extended detention wet pond for quality control also be implemented to service both Phases 2 and 3 of the development and has been named the North Water Quality Pond. The purpose of this report is to describe the detailed design of the North Pond.

Background

The justification and general design criteria for the proposed stormwater management facility are provided in the “Stormwater Management Study,” 199x. Given the quality concerns in the receiving Lake, the Study recommended that the facility consist of an extended detention wet pond sized to provide quality control of runoff for the areas tributary to it. In accordance with the 1991 MOEE/MNR Interim Stormwater Quality Control Guidelines for New Developments, the active storage requirements for quality control in the pond were based on detaining the runoff from a 25 mm storm for 24 hours. Current guidelines as given in the Stormwater Management Practices Planning and Design Manual (MOEE, 1994) recommend only 40 m^3 of extended detention per hectare of area draining to the facility. This more recent guideline tends to generate much smaller storage requirements for extended detention than the 1991 guideline. However, given the sensitive nature of the receiving Lake, the former, more conservative criteria has been retained for the purposes of determining the active storage requirements for erosion quality control in the North Pond. Permanent pool requirements for quality control will be based on the guidelines given in the 1994 MOEE SWMP Manual **[Editor’s Note: designers should refer to the 2003 SWM Planning and Design Manual for guidelines]**.

As specified in the Stormwater Management Study, all minor system flow from the areas tributary to the proposed North Pond will be directed to the facility. The minor system has been designed to convey the five year event. Therefore, the peak flow that will be conveyed to the facility under the 5 to 100 year storms is the 5 year post-development flow from the area draining to it. Major system flow generated in this area will be conveyed to the Lake by means of an overland flow route designed to convey major system flows generated up to the 100 year storm.

It should be noted that prior to the submission of the Stormwater Management Study, the estimated drainage area for the North Pond was 12.34 hectares. Given the current development scheme and grading plan, the drainage area will instead be 9.25 hectares as shown in Figure X **[Editor's Note: not included]**. The average percent imperviousness of this area will be approximately 45%.

Approval Requirements
It is anticipated that this report and the accompanying drawings will provide the required documentation for the following approvals:

- Township (Plan Approvals);
- Ministry of Natural Resources (Work Permit for Storm Outfall to Lake);
- Ministry of Environment and Energy (Certificate of Approval); and
- Conservation Authority (Plan Approvals and Fill and Construction Permit).

Design Criteria
The Lake has been classified as a Class 1 habitat requiring Level 1 protection **[Editor's Note: now referred to as enhanced protection]**. In order to ensure the protection and enhancement of the Lake and its watershed, a series of design criteria were identified for the North Pond. Criteria were established in the "Stormwater Management Study" as well as taken from the detailed design phase of the South Pond and are described below.

Functional Criteria
The following criteria must be satisfied to ensure that the water quality control requirements are met:

i) The facility should be designed as a wet pond. The minimum permanent pool volume in the facility should be 125 m^3/ha of area draining to the facility. This volume is the minimum recommended permanent pool volume in a wet pond facility designed to provide Level 1 treatment for a 45% impervious area as specified in the 1994 MOEE SWMP Manual **[Editor's Note: now referred to as enhanced protection; designers should refer to the 2003 SWM Planning and Design Manual]**. While there is the potential to create a permanent pool with a volume larger than the minimum MOEE recommended volume, consideration must be given to the permanent pool volume that can actually be sustained by the contributing drainage area. Typically, it is desirable to have a 30 day turnover in the permanent pool. The maximum permanent pool volume should be determined by taking into consideration the historical average monthly rainfall depths in the vicinity of the site and the monthly runoff expected given the imperviousness of the site and typical rainfall depth distributions for southern Ontario as specified in the MOEE SWMP Manual.

ii) The facility should have sufficient active storage for 24 hour detention of the runoff from the contributing drainage area under a 25 mm event. This criteria was established to satisfy the quality concerns for the receiving Lake.

iii) Storm runoff from the area tributary to the pond will be conveyed to the facility by means of a minor system designed to convey the five year event. The facility should be designed with sufficient active storage to pass the peak minor system flow without overflowing.

iv) The facility should be designed with an emergency overflow weir.

v) Major system flow from the subdivision will be conveyed to the Lake by means of an overland flow route. According to the Township design criteria for open channels, the maximum flow velocity in the overland flow route should be 2.5 m/s.

vi) Any ponding that occurs at the low point on the road adjacent to the pond (the major overland flow route) must not extend beyond the curb line except at the location of the entrance to the overland flow route.

Environmental, Aesthetic and Safety Criteria
The following criteria must be met to ensure that the facility provides environmental benefits, is attractively integrated into its surroundings, and presents a minimum hazard to the public:

i) The maximum permanent pool depth should be 2.0 m. The maximum active pool depth should be 1.5 m.

ii) A minimum length-to-width ratio of 3:1 should be maintained in the pond ensuring the pollutant removal benefits associated with a longer flow path.

iii) The facility should be designed with a sediment forebay to improve pollutant removal by trapping larger particles near the inlet of the pond. The forebay should be 1-2 m deep to minimize the potential for re-suspension and to prevent the conveyance of re-suspended material to the pond outlet. The forebay dimensions should be selected to provide maximum dispersion of the inflow to the pond, thereby reducing velocities in the cell.

iv) Side slopes around the facility should vary to present a natural appearance. Terraced grading should be used to discourage public access to the pond.

v) The storm outfall to the Lake should be designed to create a minimum of disturbance within the 15 m buffer around the Lake.

vi) The stormwater management block (Block 7) that will contain the proposed facility will be bordered on the north and south by a golf course. A golf cart path should extend across the eastern end of the stormwater management block connecting the paths at the northern and southern limits of the block. An easement has been created for this path.

vii) The permanent water level in the pond should be such that the pond creates a visual amenity to the golf course.

Maintenance and Access Criteria

i) A hard surface should be installed in the forebay of the quality cell. The hard surface should be capable of withstanding the weight of the small grading equipment that will be used to periodically clean the forebay **[Editor's Note: this practice is no longer recommended in the 2003 SWM Planning and Design Manual – see Chapter 4]**.

ii) An access road should be provided to and from the forebay. The outlet structure from the pond and the pond outfall to the Lake should also be made accessible.

iii) The extended detention control device should be located within an easily accessible manhole rather than within the wetted area of the pond (i.e., perforated risers should not be used).

iv) A maintenance pipe should be provided to permit draining of the permanent pool.

Hydrologic Modelling Approach

In order to determine the active storage requirements in the North Pond for quality control and the design flows for the overland flow route, the hydrologic models (OTTHYMO) described in the "Stormwater Management Study" were retrieved and updated to reflect the current drainage scheme for the Phases 2 and 3 lands. The 9.25 hectares that will drain to the North pond were modelled as one basin using the STANDHYD command. Total and directly connected impervious values used in the model were 45% and 30%, respectively. A characteristic slope of 2% was used to reflect the proposed lot and street grading on the subject lands. A curve number of 78 was used based on the silty sand soils on the site and the proposed land use. A DUHYD command was used to split the minor and major system flows. Minor system flows were taken to be the 5 year flow generated on the site. The model was run with the 4 hour 5, 25 and 100 year Chicago distribution storms, as well as a 2 hour 25 mm storm. A simulation was also conducted with a 4 hour 25 mm storm. However, since the runoff volumes generated under this storm were smaller than the shorter duration 25 mm storm, the 2 hour 25 mm storm was taken to be critical.

Modelling Results
The minor system flows and 5 through 100 year major system flows derived from the OTTHYMO simulations are summarized in Table I.1. The minor system flows are comparable to those derived using the Rational method as illustrated in the Table. Under the 25 mm storm, the runoff depth from the proposed development is 12.22 mm. This translates into a runoff volume of 1,130 m³. The detailed modelling results are included in the appendix **[Editor's Note: not included]**. The storm sewer design sheets for the areas draining to the pond are given in the appendix **[Editor's Note: not included]**.

Table I.1: Summary of OTTHYMO Results

Minor System (5 Year) Flows m³/s		Major System Flows m³/s		
OTTHYMO	**Rational Method**	**OTTHYMO 5 Year**	**OTTHYMO 25 Year**	**OTTHYMO 100 Year**
1.07	0.94	0	0.86	1.68

Functional Design of North Pond and Overland Flow Route
The following sections describe the detailed design of the North Pond and illustrates how each of the design criteria will be met.

North Pond Storage Requirements

Permanent Pool
Using the MOEE SWMP Manual guidelines, the minimum required permanent pool volume for the proposed facility is 1,160 m³ **[Editor's Note: designers should refer to the 2003 Manual]**. The maximum permanent pool volume was determined by multiplying the historical average monthly rainfall depth near the site in the driest month of the summer by a weighted runoff coefficient.

This coefficient was derived by recognizing that the amount of runoff generated under a given event will depend on the depth of the storm and by assuming that the frequency distribution of rainfall depth near the site is the same as the frequency distribution reported for typical southern Ontario sites in the MOEE SWMP Manual. A review of the historical average monthly precipitation records for the closest climatological station (with the same approximate elevation as the site) indicates that September is the summer month with the smallest average rainfall. The rainfall in this month is 65.1 mm. Using a runoff coefficient of 0.38 for the subject property, the maximum permanent pool volume is approximately 2,300 m³.

Drawing X shows the grading proposed to provide the required storage **[Editor's Note: not included]**. As can be seen in the drawing, the facility has a 1 m deep permanent pool and the permanent water level is 252.0 m. The permanent pool volume is approximately 1,980 m^3.

Active Pool

The results of the OTTHYMO modelling indicate that the required active pool volume for erosion control is 1,130 m^3. As shown in Table I.2, this volume is provided just below an active depth of 0.40 m (elevation 252.40 m). Water ponding up to this depth will drain by means of a reverse sloped pipe fitted with an orifice plate sized for 24 hour drawdown. Any water ponding above the 252.40 elevation will drain by means of a ditch inlet catchbasin located at the southeast corner of the pond. If the water elevation in the pond should reach an elevation of 252.75, the emergency weir will begin to operate.

Table I.2: Elevation – Active Storage Relationships for North Pond

Elevation (m)	Active Storage (m^3)
252.00	0
252.20	580
252.40	1,200
252.60	1,870
252.80	2,570
253.00	3,340

As stated earlier, storm runoff from the area tributary to the pond will be conveyed to the facility by means of a minor system pipe designed to convey the five year event. Since the facility will accept 5 year post-development flows from its contributing drainage area, it is important that the facility have sufficient active storage to pass the 5 year flow without surcharging. In order to confirm that no surcharging will occur, two OTTHYMO simulations were conducted:

1. to predict the maximum water elevation in the pond under a 100 year storm assuming that there is no active storage in the pond at the start of the storm and that the ditch inlet catchbasin and orifice are fully operational; and

2. to predict the maximum water elevation in the pond under a 100 year storm assuming that the water level in the pond is 252.40 m at the start of the storm and that the ditch inlet catchbasin and the orifice are blocked (i.e., the only outlet from the pond is the emergency overflow weir).

The simulations were conducted by performing a ROUTE RESERVOIR command on the minor system hydrograph calculated using the DUHYD command. The storage outflow tables used in the ROUTE RESERVOIR command were tailored to reflect the different scenarios. The results of these simulations are illustrated in Table I.3 which indicates that under normal operating conditions (i.e., outlets not blocked), the maximum water level in the pond will be 252.74 m. Under extreme operating conditions, the maximum water elevation in the pond will be 252.94 m. The detailed results of these simulations are included in Appendix X **[Editor's Note: not included]**.

Table I.3 Maximum Water Elevations – North Pond

Run 1: Water level is 252.00 m at start of storm. All outlets working			
	5 Year Storm	25 Year Storm	100 Year Storm
Peak Outflow From Pond (m^3/s)	0.17	0.30	0.44
Maximum Water Elevation (m)	252.56	252.65	252.74
Run 2: Water level is 252.35 metres at start of storm. Ditch Inlet Catchbasin (DICB) and Orifice Blocked			
	5 Year Storm	25 Year Storm	100 Year Storm
Peak Outflow From Pond (m^3/s)	0.29	0.49	0.73
Maximum Water Elevation (m)	252.86	252.90	252.94

North Pond Inlet Design

The design (5 year peak) inflow into the pond is 1.07 m^3/s. Careful consideration has been given to the design of the pond inlet in order to minimize the potential for re-suspension of previously settled material in the wet pond. The proposed inlet design is described below:

i) An 825 mm diameter pipe will convey the minor system flow from manhole 209 on the adjacent road to the pond. The invert of the pipe at the pond inlet is 252.0 m.

ii) There is a 1 m deep sediment forebay at the entrance to the pond. This pond is separated from the rest of the pond by a 0.8 m berm. The length and width of the forebay have been sized according to the dispersion, volume and surface area criteria given in the 1994 MOEE SWMP Manual **[Editor's Note: designers should refer to the 2003 SWM Planning and Design Manual]**.

iii) The inlet will be protected from erosion by placing erosion control blocks along the erosion-prone areas adjacent to the pipe.

North Pond Outlet Design

In designing the outlet for the North Pond, the following was considered:

- providing 24 hour drawdown of the volume required for extended detention;
- passing flows in excess of the first flush out of the pond without causing surcharging; and
- providing easy access for maintenance.

The outlet from the pond is described below:

i) The extended detention control device for the pond will consist of a 300 mm diameter reverse sloped pipe fitted with a 142 mm diameter orifice at its connection to MH 3 (see Drawing X **[Editor's Note: not included]**). The orifice has been sized to provide 24 hour detention of the 1,200 m^3 of active storage available below an elevation of 252.40 m. The invert of the orifice will be set at an elevation of 252.0 m. The calculations used for sizing the orifice are included in Appendix X **[Editor's Note: not included]**.

ii) A 1,200 mm × 600 mm Type A ditch inlet catchbasin will convey runoff in excess of the first flush out of the pond. The invert of the ditch inlet catchbasin will be 252.40 m. The ditch inlet catchbasin drains to a 600 mm diameter pipe connected to MH 4. A 750 mm diameter pipe will extend from this manhole to the Lake.

iii) A 4.6 m wide emergency overflow weir set at an elevation of 252.75 m will convey flows out of the facility in the event that the other outlets are not functioning properly. The weir has been sized to pass a flow equivalent to the design flow into the facility (i.e., 1.07 m^3/s) with a maximum water elevation in the pond of 253.0 m. The emergency spillway will convey flows to the overland flow route into the Lake. The emergency spillway will be protected from erosion by means of a vegetated erosion control mat. Assuming a maximum water elevation in the pond of 253.0 m, the maximum velocities on the emergency spillway will be 1.93 m/s.

The stage-storage-outflow relationships for the pond are given in Appendix X **[Editor's Note: not included]**.

Maintenance and Access Features for North Pond

Specific attention has been give to the maintenance and access features of the facility. In particular, the following items should be noted:

i) A 4 m wide access route constructed of a vegetated, perforated cellular confinement system backfilled with 30/70 topsoil/sand mix will extend from the adjacent road to the forebay of the pond. The cellular confinement system has been designed to provide load support for the small grading equipment that will occasionally be required to clean the forebay.

ii) The forebay itself will be lined with erosion control blocks which have been sized to support the maintenance equipment that will periodically be required for sediment removal **[Editor's Note: this practice is no longer recommended in the 2003 Manual]**.

iii) A 300 mm diameter maintenance pipe will be provided at the pond outlet to facilitate draining the pond. The pipe will be fitted with a gate valve as shown in Drawing 1 **[Editor's Note: not included]**.

iv) The slide frame that will contain the orifice gate at the outlet of the extended detention control pipe has been designed such that it can also be used to isolate the extended detention control pipe if required.

v) The manholes at the pond outlet will be accessible from the asphalt pathway shown in Drawing 1 **[Editor's Note: not included]**. A second pathway (to be constructed by others) will extend to the pond outfall at the Lake.

Design of Overland Flow Route

A major system outlet for the Phases 2 and 3 lands will be created between Lots 56 and 57 on the adjacent road. An overland flow route will be constructed to convey major system flows from the low point on the road, easterly between lots 56 and 57 and then through the stormwater management block towards the Lake. The average slope for the route will be approximately 6.1%. The route will be constructed as described below:

i) The first 103 m of the overland flow route will double as the maintenance access road for the pond. This portion of the route will be constructed of a vegetated, perforated cellular confinement system backfilled with 30/70 topsoil/sand mix. Given the 100 year design flow of 1.68 m^3/s, the maximum velocity on this portion of the route will be 2.24 m/s. The velocity calculations for the overland flow route are included in the appendix **[Editor's Note: not included]**.

ii) The final 47 m of the route will be lined with a vegetated, permanent erosion control mat. Given the 100 year design flow of 1.69 m^3/s (overland flow plus flow from the emergency spillway), the maximum velocity on this portion of the overland flow route will be 2.28 m/s.

iii) The overland flow route will pass over the asphalt pathway located in Part 2 of Block 7. Given the 100 year design flow of 1.69 m^3/s, the maximum flow depth and velocity on the pathway will be 0.16 m and 2.28 m/s, respectively.

iv) At the outlet of the overland flow route, a 2 m long, 5 m wide rip-rap apron will be constructed to protect the shoreline from erosion. The rip-rap will have a median diameter of 200 mm and will be placed to a depth of 400 mm. The erosion control mat that will line the overland flow route will extend underneath the rip-rap to prevent any native fines from being washed away.

v) The maximum ponding elevation at the low point on the adjacent road will be 259.30 m. The ponding limits on the road will not extend beyond the curb line except at the location of the entrance to the overland flow route and at several of the driveways located near the low point. The ponding limits are shown in Figure E-2 in the appendix. The ponding calculations are also given in the appendix **[Editor's Note: not included]**.

Summary

1. The Lake has been classified as a Level 1 habitat. Quality control of stormwater runoff for the proposed Phases 2 and 3 of the subdivision is required to meet guidelines for protecting a Level 1 habitat.

2. Quality control for the proposed development will be provided in an extended detention wet pond.

3. The permanent pool in the wet pond will have a volume of 1,980 m^3. This volume is greater than the 1,160 m^3 volume recommended in the 1994 SWMP Manual for wet ponds that are to provide Level 1 quality control **[Editor's Note: now referred to as enhanced protection in the 2003 SWM Planning and Design Manual]** of runoff from a 45% impervious area. Given the historical rainfall records in the area, it is predicted that the permanent pool will have an approximate 30 day turnover during the driest months of the summer.

4. An extended detention control device at the outlet of the wet pond will provide 24 hour drawdown of the 1,130 m^3 that will runoff from the proposed development under a 25 mm event.

5. Storm runoff from the area tributary to the pond will be conveyed to the facility by means of a minor system designed to convey the five year event. A ditch inlet catchbasin at the outlet of the pond will convey flows in excess of the first flush out of the pond. These flows will be conveyed to the Lake by means of a 750 mm diameter storm sewer.

6. An emergency overflow weir will convey flows out of the pond in the event that the ditch inlet catchbasin and/or orifice become blocked.

7. A 300 mm diameter maintenance pipe has been provided at the pond outlet in the event that the permanent pool needs to be drained.

8. The pond has been designed with a 1 m deep sediment forebay. The forebay will provide benefits with respect to settling and dispersion.

9. A 4 m wide access route constructed of a vegetated, perforated backfilled cellular confinement system with 30/70 topsoil/sand mix will extend from the adjacent road to the forebay of the pond. The cellular confinement system has been designed to provide load support for the small grading equipment that will occasionally be required to clean the forebay. The forebay itself will be lined with erosion control blocks **[Editor's Note: this practice is no longer recommended in 2003 Manual]**.

10. The major system outlet for the subdivision will be between Lots 56 and 57 on the adjacent road. An overland flow route will be constructed to convey major system flows from the low point on the road, easterly between lots 56 and 57 and then through the stormwater management block towards the Lake. The first 103 m of the overland flow route will double as the maintenance access road for the pond. This portion of the route will be constructed of a vegetated, perforated cellular confinement system backfilled with 30/70 topsoil/sand mix. The final 47 m of the route will be lined with a vegetated, permanent erosion control mat. The 100 year flow velocities on all portions of the route will be below the 2.5 m/s maximum specified in the Township criteria for design of open channels.

11. The maximum (100 year) ponding elevation at the low point on the adjacent road near the entrance to the overland flow route will be 259.30 m. The ponding limits on the road do not extend beyond the curb line except at the location of the entrance to the overland flow route and at several of the driveways located near the low point.

I.4 Example 3 – Integrated "Treatment Train" Infiltration System (Quality and Quantity Control)

This example is located within a new 28.3 hectare residential development. This development forms the first part of a larger 250 hectare subwatershed that is being developed based on the criteria contained within the design report **[Editor's Note: not included]**. A "treatment train" approach was used to design the lot level, conveyance and end-of pipe stormwater management facilities required.

The receiving outlet is a Level I coldwater stream within a Provincially Significant Wetland **[Editor's Note: requires what is now referred to as enhanced protection]**. In the undeveloped state, there is little or no surface runoff discharged to the receiving stream. Under normal rainfall events (2 to 100 year design storms), the precipitation infiltrates into the underlying outwash sands and gravels and is routed through the overburden groundwater aquifer to discharge in the creek. A primary objective of the design and construction of the stormwater management system is to maintain these characteristics.

The final design for the stormwater management system was developed through consultation with the City, the Conservation Authority and the Ministry of Natural Resources. The Ministry of Environment and Energy reviewed and issued the Certificates of Approval to construct the facilities.

The design consisted of the following components:

Lot Level Controls:	Runoff from the roof and rear yards is directed over grassed surfaces to a swale/infiltration trench system. The swale/infiltration trench system is designed to route, collect and infiltrate the runoff from all events up to the 5 year design storm.
Conveyance Controls:	The runoff from the driveway and road surfaces is routed through oil/grit manholes to pre-treat the runoff prior to the release to the end-of-pipe system. It was decided that direct infiltration of the road runoff was undesirable.
End-of-Pipe Controls:	The infiltration basin/trench system implemented for the end-of-pipe control, through the centre of the site, has the capacity to collect, filter and recharge the runoff from all rainfall events up to the 100 year design storm for the entire development. The "first flush" (2 year) storm is infiltrated through the vegetated sand filter that extends over the bottom of the greenway for the full length of the facility. Runoff volumes greater than the "first flush" event up to the 100 year event are routed to an infiltration trench system constructed along both sides of the greenway basin.

An "Environmental Implementation Plan" was prepared to compile the information generated at the conceptual design stage plus the final stormwater management design into a single comprehensive document to guide construction. Edited excerpts from this document have been included focussing on the stormwater management design and the supporting documentation required for approvals **[Editor's Note: Appendices and non-essential figures have been omitted for purposes of conciseness]**.

The following drawings are attached in reduced format to show the construction details:

- A General Plan showing the layout of Phase I of the Subdivision (Figure I.10);
- Four Plan and Profile drawings showing the construction details for the end-of-pipe greenway system (Figures I.11, I.12, I.13 and I.14);
- One Plan showing the details of the rear lot infiltration gallery system (Figure I.15); and
- One Drawing showing the landscaping details for the end-of-pipe greenway system (Figure I.16).

I.4.1 Environmental Implementation Report

Excerpts from the City of Guelph's Environmental Implementation Report are outlined below, including the rationale, design criteria and analysis results used to design and construct the stormwater management system in the Pine Ridge Subdivision.

Introduction

The Pine Ridge Subdivision received Draft Plan Approval in July 1995. The conditions of Draft Plan Approval require that the following reports and/or plans be prepared to support the detailed final design of the subdivision and the implementation of the works:

i) Stormwater Management Report;
ii) Site Grading and Drainage Plan;
iii) Erosion and Sediment Control Plan; and
iv) Tree and Hedgerow Inventory and Conservation Plan.

Instead of separate documents, the above reports are combined into one comprehensive Environmental Implementation Report for the Pine Ridge Subdivision. The preparation of this document was guided by but supersedes all previous reports. The Environmental Implementation Report was jointly prepared by various consultants to specifically address Conditions 17 and 18 of the Ministry of Municipal Affairs and Housing and Conditions 19, 20, 27, 35, 37, 41, and 46 of the City of Guelph resolution dated June 12, 1995.

The Environmental Implementation Report is intended to govern and direct the design, construction, monitoring and maintenance of the services and stormwater management facilities in the Pine Ridge Subdivision.

Location

Figure I.7 shows the location of the proposed development and the surrounding area. The site is bounded by Gordon Street to the west, the Farley Farm to the south, by Ridgeway Avenue/Malvern Crescent to the north and by other lands owned by the developer in the annexed area east to Victoria Road.

Existing Conditions

a) Land Use

The existing land use for the Pine Ridge lands is agriculture. The predominant crops grown on these lands in recent years has been corn, beans and wheat. The adjacent lands to the east and south are also in agricultural production. The lands to the north (Malvern/Ridgeway) and west (Lowes/Dawn) have been developed with individual wells and septic systems.

b) Topography

The topography on the Pine Ridge lands is relatively flat. Most of the site slopes in a northwesterly direction toward Gordon Street. The north easterly part of the site slopes toward the kettle features in the Torrance Creek Watershed. The average gradient of these lands is 0.5%.

c) Soils

The predominant surface soil type throughout the Pine Ridge lands is Burford Loam (Wellington County Soils Maps). The hydrologic soil classification for Burford Loam is AB. The good drainage characteristics and high infiltration rates for this soil type have been verified by the geologic and hydrogeologic investigations completed for the Hanlon Creek Watershed Plan (Marshall Macklin Monaghan and LGL Ltd., 1993) and the Watershed Management Strategy for the Upper Hanlon Creek and its Tributaries (Gamsby and Mannerow Limited, Cumming Cockburn Ltd., and Code MacKinnon Ltd., 1993).

The kettle lake features located on the eastern boundary of the proposed development are identified as having a layer of muck soils in the bottom.

d) Water Table Monitoring

A network of water table observation wells was installed in the area of Clair Road and Gordon Street in 1988. Monitoring of the observation wells has been carried out on a bi-monthly basis since the installation. Figure I.8 shows the monitoring wells installed on the Pine Ridge property.

e) Site Constraints

The lands in the area of Gordon Street and Clair Road, and in this particular instance the Pine Ridge lands, do not have a typical or manmade drainage connection to Hanlon Creek or its tributaries. Therefore, surface runoff from the site is negligible. The combination of flat topography and permeable soils infiltrates the precipitation from the normal range of rainfall events. Only under extreme rainfall events such as a Regional Storm will surface runoff occur.

The recommendation of the Hanlon Creek Watershed Plan and the Watershed Management Strategy is that all runoff generated by the normal range of design storms (2 to 100 year events) be pre-treated and recharged to the shallow groundwater system.

Stormwater Management Criteria

The studies, policies and guidelines used to develop the stormwater management plan for the Pine Ridge Subdivision were as follows **[Editor’s Note: some references may be out of date]**:

1) Hanlon Creek Watershed Plan, October 1993

2) A Watershed Management Strategy for the Upper Hanlon Creek and its Tributaries, June 1993

3) Environmental Impact Statement, Ariss Glen Developments, Torrance Creek/ Hamilton Corners, Class 2 Wetland Complex

4) Stormwater Management Practices Planning and Design Manual, 1994

5) Interim Stormwater Quality Control Guidelines, 1991

6) Stormwater Quality Best Management Practices, 1991

7) MTO Drainage Management Technical Guidelines, 1989

8) Urban Drainage Design Guidelines, 1987

Figure I.7: Location of the Proposed Development and Surrounding Area

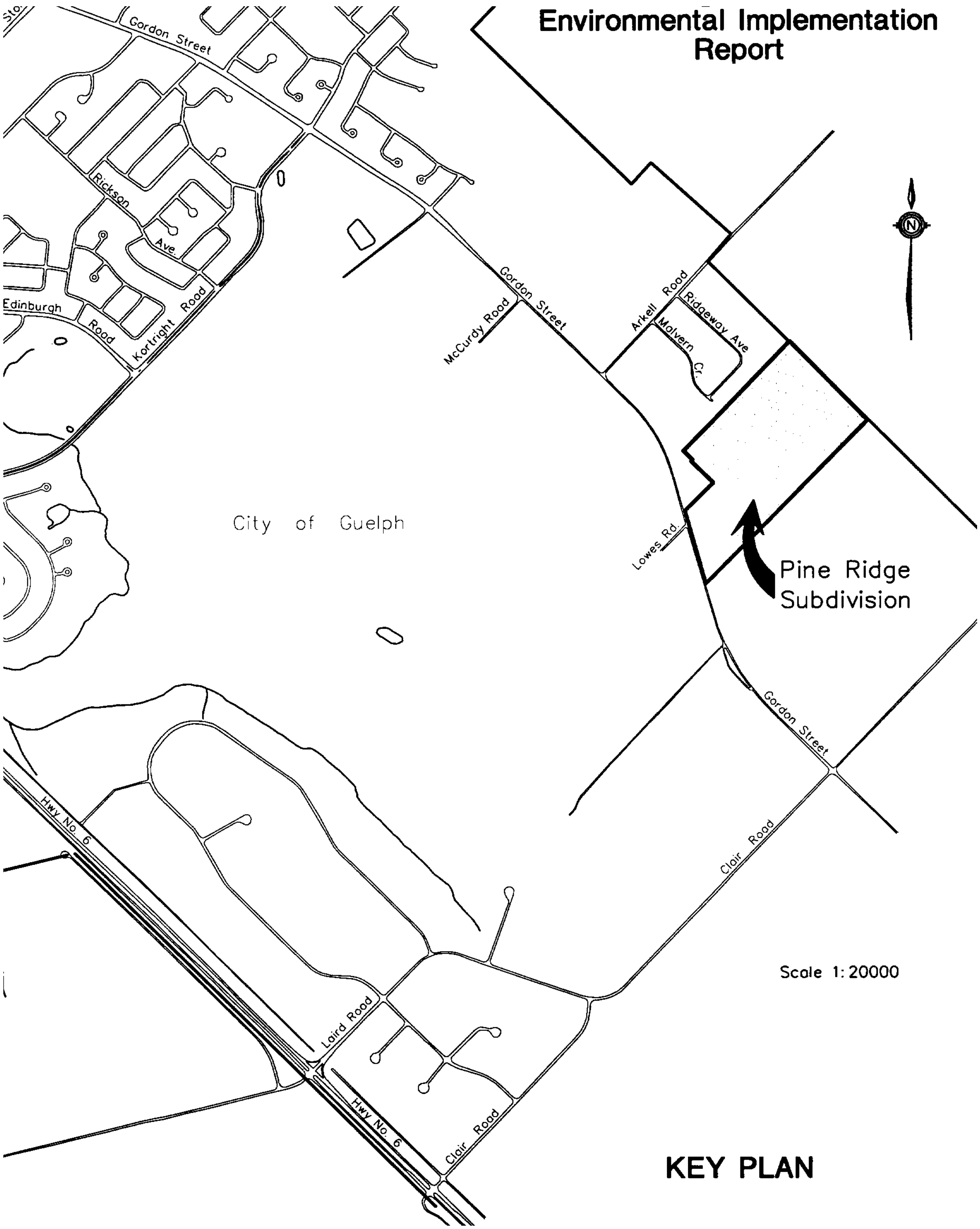
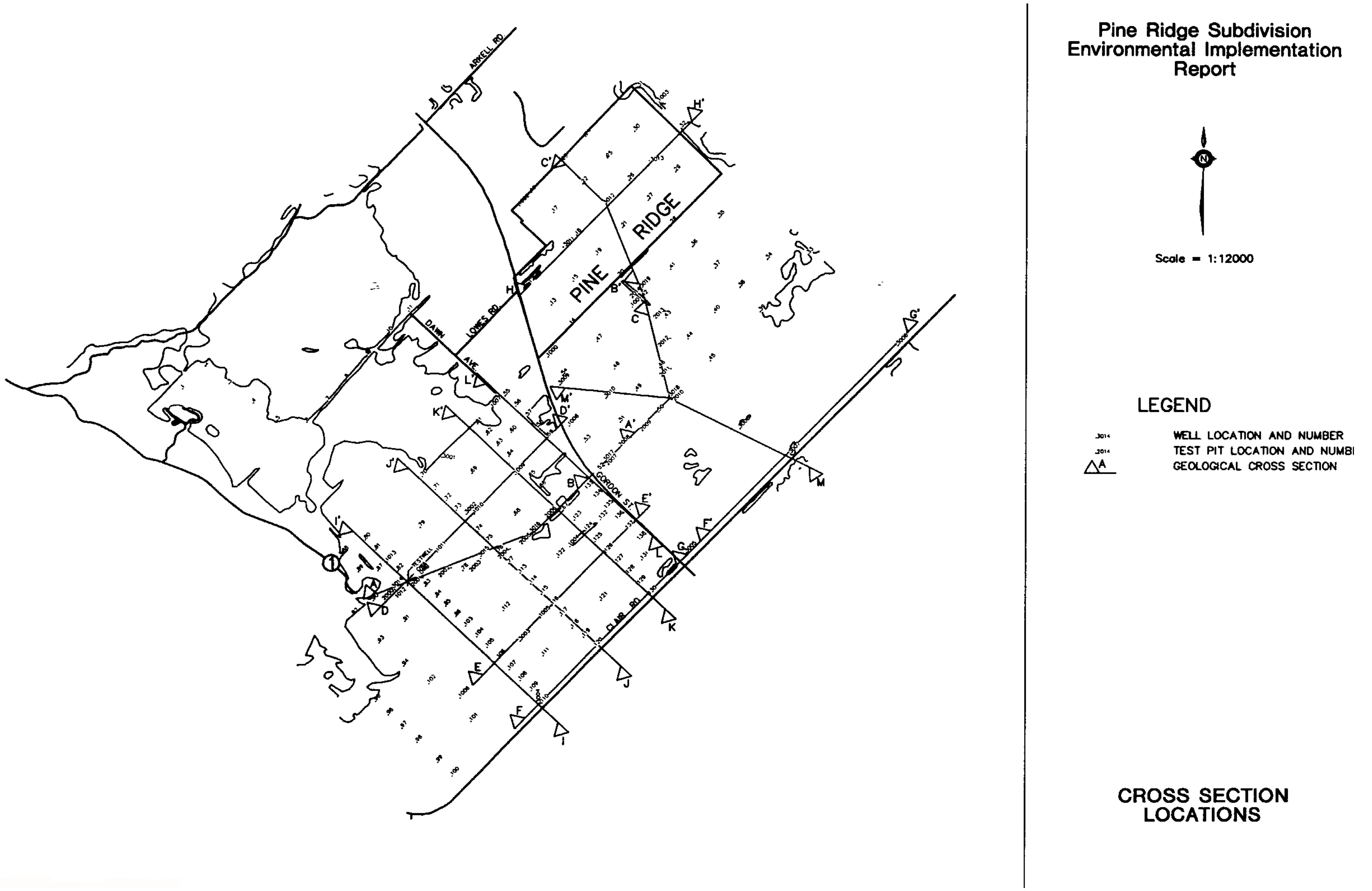


Figure I.8: Locations of Monitoring Wells on Pine Ridge Property



The objectives of the stormwater management plan are as follows:

1) Promote the recharge of storm runoff on all grassed or pervious surfaces remote from the end-of-pipe system using lot level controls.

2) Promote runoff infiltration in the end-of-pipe system after suitable pre-treatment to remove sediments that could have a detrimental impact on the functioning of the greenway system.

3) Provide stormwater quantity controls for a range of design storms (up to the 100 year event). All events within this range of storms will be contained, treated and recharged in the greenway system. Adequate storage capacity will be provided to ensure that surface runoff will not occur under any rainfall event up to the 2 to 100 year design storms.

The method used to evaluate and design the stormwater management plan was as follows:

1) The mass rainfall data for the "first flush" design storm was generated using a two hour duration rainfall event. A three hour duration rainfall event was used to generate the mass rainfall data required to model the 5 and 100 year design storms. The Chicago parameters and the total depth of rainfall for each storm are as follows:

	First Flush	**5 Year**	**100 Year**
a =	743.000	1,593.000	4,688.000
b =	6.000	11.000	17.000
c =	0.799	0.879	0.962
r =	0.400	0.400	0.400
td =	120.000	180.000	180.000
Rainfall depth (mm) =	31.200	47.200	87.300

The Horton infiltration method was used in the runoff calculations. The infiltration parameters are very conservative to account for the long-term efficiency of the proposed drainage system. The parameters used in MIDUSS were as follows:

	Impervious Areas	**Pervious Areas**
Maximum Infiltration	0.0 mm/hr	76.0 mm/hr
Minimum Infiltration	0.0 mm/hr	13.0 mm/hr
Lag Constant	0.0 hr	0.25 mm/hr
Depression Storage	1.5 mm	5.00 mm

Based on the hydrogeologic investigation completed for the Watershed Management Strategy for the Upper Hanlon Creek and its Tributaries, the estimated soil permeability for the sand and gravel overburden found on the Pine Ridge site was 1.7×10^{-1} m^3/s. In the Hanlon Creek Watershed Plan, the estimated permeability for this soil type was found to range between 1 and 1×10^{-1} m^3/s. For design purposes, the coefficient of permeability for the soils on this site was reduced to 5×10^{-2} m^3/s. The more conservative permeability has been used to account for the expected long-term efficiency of the infiltration system.

The hydrologic model MIDUSS was used to create the runoff hydrographs and to route the flows through the storage and infiltration structures.

Stormwater Management Design Concept

Under the normal range of rainfall events, storm runoff does not occur from the Pine Ridge lands. The stormwater management system implemented for this development must emulate those existing conditions. To achieve this, the stormwater management system must have the capacity to infiltrate all runoff generated for the complete range of design storms up to and including the 100 year event. Only extreme events exceeding the 100 year storm are expected to generate surface flow that will leave the site.

The approach to stormwater management on this site must be an integrated one. This involves using the highly permeable soils throughout the development to start the infiltration process as close as possible to the point where the precipitation lands on the ground. The stormwater management system will include lot level, conveyance and end-of-pipe controls.

Lot level controls will include rear lot infiltration galleries **[Editor's Note: type of infiltration trench]**, flat swale drainage and sump pumps discharging to the rear yards. With minor exceptions, all roof drainage will be directed to the rear yard.

Multiple storm sewer outlets will direct runoff to the greenway to keep the size of the drainage catchments small and to minimize the length of the impervious flow paths. Pre-treatment will be provided by oil/grit manholes (to clean the runoff by removing sediments and oils).

The end-of-pipe system is the greenway that stretches through the center of the Pine Ridge Subdivision. The greenway is comprised of three terraces that will collect, clean, filter and infiltrate the runoff. Quality control will be achieved by routing the discharge from the storm sewer outlets through settling areas to further remove sediments. The runoff will then be distributed over the surface of the greenway for infiltration through the bottom of the greenway.

To provide stormwater quantity control, for events exceeding the quality control rates identified in the current policies and guidelines, inlet structures will convey the pre-treated runoff to a gallery for direct recharge to the permeable native soils.

The greenway system will be designed with the capacity to provide treatment and recharge for the entire development site under the full range of design storms (2 to 100 year events). The lot level controls will be enhancements to the greenway. The lot level facilities will reduce the volume of runoff being conveyed to the greenway, thereby creating reserve capacity within the greenway.

The description and function of the end-of-pipe stormwater management facilities are outlined below:

a) Greenway:

The greenway is continuous from Gordon Street at the southwest corner of the site to the kettle at the northeast corner,

i) to provide stormwater access as frequently and uniformly as possible throughout its length to minimize the runoff volume and velocity that will be discharged to the ground surface at any location.

ii) to distribute the infiltration function over as much of the site as possible to maximize pervious surface contact.

iii) to permit flows that will exceed the storage capacity of the greenway (greater than the 100 year design storm) to discharge directly to the Gordon Street right-of-way and the kettles.

The operational features of the greenway will be <u>graded essentially flat</u> from end to end,

i) to provide multiple access points for storm runoff and to minimize stormwater travel distance and time from any point in the subdivision. This will direct the rainfall from hard surfaces onto vegetated surfaces as quickly as possible.

ii) to distribute the runoff to the largest possible ground surface area to maximize the contact surface and thereby minimize the length of time necessary for infiltration to occur. This also utilizes the maximum surface area for aerobic bacterial activity, thereby maximizing the treatment of any biodegradable contaminants that may be carried to the greenway.

iii) to minimize the flow velocity within the greenway and thereby minimize the potential for erosion.

iv) perimeter of the site, thereby minimizing the potential for drainage problems. Even so, the new homes adjacent to Ridgeway and Malvern will be higher than the existing ones. This is due to the grading of the road to permit sanitary and storm servicing and to ensure the operation of the rear lot infiltration gallery.

v) to maintain the natural surface and ground water drainage divides.

vi) micro variations in the topography of the bottom of the greenway terraces, below the operational levels, will be incorporated to create a meandering undulating landscape to provide enhanced visual, ecological and habitat diversity.

The greenway has been designed with <u>3:1 side slopes</u>,

i) to create a small terrace approximately a metre in height, from the rear lot line to the bottom of the greenway. This will maximize the flat area available for recharge.

ii) to create a protected area for the installation of the recharge galleries which will accept flows exceeding the infiltration capability of the greenway bottom.

iii) to create a flat area for maintenance access within the greenway and to define the edge of the public property.

iv) a variety of side slopes (3:1 to 6:1) will be incorporated throughout the greenway system to create an aesthetically pleasing landscape during final design.

The vegetation in the greenway has been <u>ecologically selected</u>,

i) to maintain the porosity of the soils and maximize the infiltration capability.

ii) to minimize the level of municipal maintenance required in the facility.

iii) to maximize the nutrient uptake from the runoff that reaches the greenway.

iv) to create an atmosphere of aesthetic, cultural, social and recreational interaction.

<u>A 300 mm thick sand filter layer</u> will be constructed for the entire length and width of the greenway bottom, at the interface between the native gravel soils and the topsoil that will be placed over top, to prevent fine surface soils and sediments from penetrating the gravelly native soils and interfering with natural percolation capacity.

At storm sewer outlets, a peat layer may be added to further filter and polish the runoff prior to spreading over the greenway bottom for infiltration.

The sand layer will also permit the use of the greenway for some stormwater management and sediment control during construction. Sand contaminated by sediment accumulations can simply be removed and replaced before the final landscaping.

The inlet distribution/gallery system will be constructed of perforated polyethylene field tile, fed by catchbasin inlet structures strategically placed along the length of the tile and the greenway.

The inlet distribution/gallery system will be located in the side slope terraces of the greenway, adjacent to the rear lot lines:

i) for more cover and protection than would be afforded in the middle of the greenway (protection from frost and damage by human activity).

ii) for aesthetic, inconspicuous placement of inlet structures.

The inlet elevation to the distribution/gallery network will be set at the 2 year storm flood storage level to ensure that all storms with runoff volumes less than the two year storm are infiltrated through the grassed surface of the greenway.

The bottom of the distribution/gallery will be located approximately 1.0 metre above the average high water table to ensure adequate soil contact to facilitate recharge.

b) Park:

The park block has soil capabilities similar to the greenway and can infiltrate not only its own rainfall, but also the runoff from adjacent lands. The park will receive runoff from the rear of Lots 7 to 12, 33 to 36, and the Malvern Crescent lots that slope toward them. Any runoff from the rear of Lots 37 to 42 will drain to the east, to Terrace 3000.

An infiltration structure is proposed along the rear of Lots 7 to 12, 33 to 36, and 37 to 42. A similar structure could be extended along Street B to ensure the collection and infiltration of any runoff that may be generated in the park.

The grading in the park has been prepared based on discussions with the City of Guelph's Parks and Recreation Department.

c) Quality Control:

Quality control on this site will consist primarily of keeping any sediment accumulations on the surface of the greenways. During construction, there could be accumulations of sediment requiring periodic clean up, especially before final landscaping.

After servicing and house building is complete, accumulations of sediment will be very small, course grained and will be distributed over a very large surface area. It will be many decades, if ever, before it will be necessary to clean up post-development deposits.

Stormwater Management Plan

The SWMPs in the Stormwater Management Practices Planning and Design Manual (1994) were screened and nearly all were found to be applicable to this site. Not all were selected, however, because not all will be acceptable to the municipality and not all are cost-effective.

A significant factor in the selection of SWMPs for this site is the "closed" nature of the stormwater management facility. There will be no runoff from the site until a rainfall exceeding the 100 year storm occurs. Thus, no routine rainfalls, sediments, or contaminants will discharge from the site to any other property or water body.

Sediment accumulation during construction is the only contamination of any concern, and this can be effectively managed through physical means, as described in Section 5.0(c) and Section 8.0 **[Editor's Note: these sections have not been included]**.

The selected SWMPs can be categorized as lot level controls, pre-treatment controls, and end-of-pipe controls (although the end-of-pipe controls could be considered "conveyance controls").

Lot Level Controls

Stormwater management practices recommended to provide lot level control on this site are as follows:

Flat Rear Yard Swales/Rear Lot Infiltration Galleries
Drawing 16 **[Editor's Note: drawing has not been included]** shows the profile of the rear lot line through Catchments 130, 160, 264, 287, 501 and 502 and the location and the construction details for the rear yard swale/infiltration gallery systems to be installed in Phase I. The grade on the rear yard swale is 1.0%. The lot grading can be adjusted to create a small amount of ponding at the rear of each lot (about 0.1 m). This will collect and infiltrate minor runoff from the rear yards. When rainfall events are intense enough to cause flow in the swale, the inlet structures will convey the runoff to the infiltration gallery for more direct recharge.

The analysis shows that the swale/infiltration gallery systems will collect and infiltrate the runoff from all events up to and including the 5 year design storm. Approximately 70% of the storage/discharge capacity of the infiltration gallery would be used to control the rear lot drainage for a 5 year event. The following tables summarize the runoff rate and volume and the routing results through the infiltration galleries in Catchments 130, 160, 264, 287, 501 and 502.

Table I.4: Uncontrolled Flow Rate and Runoff Volume

Design Storm	Catchment 130		Catchment 160		Catchment 264	
	Flow Rate m^3/s	Runoff Volume m^3	Flow Rate m^3/s	Runoff Volume m^3	Flow Rate m^3/s	Runoff Volume m^3
First Flush	0.024	32	0.068	94	0.053	72
5 Year	0.032	58	0.096	169	0.073	130
100 Year	0.064	135	0.177	392	0.142	300
Design Storm	**Catchment 287**		**Catchment 501**		**Catchment 502**	
	Flow Rate m^3/s	**Runoff Volume m^3**	**Flow Rate m^3/s**	**Runoff Volume m^3**	**Flow Rate m^3/s**	**Runoff Volume m^3**
First Flush	0.085	117	0.025	31	0.007	29
5 Year	0.118	211	0.035	55	0.080	214
100 Year	0.227	487	0.082	128	0.402	890

Table I.5: Stage/Storage/Discharge Capacities Comparison – Rear Yard Infiltration – Catchment 130 (Typical)*

Control Point	Available Capacity			Actual Capacity Used		
	Peak Flow m^3/s	Storage Volume m^3	Storage Depth m	Peak Flow m^3/s	Storage Volume m^3	Storage Depth m
Bottom of Gallery	0	0	0.00			
First Flush	—	—	—	0.02	6	0.21
5 Year	—	—	—	0.03	8	0.30
100 Year	—	—	—	0.05	18	0.66
Top of Gallery	0.08	27	1.00			

* *Editor's Note: The five tables for Catchments 160, 264, 287, 501 and 502 have been omitted for purposes of conciseness.*

Conveyance Controls

Figure I.9 shows the drainage sub-catchments, drainage areas and the location of the storm outlet for each catchment. The catchments are as small as possible to minimize the discharge at any one location. The multiple storm sewer outlets will reduce the potential sediment accumulation.

The direct infiltration of runoff is not acceptable because adequate pre-treatment cannot be provided. However, the conveyance methods that will remove sediment and other potential contaminants from the runoff prior to discharging to the greenway will be implemented.

It is recommended that oil/grit manholes be installed to pre-treat the runoff from the streets in Phase I prior to discharging it to the greenway.

Oil/grit manholes are recommended for catchments with a drainage area less than or equal to 2 hectares. The sub-catchments for this development meet that criteria.

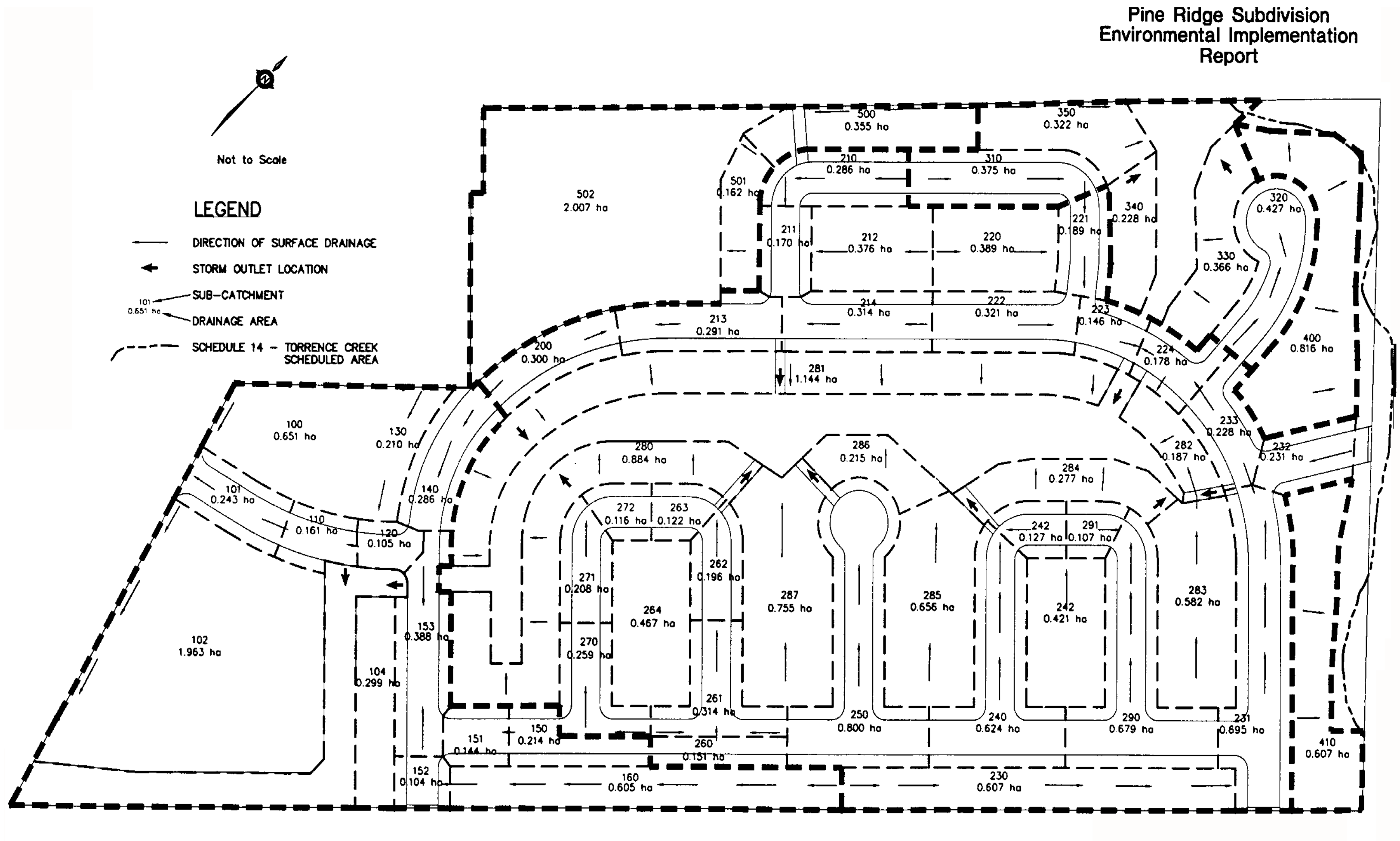
The removal of sediments through the use oil/grit manholes followed by the sediment forebays at the stormsewer outlets will provide pre-treatment of the runoff entering the greenway terraces.

End-of-Pipe Management

The end-of-pipe system is the greenway that stretches from Gordon Street through the center of the site to the kettle in the northeast corner. The greenway is comprised of three ponding terraces. The terrace at Gordon Street (Terrace 1000) is set slightly lower than the central terrace (Terrace 2000) which will be slightly lower than the kettle terrace (Terrace 3000).

The entire greenway system will be pre-graded as part of Phase I of the development. Terrace 1000 and part of 2000 will be constructed as part of Phase I. The rest of Terrace 2000 and Terrace 3000 will be topsoiled and seeded after pre-grading with the final construction occurring during the subsequent phases of the Pine Ridge Subdivision.

Figure I.9: Drainage Area Plan



Pre-treated runoff from the street network is released to the greenway in small quantities at multiple locations. A settling forebay will be constructed at each of the storm sewer outlets. These areas will provide energy dissipation and some sediment removal. The attached drawings show the construction details for the greenway system. A planting scheme for the greenway system is detailed on the attached drawings and in Section 9.0 **[Editor's Note: these drawings and this section has not been included]**.

The discharge from the settling bays will spread over the adjacent surface of each greenway terrace and will infiltrate through the vegetated surface of the greenway. Any suspended solids will settle on the surface. A sand filter will be constructed in the bottom of the greenway to prevent the surface soils from clogging the permeable native soils below. The sand filter will allow plant roots to maintain a porous interface between the soil surface and the underlying permeable soils.

Runoff volumes exceeding the quality control depth (first flush/2 year design storm) will flow by way of a series of inlet structures into the distribution/gallery network for direct recharge to the groundwater system.

The attached drawings show the location and extent of the greenway gallery network in Phase I of the Pine Ridge Subdivision **[Editor's Note: see Figures I.10 to I.16 at the end of this appendix]**.

Summer Operation

The greenway is comprised of three terraces identified as Terrace 1000 (Gordon Street), Terrace 2000 (centre) and Terrace 3000 (kettle). The depth of the terraces from the pond bottom to top-of-bank (rear lot line) is 1.80, 1.20 and 1.20 metres, respectively. The active storage depth in each terrace is 0.95, 0.65 and 0.53 metres, respectively. The remaining depth in each terrace up to the overflow weir is freeboard. The greenway system has been designed to contain the 100 year design storms within the above storage depths. The freeboard provides reserve storage and attenuation capability for events exceeding the 100 year design storm while protecting basements and foundations.

Table I.6 lists the total flow rate and the total runoff volume received by the each terrace under the "first flush," 5 year and 100 year design storms.

Table I.6: Uncontrolled Flow Rate and Runoff Volume (Total) – Summer Operation

Design Storm	Terrace 1000		Terrace 2000		Terrace 3000	
	Flow Rate m^3/s	Runoff Volume m^3	Flow Rate m^3/s	Runoff Volume m^3	Flow Rate m^3/s	Runoff Volume m^3
First Flush	0.74	1,021	1.61	2,305	0.2	287
5 Year	1.02	1,738	2.32	4,066	0.29	509
100 Year	1.95	3,737	4.72	9,110	0.61	1,140

Table I.7 compares the greenway routing results with the available stage-storage-discharge capacities for each terrace.

Table I.7: Terrace 1000 – Stage/Storage/Discharge Comparison – Summer Operation (Typical)*

Control Point	Available Capacity			Actual Capacity Used		
	Peak Flow m^3/s	Storage Volume m^3	Storage Elev. m	Peak Flow m^3/s	Storage Volume m^3	Storage Elev. m
SURFACE CONTROL						
Pond Bottom	0	0	332			
First Flush	0.03	1,080	332.50	0.03	856	332.42
5 Year	—	—	—	0.1	1,304	332.57
100 Year	—	—	—	0.26	2,651	332.95
Weir	0.41	6,232	333.6			
Rear Lot Line	3.67	7,531	333.80			
GALLERY CONTROL						
Bottom of Gallery	0	0	332			
First Flush	—	—	—	—	—	—
5 Year	—	—	—	0.07	22	332.23
100 Year	—	—	—	0.23	77	332.79
Top of Gallery	0.29	97	333			

* *Editor's Note: The tables for Greenway Terrace 2000 and Terrace 3000 have been omitted for purposes of conciseness.*

The attached drawings indicate the storage elevations for the “first flush,” 5 year and 100 year design storms for Phase I.

The estimated “drawdown” time for the “first flush” storm is 8 hours, for the 5 year storm 10 hours and for the 100 year storm 11 hours.

Water Quality

‘Reasonable Use’ Guideline MOE

The MOE ‘Reasonable Use’ guideline (Guideline B-7: The Incorporation of the Reasonable Use Concept into Groundwater Management Activities) was applied to this site to protect water quality.

Landscape Strategy and Vegetation

The following section presents the landscaping strategy for the Greenway System. The planting strategy has been designed to address concerns regarding the pre-treatment of stormwater runoff prior to infiltration to the groundwater system and the maintenance of the infiltration characteristics of the site.

The end-of-pipe control for the proposed development is provided by the Greenway System. Pre-treated runoff from the road network will be released to the Greenway at several locations. At each of these outlet points, a shallow (i.e., 30-45 cm deep) sediment forebay will be constructed to provide energy dissipation and additional removal of sediments, nutrients and heavy metals from the runoff.

Sediment Forebay Planting Strategy

The sediment forebays will be graded with 0.3 m of lower permeability soils (i.e., organics) to retain stormwater for a longer duration providing opportunities for the creation of a wet-mesic meadow habitat. By providing a wet meadow habitat within the sediment forebays, water quality can be enhanced through a variety of processes such as:

- sedimentation and physical filtration through root entrapment and sediment stabilization;
- adsorption to wetland vegetation, substrates and organic detritus; and
- nutrient uptake by plant root systems.

The wet meadow concept provides increased ecological, habitat and visual diversity. It is a safe method of pre-treating runoff since no permanent standing water will be present.

The following species that are tolerant of periodic short-term inundation with water have been recommended for planting within or around the margin of the wet meadow:

Typical Trees:

- eastern white cedar, tamarack, green ash, trembling aspen, balsam poplar, red maple, silver maple.

Typical Shrubs:

- red-osier dogwood, shrub willow spp., nannyberry, elderberry, chokecherry, Juneberry, grey dogwood, highbush cranberry, alternate-leaved dogwood.

The following low maintenance hydroseed mixture is recommended for ground cover establishment within the wet meadow:

25%	Canada blue joint grass (Calamagrostis canadensis)
25%	Rough-stalked meadow grass (Poa trivialis) or native substitute
20%	Highland Colonial bentgrass (Agrostis capillaris) or native substitute
15%	Creeping red fescue (Festuca rubra var. genuina)
5%	Tall White Aster (Aster lanceolatus)
10%	New England Aster (*Aster novae-angliae*)

The following native/non-invasive ground covers are recommended to supplement the above wet-mesic meadow seed mixture:

- sedge species, ostrich fern, virginia creeper, aster species, reed canary grass, tall manna grass, rattlesnake manna grass, common cattail.

Annual mowing with standard Parks and Recreation Department equipment following the release of plant seeds (i.e., fall) in the wet meadow/forebay areas is recommended to reduce biomass accumulation and maintain the infiltration characteristics of the site. Wetter areas within the sediment forebay area should be cut by hand rather than with a tractor to avoid disturbance to the vegetation and substrate. It should be noted that the annual detritus build up following mowing/dieback and subsequent decomposition is an important source of plant nutrients necessary to maintain the meadow system.

Balance of the Greenway

Once the storage volume within the settling bays is exceeded, runoff will flow in a diffuse manner into the adjoining greenway. A sand filter will be installed in the base of the greenway to trap sediments and maintain the permeability of the underlying native soils. The greenway will be vegetated with a low maintenance, successional dry-mesic meadow seed mixture to maintain and enhance the infiltration characteristics of the site.

Micro-grading of the greenway is recommended to create a gently undulating appearance. This will provide a slower and rougher conveyance system to promote additional sediment/pollutant removal and nutrient uptake by plants.

Micro-variations in the topography of the bottom of the greenway and a variety of side slope grades (i.e., 3:1 - 6:1) will also provide enhanced visual, ecological and habitat diversity. A 3 metre wide maintenance access with a permeable base (i.e., crushed limestone) is proposed around the perimeter of the greenway terraces and sediment forebays, and would be suited for a pedestrian walkway.

The following low maintenance successional dry-mesic meadow seed mixture is recommended for hydroseeding within the balance of the greenway:

25%	Canada blue grass (Poa compressa)
25%	Creeping red fescue (Festuca rubra var. genuina)
25%	Perennial ryegrass (Lolium perenne var. perenne)
10%	Red clover (Trifolium pratense)
10%	Black-eyed susan (Rudbeckia hirta)
5%	New England Aster (Aster *novae-angliae*)

Random clusters of native trees and shrubs are also recommended within the greenway to provide habitat diversity, aesthetic value and visual buffering. The following tree and shrub species are recommended for planting within the dry-mesic meadow component of the greenway:*

Trees:

- Eastern white cedar, white pine, white spruce, white ash, trembling aspen, balsam poplar, large tooth aspen, sugar maple, white oak and bur oak.

Shrubs:

- Elderberry, chokecherry, pin cherry, Juneberry, highbush cranberry, nannyberry, grey dogwood, red-osier dogwood and staghorn sumac.

Annual mowing with standard Parks and Recreation department equipment (as described above) is also recommended within this portion of the greenway to reduce the build up of detritus and maintain the infiltration characteristics of the site.**

* *This is not intended to be an all-inclusive species list. Other native/non-invasive species can be considered for upland side slopes and top-of-bank areas.*

** *It should be noted that 75% of the dry-mesic meadow seed mixture is comprised of the same grass species used in standard MTO applications. This grass mixture is generally low growing (i.e., 25 cm - 40 cm in height), requires little maintenance (once a year cutting), is drought/salt resistant and is also tolerant of periodic short-term inundation from runoff.*

Sediment and Erosion Control Plan

Prior to the start of construction activity, silt fencing will be installed along the property boundary. The silt fence will serve two purposes. The first will be to eliminate the opportunity for water borne sediments to be washed on to the adjacent properties. The second will be to delineate the environmental protection zones for trees and vegetation around the perimeter of the site. The ecologist will flag the location of the silt fence with the contractor to ensure that the drip line and root zones are protected.

Two types of silt fence will be used. Type 1 silt fence is a geotextile material attached to wooden stakes. Type 2 silt fence is steel T-bar fence posts with wire fencing to which a geotextile material will be attached. The Type 2 fencing will be placed in the more critical environmental preservation areas such as along the Torrance Creek/Hamilton Corners Wetland kettle formations and along the Norway Spruce hedgerow on the townhouse block (formerly commercial) in the northwest corner of the site near Gordon Street.

Once catchbasins or ditch inlets connecting to the infiltration galleries have been installed, the grates will be wrapped in filter cloth. This feature will be maintained until all building and landscaping has been completed in the individual drainage catchments.

A temporary berm will be placed at the upstream end of the first phase to prevent sediments from the following phases from contaminating the finished works. The procedure described above will be repeated for each phase of development.

Inspection and maintenance of all silt fencing and the temporary sediment pond will start after installation is complete. The fence and/or ponds will be inspected on a weekly basis or after a rainfall event of 13 mm or greater. Maintenance will be carried out, within 48 hours, on any part of the facility found to need repair.

Monthly reports on the condition of the sediment and erosion control measures will be submitted to the City of Guelph and the Grand River Conservation Authority.

Once all construction and landscaping has been substantially completed in a development phase, the sand filter will be inspected and any contaminated material removed. The sand filter will then be re-constructed and the final grading completed. The distribution/gallery system will then be installed and the terrace topsoiled and planted.

After construction of the complete development, erosion will not occur and sediment transport will be minimal. The swale drainage in the rear lot areas will be as flat as possible to minimize flow velocities. Sediment forebays at the storm sewer outlets will provide energy dissipation and sediment removal.

Maintenance Plan

A two-phase maintenance plan is recommended. Phase I will address the short-term, more intensive maintenance necessary during and immediately after construction. Once all landscaping has been completed, maintenance will shift to Phase II.

Phase I will include weekly inspections of all sediment control devices plus “as needed” inspection after any rainfall event exceeding 13 mm, with repairs completed within 48 hours of any damaged works and the collection of captured sediment. This work will be carried out by the consultant on behalf of the owner during the construction of the works. A monthly status report will be prepared and distributed to the City and the Conservation Authority.

Phase II will be the maintenance carried out by the City after all construction has been completed. This work will include the following:

i) The catchbasin sumps and the oil/grit type manholes will require pumping and cleaning twice a year (spring and fall) to remove accumulated silt.

ii) The sediment forebay areas will require a yearly visual inspection to determine sediment accumulation. When sediment removal is required, the surface of the forebay should be removed, the sand filter restored, and the recommended vegetation replanted.

iii) The remaining surface in the greenway should be mowed once a year. After many years, some areas of the terrace bottom may show signs of silt accumulation. If so, the surface should first be aerated. If this does not restore the infiltration characteristics, then the surface of the sand filter should be removed, re-constructed, topsoiled and reseeded with the recommended vegetation.

iv) The gallery system should be inspected regularly to ensure the system is draining. The inlets should be inspected seasonally to ensure that there is no blockage by leaves and debris.

v) The road grades throughout the development are flat (0.5%). The City of Guelph should re-evaluate their winter sanding practices to minimize the application within this development. This will reduce the potential impact from chlorides and sediments being directed to the greenway terrace system.

Conclusions

The stormwater management system has been designed to collect, clean, filter and recharge all the runoff up to the 100 year design storm within the boundaries of the development. Reserve capacity has been provided in the freeboard of the greenway terraces to store and attenuate more severe rainfall events such as the Regional Storm. The greenway system also creates an amenity for passive recreation by the residents.

From the foregoing analysis, the following conclusions are drawn:

1. The lot level controls will collect and infiltrate the runoff from roofs and rear lot drainage catchments, for all storms up to the 5 year event, through a rear lot swale/infiltration gallery system.

   This will reduce the volume of runoff directed to the greenway. It will also separate the cleaner roof and yard runoff from the potentially more contaminated runoff generated on the street right-of-way.

2. Oil/grit separators (pre-treatment controls) can pre-treat the road runoff prior to discharge to the greenway by removing sediments. This, in turn, will minimize any long-term deterioration of the infiltration function.

   The use of infiltration techniques on the municipal right-of-way is not recommended because of the limited ability to pre-treat the runoff.

3. The greenway system has been designed as a stand-alone system. The greenway terraces have the capacity to retain, filter and infiltrate the full range of design storms (up to the 100 year events) from the entire development. The “first flush” storm will infiltrate through the bottom of the greenway terraces. The larger design storms will be partially infiltrated and partially conveyed to the inlet distribution/gallery system for more rapid recharge.

   Under winter operating conditions, the greenway terrace system has the capacity to retain and infiltrate the runoff generated by a 100 year design storm.

4. The proposed stormwater management system for this development will maintain the existing surface and groundwater divides for all design storms up to and including the 100 year event.

5. Under Regional Storm conditions, the freeboard provided in the greenway terraces (approximately half the total storage depth) will provide further attenuation and storage prior to overflow to either Gordon Street in the west or the kettle to the east. This storage and attenuation will reduce the Regional Storm flows released from the site below pre-development levels.

   Any flows released from the site at Gordon Street will be directed to the north to match the existing drainage patterns. When development occurs to the south of this site, the City of Guelph and the Grand River Conservation Authority can consider re-directing the Regional Storm flows to the extended greenway system being proposed on those lands.

6. The major/minor system has the capacity to convey storm runoff to the greenway system under all rainfall events.

7. Development of this site will provide a net improvement to the water quality in the area by bringing sanitary services to existing residences and by reducing the amount of fertilizer and herbicides applied relative to the current agricultural practices.

8. Environmental management measures have been specifically developed to provide a high level of protection for vegetation and wildlife habitat features adjacent to the site. These measures include protective fencing, erosion and siltation control, infill plantings, naturalized buffer zones and a public education/awareness program.

9. The landscaping strategy for the Greenway System has been designed to address concerns regarding the pre-treatment of stormwater prior to infiltration to the groundwater system and the maintenance of the infiltration characteristics of the site. In addition to improving stormwater quality, the planting strategy has been developed to enhance habitat diversity and aesthetic value, and to provide passive recreational opportunities for the future residents of the proposed development.

In our opinion, the proposed stormwater management system meets the intent of the Hanlon Creek Watershed Plan and the Watershed Management Strategy for Hanlon Creek and its Tributaries.

References for Design Example 3 [Editor's Note: some references may be out of date]

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Figure I.10: General Plan showing the Layout of Phase I of the Subdivision

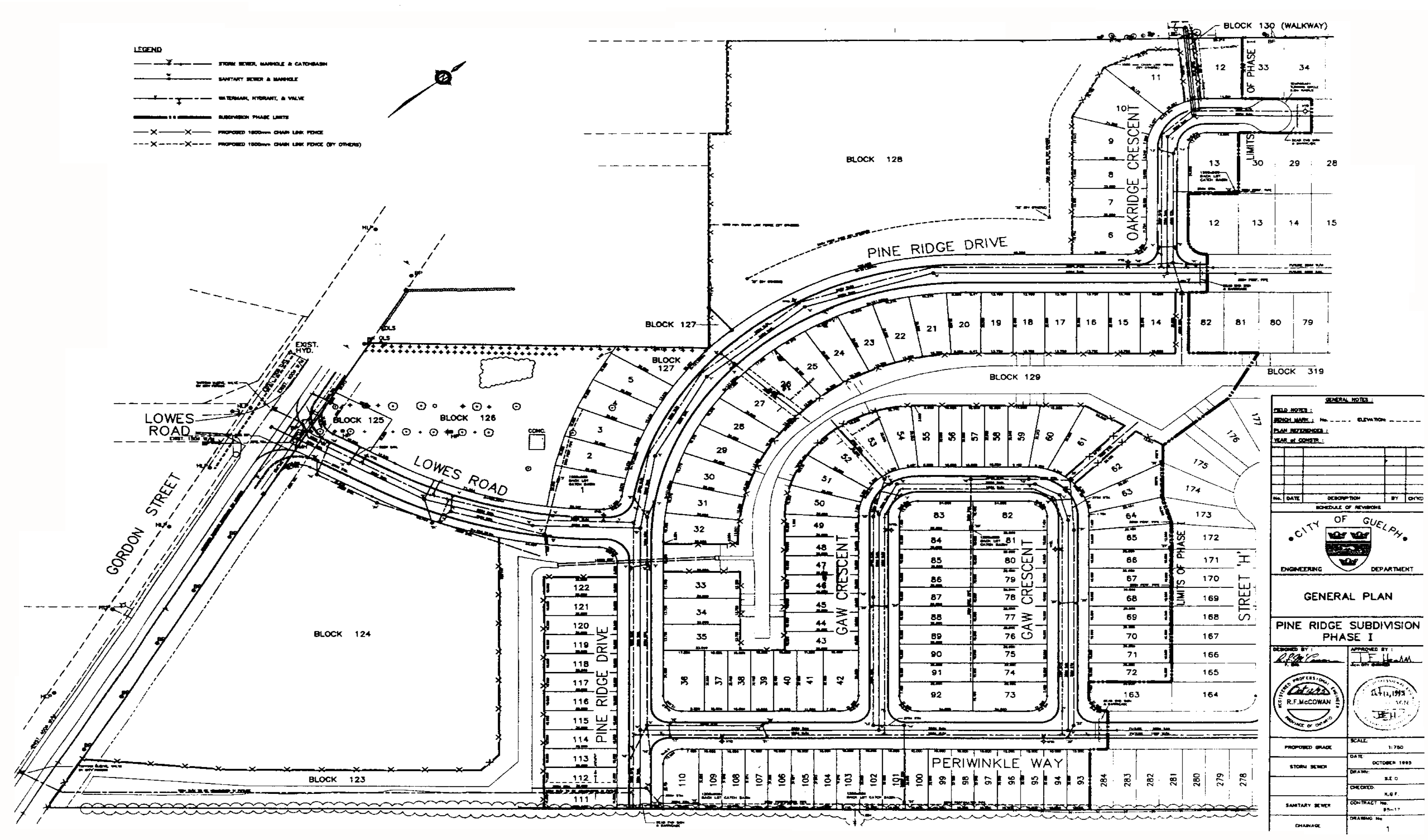


Figure I.11: Plan and Profile Drawing showing Construction Details for the End-of-pipe Greenway System

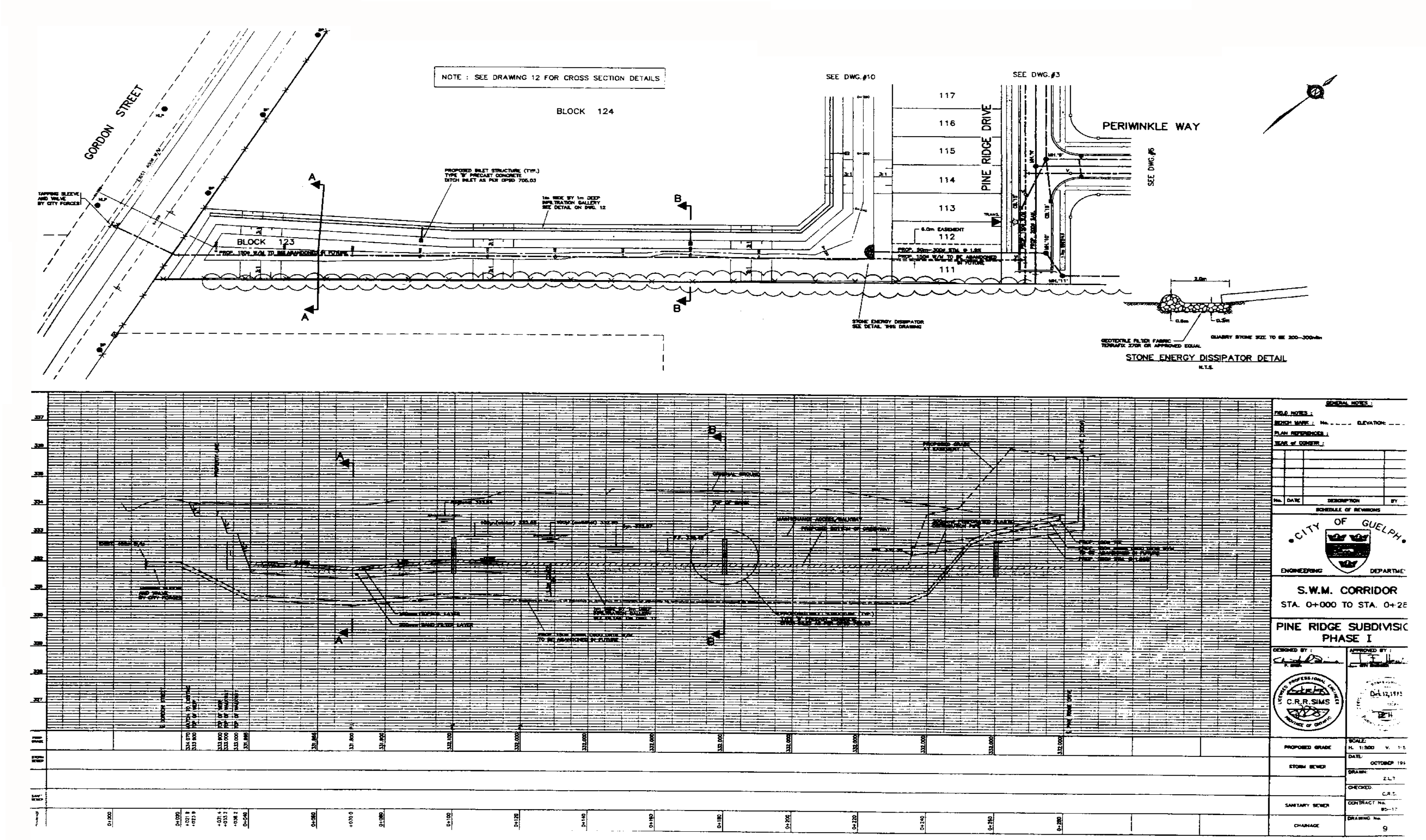


Figure I.12: Plan and Profile Drawing showing Construction Details for the End-of-pipe Greenway System

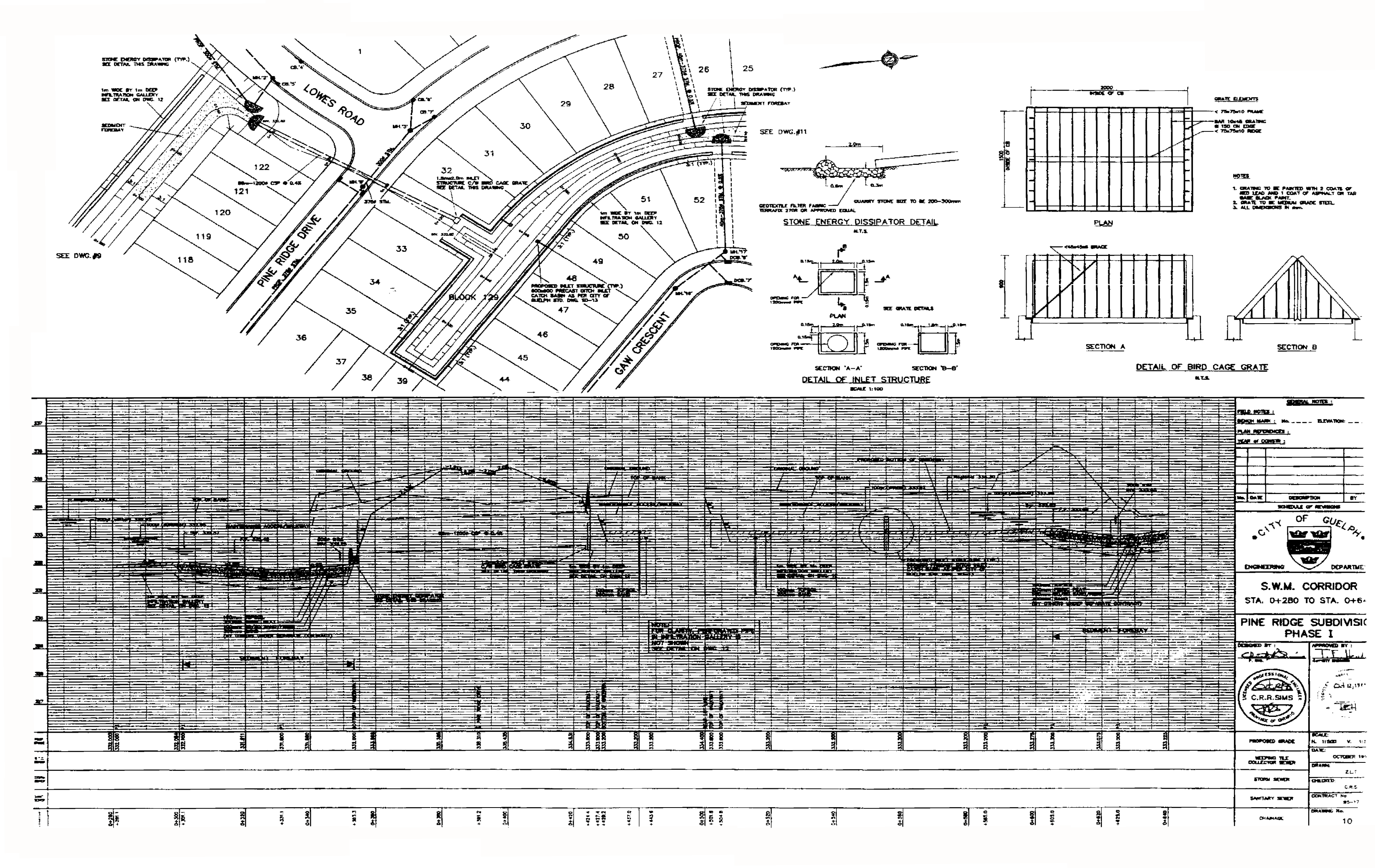


Figure I.13: Plan and Profile Drawing showing the Construction Details for the End-of-pipe Greenway System

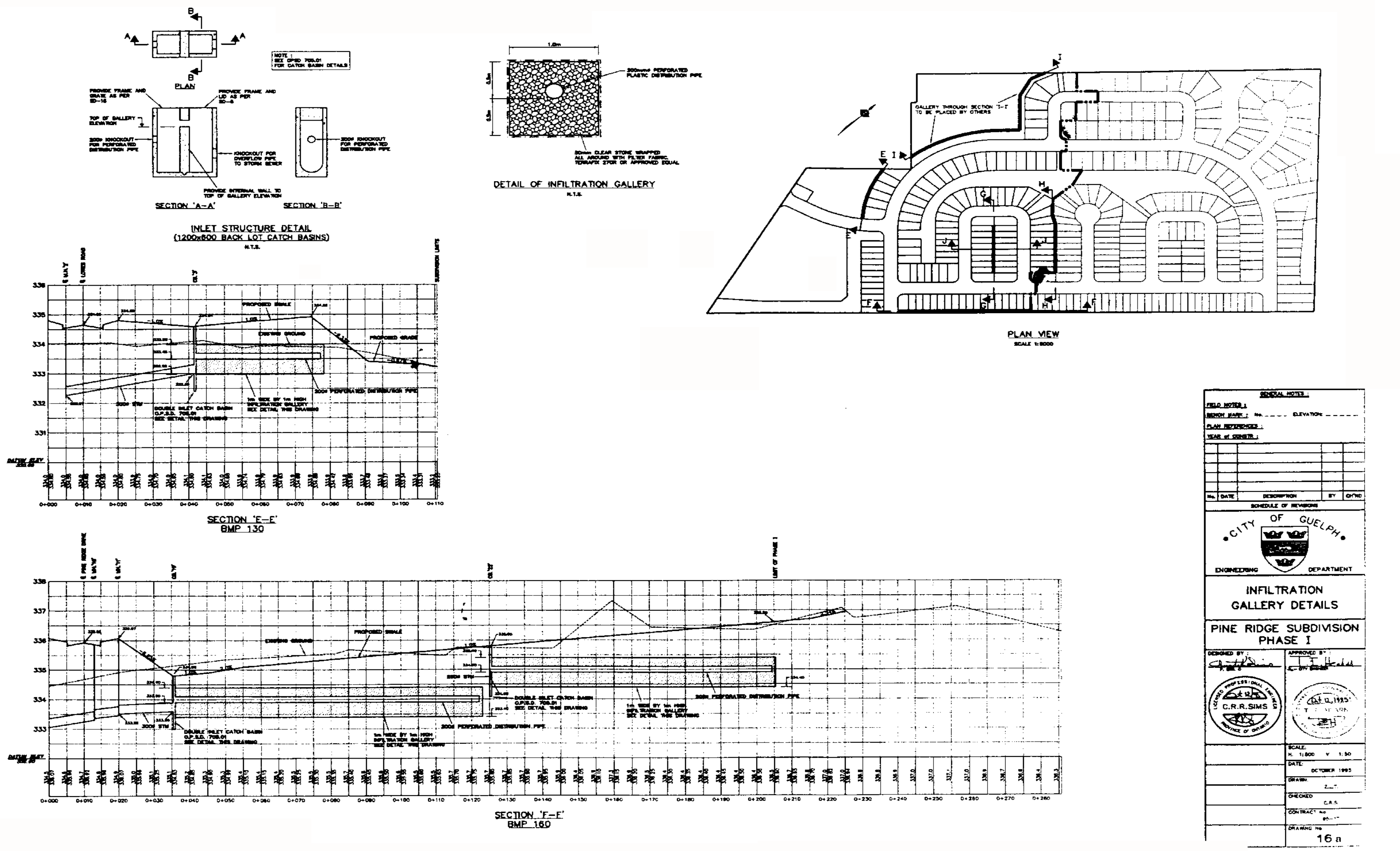


Figure I.14: Plan and Profile Drawing showing the Construction Details for the End-of-pipe Greenway System

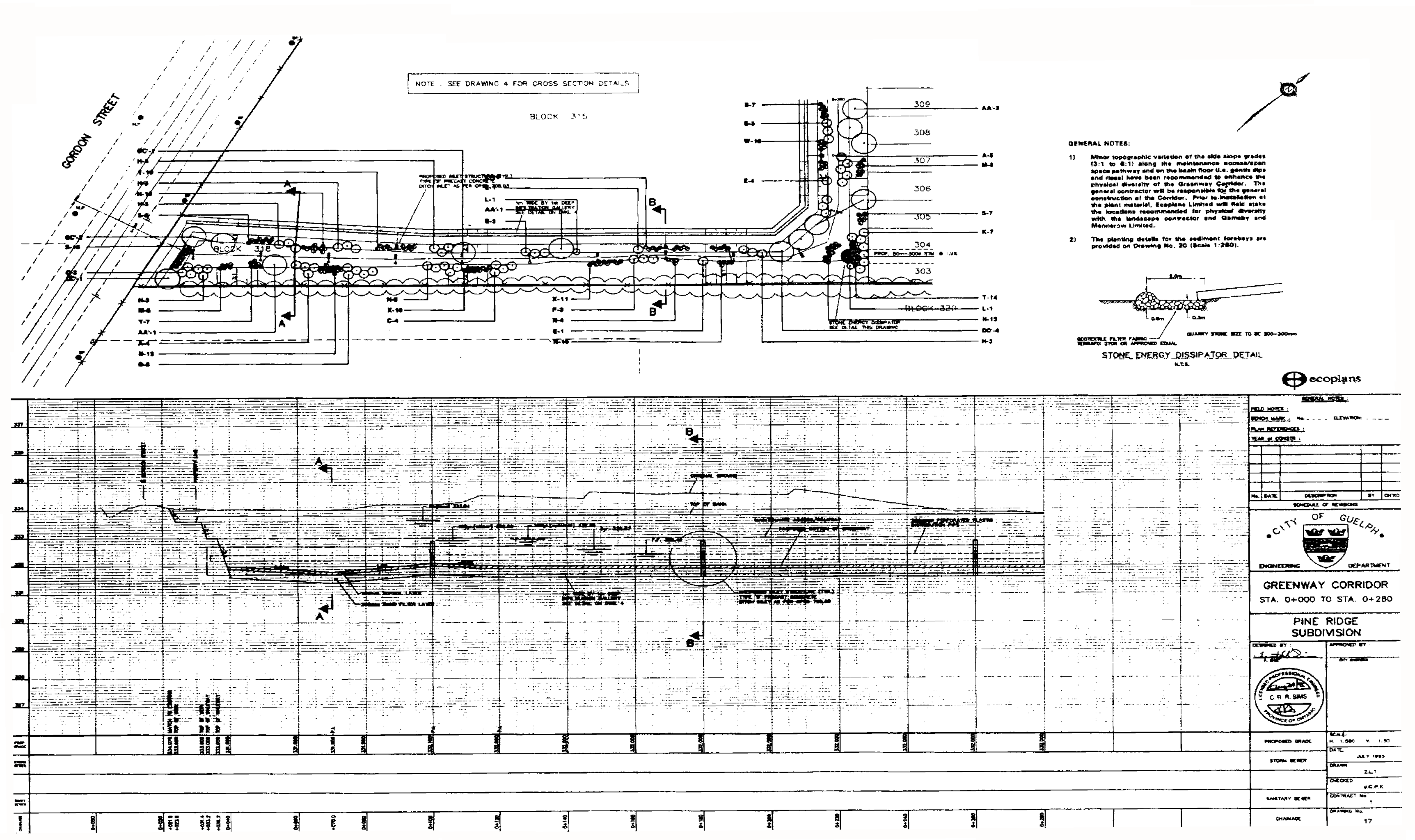


Figure I.15: Plan showing Details of the Rear Lot Infiltration Gallery System

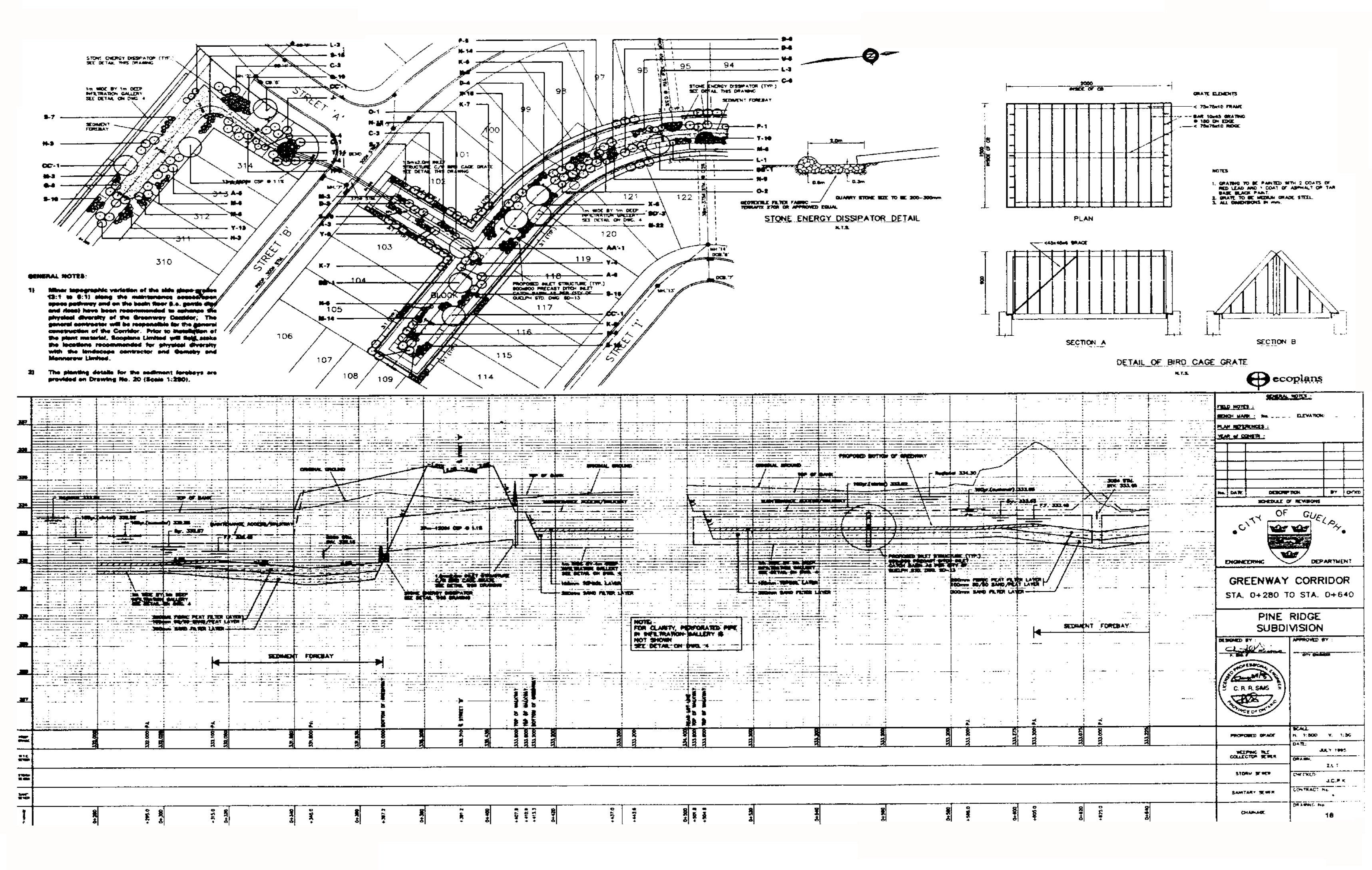
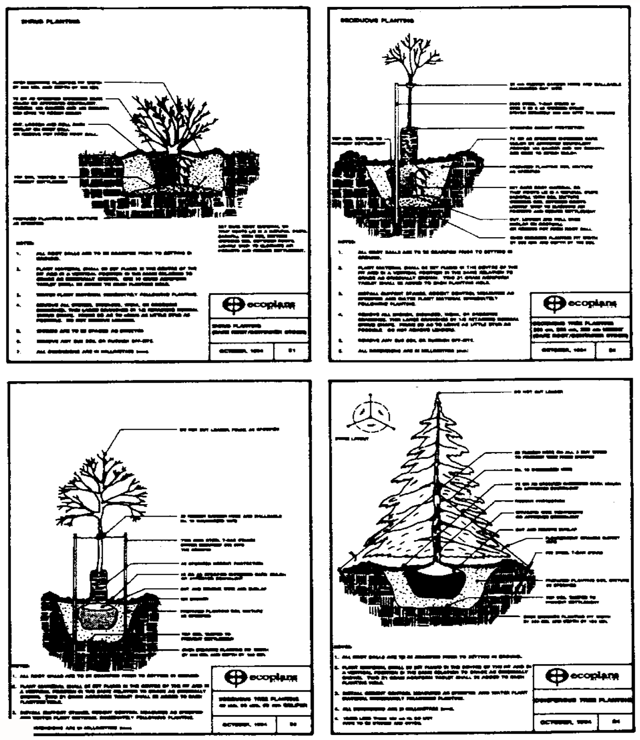


Figure I.16: Landscaping Details for the End-of-pipe Greenway System



GREENWAY CORRIDOR PLANT LIST (Drawing Nos. 17, 18 & 19)

Key	Botanical Name	Common Name	Caliper /Size	Condition	Spacing	Quantity	Bedding
Trees:							
AA'	*Acer saccharum*	Sugar maple	60 mm	W.B.	As per plan	11	Mulch
A	*Acer saccharum*	Sugar maple	300 cm	B.&B.	2.5 m O.C.	23	Mulch
BB'	*Acer saccharinum*	Silver maple	60 mm	W.B.	As per plan	5	Mulch
B	*Acer saccharinum*	Silver maple	300 cm	B.&B.	2.5 m O.C.	4	Mulch
CC'	*Fraxinus americana*	White ash	60 mm	W.B.	As per plan	9	Mulch
C	*Fraxinus americana*	White ash	250 cm	B.&B.	2.5 m O.C.	30	Mulch
DD'	*Fraxinus pennsylvanica*	Red ash	60 mm	W.B.	As per plan	9	Mulch
D	*Fraxinus pennsylvanica*	Red ash	250 cm	B.&B.	2.5 m O.C.	27	Mulch
E	*Pinus strobus*	White pine	250 cm	W.B.	As per plan	13	Mulch
F	*Populus balsamifera*	Balsam poplar	175 cm	B.&B.	2.5 m O.C.	23	Mulch
G	*Populus grandidentata*	Largetooth Aspen	175 cm	B.&B.	2.5 m O.C.	13	Mulch
H	*Populus tremuloides*	Trembling aspen	175 cm	B.&B.	2.5 m O.C.	36	Mulch
I	*Quercus alba*	White oak	300 cm	B.&B.	2.5 m O.C.	8	Mulch
J	*Quercus macrocarpa*	Bur oak	300 cm	B.&B.	2.5 m O.C.	8	Mulch
K	*Thuja occidentalis*	Eastern white cedar	175 cm	B.&B.	2.5 m O.C.	79	Mulch
Shrubs:							
L	*Amelanchier canadensis*	Juneberry	175 cm	F.Pot	1.2 m O.C.	14	Mulch
M	*Cornus racemosa*	Gray dogwood	80 cm	F.Pot	1.2 m O.C.	68	Mulch
N	*Cornus sericea*	Red-osier dogwood	80 cm	F.Pot	1.2 m O.C.	198	Mulch
O	*Prunus virginiana*	Chokecherry	125 cm	F.Pot	1.2 m O.C.	20	Mulch
P	*Prunus pensylvanica*	Pin Cherry	125 cm	F.Pot	1.2 m O.C.	2	Mulch
Q	*Rosa carolina*	Carolina rose	80 cm	F.Pot	1.2 m O.C.	26	Mulch
R	*Rosa palustris*	Swamp rose	80 cm	F.Pot	1.2 m O.C.	32	Mulch
S	*Rhus typhina*	Staghorn sumac	100 cm	F.Pot	1.2 m O.C.	129	Mulch
T	*Rubus allegheniensis*	High-bush blackberry	80 cm	F.Pot	1.2 m O.C.	62	Mulch
U	*Rubus odoratus*	Flowering raspberry	80 cm	F.Pot	1.2 m O.C.	12	Mulch
V	*Salix discolor*	Pussy willow	80 cm	F.Pot	1.2 m O.C.	11	Mulch
W	*Sambucus canadensis*	Common elder	80 cm	F.Pot	1.2 m O.C.	18	Mulch
X	*Viburnum lentago*	Nannyberry	125 cm	F.Pot	1.2 m O.C.	63	Mulch
Y	*Viburnum trilobum*	High-bush cranberry	125 cm	F.Pot	1.2 m O.C.	86	Mulch

Sedimentation Basin Plant List (Drawing No. 20):

Key	Botanical Name	Common Name	Size/Condition	Quantity	Spacing	Orientation
a	*Carex lacustris*	Lake sedge	10 cm F.Pot	218	Even distribution	Clusters
b	*Eleocharis palustris*	Spikerush	10 cm F.Pot	280	Even distribution	Clusters
c	*Equisetum variegatum*	Variegated scouring-rush	10 cm F.Pot	460	Even distribution	Clusters
d	*Glyceria canadensis*	Rattlesnake manna grass	10 cm F.Pot	585	Even distribution	Clusters
e	*Glyceria grandis*	Tall manna grass	10 cm F.Pot	944	Even distribution	Clusters
f	*Juncus effusus*	Rush	10 cm F.Pot	786	Even distribution	Clusters
g	*Matteuccia struthiopteris*	Ostrich fern	10 cm F.Pot	118	Even distribution	Clusters
h	*Mimulus ringens*	Square-stemmed monkey flower	10 cm F.Pot	180	Even distribution	Clusters
i	*Onoclea sensibilis*	Sensitive fern	10 cm F.Pot	124	Even distribution	Clusters
j	*Parthenocissus inserta*	Virginia creeper	10 cm F.Pot	70	Even distribution	Clusters
k	*Salix discolor*	Pussy willow	10 cm F.Pot	33	Even distribution	Clusters
l	*Scirpus atrovirens*	Black bulrush	10 cm F.Pot	800	Even distribution	Clusters
m	*Scirpus cyperinus*	Wool-grass	10 cm F.Pot	400	Even distribution	Clusters
n	*Scirpus validus*	Softstem bulrush	10 cm F.Pot	400	Even distribution	Clusters
o	*Typha latifolia*	Common cattail	10 cm F.Pot	751	Even distribution	Clusters

GENERAL NOTES

STOCK

All plant material shall be true to type, structurally sound, healthy and vigourous. Any substitutions as to variety or grade must be accepted by Ecoplans Ltd.

SITE PREPARATION

Soils shall be fertile, friable, stone-free and not in a frozen or muddy condition at grading and planting.

PLANTING

Planting shall be conducted during the spring (before May 15) or in the fall (after October 15).

Plant material shall be set plumb in the centre of the pit and in a vertical position in the same relation to grade as originally grown. Two Agriform 21 gram tablets shall be added to each planting hole for all trees and a 10 gram tablet for all shrubs.

Burlap and ties shall be removed from the top of the rootball by folding down at least 100 mm into area of backfill. Fibre pots shall be removed by cutting the pot and folding it back from the root mass.

A minimum of 150 mm of topsoil shall be placed in the bottom of each planting pit. The planting pit shall be backfilled with topsoil in layers 150 mm deep, firmly tamped into place.

A shallow saucer shall be created over the planting pit area to retain water.

Trees shall be pruned and dead/broken branches removed in accordance with good arboricultural practices.

Plant material shall be thoroughly watered at the time of planting.

All plants shall be mulched immediately after planting and watering using a shredded bark or wood chip mulch 75 mm deep.

Trees (> 2000 mm ht.) Shall be properly staked (see diagrams) immediately following planting.

MAINTENANCE

The contractor shall provide maintenance procedures throughout the thirteen (13) month warranty period consistent with proper horticultural practices to ensure healthy growth of the trees (i.e. Regular watering, remulching, stake removal and tree/shrub replacement if necessary).