An Evaluation of Roadside Ditches

And Other Related Stormwater Management Practices

Second Edition

February, 2000

THE TORONTO AND REGION CONSERVATION AUTHORITY

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Ontario Ministry of the Environment

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J.F. Sabourin and Associates Inc.
Water Resources and Environmental Consultants

In cooperation with: City of Ottawa, City of Toronto, Town of Richmond Hill, Rideau Valley Conservation Authority, Totten Sims Hubicki Associates, and Donald G. Weatherbe Associates Inc.

Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

Final Report
Second Edition

prepared for:

The Toronto and Region
Conservation Authority

by:

J.F. Sabourin and Associates Inc.
Ottawa, Ontario

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The Great Lakes 2000 Cleanup Fund is a component of the Federal Government's Great Lakes 2000 program. The Cleanup Fund provides resources to demonstrate and implement technologies and techniques to assist in the remediation of Areas of Concern and other priority areas in the Great Lakes. The report that follows was sponsored by the Great Lakes 2000 Cleanup Fund and addresses stormwater management issues in the Toronto and Region Area of Concern in Toronto, Ontario. Although the report was subject to technical review, it does not necessarily reflect the views of the Cleanup Fund or Environment Canada.

Preface to the First Edition

Stormwater management plays an integral role in the protection of developing watersheds and in the regeneration of degraded environments. *An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices* was undertaken to promote the use of alternative road drainage measures that could meet current environmental objectives, while also meeting other social and economic objectives. The Metropolitan Toronto and Region Conservation Authority, Lake Simcoe Region Conservation Authority, Ryerson University and Environment Canada's Great Lakes 2000 Clean Up Fund sponsored the study, while significant input was provided by municipal and provincial representatives on a review committee.

The study has compiled information and developed tools that will assist designers and reviewers in determining the appropriate road drainage system for a given location, based on environmental, social and economic objectives. Results of this study underscore the fact that no road drainage system is suitable everywhere, but rather a range of alternatives must be evaluated according to site specific considerations. Although the study focused on conveyance systems, the results support a comprehensive approach to stormwater management by involving the maximal use of source controls and employing end-of-pipe facilities where necessary.

This study marks a beginning - not an end. The tools and procedures proposed herein must be tested and refined, as new information becomes available. The report documents the state-of-the-art. Many questions remain. The study partners look forward to further opportunities to advance this field.

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Preface to the Second Edition

This edition updates chapters 10 (Economic Considerations) and 12 (Alternative Drainage System Selection Tool) of the final report from *An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices* (J.F. Sabourin and Associates Inc., 1997). In the updated chapters, the road drainage system Selection Tool has been enhanced in the following areas:

- revised cost tables, allowing for a comparison of present values using discount rates and life cycles;
- the addition of standardized objective setting tables;
- update and completion of stormwater management performance tables; and
- clearer documentation for the tool's use.

One significant enhancement is the transformation of the tool from a paper copy to a digital spreadsheet format, for on-screen application of the tool. It is expected that this latter improvement will make the tool much easier to use, and will thereby enhance its adoption by designers.

Revisions to the Selection Tool have been made in response to recommendations from a demonstration study (Totten Sims Hubicki and Associates and Donald G. Weatherbe and Associates, 1999). That study, commissioned by the TRCA, tested the Selection Tool in the design of four urban road reconstruction projects, located in the City of Toronto, Town of Richmond Hill, and City of Ottawa. Other partners in the study included: the City of Ottawa, City of Toronto, Town of Richmond Hill, Environment Canada's Great Lakes 2000 Cleanup Fund (GL2000CUF), the Ministry of the Environment (MOE), the Rideau Valley Conservation Authority, Lake Simcoe Region Conservation Authority, and Ryerson University.

The information and tools provided in this report are intended to assist designers and reviewers in determining the appropriate road drainage system for a given location. Results of the study again underscore the fact that no single road drainage system is suitable for all cases. The project partners hope that this information will promote further consideration and testing of alternative technologies.

NOTE: *As of January 1, 1998, the Metropolitan Toronto and Region Conservation Authority (MTRCA) changed its name to Toronto and Region Conservation Authority (TRCA).*

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FINAL REPORT

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FINAL REPORT
(April 1997)

Abstract

This report presents the findings of a study in which the use of roadside ditches and other alternative road drainage systems are compared and evaluated. The comparison and evaluation are based on the systems' social acceptance, their economic feasibility, their potential environmental benefits, their use for stormwater management and their engineering and planning compatibility. These individual issues were addressed by means of a literature review, a mailout questionnaire / survey, a review of system specifications and an economic analysis.

Based on the findings of the study, a systematic evaluating procedure was developed to help in the assessment and selection of alternative drainage systems. The procedure accounts for site and development characteristics as well as potential stormwater management benefits. Other factors such as costs (capital and maintenance) and public expectations can further be considered in the final comparison and selection of alternative drainage system components.

The report further makes recommendations for the improved design and maintenance of conventional roadside drainage systems.

The study was coordinated by the Metropolitan Toronto and Region Conservation Authority (MTRCA) with a review committee comprised of representatives from the Lake Simcoe Region Conservation Authority (LSRCA), the Ministry of the Environment and Energy (MOEE), the Ministry of Natural Resources (MNR), the Ontario Ministry of Transportation (MTO), the Town of Richmond Hill, the City of Etobicoke, Environment Canada and Ryerson Polytechnic University.

Funding for the study was received from Environment Canada's Great Lakes 2000 Cleanup Fund, Ryerson Polytechnic University, Lake Simcoe Region Conservation Authority and the Metropolitan Toronto and Region Conservation Authority.

Executive Summary and Study Findings

Background and study objectives

It is now well accepted that urbanization can have adverse impacts on streams and other receiving water bodies. The resulting change in hydrologic regime from increased stormwater runoff may cause flooding, streambank erosion and water quality problems such as pollutant loadings, temperature effects, baseflow reduction, habitat changes and groundwater impacts.

Stormwater management measures which are often implemented in order to mitigate the negative environmental impacts related to urbanization include;

i) **"Lot Level Controls"** which are oriented towards maintaining the hydrologic cycle and are based on the premise of controlling problems at their source,

ii) **"Stormwater Conveyance Controls"** which recognize that the timing of stormwater runoff, and what happens to stormwater as it is being conveyed to a receiving water, can have a major impact on water quality, flooding, erosion, and groundwater recharge, and,

iii) **"End-of-Pipe Stormwater Management Facilities"** which are the more traditional dry / wet ponds and wetlands and deal with the problems at the outlet.

In most cases, it is a combination of various stormwater management practices which should be adopted for a given site. However, because of a potential lack of information and possibly biassed perceptions, the adopted drainage alternatives do not always represent the optimum balanced solution between local environmental, social and economic expectations.

One traditional type of stormwater conveyance system which can offer some advantages over a cub-gutter-sewer system by providing some level of stormwater quality and quantity control is the roadside ditch. This type of system often receives opposing opinions from designers and reviewers over its merits and is therefore often disregarded as a possible component of the drainage alternative.

In order to better understand how, when and where various alternative roadside drainage techniques could be used to provide a system with an optimum balance between the various objectives, the present study was commissioned by Metro Region Conservation. *A copy of the Terms of Reference are provided in Appendix A.*

In general terms, the objectives of the study were to further investigate and report on the environmental, engineering, social, and economic advantages/disadvantages associated with the use of roadside ditches and provide a comparison with other possible alternative road drainage systems.

Study approach

The study objectives were addressed by:

Conducting a Literature Review in order to further document the experience of other jurisdictions with roadside ditches and with other types of BMP's associated with roadside drainage.

Conducting Surveys and Interviews in order to identify and quantify public attitudes and perceptions, the experiences and costs associated with various types of roadside drainage alternatives. Other issues which were identified through such inquiries included safety and possible effect on property values.

Comparing Drainage Alternatives in terms of their capacity for water conveyance, water quality treatment, groundwater recharge and ability to meet SWM requirements, safety, Right-of-Way and lot planning, public attitudes and perceptions, and economics (capital and operational costs).

Developing an Assessment Tool to help identify and compare applicable alternative drainage systems for a given site. The selection tool accounts for site and development characteristics as well as the potential stormwater management functions of the various alternative drainage features and their capital and operational costs.

Highlights of study

Literature Review

Close to 250 relevant references comprised of scientific articles, books and newspaper clippings were collected during the literature search. Most (70%) of the collected literature was published within the last 6 years and from the source of the literature it is clear that concerns related to the management of stormwater runoff is wide spread throughout developed countries.

Very little information was found on the specific use of typical roadside ditches as a BMP option or as part of the treatment train. Although some design information on roadside ditches is available, the information is rarely related to hydraulic or hydrologic considerations.

The literature shows a trend toward the emergence of new approaches to SWM and initial testing to determine advantages / disadvantages. Design information on alternative drainage systems is adequate. However, monitoring data is still sparse and sometimes inconsistent. Furthermore, the literature is weak in areas of maintenance, long term performance, public preference and overall costs.

The potential use of alternative drainage systems is seldom completely and jointly evaluated in terms of SWM objectives, cost, ease of integration in the ROW, and public acceptance. In many European communities, the use of non-structural BMP's, such as public education and citizen involvement programs are emphasized.

The report provides an overall summary of the literature review in Section 2 of the report and a complete list of the collected references is provided in Appendix B.

Actual roadway with conventional ditch

Computer enhanced photo with a grass swale system

Computer enhanced photo with curb and gutter system

Surveys and Interviews

Two questionnaires were formulated for the purpose of the survey. A technical survey was sent to 125 municipal engineers and planners while a more qualitative survey was sent to 72 real estate agents and developers. Because a door to door survey was not feasible, the latter group was selected to reflect public opinions. In order to provide the most realistic and representative sample, the sample group of real estate agents and developers were selected throughout the Greater Toronto Area.

The use of computer enhanced photos (see above) were incorporated to help better visualize a roadway with a ditch, a grass swale, or a curb. By means of sketches, the surveys also made reference to other alternative drainage systems some of which are listed in the table below.

Alternative drainage systems considered in surveys

▸ Grass swales	▸ Grass swales with storm sewers
▸ Grass swales with raised culverts	▸ Grass swales with dipped driveways
▸ Grass swales with infiltration systems	▸ Grass swales with infiltration manhole system
▸ Grass swales with perforated pipe systems	▸ Curb & gutter and sewer with exfiltration system
▸ Curb & gutter with greenbelts	▸ Curb & gutter and sewer with filtration system
▸ Oil & grit separator and sumpless catchbasins	▸ Grass swales with curb and gutter (no sewers)
▸ Grass swales with curb & gutter and sewer	▸ Grass swales with check dams

Out of the 197 questionnaires which were sent out, a total of 52 were filled out and returned (32 from the municipal engineers and planners and 20 from the real estate agents and developers). In the latter group, 90% of the respondents were developers.

The questionnaire survey with municipal engineers and planners identified a strong willingness to try alternative drainage systems in either new developments or retrofit situations. In fact, over 30% of the municipalities who participated in the survey have

already implemented some types of alternative drainage systems. When asked if they would used such systems again, most said yes. Reasons for not wanting to try alternative types of road drainage systems were highly focussed on the perception that such systems are in general more expensive to construct and maintain.

Although the survey with real estate agents and developers did indicate a preference for the curb and gutter system in urban areas and grass swales and ditches in rural areas it was not concluded if in fact this is a preference or an expectation of what is commonly seen.

The survey results were used in various sections of the report and a general summary is provided in Section 3 while the questionnaires and a complete breakdown of responses are presented in Appendix C.

Comparison of drainage alternatives

The comparison and the selection of drainage alternatives cannot be limited to how well they convey or treat stormwater but should also consider how well they can be integrated in our communities and at what cost. Some of the issues which are addressed in Sections 4 through 10 of the report are described below.

Stormwater conveyance: When the use of surface conveyance systems such as ditches and swales are contemplated, their successful design and implementation will often be based on the proper consideration of: i) the available space, ii) the desired level of service, iii) the type of surface vegetation, and iv) slopes and the effects of culverts. The advantages and constraints associated with such design parameters were addressed in the study through the development and application of a step by step hydrologic / hydraulic analytical procedure which is described in Section 4.

Based on simple geometry it was demonstrated that roadside ditches with 3:1 or 2:1 side slopes can effectively be constructed within Right of Way widths of 20 to 27 m if sidewalks are not present. When sidewalks are located 1 m from the property line, the available space between the sidewalk and the road is significantly reduced such that ditches with 3:1 side slopes are too shallow to provide adequate road base drainage if required. Under such conditions, the use of roadside ditches or grass swales would require the use of under drains.

With respect to the required level of service, and based on the survey results, the conveyance capacity of any drainage system should in general be 1:5 yrs for the minor system and 1:100 yrs for the major system.

The type of surface vegetation in roadside ditches and swales was found to have an important role in controlling flow velocities below critical levels for erosion in steeper areas. For example, the allowable flow in a typical roadside ditch can be more than tripled when

the vegetation height is maintained at 30 cm as compared to 5 cm.

The combined effect of the shape of a roadside ditch or swale and the type of vegetation can also significantly attenuate runoff peak flows. As such it was demonstrated that for a 5 ha area with 40% imperviousness, the design peak flow in a roadside ditch with 3:1 side slopes and natural vegetation could be 30% lower than the design peak flow of a conventional curb and gutter system. Such reductions in flows could represent significant savings for downstream infrastructure.

Culverts and their spacing can significantly reduce the maximum drainage area which can be serviced by roadside ditches or swales. For example, it was found that the use of 450 mm culverts spaced at 20 m could limit the maximum serviceable area to 2.5 ha (per side of road) as compared to approximately 30 ha if culverts were not present.

The use of check dams or raised culverts was shown to be most effective where surface slopes are small (ie. 0.5% or less). The maximum height of check dams or raised culverts should be based on the consideration that the retained water must infiltrate within a reasonable time (ie. less than 12 hours). For typical infiltration rates of 3 to 7.5 mm/hr for a topsoil layer and grass cover this would possibly limit the height of a check dam or raised culvert to 50 mm or less. At such low heights, raised culverts or check dams would only provide some tangible benefits if they were used in swales with side slopes of 5:1 or less.

Stormwater quality treatment erosion and groundwater recharge: The potential effectiveness of a given drainage feature in providing some level of quality control is dependent on many factors, some of which are still being studied and understood. Although monitoring data is still limited for some types of BMP's, they can nonetheless provide an indication of performance. The table below provides a summary of documented pollutant removal rates for various BMP's. It is clear from the reported variability in the effectiveness of some BMP's that design and maintenance standards are still evolving. Stormwater quality, erosion, groundwater recharge and maintenance issues are discussed in Section 5 of the report.

Ranges of BMP pollutant removal rates (%)

Type of BMP	TSS	TP	TN	Zn	Pb	BOD	Bacteria	Oil & grease
Infiltration	0-99	0-75	0-70	0-99	0-99	0-90	75-98	---
Infiltration Trenches	90-99	60-75	60-70	90-99	90	90	90-98	---
Grass swales	65-98	9-100	24-100	50-90	50-91	---	---	---
Grass swales w/perforated pipes	90	75	----	75	93	----	---	---
Grass swales with check dams	20-40	20-40	20-40	0	0	----	---	---
Curb and gutter with exfiltration system	Such a system was constructed in the City of Etobicoke. Preliminary monitoring results indicate that 100% of runoff is infiltrated at the site. Theoretical volumetric retention is in the order of 90%.							
Vegetative buffer strip	28-70	70	----	51	25	---	----	---
Sand Filters	60-85	60-80	(-110)35	10-80	60-80	60-90	50-70	---
Curb and gutter with filtration system	Such a system was constructed in the City of Etobicoke. Monitoring results were not available during the study.							
Extended Detention pond (dry)	29-75	10-56	24-60	40-57	24-61	---	50-90	---
Extended Detention pond (wet)	60-91	30-90	40-80	50	57	----	75	---
Wetland	40-94	(-4)-90	21	(-29)-82	27-94	18	n/a	---
Stormceptors*	50-80	---	----	39	51	---	----	98
Porous pavement	80-95	60-65	75-85	98	80	80	n/a	---

* Stormceptors represent one type of oil/grit separators for which data were readily available during this study. Data from other oil/grit separator manufacturers should also be referenced when possible. Mention of Stormceptor does not constitute endorsement or recommendation for use.

Public attitudes, perceptions and preferences: The knowledge and/or the understanding of public attitudes, their perceptions and preferences with respect to streetscape features can become a valuable asset in determining what type of alternative drainage systems could be acceptable or could become a resistance factor. From the interpretation of the survey responses, it was found that public opinions can vary from area to area and mostly between urban and rural settings. As such, general public opinions are summarized in the table below and further discussed in Section 6.

Summary of general public preferences

Urban Setting	Rural Setting
▸ A curb & gutter drainage system is somewhat expected ▸ One sidewalk located next to or away from the curb. ▸ Underground franchise utilities. ▸ Street lighting should be available. ▸ Municipal trees should be planted. ▸ Curved street layouts. ▸ Parking on streets allowed. ▸ No pooling of water on street.	▸ Grass swales or roadside ditches are acceptable but grass swales are somewhat preferred in terms of maintenance requirements and perception of safety. ▸ Sidewalks are not important. ▸ Above or below ground franchise utilities. ▸ Street lighting should be available. ▸ Municipal trees should be planted. ▸ Curved street layouts are somewhat preferred but not has much as in an urban setting. ▸ Parking on streets is not as important as in an urban setting. ▸ No pooling of water on street.

Municipal perspective and tendencies: According to the surveys and interviews conducted with municipal representatives, the majority of the respondents indicated the willingness to positively consider the use of alternative drainage systems in new developments or retrofit situations in either urban or rural settings.

The most popular alternative drainage systems that have been or would be considered are; i) grass swales, ii) grass swales or ditches with raised culverts, iii) grass swales or ditches with infiltration trench systems, iv) grass swales with perforated pipe systems, and v) curb and gutter with greenbelt system (ie. backyard swale system). Reasons which were given for not wanting to consider the use of alternative drainage systems are presented in Section 7 and include; i) perceived additional maintenance costs, ii) perceived lower level of standards for road, and iii) lack of long term maintenance and operations history of systems.

Safety considerations: Safety issues can be related to motorists, pedestrians, cyclists and homeowners. Drainage components which may have an influence on safety include: i) the presence of a curb, ii) the presence of ditches, iii) the presence of culverts, and iv) the presence of catch basins. Drainage functions which may influence the level of safety include: i) depth of water on street, ii) surface flow velocity, iii) system backups and basement flooding.

With respect to documented causes of accidents very little information has been found during the course of this study to provide viable statistics on urban accidents or damages which may been caused by drainage related features or functions. Inquiries with insurance companies have found that such information is not collected or analysed. Even basement

flooding is not documented to determine if the cause was from the failure of a sump pump, a sewer backup or from water entering through a basement window.

However, some statistics of highway accidents in which drainage structures were involved are available and are presented in Section 8 of the report.

Right-of-way, road and lot planning: The potential use of alternative drainage systems must consider; i) possible integration of the system within development and right-of-way widths, ii) presence and location of sidewalks, iii) presence and location of trees within the public road allowance, iv) type of roadside landscape treatment, v) presence and location of utilities, vi) road design, and vi) lot imperviousness, widths and drainage. Each of these issues are discussed in Section 9 of the report and are incorporated in the Selection Tool.

Economics (capital and maintenance costs): Details on capital and maintenance costs were obtained from various municipalities, developers and literature. The information was used to develop itemized tables of annualized costs for most features which can be found in a drainage system. Annualized costs were obtained by dividing the construction or replacement cost of a given item by its expected longevity and by then adding the associated annual repair and maintenance costs. This information was updated in the 1999 Study using a Present Value approach.

Although it was found that prices and the frequency of various maintenance activities can vary from one municipality to another, the approach developed in the study provides a method with which a comparison of total annual costs can be made between practically any drainage systems. Based on this approach it was found that the total present value cost (capital and maintenance) associated with roadside ditches is much less than usually perceived.

As an example, the total present value capital and maintenance costs for four different systems, designed to provide at least a 1:5 year level of service with quality and erosion controls based on a 25 mm storm, are compared in the table below.

Comparison of Total Present Value Costs per 10 ha of drainage area at 40% imperviousness based on 1000 x 8.5 m of roadway with a 20 m ROW and 20 x 40 m deep lots (using a 7% annual discount rate and an 80 year life cycle)			
System #1 Conventional curb and gutter system with concrete pipes and end of pipe facility for quality and erosion control.	**System #2** Like System #1 but with Stormceptor units for source control and an end of pipe facility for additional quality and erosion control.	**System #3** Conventional ditch system with end of pipe facility for quality and erosion control. Road has no subdrains.	**System #4** Grass swale system with perforated pipe system and infiltration trenches capable of retaining and infiltrating the runoff of a 25 mm storm.
$1,352,283*,2	**$1,396,174*,2**	**$821,679*,1,2**	**$1,001,097 2**

Notes: *) Because of the potentially large differences from one area to another, the cost for land required by end of pipe facility or losses in tax revenues are not included.
1) Cost assumes that ditches are 50% efficient at removing sediments. If properly constructed, ditched roads may not require an end of pipe facility in which case the cost can be reduced by $70,747. Total cost can be further reduced by $95,384 if subdrains can be installed.
2) Total annual costs are based on "average" total costs and individual costs may vary between municipalities

Details on the compilation of the various costs are presented in Section 10 of the report.

Assessment tool: The selection and identification of the most appropriate drainage alternative(s), for a given site, can be complicated and, unless a detailed assessment is conducted, the results of such an exercise can easily be regarded as subjective.

Based on the study findings, a simple to use systematic procedure was developed in order to help determine which types of alternative drainage features could be incorporated within a specific project while at the same time addressing the local environmental, social and economic expectations.

Drainage features are defined as components which are part of a drainage system. Examples of drainage features include; curbs, porous pavements, ditches, swales, perforated pipes, dipped driveways, check dams, culverts, oil & grit separators, storm sewers, infiltration trenches, ponds, etc... A drainage system is the result of the combined use of various drainage features.

The developed procedure can be used for new developments or retrofit situations and accounts for the following aspects;

i) compatibility with physical site characteristics;
ii) compatibility with planning objectives and ease of integration within the road right of way;
iii) ability to meet stormwater management objectives:
iv) economics;
v) public acceptance;

Through a process of elimination, drainage features which are compatible with site characteristics and/or with the type of development are first identified. Based on the identified list of compatible drainage features, the designer can proceed to formulate various conceptual drainage systems which are then compared in terms of their ability to meet local stormwater management objectives, and in terms of costs (capital and maintenance), and public expectations.

The selection tool, complete with examples, is described and presented in Section 12.

Other Conclusions and Recommendations

Other conclusions and recommendations are presented in Section 13 of the report.

Acknowledgments

This report was prepared for the Metropolitan Toronto and Region Conservation Authority (MTRCA) by J.F. Sabourin and Associates Inc (JFSA). The project manager and principal writer of the report was Mr. J.F. Sabourin. The project officer was Ms. Sonya Meek of MTRCA to whom special thanks are extended for her continuous support and valuable comments. In addition, many other individuals and organizations which are listed below, have also positively collaborated towards the execution and completion of this study. Their assistance and guidance are most gratefully acknowledged.

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