The Stratford-Avon River Environmental Management Project

GRASSED WATERWAY DEMONSTRATION PROJECTS

TECHNICAL REPORT R-7

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Rural Sub-Committee

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PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two year Project was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P. is funded entirely by the Ontario Ministry of the Environment. The purpose of the Project is to provide a comprehensive water quality management strategy for the Avon River Basin. In order to accomplish this, considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The Project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the Project. In certain cases the results presented are interim in nature and should not be taken as definitive until such time as additional support data is collected.

Reference to equipment, brand names or supplies in this publication is not to be interpreted as an endorsement of that particular product or supplier.

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This report has been prepared using Imperial measures, as were the plans and specifications attached hereto. This was done purposely for ease of interpretation by contractors, the landowner, and project staff. A metric conversion table has been included in the Appendix.

ABSTRACT

A series of four grassed waterways were constructed in the upper part of the Avon River Basin during 1981. The purpose of the projects is to demonstrate the cost-effectiveness of grassed waterways in relation to the overall goals of the Rural Sub-Committee of reducing non-point source pollution through runoff and erosion control. Average costs of construction varied from $1.00 - $3.00 per foot depending on length of run, size of drain tile, placement of catch basin, and outlet structure. Recommended varieties of grasses and legumes have stabilized the waterways. The installation of drop inlets, tile drainage and the construction of protected outlets have further controlled erosion. Landowner acceptance and local reaction has proven favourable to project implementation. Additional monitoring of these projects will further establish their effectiveness in reducing sediment and phosphorus loadings to downstream areas.

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1.0 INTRODUCTION

The impact of soil loss from gullies and other erosion prone sites on agricultural land affects landowners through decreased productivity and farming efficiency. However, the movement of this sediment into watercourses downstream has many other detrimental effects such as sedimentation of drainage channels and deterioration of the aquatic habitats of fish and wildlife. Fertilizer phosphorus associated with this agricultural runoff stimulates aquatic plant growth, causing decreased dissolved oxygen levels at night in streams, thus threatening aquatic life. In addition, nutrient-enriched streams have reduced recreational and aesthetic potential.

As part of the Stratford-Avon River Environmental Management Project, demonstration projects have been undertaken to present solutions to local problems and thus provide examples to other landowners of cost-effective remedial measures which reduce soil loss from rill and gully erosion.

One way to reduce gully erosion and its associated soil and nutrient loss is to direct concentrated overland storm flows through a grassed waterway. A grassed waterway is a natural or constructed watercourse which is kept permanently vegetated, and which is designed to carry surface runoff downslope with a minimum of erosion. Grassed waterways are relatively inexpensive to construct and can provide a cost-effective solution to landowners experiencing such channel erosion problems. Proper design of a waterway must be undertaken, including assessment of channel grade, peak flow characteristics, and soil type. The channel depth and width selected must not only satisfy design requirements but should also be acceptable to the landowner. A waterway will generally have gentle side-slopes which spread water out to reduce velocity and soil erosion potential. This also allows a field once divided by gullies to be treated as a unit, thus increasing farming efficiency. The establishment of a dense uniform vegetative cover ensures protection against channel erosion while providing forage crops and visually enhancing the farm landscape.

The disadvantages of grassed waterways are few and are easily offset by the benefits of erosion control. Most disadvantages involve farm operating techniques which may have to be adjusted to protect the waterway structure. For example, in crossing the waterway the farm operator must raise his implements and shut off his sprayers to protect the vegetative cover. The waterway should not be crossed with machinery under wet field conditions when there is a danger of creating ruts which decrease the effectiveness and long-term stability of the waterway. Finally, under certain circumstances, a wide area of land may be taken up by the waterway.

Because it may take a number of years for the waterway to stabilize and any water quality impacts to become apparent, no quantitative analysis of changes in local water quality has yet been undertaken by the Stratford/Avon Project in conjunction with these waterways. Consideration must therefore be given to benefits of reducing soil loss from eroding channels and the subsequent improvement of farming efficiency.

2.0 METHODS

2.1 General Guidelines

The construction procedure for a grassed waterway involves grading the channel with an earth-levelling machine, according to designs taken from a survey of the waterway and criteria such as soil type, watershed area, and peak flow determinations for a one-in-ten year storm. The placement of drainage tile beneath the grassed waterway assists in handling normal flows and in draining residual water from the waterway, thus allowing earlier crossing by field machinery. With constant or intermittent flows from above the waterway, catch basins may be installed to capture this flow and direct it through the tile system beneath the waterway. In other situations a blind inlet may be constructed at the head of the waterway, or the tile can be capped when flows are a result of rainfall and snowmelt in the immediate area. Both surface and subsurface flows should be outletted from the waterway through a protected structure such as a rock chute or other drop structure.

In order to provide a good seedbed the waterway is cultivated and harrowed, and a seed mixture of recommended varieties of grasses and/or legumes is broadcast at approximately 85 lb/ac, along with about 200 lb/ac of fertilizer to ensure establishment and dense growth of the vegetative cover. A straw mulch is then applied to the waterway at rates of 1-½ to 2 tons/acre in order to protect the bare soil from the erosive impact of rainfall, and to assist in conserving soil moisture for early seed germination.

The methods used in waterway construction for the Stratford-Avon Project varied with individual sites. Detailed methods are described below for the waterway constructed on the property of Mr. Ron Hyde. The results, discussion, and conclusions which follow cover this project as well as the waterways on the properties of Messrs. H. Wyllie (now W. Shivas) and G. Bickle, which were constructed as part of the Stratford/Avon Project during 1981. The procedures used in the construction of the four waterways were similar enough

TABLE 1. Comparison Of Grassed Waterway Demonstration Projects

Property	Dimensions	Seed Rates	Tile and Drop Inlet Cost [1]		Total Project Cost [2]
1. R. Hyde Waterway - Constructed 21/8/81	- 850-foot length 30-foot avg. width 1.1-foot avg. depth - 96-acre drainage area	- 45% Kentucky Bluegrass 30% Bromegrass 25% Birdsfoot Trefoil - Sown at 50 lb/ac with 40 lb/ac mixed grain	- 800 feet of 8"tile - 4" diameter x 4' riser heavy plastic inlet	$1291.95- $326.69	$2,712.54 ($3.19/ft)
2. H. Wyllie Farm - North Waterway - Constructed 26/5/81	- 700-foot length 25-foot width 1.5-foot depth - 130-acre drainage area	- 100% Tall Fescue (Rebel) - Sown at 129 lb/ac with 40 lb/ac mixed grain	- 800 feet of 4" tile - 18"diameter x 3'riser corrugated steel inlet	$177.80- $45.56	$925.46 ($1.32/ft)
3. H. Wyllie Farm - South waterway - Constructed 26/5/81	- 750-foot length 20-foot width 1.75-foot depth - 50-acre drainage area	- 30% Canada Bluegrass 25% Chewings Fescue 30% Rebel Tall Fescue 15% Perennial Ryegrass - inc. 25 lbs Leo Trefoil - sown at 90 lbs/ac with 40 lb/ac mixed grain	- 775-feet of 4" tile - 18"diameter x 3'riser corrugated steel riser	$173.40- $45.56	$1028.21 ($1.20/ft)
4. G. Bickle Waterway - Constructed 5/10/81	- 1800-foot length 60-foot avg. width 1.3-foot avg. depth - 265-acre drainage area	- 50% K-31 Fescue 25% Timothy 25% Bromegrass - Sown at 100 lb/ac with 120 lb/ac winter wheat	- 340-feet of additional 8" tile - Concrete inlet with 24" diam. x 4' riser	- $419.00 $128.00	$2145.70 ($1.19/ft)

[1] does not include cost of installation

[2] costs shared 60% SAREMP, 40% landowner

to allow the specifications and costs pertaining to each project to be presented in tabular form (Table 1). Complete material cost sheets for each waterway are given in the Appendix.

2.2 Demonstration Site - R. Hyde Property

Staff of the Stratford/Avon River Environmental Management Project were approached in the late fall of 1980 by Mr. Ron Hyde, to examine a badly eroded private drain located on his property. Project staff had previously been involved with erosion control work on the Avon Municipal Drain which runs through the farm, so Mr. Hyde was fully aware of the technical and financial assistance available to him.

Available information pertaining to the watercourse was reviewed. The landowner reported that the drain had been dug a number of years ago to drain a swamp which is located upstream. The drainage area was quite small with gently rolling hills and silt to sandy loam soils. Although the drain did contain a considerable flow volume in the spring, the flow all but disappeared by the end of June.

The open ditch presented the farmer with a number of problems. Over the years, severe bank erosion had occurred, leading to undercutting and slumping of the banks. Along with contributing to the siltation of watercourses downstream, the drain was both unsightly and a safety hazard. Its channel cut diagonally across the north-east corner of the farm property, forcing the landowner to work irregularly-shaped fields.

Project staff suggested that the best way to solve these problems would be to construct a grassed waterway over the existing channel and provide a subsurface tile system to carry the prolonged flow. The grassed waterway would effectively carry the runoff from the upstream and surrounding areas down to a protected outlet with a minimum of erosion and soil loss. In the growing season, during good field working conditions, the waterway would allow farm machinery to cross safely and efficiently at any given point.

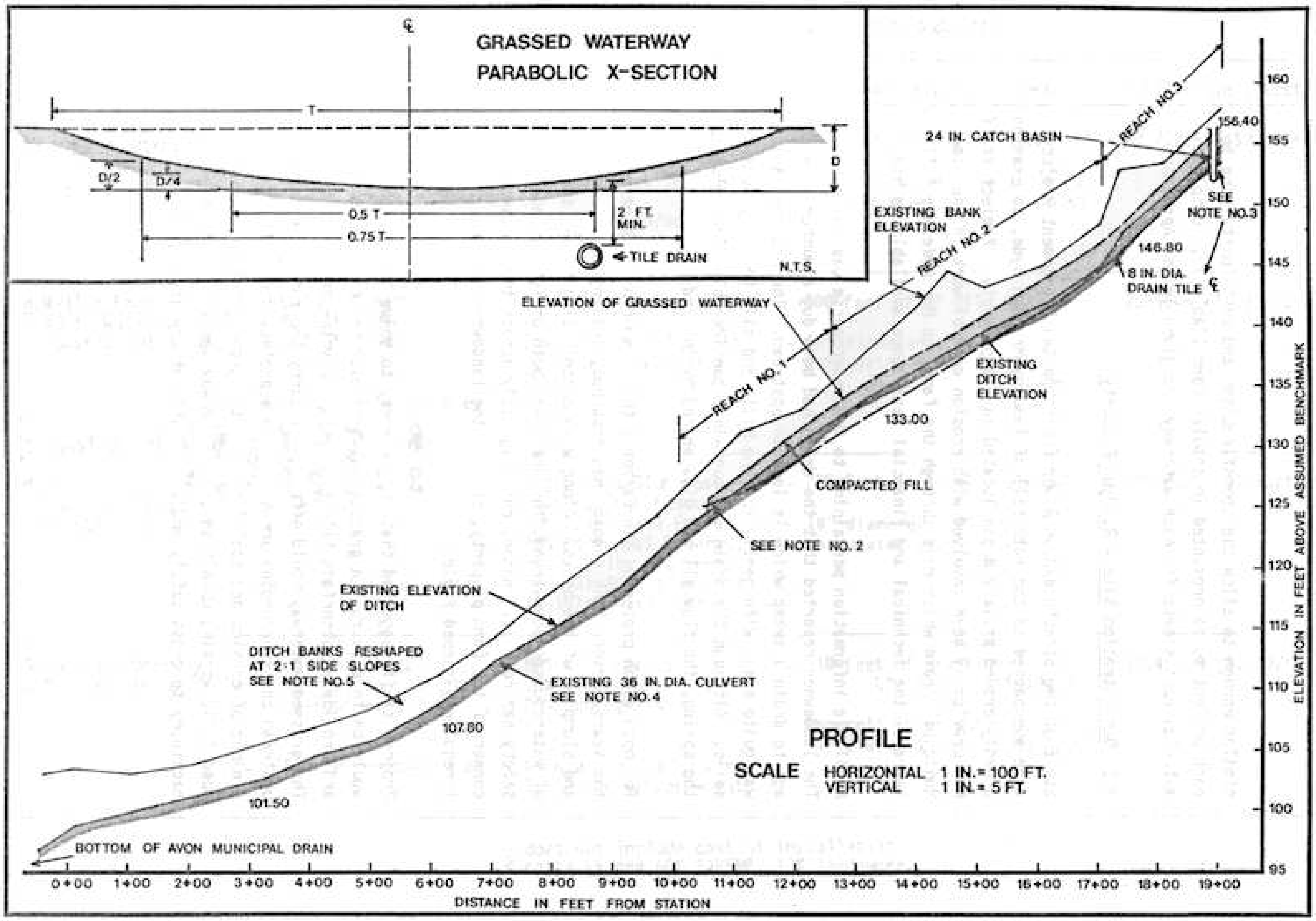


Figure 1: Plans and Specifications for R. Hyde's Waterway

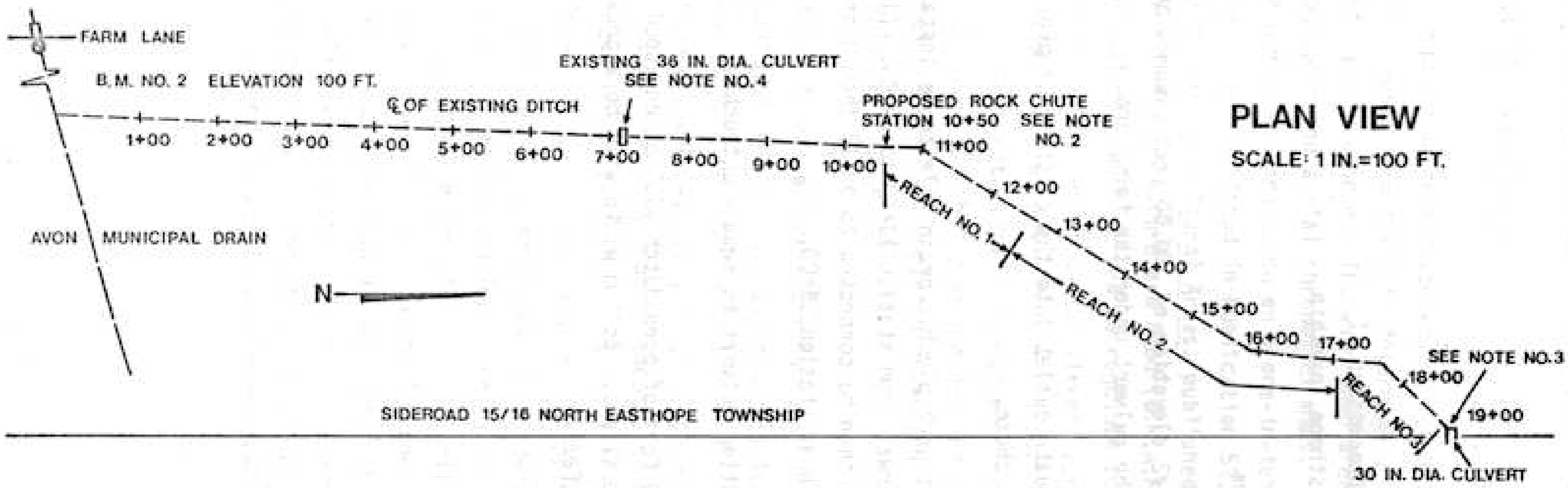


Figure 1: Plans and Specifications for R. Hyde's Waterway (cont'd)

FIGURE 1 (continued)

R. Hyde Waterway:

Location - Lot 16, Concession II
North Easthope Township

Designer - A. Graham

Notes:

1. B.M.#2 elevation of 100.00 feet assumed at the top of the culvert under the farm lane.

2. Adequate outlet into the ditch to be provided by a rock chute.

3. Eight inch plastic drain tile to be installed under waterway from station 10+50 to 19+00. Tile drain will then be connected to an 18 inch diameter catch basin at station 19+00.

4. Existing culvert to remain untouched.

5. 1050 feet of open ditch will be reshaped with 2:1 side slopes . Bottom width will be approximately 3.0 feet.

2.3 Design of the Erosion Control Demonstration

2.3.1 Waterway Design

The proposed waterway site was surveyed in early December, 1980. Levels were taken to determine the channel grade of the existing watercourse. The watershed area was determined from topographic and aerial chronoflex maps. Peak flow determinations were based on a one-in-ten year storm event using methods outlined in Publication 52, Determination of Runoff from Agricultural Areas, published by the Ontario Ministry of Agriculture and Food (O.M.A.F.). Two existing steel culverts also served to regulate the downstream flow. The peak capacities of these culverts were determined and were utilized in the waterway design calculations. Once design flow had been established, the dimensions of the grassed waterway were set, based on the desired flow velocities and channel grade. The completed plans and specifications are presented in Figure 1.

The total length of the watercourse as it crosses Lot 16 is approximately 1900 feet. The plans called for the first 1000 feet of open channel to be left as a ditch. The banks would be re-graded at a 1-½:1 side slope (horizontal:vertical) and seeded down immediately after excavation with a recommended grass and legume mixture. This stretch of the old drain did not interfere with the landowner's cropping and tillage practices because it ran straight and parallel to the direction of field operation. The channel grade through this section was great enough that channel siltation was not a problem. It was felt that a stable, open ditch would be the best alternative in such a situation. It could easily accommodate the one-in-ten year peak storm and, once the banks were improved and permanent buffer strips established, the ditch would remain virtually maintenance-free.

The upper 900 feet of the watercourse ran diagonally across the north-east corner of the farm. The waterway was designed over three 'reaches', each reach exhibiting a different channel grade and design peak flow. In accordance with O.M.A.F. recommendations, the maximum flow velocities are based on a 'D' and 'B' retardance figure. This refers to the retardance in the drain offered by the permanent sod vegetation; 'D' being a mowed condition giving the least retardance, and 'B' being an unmowed condition offering the most retardance. As a general rule, it is recommended that on this type of soil (silt loam complex), maximum flow rates be kept between 3.0 and 4.0 feet per second.

2.3.2 Tile Drain Design

The waterway was designed to accommodate a subsurface tile run for its total length. The purpose of the tile in this case was two-fold. First, it would serve to keep the waterway in a dry condition to allow for machinery crossing during normal field-working conditions. Second, the tile would have to accommodate the prolonged flow from the upstream swamp which extended well into the growing season. With this purpose in mind, an 8-inch diameter perforated plastic tile was installed. Because of the fine texture of the local soils, a cloth filter sock around the tile was used to prevent fine soil particles from entering the subsurface drain and reducing its capacity. The tile is buried about 2-½ feet underground and offset one-quarter of the top width of the waterway. For example, in 'Reach 3' of the waterway, where the top width is 33 feet, the tile is situated slightly more than 8 feet off the center line of the waterway. This is done primarily to prevent washout of the tile if severe scouring of the waterway does occur.

2.3.3 Catch Basin Design

At the upper reach of the waterway a plastic catch basin was installed to intercept a portion of the flow from the road culvert. The catch basin is 24 inches in diameter and is designed with a 12-inch silt trap at its base. The lip of the catch basin was to be positioned 3 to 4 inches above the ground during installation to encourage lower water flows to drop suspended sediment before entering the tile. The plastic structure was chosen because of its light weight and durability. A typical catch basin design is illustrated in Figure 2 (this design was used on the Bickle waterway).

2.3.4 Straw Bale/Stone Filter Design

A straw bale and stone filter structure was planned to constrict the runoff from the roadside ditch. The flow would then be channeled over the catch basin to either enter the subsurface tile or flow into the waterway over the catch basin. A small rock and earth berm constructed below the catch basin served to channel this water safely. The straw bales provide temporary protection, giving the surrounding soil a chance to settle and to establish a good vegetative cover to resist soil erosion.

2.3.5 Rock Chute Design

A rock chute structure was designed to direct surface runoff from the outlet of the grassed waterway into the open ditch with a minimum of erosion. Without the rock chute, a gully would develop where the runoff collects to make its way to the ditch bottom. Provision would be made to outlet the 8-inch drainage tile into the ditch at this point. A 10-foot length of corrugated steel pipe would be installed on the outlet of the plastic pipe and exit into the chute portion of the rock structure. A typical rock chute design is depicted in Figure 3.

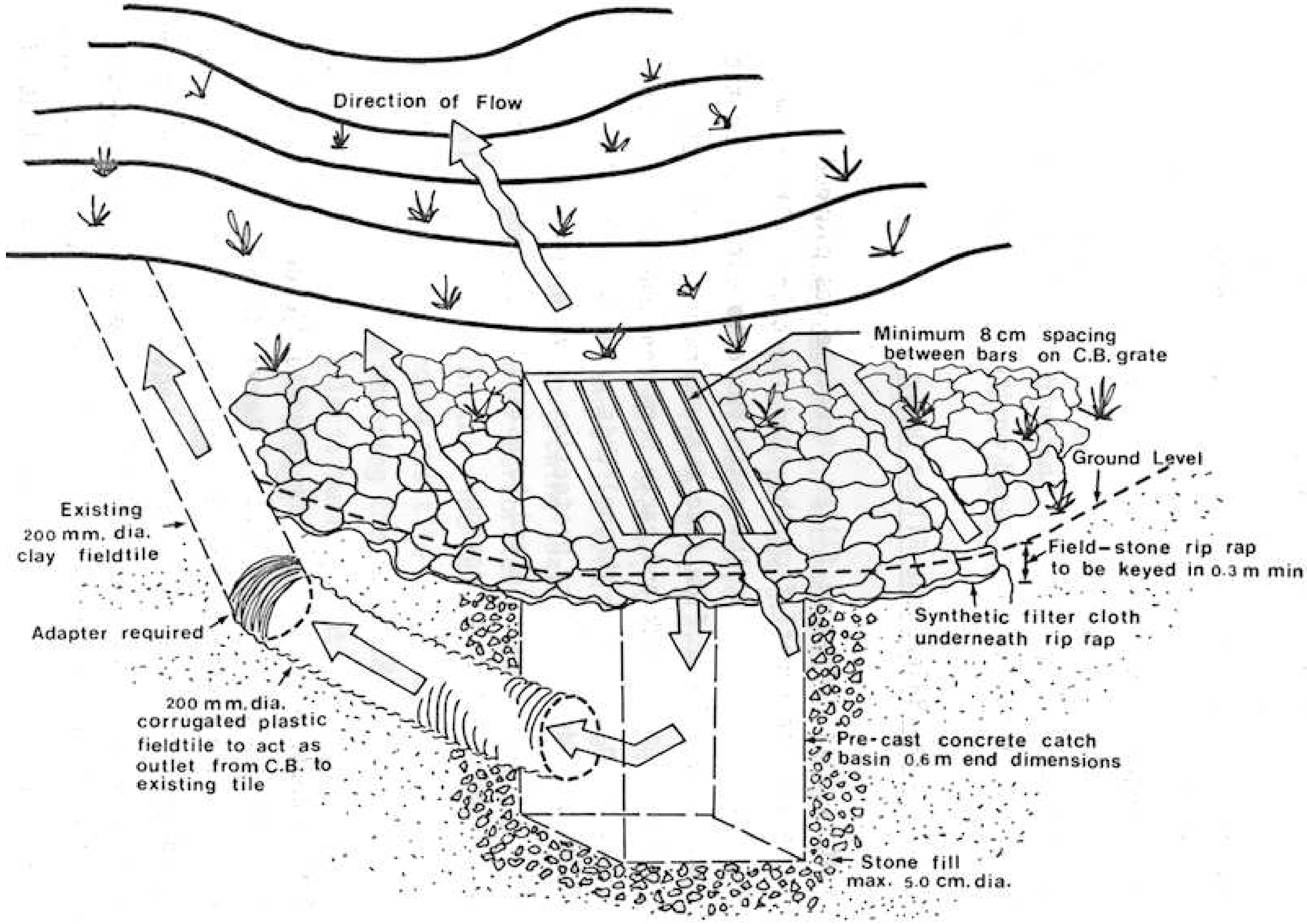
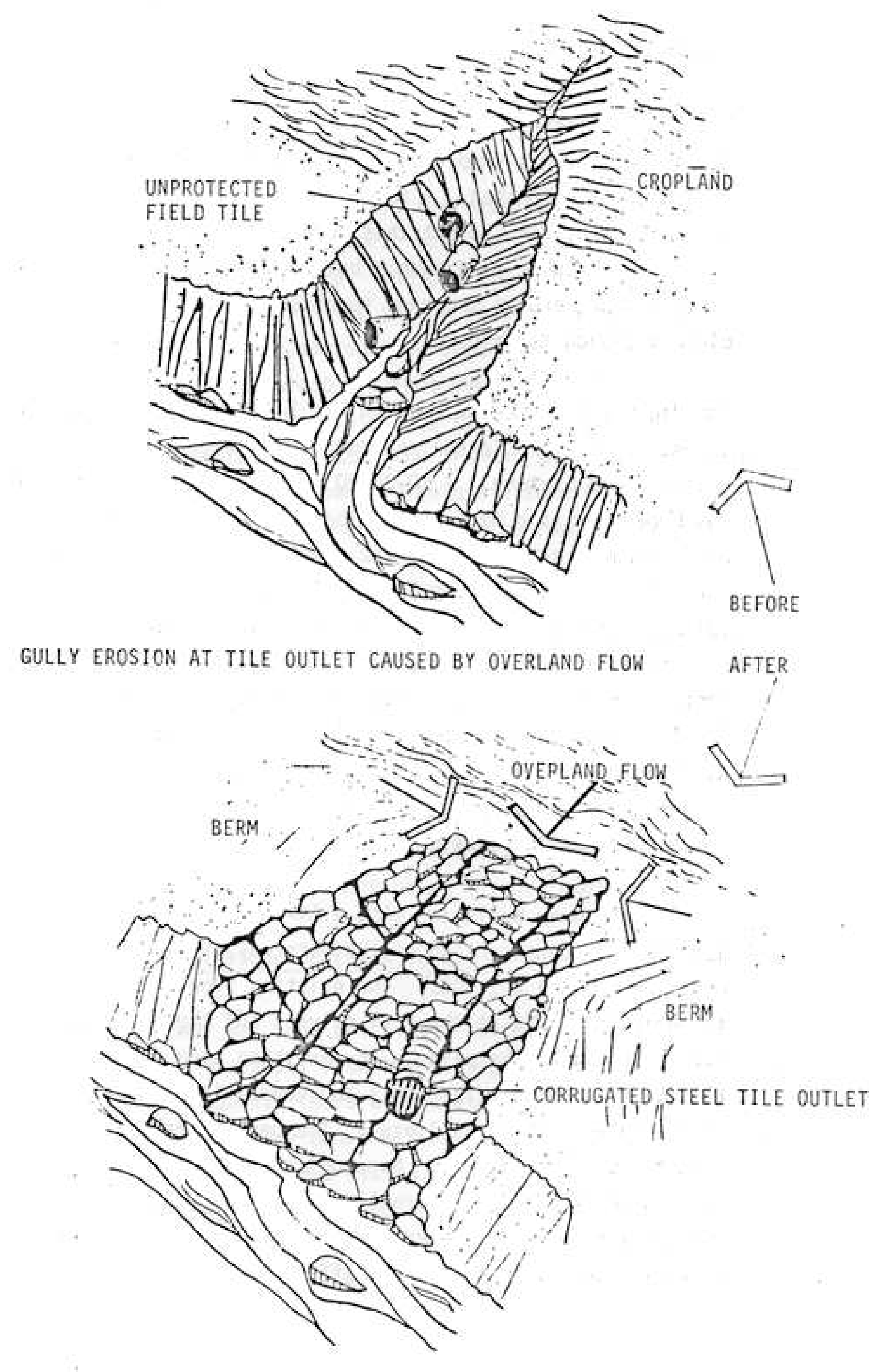


FIGURE 2: Catch Basin Installation



GULLY EROSION AT TILE OUTLET CAUSED BY OVERLAND FLOW

ROCK CHUTE AND PROTECTED TILE OUTLET

FIGURE 3: Typical Rock Chute Design

2.4 Scheduling and Construction

2.4.1 Open Ditch Improvement

The 1000-foot stretch of open ditch was the first work to be undertaken and was completely finished before the waterway itself was constructed. A contractor with previous experience on the Project carried out this work using a hydraulic hoe with a 1-½ cubic yard smooth bottom bucket. This piece of equipment had proven superior to other types for ditch cleanouts such as this.

Immediately after excavation of the 1-½:1 side slopes, the exposed banks were fertilized and seeded down with an approved grass/legume mixture. A 10-20-20 composition dry fertilizer was broadcast at a rate of 150 lb/acre. Seed was applied by a hand-operated cyclone seeder at a rate of 70 lb/acre. The mix consisted of 45% Kentucky-31 tall fescue, 30% bromegrass and 25% Leo birdsfoot trefoil. The seed bed was then raked by hand in an effort to incorporate as much of the seed and fertilizer as possible. These operations were completed by May 13, 1981. Materials and equipment costs and time associated with each are given in the Appendices.

2.4.2 Waterway Excavation

A 150-horsepower bulldozer with a 14-foot straight blade was used for the construction of the waterway. This work was completed on May 20, 1981. The existing flow in the drain was temporarily dammed at the road culvert and the waterway staked out according to the plans. The existing open drain was filled by pushing in the banks and compacting the fill as much as possible with the bulldozer. The next operation was to form the shallow channel. Numerous shallow excavations were made according to the instructions given by the project staff who constantly measured depth and channel grade using a surveying level. When the specified dimensions were achieved, the waterway was 'backbladed' by the bulldozer to leave a very smooth, graded surface. The flow in the drain was then released.

2.4.3 Tiling Operation

During trenching operations, the water was again temporarily dammed upstream of the work, and then released once the tiling operation was completed. The plastic tile was delivered in 30-foot sections with the filter sock installed. These sections were coupled together before laying them in the trench bottom at about a 3 foot depth. The grade of the trench was easily maintained by the backhoe operator. The backhoe operator excavated the trench, while the tile was installed by the landowner with assistance from the project staff. This procedure conforms to the requirements of the Ontario Drainage Act.

The tile was outletted into the rock chute structure and a steel outlet pipe was installed. A number of rocks which had been uncovered in the grading and tiling operations had to be moved from the waterway; this was done by project staff using the landowner's equipment. The plastic catch basin was installed at the upper reach of the waterway according to design specifications. The backfilling operation was completed by the landowner using his own equipment.

2.4.4 Cultivation of the Waterway

The waterway was then cultivated twice and harrowed twice to smooth out the spoil from the tiling operation and prepare a suitable seedbed. There was no excess or shortage of soil during the waterway construction. No stockpiling of topsoil was required for top-dressing because no adverse soil conditions were anticipated during seeding operations. It is anticipated that some settling of the fill will occur over the next two seasons, particularly over the subsurface tile.

Topsoil can be top-dressed into these depressed areas if required in the future.

2.4.5 Seeding and Fertilizing

Once the seedbed had been prepared, fertilizing and seeding operations were carried out. This was done prior to completion of the inlet and rock chute structures to establish the seed as soon as possible when soil conditions were at their optimum. A 10-20-20 fertilizer analysis was broadcast at 180 lb/acre. A permanent seed mix was then spread using a hand cyclone seeder. A recommended mixture of 45% Kentucky-31 tall fescue, 30% bromegrass and 25% Leo birdsfoot trefoil was used at 50 lb/acre. A cover crop of mixed grain (60% Perth barley, 40% Elgin oats) was broadcast at 40 lb/acre. These small grains establish quickly and offer good protection in holding the soil until the permanent sod cover becomes established.

Following these operations the waterway was once again harrowed in an attempt to incorporate the seed and fertilizer. The waterway was then mulched with straw at a rate of approximately 3000 lb/acre. The landowner used a tractor and packing implement to firm the seedbed which also served to partially crimp the straw mulch into the topsoil in an effort to hold it in place. The fertilizing, seeding and mulching operations were completed May 22, 1981.

2.4.6 Rock Chute Construction

The rock chute was constructed from stone which was available on-site. Approximately 15 cubic yards of various sizes of rock were required for the chute. The structure was first shaped into the existing soil bank, and synthetic filter cloth was laid down according to the plans and specifications. The filter cloth acts to prevent seepage from undermining the structure which may cause the chute to collapse and wash severely. The rock chute was built entirely by project staff using the landowner's machinery when needed.

The straw bale and stone filter structure at the inlet of the waterway was completed on June 30, 1982. After final seeding around the inlet structure, the demonstration project was essentially complete. A sign was erected at the site, stating the work done and identifying the Stratford/Avon Project's involvement.

3.0 RESULTS OF GRASSED WATERWAY DEMONSTRATIONS

3.1 Construction Specifications and Costs

Reference is made to Table 1 which lists the comparative specifications for each of the waterways constructed by SAREMP. It should be noted that all measurements are listed in Imperial units in part as these units were used in design and plan procedures, and also to serve as a ready reference to landowners. A metric conversion table is given in Appendix 1.

A complete list of materials and equipment used and associated costs for the Hyde waterway are presented in Table 2. The total cost of waterway construction was $2713 with an additional $1290 for the open drain improvement. These figures were used in calculating the 60% capital cost subsidy offered by the Stratford/Avon River Environmental Management Project to Mr. Hyde according to the Engineering Practice Agreement (see Appendix 3). Costs for the remaining waterways are listed in Appendix 2.

3.2 Seed Establishment

Of the grasses and legumes seeded on the waterways, 'Rebel' tall fescue showed the most favourable growth characteristics with a rapid formation of dense ground cover and a large amount of coarse, tough roots which provide resistance to erosion. 'Leo' birdsfoot trefoil established well as a legume, showing early growth and good ground protection. Higher total seed application rates using a cyclone seeder (125 lb/ac vs 50 lb/ac) resulted in increased density of vegetation cover and improved erosion resistance.

The mixed grain sown as a cover crop established before the grasses, and provided early protection to the waterways. Application rates of 1 bushel/ac appear sufficient for this purpose. On the fall-seeded waterway, winter wheat sown in early October 1981 emerged 2-3 inches before freeze-up. There was little grass-seed germination to report for this waterway in 1981; it was re-seeded in 1982 with an additional 65 lb/ac of grass seed mixture.

TABLE 2: R. Hyde Grassed Waterway And Drain Improvement Cost Information

Qty.	Materials and Equipment	Unit	Unit Cost	Total Cost
	Waterway Construction			
10	Bulldozing	HR	$40.00	$400.00
1	Moving Charges	HR	40.00	40.00
7.5	Backhoe	HR	35.00	262.50
870	8-Inch Filter Tubing	FT	1.44	1252.80
29	8-Inch Couplings		1.35	39.15
1	Drop Inlet with 12 x 8 Inch Adaptor		245.42	292.69
1	Catch Basin Cover		34.00	34.00
1	Corrugated Steel Tile Outlet Pipe 10" Dia.		38.00	40.56
3	10-20-20 Bagged Fertilizer (33.3 kg/per)	BAG	8.83	26.49
31	Tall Fescue/Bromegrass Mix	LB	1.15	35.65
16	Birdsfoot Trefoil	LB	4.70	75.20
56	Straw Bales	BALE	0.75	42.00
	TOTAL			$2712.54
60%	Total Capital Costs - Stratford/Avon Project	$1627.52		
40%	Total Capital Costs - Co-operator	$1085.02		
	Open Drain Improvement			
13.5	Hydraulic Hoe	HR	$55.00	$742.50
21	Trucking	HR	24.00	504.00
14	Tall Fescue/Bromegrass Mix	LB	1.15	16.10
4	Birdsfoot Trefoil	LB	4.70	18.80
1	10-20-20 Bagged Fertilizer (33.3 kg per)	BAG	8.83	8.83
	TOTAL			$1290.23
60%	Total Capital Costs - Stratford/Avon Project	$774.14		
40%	Total Capital Costs - Co-operator	$516.09		

The application of straw mulch to the waterways provided excellent soil cover during periods of heavy rainfall. The mulch also reserved soil moisture for the seeded grasses during the early summer period. The heavier application rates (3000 lb/ac vs 1500 lb/ac) offered more complete ground protection. Parts of bales which were not sufficiently broken up prevented seed germination and resulted in bare patches of soil beneath them. The use of a properly adjusted manure spreader resulted in uniform spreading of straw mulch, while greatly reducing the man hours required for manual spreading.

Increased application rates of fertilizer (300 lb/ac vs 180 lb/ac) showed improved early growth characteristics of the grasses and legumes. Response to topdressing the waterways later in the growing season resulted in a favourable increased density of vegetation cover.

Weed populations in the waterways (foxtail, bindweed, pigweed, ragweed) competed with the grasses. Maintenance practices such as topdressing with fertilizer and mowing the waterway to encourage more rapid and dense grass growth reduced the interference of weeds.

Some local re-seeding of grasses was necessary on the waterways in the spring of 1982 where (a) there was insufficient density of grasses in sections of a waterway; (b) where premature machinery crossing damaged vegetative cover; (c) where installation of drop inlets disturbed upper portions of two waterways; and (d) where washing caused by overland flows on the fall-seeded waterway required additional reworking and seed application.

3.3 Drainage and Channel Erosion Control

3.3.1 Hyde Waterway and Open Drain Improvement

The construction of the grassed waterway and improved open drain in place of the open ditch on the Hyde farm has dramatically changed the hydraulic characteristics of the channel with regards to erosion control. Whereas the previous ditch demonstrated severe erosion with undercutting and swamping of the banks, the wide shallow waterway spreads the water uniformly over a relatively large area. The dense vegetation cover stabilizes the soil and promotes infiltration of runoff. Low flows from upstream areas have been effectively drained off through the drop inlet and tile system. The rock chute continues to provide a protected outlet for the 8-inch tile and serves as a controlled drop structure for surface runoff entering the open drain. The improved drain provides stable sideslopes, full-cover vegetation on the banks and buffer strips. These conservation measures applied to what was previously an actively eroding drain have reduced soil erosion potential to a minimum.

3.3.2 Wyllie Waterways

Continuous surface flows entered the waterways beginning in mid-October 1981. Project staff anticipated flows would diminish or terminate prior to harvesting and tillage operations, however heavy rains sustained these flows. Staff requested that the landowner keep off the waterways until the drainage problem was resolved. Corrugated steel drop inlets (approximately 18-inch diameter by 3-foot riser) were installed at the heads of both waterways to intercept part of the prolonged flows and to improve the soil moisture conditions for future machinery crossing. The 4-inch drainage tiles beneath the waterways were connected to the inlet structures and rocks were placed around the inlets, underlain with filter fabric to reduce scouring potential.

The broad shallow channels of the waterways have replaced the gullies which formed across the field. Excellent erosion resistant vegetative cover has been established, and protected outlets constructed for surface and subsurface flows have remained stable. The waterways improve upon the previous system of open channels which demonstrated active bank erosion.

With continued roadside gravel and sediment loadings to the drop inlets observed over the spring period, and with the prolonged flow rates entering the north waterway, additional modifications are necessary to maximize the efficiency of this waterway. Presently, consideration is being given to additional tiling and the installation of a more efficient drop inlet structure to control sedimentation problems with the tile system.

3.3.3 Bickle Waterway

With a drainage area of 265 acres, this waterway is subject to considerable flow volumes following intense storms and snow melt. Although the waterway was designed to carry these flow volumes, the construction of the waterway late in 1981 did not allow sufficient vegetative cover to be established to control channel erosion. The location of the catch basin 330 feet downstream from the waterway inlet had also caused this section to erode, and required improvement. This section had been tiled years ago but the 8-inch clay tile had since been exposed by gully erosion.

Staff met with the landowner and remedial measures were implemented in the summer of 1982. Plastic 8-inch tile was extended from the existing 8-inch clay tile drain to the catch basin, which was relocated 330 feet upland at the property line. Rock work was also extended from the chute outletting the neighbouring waterway to protect the inlet and spillway of the catch basin. Topsoil was delivered to fill in the centre portion of the waterway where the soil had eroded. Bare sections of the waterway were cultivated and an additional grass seed mixture was applied at 65 lb/ac.

Modifications to this waterway were carried out in consultation with the landowner, and met with his approval. Costs of additional tile, backhoe time and seed were shared between the Stratford/Avon Project (60%) and the landowner (40%). Topsoil costs were considered to be repairs and were paid for by the Project. Staff contributed their time and resources to complete the modifications correctly and efficiently.

3.4 Landowner Acceptance

Control of soil erosion caused by gullying and bank erosion was of prime concern to the landowners. The grassed waterways effectively resolve this problem, and allow the crossing of farm machinery, thus increasing farming efficiency. Project staff were in frequent contact with the co-operating landowners throughout the construction and implementation phases of the grassed waterways. The 'hands-on' approach taken by project staff which meant constant field supervision of construction with the provision of labour, advice, and follow-up was of considerable importance to project success.

The cost-sharing offered by the Stratford/Avon Project was also a significant factor in the landowner's approval of the work, particularly when other costs were incurred on the same property (i.e. open drain improvement on the R. Hyde property and the fencing and stone-clearing charges on the G. Bickle property).

4.0 DISCUSSION

In order to promote the use of these erosion control structures, many demonstrations of grassed waterways have been undertaken throughout the province by the Ministry of Agriculture and Food, soils and Crops Improvement Associations, the Conservation Authorities, the Thames River Implementation Committee, and other watershed study groups. Results from the Black Creek Project in Indiana[1] where a total of 64 acres of grassed waterways were implemented over the 5-year study period, may be noted. The significance of these structures in relation to the overall project goals of improving water quality was great enough to place them in a select list of 12 best management practices which were evaluated according to these goals. Conservation practices applied in the Black Creek Project were categorized into four groups:

1. Those which benefit water quality.
2. Those which protect the soil resource base.
3. Those which enhance production capability.
4. Those which accomplish other conservation purposes.

An evaluation of grassed waterways was made on the basis of these classifications, with both water quality and soil protection given as primary benefits. Few crop production or other benefits were associated with the implementation of these structures, however the management practices of adjacent cropland must be given significant attention when considering a total conservation approach to the drainage areas of grassed waterways. The impact of grassed waterways alone in reducing erosion and improving water quality may be small, but when combined with other conservation measures which reduce the overall erosion potential of a given area, the combined impact of both reduced soil movement and delivery may be great.

1 Lake, J., and J. Morrison, Environmental Impact of Land Use on Water Quality, EPA-905/9-77-007-B, Chicago, Illinois, 1977 p.246.

Alternatives to grassed waterways should be considered on farmlands where there are cost considerations or hesitations about the loss of productive land to a fully-designed waterway. Strips of corn stubble or other crop residues are sometimes left unploughed when erosion is recurring in natural draws. These strips provide some stability to the soil and allow tillage and planting operations to be carried out across them, but do not offer the full erosion protection of a well-designed and permanently vegetated waterway.

Landowners may use their farm machinery to fill in some gullies, shape them, and seed them down with recommended varieties of grasses at a fraction of the cost of waterway construction of the sort described here. In more severe cases of gully erosion where extensive land shaping and tile installation is required, hiring a contractor with suitable machinery may be necessary.

Technical and financial assistance in designing and constructing grassed waterways is available to landowners from many Conservation Authorities and from the Ontario Ministry of Agriculture and Food. For example, the Stratford/Avon Project estimated total costs of design, construction and maintenance for a typical grassed waterway (average dimensions, 800-foot length, 4-inch tile installed), based on 1981 prices, at $1735.00. The use of resources available on the farm as well as material supplied by project staff reduced this cost to $875.00, of which the co-operator was billed 40%.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Seed Establishment

The application of mulch has proven beneficial to the early establishment of grass and legume seed, particularly in the spring when heavy rains may have caused washing of soil and in the summer when the straw held enough moisture for the seed during drier periods. Rates of 3000 lb/ac provide proper ground protection. Even spreading of the mulch by hand or by manure spreader is essential to ensure full and uniform germination of seed.

Immediate seeding of a waterway after excavation and seedbed preparation is a vital necessity. Use of a cyclone seeder provides uniform seed distribution. Higher application rates (125 lb/ac vs 80 lb/ac) provide increased soil protection. Of seed mixtures found particularly adaptable to waterway protection, tall fescue and birdsfoot trefoil have shown rapid growth and good soil cover. Leading seed companies either have available or are developing appropriate seed mixtures for grassed waterways.

Adequate fertilizer applications at seeding time (180 lb/ac) assist in early growth of vegetation particularly on poorer soils. Top dressing later in the growing season with an additional 100-140 lb/ac results in a favourable thickening response of the grasses.

Construction too early in the spring should be avoided when soil moisture conditions are high. Construction too late in the fall does not allow sufficient cover to be established before winter, with subsequent erosion problems in the spring of the following year.

5.2 Drainage and Maintenance

Prior to waterway construction it is useful to have a complete subsurface drainage map of the site in order to avoid delays during construction caused by intercepting tile drains. Proper planning and design work will increase the efficiency of the construction procedure.

Recommended design procedures must be followed to establish the specific dimensions and carrying capacity of the waterway.

A level should be used continuously by experienced field workers to maintain design dimensions and gradients. A contractor who knows his machine and preferably has experience in waterway construction should be hired to complete the work efficiently and correctly.

Tile drainage is often essential in maintaining the efficiency and extended life of the waterway by keeping the surface in a drier state. Drop inlets at the heads of waterways assist greatly in trapping prolonged surface flows entering the waterway, and directing the runoff through the subsurface tile system. Provisions must be made to protect the drop inlet and tile system from plugging where heavy sediment loads may be entering the inlet during spring runoff. Installation and backfilling operations of both drop inlets and drainage tile should be carried out with the use of a level to maintain precise grades and ensure effective long term drainage.

The presence of stones should be excluded from fill around the tile. A filter sock provided for the tile in finer soils prevents siltation and future failure of the system.

Proper outlets must be constructed for waterways where runoff drops into a drain or outlets onto adjacent land. A rock chute underlain with filter fabric will dissipate the concentrated energy of falling water and prevent outlet erosion.

Proper maintenance is essential to the long-term efficiency of the waterway in providing surface drainage and gully erosion control. Spraying herbicides across or near the waterway will destroy the vegetative cover and should therefore be avoided. Tillage equipment should be lifted before crossing the waterway. Ploughing perpendicularly to the waterway and leaving staggered rows will prevent parallel rills and gullies from rendering the waterway ineffective. Crossing of the waterway should be avoided under flow conditions or when machinery tracks will leave ruts which can limit the stability and erosion control capability of the waterway. Periodic livestock grazing or forage harvesting is possible under drier conditions only. Mowing the waterway once or twice during the season will increase the density of the grass stand. Inspecting the waterway regularly will prevent or correct problems before permanent damage results.

5.3 Channel Erosion Control

Grassed waterways can effectively stabilize many rill and gully erosion sites only if they are properly designed, constructed and maintained. Waterways provided with subsurface drainage can increase on-farm efficiency by unifying once-divided fields, and more importantly will result in a reduction of soil loss from erosive channels. This conservation of soil has on-farm benefits as well as downstream benefits of reducing sedimentation and contributing to some improvement of water quality.

To manage water effectively, conservation practices must be planned and applied as components of water management systems on watersheds and land units. Maximum benefits can thus be attained for the greatest period of time[2]. A properly designed waterway will carry runoff safely to an outlet, but unless soil loss from the land above the waterway is controlled, the waterway will soon fill with sediment and lose its capacity. Water management and soil erosion control are complementary parts of land treatment systems which can result in reductions of non-point source pollution to watercourses.

2 Jeschke, J. L., R. C. Moe, W. J. Carmach, "Mechanical Erosion Control for Agricultural Areas" in Soil Erosion and Sedimentation, Proceedings of National Symposium on Soil Erosion and Sedimentation by Water, Chicago, Illinois: ASAE Publication 4-77, Pg. 107.

APPENDICES

APPENDIX 1

METRIC EQUIVALENTS

LENGTH

inch	= 2.54 cm	millimetre	= 0.039 in.
foot	= 0.3048 m	centimetre	= 0.394 in.
yard	= 0.914 m	decimetre	= 3.937 in.
mile	= 1.609 km	metre	= 3.28 ft

AREA

square inch	= 6.452 cm^2	cm^2	= 0.155 sq in.
square foot	= 0.093 m^2	m^2	= 1.196 sq yd
square yard	= 0.836 m^2	km^2	= 0.386 sq mile
square mile	= 2.59 km^2	ha	= 2.471ac

VOLUME (DRY)

cubic inch	= 16.387 cm^3	cm^3	= 0.061 cu in.
cubic foot	= 0.028 m^3	m^3	= 31.338 cu ft
cubic yard	= 0.765 m^3	hectolitre	= 2.8 bu
bushel	= 36.368 litres	m^3	= 1.308 cu yd
board foot	= 0.0024 m^3		

VOLUME(LIQUID)

fluid ounce(imp)	= 28.412 ml	litre	= 35.2 fluid oz
pint	= 0.568 litre	hectolitre	= 22 gal
gallon	= 4.546 litres		

WEIGHT

ounce	= 28.349 g	gram	= 0.035 oz avdp
pound	= 453.592g	kilogram	= 2.205 lb avdp
hundredweight(imp)	= 45.359 kg	tonne	= 1.102 short ton
ton	= 0.907 tonne		

PROPORTION

1 gal/acre	= 11.232 litres/ha	1 litre/ha	= 14.24 fluid oz/acre
1 lb/acre	= 1.120 kg/ha	1kg/ha	= 14.5 oz avdp/acre
1 lb/sq in.	= 0.0702 kg/cm^2	1 kg/cm^2	= 14.227lb/sq in.
1 bu/acre	= 0.898 hl/ha	1 hl/ha	= 1.112 bu/acre

APPENDIX 2: Waterway Costs: H. Wyllie Grassed Waterway (North) Costs

Qty.	Materials and Equipment	Unit	Unit Cost	Total Cost
	Section 'A'- Material and Equipment Costs			
7	Bulldozing	HR	$40.00	$280.00
1	Moving Charges	HR	40.00	40.00
3.5	Backhoe	HR	35.00	122.50
2.5	Backhoe	HR	26.00	65.00
800	4-Inch Perforated Tubing	FT	0.22	176.00
4	4-Inch Couplings and End Cap		0.45	1.80
1	6-Inch x 10 Inch Steel Tile Outlet with Grate		31.58	31.58
1	Corrugated Steel Drop Inlet with Grate	UNIT	45.56	45.56
200	Filter Cloth	FT^2	0.225	45.00
50	Tall Fescue Seed	LB	1.69	84.50
1	Mixed Grain	BU	4.20	4.20
4	15-15-15 Fertilizer	BAG	8.83	35.32
25	Straw Bales	BALE	1.00	25.00
	SUB-TOTAL			$956.46
60%	Total Capital Costs - Stratford/Avon Project	$537.87		
40%	Total Capital Costs - Co-operator	$382.59		
	Section 'B'- North Tile Run			
4	Backhoe	HR	35.00	140.00
775	4-Inch Perforated Tubing	FT	0.22	170.50
4	4-Inch Couplings and End Cap		0.45	1.80
2	4-Inch T-Joints		1.00	2.00
1	4 x 2 Inch Adapter		2.99	2.99
1	6 x 10 Inch Steel Tile Outlet		31.58	31.58
	SUB-TOTAL			$348.87
60%	Total Capital Costs - Stratford/Avon Project	$209.32		
40%	Total Capital Costs - Co-operator	$139.55		
	TOTAL			$1305.33
60%	Total Capital Costs - Stratford/Avon Project	$783.20		
40%	Total Capital Costs - Co-operator	$522.13		

H. Wylliе Grassed Waterway (South) Costs

Qty.	Materials and Equipment	Unit	Unit Cost	Total Cost
8	Bulldozing	HR	$40.00	$320.00
1	Moving Charges	HR	40.00	40.00
4	Backhoe	HR	35.00	140.00
775	4" Perforated Tubing	FT	0.22	170.50
4	4" Couplings & End Cap		0.45	1.80
1	6" Clay Tile Adapter		1.10	1.10
1	6 x 4 Inch Reducer		1.50	1.50
150	Filter Cloth	FT^2	0.225	33.75
50	Seed Mixture (30% Canada Bluegrass, 15% Ryegrass, 30% Tall Fescue 25% Chewings Fescue, 25 lb/ac Birdsfoot Trefoil)	LB	3.50	175.00
1	Corrugated Steel Drop Inlet with Grate			45.56
	Materials Bought and Supplied by H. Wyllie			
25	Straw Bales	BALE	1.00	25.00
300	7-27-27 Fertilizer	LB	0.14	42.00
	TOTAL			$996.21
60%	Total Capital Costs - Stratford/Avon Project	$597.73		
40%	Total Capital Costs - Co-operator	$353.46		

G. Bickle Grassed Waterway Costs

Qty.	Materials and Equipment	Unit	Unit Cost	Total Cost
40	Bulldozing	HR	$40.00	$1600.00
1	600 mm x 600 mm D.I.		122.00	122.00
23	Timothy/Bromegrass Mixture	KG	6.70	77.00
4	Backhoe Work	HR	26.00	104.00
30	200 mm Diam. Plastic Subsurface Tile	FT	0.64	19.20
100	10-20-20 Bagged Fertilizer	KG	0.26	26.00
23	Tall Fescue	KG	2.64	60.72
	8' of 10" diam. & 4'of 4" diam. Concrete Tile			14.08
120	Filter Cloth	FT^2	0.22	26.40
	Materials Bought and Supplied by G. Bickle			
	Cedar Posts:			30.00
3	- Anchors			
4	- Brace Posts			
4	- Braces			
1	Catch Basin Grate	UNIT	6.00	6.00
87	Straw Bales	UNIT	0.75	65.25
	Winter Wheat			25.00
	TOTAL			$2565.50
60%	Total Capital Costs - Stratford/Avon Project	1539.30		
40%	Total Capital Costs - Co-operator	1026.20		

ENGINEERING PRACTICE AGREEMENT

This agreement between:

Ron Hyde (Co-operator),

Lot 16, Conc. II, N. Easthope Twp.

and

Stratford-Avon River Environmental Management Project (SAREMP)

1. The Co-operator agrees to assist the **SAREMP** with implementation of the following soil conservation practices on his property as noted below:

- **Grassed waterway (Approx. 900 ft. length)**
- **Ditch Bank improvement & Re-shaping (Approx. 1000 ft length)**

2. The Co-operator agrees that for the purposes of demonstration; practices shall be accessible for viewing by others, that photographs may be taken for documenting the success of the practice, and that a sign may be installed identifying the practice as part of a **SAREMP** Project.

3. The **SAREMP** and the Co-operator jointly agree to undertake the above-noted demonstration in accordance with this Agreement and the plans and specifications attached hereto.

4. Modifications to the demonstration specifications and/or Agreement may be made in the future, subject to the approval' of both Co-Operator and **SAREMP**.

5. The **SAREMP** agrees to have a staff member or representative at the site to oversee the implementation of the demonstration, according to the demonstration specifications. If none are available, the Co-operator agrees to keep detailed records on all activities at the site during that period.

6. The Co-operator agrees to have at the demonstration site, in working order, those machines to be provided by him, as stated in the demonstration specifications. The Co-operator should be available to operate such tractors and/or machinery.

7. The **SAREMP** agrees to document changes in each project (eg. grass establishment on grassed waterways), throughout the life of the demonstration.

8. The Co-operator agrees to maintain the demonstration according to the specifications, for at least 3 years from the time of installation.

9. Should the **SAREMP** staff or the Co-operator note any problems that could jeopardize the success of the demonstration, both parties will be notified, and mutually acceptable, appropriate, corrective measures undertaken.

10. The Co-operator agrees not to undertake any cultural practices in the demonstration area without the consent of the **SAREMP** staff.

11. The **SAREMP** agrees to inform the Co-operator when a tour stop is to be made at the site, and will invite, on occasion, the Co-operator to attend the site while the tour is being conducted.

12. The **SAREMP** agrees to pay 60% of the total cost (exclusive of project staff and Co-operator labour), of the engineering practices noted above, subject to the satisfactory completion of the project and the provision of acceptable invoices.

13. Financial assistance will be made available by **SAREMP** in the following manner :

- **All contracting and material costs to be charged 100% to the SAREMP:**
- **Upon completion of the work, 40% of the Total Cost will be charged back to the Co-operator**

14. The Co-operator agrees to release the project, its staff and associated agencies from all liability which might arise as a result of the activity proposed.

____________________ _________________________

Co-operator Program Co-ordinator

Date: ______________________________

STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2 Physical Characteristics of the Avon River
S-3 Water Quality Monitoring of the Avon River - 1980, 1981
S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5 Experimental Efforts to Aerate the Avon River with Small In-stream Dams
S-6 Growth of Aquatic Plants in the Avon River
S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9 Avon River In-stream Water Quality Modelling
S-10 Fisheries of the Avon River
S-11 Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
S-12 Phosphorus Bioavailability of the Avon River
S-13 A Feasibility Study for Augmenting Avon River Flow by Ground Water
S-14 Experiments to Control Aquatic Plant Growth by Shading
S-15 Design of an Arboreal Shade Project to Control Aquatic Plant Growth

U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
U-2 Inflow/Infiltration Isolation Analysis
U-3 Characterization of Urban Dry Weather Loadings
U-4 Advanced Phosphorus Control at the Stratford WPCP
U-5 Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
U-6 Analysis and Control of Wet Weather Sanitary Flows
U-7 Characterization and Control of Urban Runoff
U-8 Analysis of Disinfection Alternatives

R-1 Agricultural Impacts on the Avon River - An Overview
R-2 Earth Berms and Drop Inlet Structures
R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
R-4 Identification of Priority Management Areas in the Avon River
R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
R-6 Open Drain Improvement
R-7 Grassed Waterway Demonstration Projects
R-8 The Controlled Access of Livestock to Open Water Courses
R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Strip cropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of In-stream Phosphorus
R-16 Gully Erosion Control Demonstration Project
R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites