SAUBLE RIVER WATERSHED HYDROLOGIC STUDY

Prepared for:

GREY SAUBLE CONSERVATION AUTHORITY

Prepared by:

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A Division of ecologistics limited

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Grey Sauble Conservation Authority
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Inglis Falls Road
Owen Sound, Ontario
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Attn: Mr. J.W. Manicom
General Manager

Dear Sir:

We are pleased to submit our final report on the Sauble River Watershed Hydrologic Study. This report presents the results of our analysis of future agricultural land drainage development and its effect on streamflows in the Sauble River watershed upstream of Allenford. We trust this report will assist the Conservation Authority in anticipating these effects as agricultural drainage develops in the watershed.

It has been a pleasure working with the Authority on this project and we would like to express our appreciation to the staff who provided valuable input and assistance during the study.

Sincerely,
CONSERVATION MANAGEMENT SYSTEMS

D.R. Green, M.Sc., P.Eng.
Water Resources Engineer
DRG/vw

Enclosure

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1.0 INTRODUCTION

In 1983, the Sauble Valley Conservation Authority initiated a study of the potential effects of agricultural drainage on the resources of the 360 km^2 Sauble River watershed upstream of Highway 21 (see Figure 1). The purpose of that study was to develop and recommend a management plan which the Authority could use in negotiating with its member municipalities a new approach for dealing with potential problems related to agricultural drainage. The final report, entitled the "Sauble River Watershed Drainage Study," was prepared by Ecologistics Limited (1984).

One of the recommendations of the 1984 study was that the Authority undertake a hydrologic investigation on the effects of future agricultural drainage on flooding in the study area. The Authority, now called the Grey Sauble Conservation Authority, retained Conservation Management Systems, a division of Ecologistics Limited, to undertake the study. The primary objectives of the study were:

- to determine how the future development of agricultural drainage in the study area will affect peak stream flows,
- to determine whether or not flooding in the study area is likely to increase or decrease as agricultural drainage develops,
- to outline preliminary strategies to alleviate the identified problems.

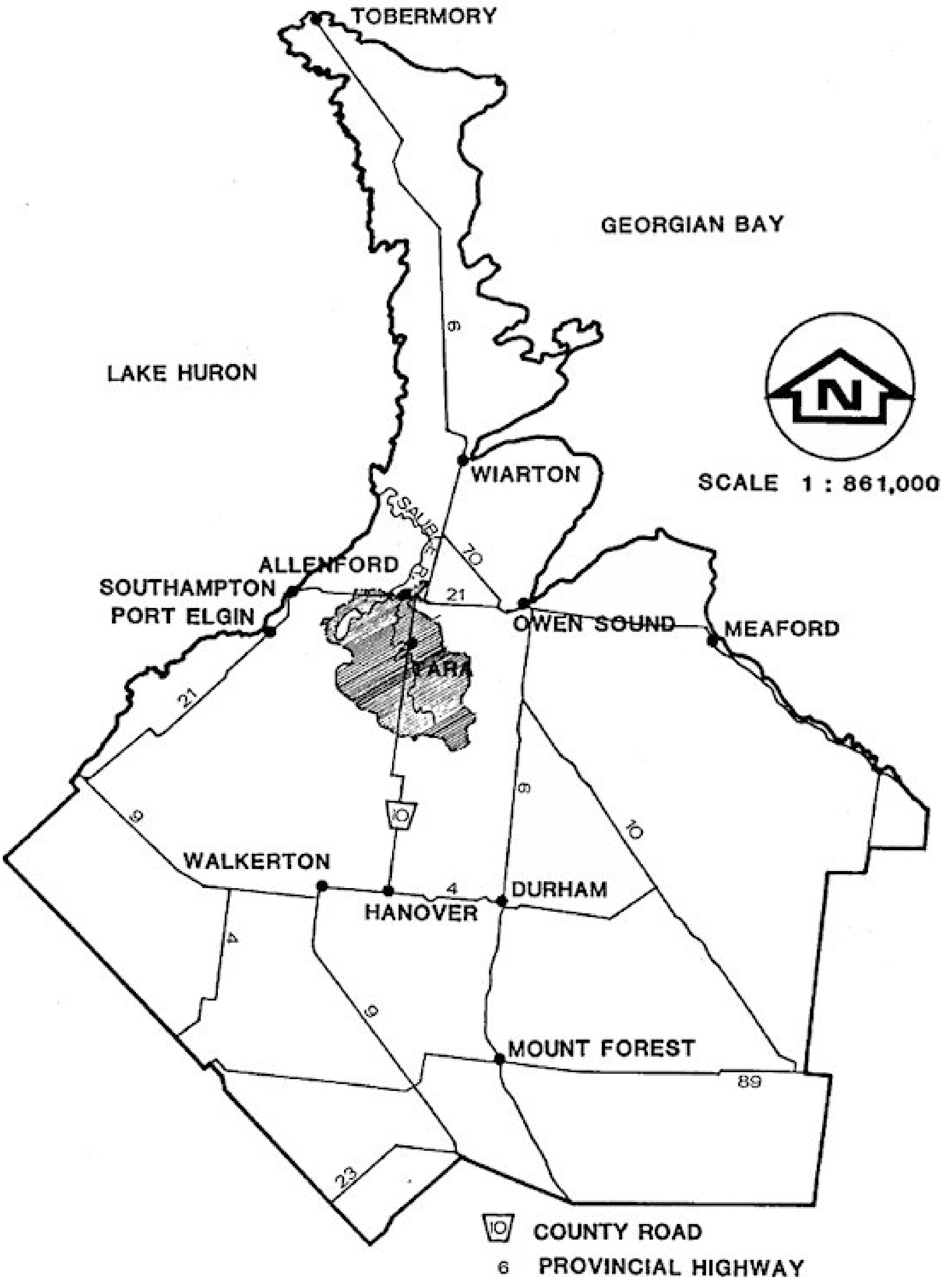


FIGURE 1: Sauble River Watershed Study Area**.**

This report outlines the procedures used to model the impact of future agricultural drainage development on stream flows. It also presents an analysis of these impacts and discusses preliminary measures to alleviate them.

2.0 HYDROLOGIC MODEL

2.1 Existing Conditions Without Agricultural Drainage

This study uses the HYMO approach to watershed modelling. HYMO is a computer language for the hydrologic modelling of surface runoff from watersheds (Williams and Hann, 1973). It was designed for planning flood prevention projects, forecasting floods and research studies. The model transforms rainfall data into runoff hydrographs and routes these hydrographs through the water courses and reservoirs of a drainage network.

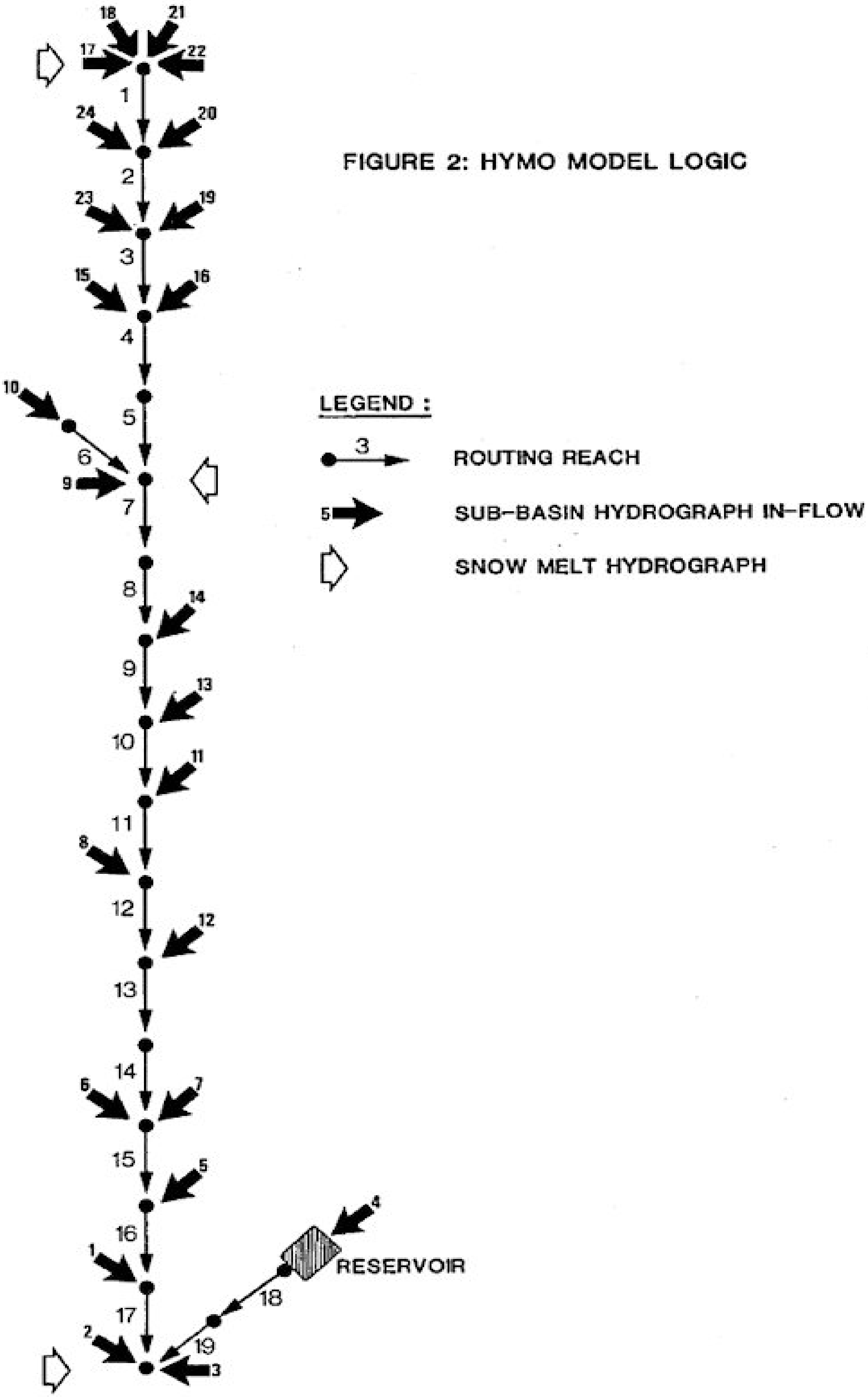
The study area was subdivided into 24 sub-basins based on the original 22 management zones in the Sauble River Watershed Drainage Study (Ecologistics Limited, 1984). The sub-basin boundaries indicated on Map 1 (inside back cover) delineate areas of homogeneous drainage. The three levels of drainage used were:

(i) all natural,
(ii) partially natural and agricultural, and
(iii) predominately agriculturally drained.

Figure 2 illustrates the HYMO model sub-basin and routing logic.

HYMO requires information on the hydrologic condition, soil group, land use, length of longest flow path, and change in elevation along the flow path for each sub-basin. This information is used to develop the runoff curve number and the hydrograph time to peak and recession constant for each sub-basin.

FIGURE 2: HYMO MODEL LOGIC



This information is in turn used to compute the runoff hydrograph from each sub-basin. Table 1 contains this information for the study area, assuming there is no agricultural drainage.

The hydrologic condition in Table 1 describes the plant cover, ranging from poor for plant cover on less than 50% of the area to good for plant cover on more than about 75% of the area. The soil group represents the storm runoff potential from different soil types, ranging from Group A having the lowest storm runoff potential through to Group D having the highest. The soils of the watershed are shown on Map 2 (inside back cover) and the soil group classification for each soil type is given in Table 2.

The land use classification was obtained from information in the Sauble River Watershed Drainage Study (Ecologistics Limited, 1984). The generalized land use designations were defined as:

A - corn systems with mixed grain and hay systems and minor occurrences of pasture systems
B - mixed grain system with hay systems and minor occurrences of pasture and corn systems
C - hay and pasture systems with occurrences of mixed grain systems and minor occurrences of corn systems

The length and change in elevation are the sub-basin's maximum flow travel length and the difference in elevation between the ends of the travel length, respectively.

TABLE 1: Existing Sub-basin Characteristics Assuming No Agricultural Drainage.

Sub-basin	Area (km^2)	Hydrologic Condition	Soil Group	Land Use	Length (km)	Change in Elevation (m)	Curve Number	
							Summer	Spring
1	7.5	Good	D	C	4.5	19.8	80	94
2	7.3	Good	B	C	8.2	4.6	61	81
3	11.5	Good	B/C	C	6.5	13.7	68	86
4	35.1	Good	B/D	C	13.5	16.8	71	88
5	21.5	Fair	B/D	A/C	10.5	24.4	81	95
6	11.8	Good	B/D	C	10.0	26.5	71	88
7	8.3	Poor	B	A	7.4	6.1	81	95
8	11.5	Fair	B/D	A/C	5.4	24.4	81	95
9	13.3	Good	D	C	6.8	8.5	80	94
10	12.4	Fair	B/D	B	6.5	30.5	82	92
11	4.6	Good	B	C	4.7	4.6	61	81
12	34.9	Fair	B	A/C	15.1	35.7	75	91
13	35.5	Poor	B	A	15.4	13.4	81	95
14	12.5	Poor	D	A	6.0	3.7	91	98
15	34.4	Fair	B/D	B	15.9	50.9	82	92
16	8.7	Fair	D	B/C	4.0	3.0	86	97
17	8.4	Fair	C	B/C	4.0	35.1	81	95
18	36.4	Good	B	C	15.3	83.8	61	81
19	9.2	Poor	D	A	4.2	21.3	91	97
20	8.2	Fair	D	B	6.6	41.2	88	97
21	16.6	Good	B	C	9.5	38.1	61	81
22	4.9	Good	B	C	2.6	18.3	61	81
23	2.5	Fair	D	B/C	1.9	1.8	86	97
24	2.7	Good	B/D	C	1.0	1.8	71	88
TOTAL	359.6							

TABLE 2: Soil Group Classification

Soil Series	Symbol	Soil Group	Soils Requiring Tile Drainage [1]
Bookton	BOL	B	
Brookston	BNL/BNM	D	yes
Burford	BGL	A	
Chesley	CSM	D	yes
Donnybrook	DBL	A	
Elderslie	ELL/ELM	C	yes
Granby	GRS	C	
Harkaway	HAL	B	
Kemble	KSM	C	yes
Osprey	OLL	B	
Parkhill	PAL	C	yes
Sargent	SGM	A	
Saugeen	SSC/SSM	C	yes
Vincent	VSL	B	
Waterloo	WSL/WSM	A	
Wauseon	WAL	C	yes
Wiarton	WLL	B	
Bottom Land	BLD	-	yes
Marsh	Marsh	D	
Organic	Org	D	

[1] These soils would require tile drainage in order to realize their full agricultural production potential.

The sub-basin characteristics of hydrologic condition, soil group and land use are used to determine the runoff curve number, representing the proportion of the rainfall that becomes storm runoff. The curve numbers for the summer condition are based on average antecedent soil water conditions for large flow events while the spring curve numbers represent very wet spring soil conditions.

Another difference between spring and summer conditions is the presence of snow melt and the volume of water it adds to the streamflow. Snow course information provided by the Conservation Authority is shown in Table 3. The most rapid snowmelt commonly occurs between March 15 and April 1 at both stations, with an average melt rate of 2.80 mm/day. This results in an average snow melt flow from the study area of 11.6 m^3/s during the main snow melt period.

2.2 Existing Conditions with Agricultural Drainage

HYMO is a surface storm runoff model and does not allow for the direct modelling of agricultural tile drainage. However, its parameters do lend themselves to adjustment of the storm runoff characteristics to be representative of those experienced with agricultural drainage systems. These types of changes were deemed suitable for the type of flow analysis being undertaken in this study.

TABLE 3: Snow Course Data.

Station	Length of Record (yr)	Snow Water Content (mm)					
		Feb 1	Feb 15	Mar 1	Mar 15	Apr 1	Apr 15
Tara	14	102.2	110.3	89.6	81.9	29.8	4.5
Chesley [1]	24	76.4	85.6	94.2	73.9	36.4	7.5

[1] just south of study area

2.2.1 Tile Drainage

Tile drains provide a means of removing excess soil water from the soil profile. The drainage of this soil water provides for an increase in the amount of water that may infiltrate into the soil since it is being more efficiently removed from the soil profile by the tile. This increase in soil infiltration capacity in turn results in less surface runoff.

The parameter in HYMO used to reflect this change is the soil group, representing the runoff potential of a soil. For sub-basins that are currently predominately drained and with soils in groups D and C, the soils in groups D and C were upgraded to groups C and B, respectively, reflecting improved drainage efficiency. Soils currently classified as either group B or A were not adjusted as these soils already have above average drainage capacity and generally do not require drainage.

For the existing drainage conditions, these changes only applied to two sub-basins, numbers 8 and 19. The changes are indicated in Table 4.

2.2.2 Open Channel Drainage

Generally associated with tile drainage is an improvement in open channel drainage. The primary change that occurs is the deepening of the existing channel to provide an outlet for the drainage tile. This deepening is also usually associated with channel widening to provide a stable channel cross-section. This improvement in channel cross-section in turn provides an improvement in channel flow capacity through increased channel flow velocity and area.

TABLE 4: Existing Sub-basin Characteristics Including Agricultural Drainage[1].

Sub-basin	Hydrologic Condition	Soil Group	Land Use	Length (km)	Change in Elevation (m)	Curve Number	
						Summer	Spring
1				6.1			
2							
3							
4				18.4			
5							
6							
7							
8		B/C				78	93
9							
10				8.8			
11							
12				20.6			
13							
14							
15				21.6			
16							
17							
18				20.8			
19		C				88	97
20							
21				12.9			
22							
23							
24							

[1] only subwatershed changes from Table 1 indicated.

The effect of this type of channel improvement was reflected in HYMO by adjusting the time to peak of the sub-basin hydrographs. Experience in Ontario has shown that HYMO generally develops sub-basin hydrographs with faster times to peak than the actual natural basins experience. HYMO was originally developed on watersheds in Texas where stream channels tend to be more efficient and produce faster responses to rainfall. It was decided that the times to peak generated by HYMO for the study area actually represented those of the improved channels.

Therefore, the times to peak in sub-basins that are currently drained by a natural channel system had to be lengthened. A similar adjustment to the HYMO times to peak was made by James F. MacLaren Ltd. (1979) in a study for the Metro Toronto and Region Conservation Authority to reflect what they termed the "calibrated rural runoff." This change was made by increasing the channel length parameter. The changes made are shown in Table 4, following the procedure outlined below.

Changes in channel velocity from natural to improved conditions were used as a basis for the adjustment of the time to peak for natural channels. This was done by adjusting the time to peak by the ratio of improved velocity to natural velocity. Table 5 indicates the channel information used in the assessment along with the ratios of improved to natural channel velocities. The flow used is one-half of the existing 10 year flow through each section as a representative (i.e. rough median) flow for the duration of the event.

TABLE 5: Assessment Of Natural And Improved Channel Velocities.

Channel (No.)*	Flow (m^3/s)	Flow Depth (m)	Flow Area (m^2)	Velocity (m/s)	VI/VN
natural (1N)	7.01	1.10	8.46	0.83	1.28
improved (1I)	7.01	1.46	6.60	1.06	
natural (2N)	5.73	0.88	11.80	0.80	1.19
improved (2I)	5.73	1.04	8.64	0.95	
natural (3N)	2.73	1.19	4.65	0.48	1.38
improved (3I)	1.16	0.70	1.77	0.66	
natural (4N)	1.33	0.37	1.67	0.59	1.12
improved (41)	1.33	0.43	1.39	0.66	
				MEAN	1.24

* see Map 3 for channel locations.

Each channel section pair represents channel sections measured in the field as natural and improved along the same drainage course. Because the ratio of improved velocity to natural velocity generally correspond, the mean ratio of 1.24 was selected as the increase required in the natural sub-basin's times to peak.

HYMO calculates the time to peak for each sub-basin from the sub-basin length and change in elevation information input to the model. Although HYMO does allow direct input of the time to peak, it was decided to adjust it indirectly by adjusting the sub-basin length parameter. This was considered realistic since the time to peak varies directly with length and since the length of a natural sub-basin will generally be longer than its length after channel improvement.

Two naturally drained sub-basins were selected and modelled separately with HYMO to assess what proportional increase in length was required to increase the time to peak in each sub-basin by 1.24. As expected, the analysis using the two sub-basins showed that the proportional increases needed in length for a 1.24 times increase in the time to peak were the same, being 1.36. Therefore, the length of all existing naturally drained sub-basins were increased by 1.36. These revised lengths are shown on Table 4.

2.3 Future Agricultural Drainage Scenarios

To model anticipated future stream flows from the basin as agricultural drainage develops it was necessary to assess the potential for drainage. The imperfectly and poorly drained Class 1, 2 and 3 soils that would benefit agriculturally from tile drainage were identified, as indicated in Table 2, and delineated on a working map as areas available for tile drainage.

The mapping was further refined by taking out large woodlots and existing tile drained areas. The final areas with tile drainage potential are delineated on Map 3 (inside back cover), along with the existing drainage system. It must be noted that these areas are considered to be the drainable areas but, as was learned during the previous Sauble River Watershed Drainage Study (Ecologistics Limited, 1984), some land owners are draining "well drained" soils to remove scattered wet low spots or seepage areas. This delineation does not include tile drainage work in these areas.

It is not expected that the study area will develop uniformly with respect to drainage but rather follow a patchy pattern based on existing land use and drainage. Four stages of drainage development were identified and are defined as the following drainage scenarios:

1. existing drainage conditions;

2. drainage development in areas now dominated by mixed and hay-grain land use systems with some corn systems and evidence of existing drainage;

3. drainage development in areas now dominated by hay and pasture systems with little mixed or hay-gray systems and virtually no corn systems, along with very little existing drainage;

4. channelization of the Sauble River through the Tara Wetland downstream to the channel constriction caused by the bedrock outcrop just upstream of Tara.

Table 6 indicates the future drainage development scenarios for each sub-basin. Once an area develops in any particular scenario, it remains developed for each succeeding scenario.

Adjustments of HYMO to reflect these developments in each sub-basin were the same as those outlined earlier for the modelling of the existing drainage conditions. Soil in Groups C and D that become drained were upgraded and the sub-basin lengths were adjusted to reflect the change to an improved channel drainage system.

Another sub-basin characteristic that had to be changed to reflect improved drainage conditions was the land use. It was assumed that all drainage improvement would be accompanied by a change in land use. Based on the land use information collected for the Sauble River Watershed Drainage Study (Ecologistics Limited, 1984), the following

TABLE 6: Future Drainage Development Scenarios.

Sub—basin	Scenario	Subwatershed	Scenario
1	2	13	2
2	2	14	2
3	2	15	3
4	None*	16	3
5	2	17	3
6	2	18	3
7	2	19	2
8	2	20	2
9	2	21	3
10	3	22	3
11	2	23	3
12	2	24	3

* no further drainage anticipated due to the distribution of the small amount of drainable soil.

distribution of land use in each sub-basin as it becomes drained was assumed:

Row crops	20%
Small grains	20%
Hay	25%
Pasture	25%
Woodlot and Other	10%
	100%

This distribution is based, in part, on the well developed agricultural system of the Dobbington enumeration area.

The future sub-basin characteristics used in HYMO for drainage development are shown in Table 7, including the resulting runoff curve numbers.

Scenario 4 was modelled by changing the channel length, cross-section and roughness along the reach between the Tara Wetland and the bedrock outcrop (indicated on Map 1) to represent an improved channel. This improved channel was designed to contain the 10 yr spring flow that would be produced by the modelled Scenario 3 drainage condition.

2.4 Rainfall

As the study area itself is an ungauged watershed, the flows used for analysis had to be based on developed rainfall events determined from probability analyses.

TABLE 7: Future Sub-basin Characteristics.

Sub-basin	Hydrologic Condition	Soil Group	Land Use	Length (km)	Change in Elevation (m)	Curve Number	
						Summer	Spring
1	Fair	C	A/B	4.5	19.8	85	96
2	Fair	B	A/B	8.2	4.6	77	92
3	Fair	B	A/B	6.5	13.7	78	93
4	Good	B/D	C	18.4	16.8	71	88
5	Fair	B/C	A/B/C	10.5	24.4	79	93
6	Fair	B/C	A/B/C	10.0	26.5	79	93
7	Poor	B	A	7.4	6.1	81	95
8	Fair	B/C	A/B	5.4	24.4	81	95
9	Fair	C	A/B/C	6.8	10.1	83	95
10	Fair	B/C	A/B	6.5	30.5	81	95
11	Fair	B	A/B/C	4.7	4.6	75	91
12	Fair	B	A/B/C	15.1	35.7	75	91
13	Poor	B	A	15.4	13.4	81	95
14	Poor	C	A	6.0	3.7	88	97
15	Fair	B/C	A/B	15.9	50.9	81	95
16	Fair	C	A/B/C	4.0	3.0	83	95
17	Fair	B	A/C	4.0	35.1	78	93
18	Fair	B	A/B	15.3	83.8	78	93
19	Poor	C	A	4.2	21.3	88	97
20	Fair	C	A/B	6.6	41.2	85	96
21	Fair	B	A/B	9.5	38.1	78	93
22	Fair	B	A/B/C	2.6	18.3	75	91
23	Fair	C	A/B/C	1.9	1.8	83	95
24	Fair	B/C	A/B	1.0	1.8	83	95

In this case, the return period of the flow is assumed to be the same as the return period of the rainfall. Three important characteristics of the rainfall had to be determined; these were the rainfall amounts, the duration, and the distribution of the rainfall within the duration.

The intensity-duration-frequency rainfall data was obtained for the two nearby Atmospheric Environment Service meteorologic stations of Owen Sound (17 yr of record) and Douglas Point (7 yr of record). The centroid of the study area is approximately one third of the distance from Owen Sound to Douglas Point, therefore, the rainfall amounts for the study area were taken as the sum of two thirds the Owen Sound amounts and one third the Douglas Point amounts for the 5, 10, 25, 50 and 100 yr return period annual maximum rainfall amounts. These amounts are referred to as the summer rainfalls for the purposes of this study.

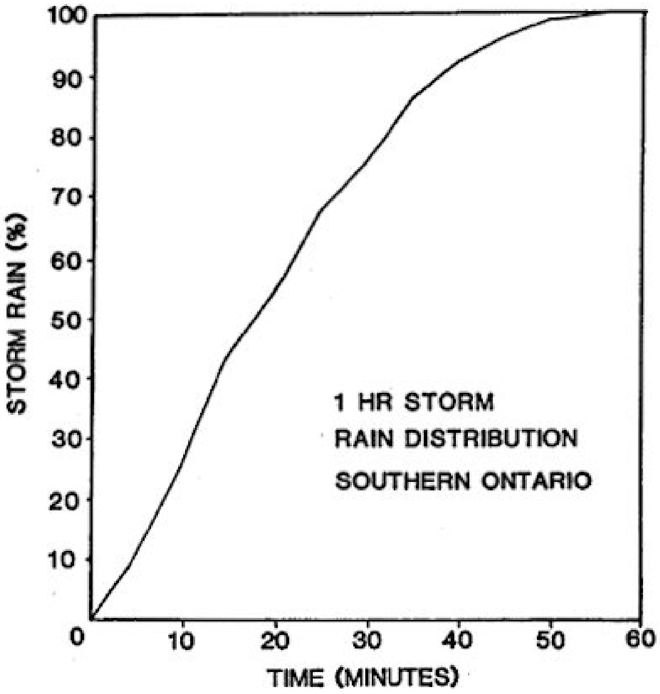
The rainfall distribution selected for use in this study is one developed by Hogg (1980) for southern Ontario storms. It is based on 25 yr of southern Ontario data. Hogg developed several distributions for both 1 hr and 12 hr rainfall durations. The different distributions for each duration are based on the probability that similar storm event would produce a range of peak flows. Hogg presented distributions based on 10, 30, 50, 70 and 90% probability of storm rain being greater than or equal to the amounts plotted for specified times during the storm duration. He recommended that the 30% distribution is the one that most closely matches rainfall/runoff events in southern Ontario and should therefore be used for design purposes (Hogg, 1982).

Figure 3 shows the 1 hr and 12 hr rainfall distribution used in this study. The 1 hr distribution was used for storm durations of 4 hr or less while the 12 hr distribution of rainfall was used for storms with greater than 4 hr duration (Hogg, 1985, personal communication).

Before the "design" rainfall duration is selected, several must be analyzed to determine which duration of rainfall produces the greatest flow rates from the study area. For this study the duration was selected that resulted in the greatest peak flow from the watershed. The time of concentration for the watershed is approximately 14 hr. Therefore, the flow resulting from rainfall durations of 3.5 hr, 7.0 hr, 14.0 hr and 21.0 hr durations were computed using HYMO for both the 5 yr and 100 yr annual rainfall amounts.

The peak flows computed by the model increased with each increase in duration and showed no sign of reaching a maximum. A 36 hr duration was used and still the peak flows went higher. It was not until a 48 hr duration was used that the flows began to level off. Because this study is concerned with peak flows, it was decided that the 48 hr duration for all storms modelled would be used.

Although summer storms generally yield the greatest rainfall amounts (Dickinson, 1976), the Water Survey of Canada flow records of the Sauble River at Sauble Falls indicate that the maximum flows usually occur in the spring. It was, therefore, necessary to determine spring rainfall amounts to be used in the assessment of spring flows.



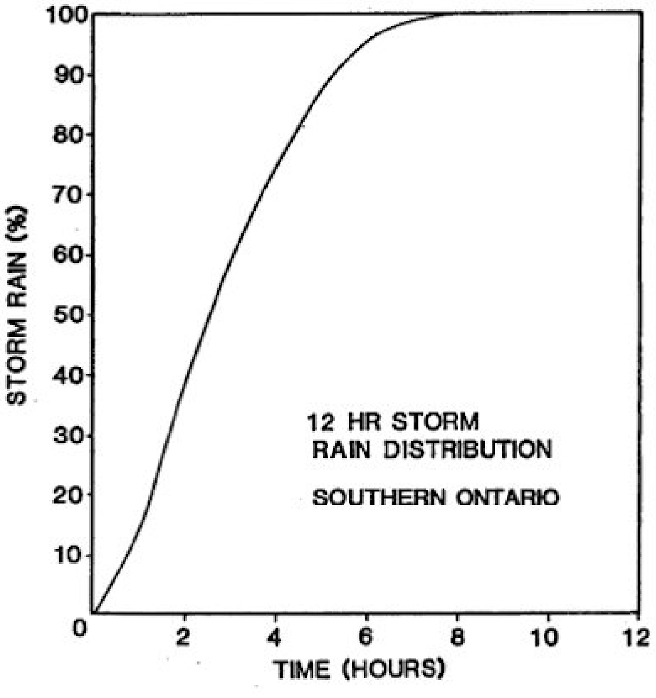


FIGURE 3: Rainfall Distributions.

A procedure developed by Dickinson (1976) provides a method by which the mean monthly extreme rainfall amounts for any given month of the year may be adjusted to represent the mean rainfall amounts of another selected month. Although the procedure did not directly indicate the amount of reduction from the annual rainfall extreme to a spring (April) rainfall amount, it did contain enough information to develop one.

The amount of rainfall reduction from both annual and July rainfall amounts to April amounts for the 5, 10, 25, 50 and 100 yr rainfall amounts for a 30 min rainfall in southern Ontario were developed. The ratio of the annual reduction to the July reduction was used to adjust the reduction factor for a 48 hr July rainfall to an April amount. This produced the 28.5% reduction to be applied to a 48 hr annual extreme rainfall amount to produce a 48 hr April (spring) rainfall amount. The 48 hr rainfall amounts used are shown in Table 8.

TABLE 8: Rainfall Amounts Used In Model.

	48 hr Rainfall Amounts (mm)	
Return Period	Summer (Annual)	Spring (April)
5	91	65
10	106	76
25	125	89
50	139	99
100	163	117

3.0 HYDROLOGIC ANALYSIS

3.1 Model Validation With Existing Conditions

After the HYMO model for the existing conditions of Scenario 1 had been prepared, it was run for both the summer and spring rainfall of 5, 10, 25, 50 and 100 yr return periods. Before the other drainage scenarios were run, the flows resulting from Scenario 1 had to be validated to ensure that the HYMO model was adequately modelling the existing physical system.

A preliminary flow analysis was performed in the earlier Sauble River study (Ecologistics Limited, 1984) and resulted in the estimation of peak flows, based on a regional flow analysis, from the study area for the 5, 10, 25, 50 and 100 yr return periods, being 118, 141, 169, 194 and 216 m^3/s, respectively. A comparison of these flows with the summer and spring flows computed by HYMO for Scenario 1 (Table 9) confirmed that the HYMO model was providing an adequate representation of the existing hydrologic system of the study area.

3.2 Modelling Future Drainage Scenarios

With the HYMO model validated, drainage Scenarios 2 and 3 could be modelled, resulting in the flows shown in Table 9. The design of the Scenario 4 channel realignment was based upon the 10 yr spring flow condition of Scenario 3 through the channel section to be improved.

TABLE 9 : Study Area Outflows.

	Summer Peak Flows (m^3/s) at the Outlet			
Return Period (yr)	Scenario 1	Scenario 2	Scenario 3	Scenario 4
5	104	108	125	131
10	133	137	160	167
25	173	179	207	216
50	205	212	245	254
100	262	270	310	319

	Spring Peak Flows (m^3/s) at the Outlet			
Return Period (yr)	Scenario 1	Scenario 2	Scenario 3	Scenario 4
5	123	127	146	151
10	150	155	177	182
25	185	190	216	222
50	212	217	251	252
100	258	265	298	303

Scenario 4 represents the channelization of the Sauble River through the Tara Wetland downstream to the channel constriction caused by the bedrock outcrop just upstream of Tara. Flooding generally occurs along this channel section each spring due to the channel configuration. This flooding delays farmers in working their land not only directly along the river but also in other areas where a drainage system back up is caused. Many of the farmers owning land in the affected areas would like to see the Sauble River channelized, as outlined in Scenario 4, to allow them to work their lands earlier in the spring.

A properly designed channel improvement would involve the lowering of the channel bottom to provide more below bank full channel flow rate capacity. The lower portion of this reach, however, is on top of bedrock that must be removed if the channel is to be deepened. The removal of this bedrock, at a cost[1] of \$50/m^3, would result in a total cost of something in the order of one million dollars. Although this would likely be an uneconomical alternative, Scenario 4 was modelled without regard to cost to assess its impact should such an alternative ever be undertaken.

The Scenario 4 channel was realigned, as indicated on Map 1, to reduce the amount of meander, thus reducing its length. The channel roughness was also decreased to reflect the straighter and smoother channel configuration.

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[1] bedrock removal cost as applied by the drainage engineer of the Clavering Creek Drain, 1980, and the Fenton Drain, 1985.

The improved channel cross-sections were both deepened and widened to provide the necessary capacity for the design flow. Table 10 shows the existing and improved channel cross-section characteristics for Scenario 4. The channel reaches referred to in the table are located on Map 1.

Although the intent of Scenario 4 was to provide improved drainage efficiency for reaches 2 through 5 and 7, the deepening of these reaches required that the further downstream reaches of 8 and 9 also be deepened to maintain a positive channel slope. For this reason, reaches 8 and 9 were not completely improved but were only deepened with their existing side slopes remaining. The side slopes of reaches 2 through 5 and 7 were designed at 2:1. As shown in Table 10, the largest channel deepening took place in the reaches of 5, 7 and 8, these reaches being in the vicinity of the bedrock outcrop channel constriction.

With the Scenario 4 channel improvement designed, the appropriate changes to the model were made, thus allowing the modelling of Scenario 4 channelization with the Scenario 3 drainage condition. The Scenario 4 flows are also shown in Table 9.

3.3 Analysis of Flows

The outflows of the study area for each of the four modelled drainage scenarios are in Table 9. In most instances, the spring flows are greater than the corresponding summer flows, with the exceptions of all the 100 yr summer flows being greater than the 100 yr spring flows and the 50 yr summer flow being greater than the 50 yr spring flow for Scenario 4.

TABLE 10 : Scenario 4 Channel Characteristics.

	Depth (m)			Bottom Width (m)		
Reach	Existing	Improved	Increase	Existing	Improved	Increase
2	1.5	2.1	0.6	3.0	12.2	9.2
3 (upper)	1.2	2.1	0.9	11.9	12.2	0.3
3 (lower)	1.5	2.1	0.6	4.3	15.2	10.9
4	2.1	2.7	0.6	10.7	15.2	4.5
5	0.9	3.0	2.1	18.3	- -	- -
7	0.9	3.0	2.1	18.3	- -	- -
8	2.7	4.9	2.2	14.0	- -	- -
9	0.9	2.1	1.2	9.8	- -	- -

The increase in flows between Scenarios 1 and 2 and Scenarios 3 and 4 is not considered significant while the increases between Scenarios 2 and 3 are more substantial. It would appear from Table 9 that agricultural drainage development in the study area will serve to increase peak flows. The summer flow increased an average of 20% from Scenario 1 to 3 while the spring flows increased an average of 18%. The channelization of Scenario 4 further increased the peak flow of Scenario 3 by an average 4% for summer and 3% for spring flows.

It is interesting to note the locations of the various sub-basins in the study area with respect to which scenario they are developed in. Eight of the 14 sub-basins developed in Scenario 2 enter the Sauble River downstream of Tara. Of the six sub-basins upstream, four are directly upstream and the other two are smaller headwater sub-basins. The negligible increase in Scenario 2 peak flows appears to be the result of the Scenario 2 sub-basins draining out of the study area before the main volume of runoff from the headwater sub-basins reaches the lower end of the study area.

Another reason for the negligible flow increase is that of the 14 sub-basins developed in Scenario 2, a majority of them have some degree of existing drainage (Scenario 2). The increase in drainage from Scenario 1 to 2 is relatively small.

The nine sub-basins developed in Scenario 3 are all upstream of Tara and a majority of them are large headwater sub-basins in Grey County with virtually no Scenario 1 drainage. The combination of these sub-basins' size and the large amount of improved drainage area results in the larger Scenario 3 peak flow increases.

The flows in Table 9 for Scenarios 2 and 3 are not only the result of agricultural drainage development but also the corresponding changes in land use. To get a better understanding of how agricultural drainage development itself would affect the existing flow, the 10 yr spring flow was computed again for Scenario 3 without the associated land use changes, i.e. for agricultural drainage only. HYMO was used to model Scenario 3 drainage development with Scenario 1 land use. The resulting 10 yr spring outflow was 153 m^3/s, only 2% greater than the existing Scenario 1 flow. It is expected that this procedure using the other flows would reveal the similar results of not having much affect on the peak flows. For example, the same analysis using the 10 yr summer flow led to a 2% decrease in peak flow.

The small changes in flow due to drainage development only, indicate that the larger changes indicated in Table 9 are primarily the result of the land use changes. Although drainage development will usually be accompanied by land use changes, it is important to note that it is the land use change itself that appears to be responsible for the flow increases.

3.4 Effects of Storm Water Management

Another impact on flow could be the installation of remedial measures to provide storm water management and lessen the impact caused by drainage. Because the nature of this study is basin—wide, it is not possible to target specific remedial measures but rather to assess their overall impact on storm water runoff.

The drainage scenarios are each accompanied by a set of runoff curve numbers representing the amount of rainfall that becomes storm runoff. Land use is one of the parameters on which the curve numbers are based. When the curve numbers for each of the scenarios were developed, standard agricultural practices for each land use were used, i.e. straight row cropping with no conservation practices. Conservation practices are important soil and storm water management techniques in that they not only provide soil erosion control but also serve to reduce storm water runoff and improve water quality.

It was decided to model on—land conservation practices to determine the extent to which they could affect flow increases caused by drainage development. Contour cropping and field terracing with grassed waterway outlets were modelled on Scenario 3 by determining new runoff curve numbers taking into account these practices. The resulting 10 yr spring flow in, Scenario 3 with the remedial measures included, was 154 m^3/s, which is 13% lower than Scenario 3 without remedial measures and only 3% higher than Scenario 1. The remedial measures modelled clearly have an effect on peak flow.

Although it is not practical to assume the entire study area will adopt such remedial measures for the control of storm water runoff, the model does illustrate their potential impact on peak flows if used over a large area.

Another storm water management technique that could affect peak flows is temporary in-channel storage. In this practice channels are enlarged to provide storage of runoff water while channel culverts remain small, thus lowering the peak outflow. An example would be to enlarge a channel that drains a couple of farms to provide storage for a 10 yr storm while having the channel drain through a culvert with the capacity of a 5 yr storm. This serves to reduce the peak of a 10 yr storm to one similar to a 5 yr storm. The channel, in effect, acts like a small reservoir. For such a storm water management technique to have an effect on the study area, many channel storages would have to be in place through the basin.

HYMO does not provide channel routing procedures within sub-basins. This means that any internal sub-basin routing, such as flow through a reservoir, may only be applied to the total sub-basin outflow hydrograph. The temporary in-channel storage practice is a small scale remedial measure and would generally be constructed at many locations within a sub-basin. This practice was, therefore, not modelled because it was impractical to use HYMO to model several of these practices in a sub-basin by combining their effects and applying to the sub-basin hydrograph.

3.5 Effects on Flooding

Although it is anticipated that increased drainage activity in the study area will serve to increase peak flows, it is important to assess the impacts of these flow increases on flooding. Little is known about the locations and extent of seasonal flooding within the study area. The Conservation Authority and area residents have indicated that seasonal flooding does occur in the two urban centres of Tara and Allenford, and in the area of the Tara Wetland but that flood damages are minimal. The effect on flooding was addressed at two locations in the study area, Tara and the study area outlet at Highway 21, just downstream of Allenford.

Table 11 illustrates the 10 yr spring and 100 yr summer flows through the downstream end of Tara for the four drainage scenarios. These are accompanied by the 10 yr spring flows for Scenario 3 without land use changes and with the on-land remedial measures. Also included in the table are the depth of overbank flow for each scenario.

Again, as with the outlet peak flows, Scenario 2 has virtually no effect on flow, or depth over bank. Even the Scenario 3 drainage only (i.e. no land use changes) and remedial measure flows change little from Scenario 1. The most notable change is that caused by Scenarios 3 and 4. Although the 10 yr spring and 100 yr summer Scenario 4 flows increased about 22% over Scenario 1, the increases in the depth over the bank are only 8% and 13% respectively, about one to two tenths of a metre.

TABLE 11: Flows At Tara.

Return Period:	10 yr (Spring)		100 yr (Summer)	
Scenario	Flow (m^3/s)	Depth Over Bank (m)	Flow (m^3/s)	Depth Over Bank (m)
1	111	1.2	197	1.5
2	111	1.2	198	1.5
3	133	1.3	237	1.6
4	136	1.3	240	1.7
3D[1]	113	1.2	-	- -
3RM[2]	117	1.2	-	- -

NOTE: bank full flow is 22 m^3/s

[1] outflow of modelled Scenario 3 drainage development without accompanying change in land use.

[2] outflow of modelled Scenario 3 drainage development with implementation of contour and terraced remedial measures.

The depth of flow over the bank at the study area outlet was compared graphically for the same two return period flows. Figure 4 illustrates the depth and time of flow over the bank for the drainage scenarios caused by the 100 yr summer flow. Figure 5 is a similar illustration for the 10 yr spring flow. As with the analysis at Tara, the changes in flow for the different scenarios appears to have little affect on the flooding situation, both in the depth and time the flow is over the bank.

It appears that agricultural drainage development will not significantly aggravate existing flooding conditions in the study area. The impact of Scenario 4 on flooding is also considered minor although the flows reach flood depths faster due to the increased main channel drainage efficiency. This is particularly well illustrated by the 10 yr Scenario 4 depths shown in Figure 5.

It must be noted that while the HYMO model works with channel flows and routing, it does not take into account the effects of structures such as bridges and culverts on the flows. These structures tend to reduce peak flows. For this reason it is important that the information on flooding depths not be considered definitive; rather should be used to assess the general effects of flooding caused by agricultural drainage.

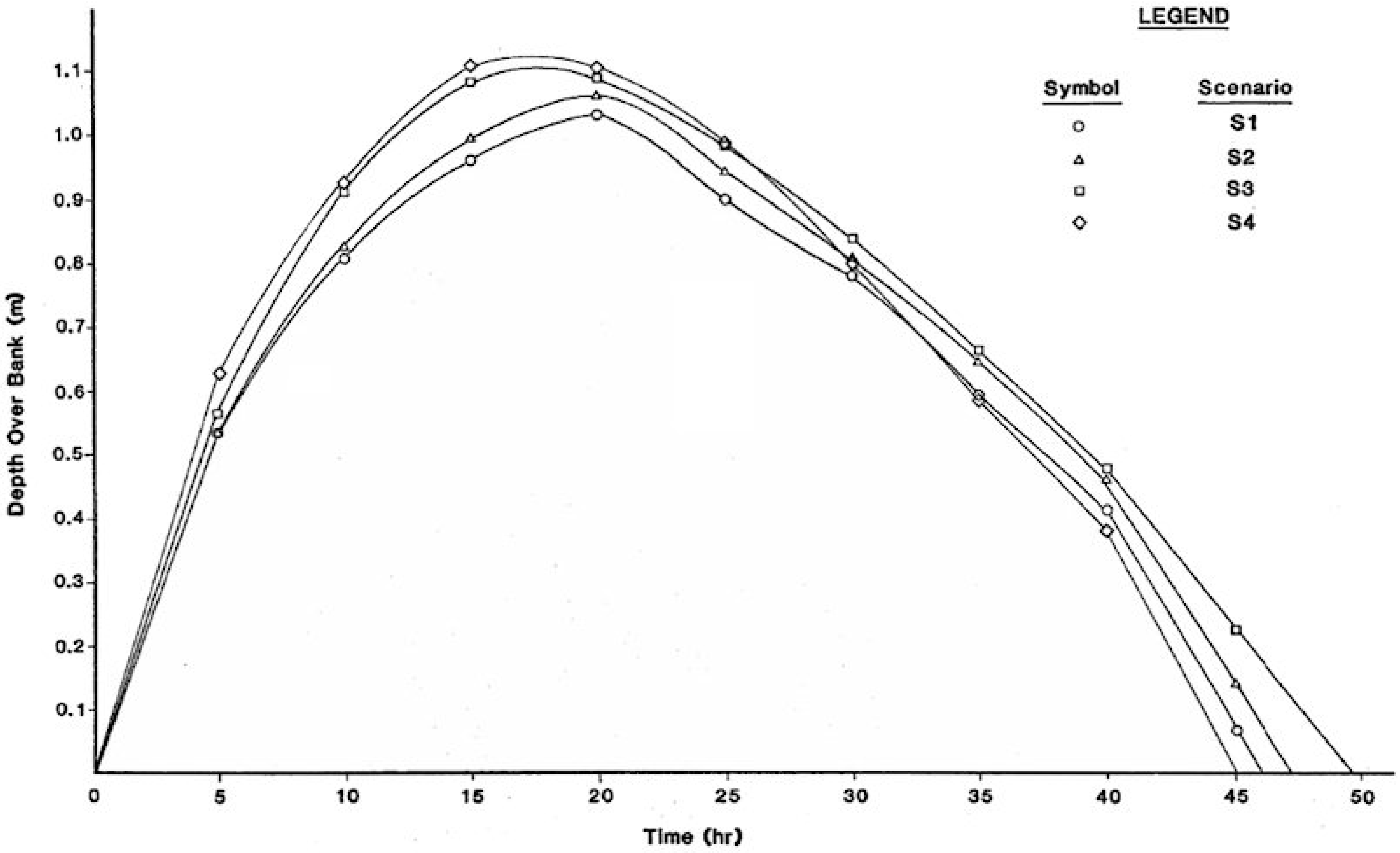

FIGURE 4: Depth Over Bank From 100 Year Summer Flow At Study Area Outlet.

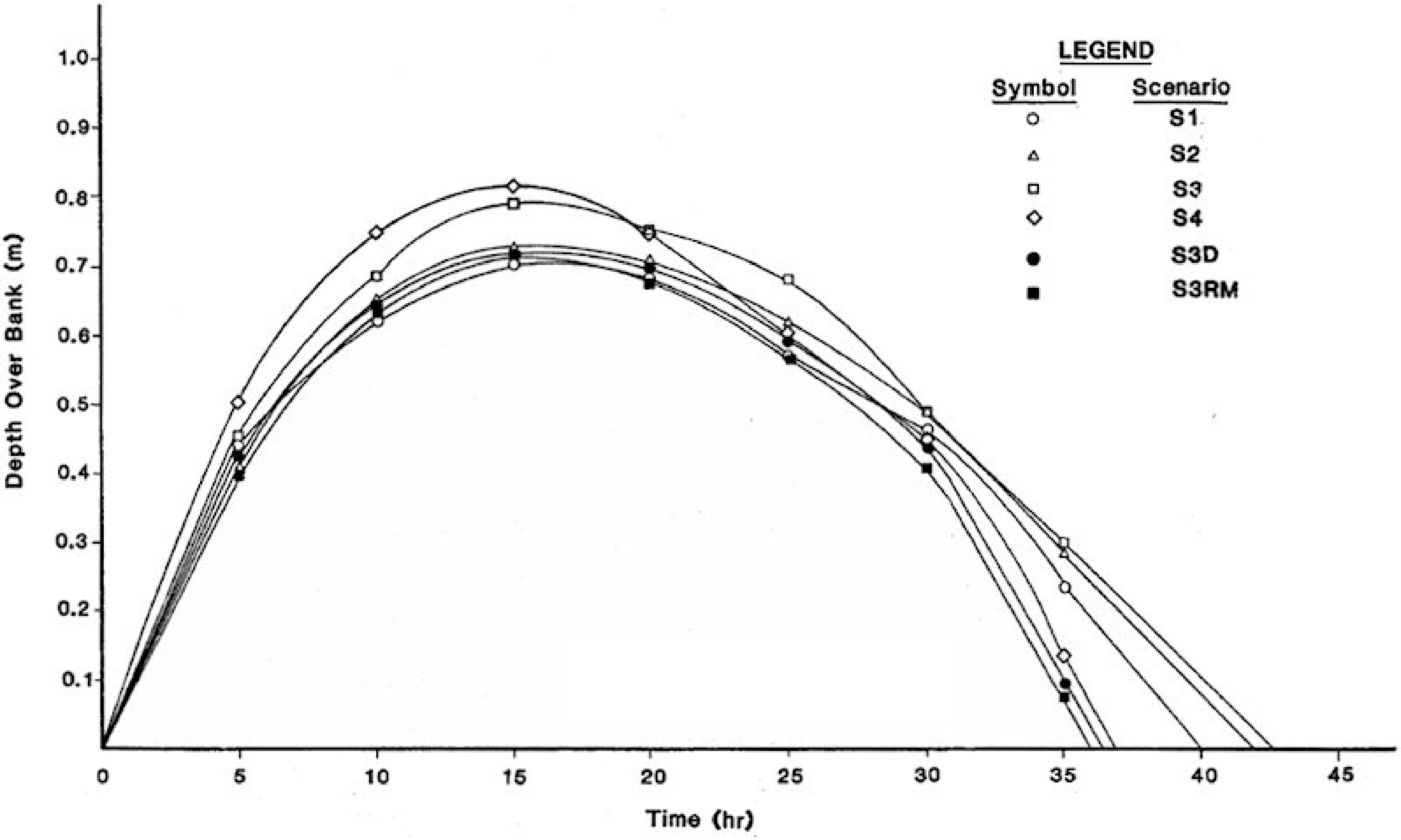

FIGURE 5: Depth Over Bank From 10 Year Spring Flow At Study Area Outlet.

4.0 CONCLUSIONS AND RECOMMENDATIONS

It is apparent that the agricultural potential of the area could be substantially improved through further drainage development. This development would lead to an increase in peak flow from the study area although the current flooding situation as measured by depth and duration of overbank flow would not likely be significantly increased.

In specific instances where increased downstream peak flows would prove problematic, the peak flow increase may be lessened by implementing storm water management practices. These practices would provide soil erosion control, improved water quality and the reduction of storm water runoff by slowing runoff velocities and temporarily storing water for a more controlled outflow.

The specific conclusions of this study are as follows:

- agricultural drainage development in the study area increases peak flows, largely because of the accompanying changes in land use;

- although agricultural drainage development in the study area increases peak flows, the resulting increases in flooding are considered minor;

- drainage of the large and currently undrained headwater areas in Grey County will have the greatest impact on the flow regime as they develop;

- basin—wide storm water management techniques would serve to lessen the impact of agricultural drainage development on peak flows, particularly if applied to the large headwater areas in Grey County; and

- the reduction of spring flooding in the Sauble River through the Tara Wetland by channelization would cause relatively minor increases in flooding downstream.

Two specific recommendations of the study are:

- the Conservation Authority should promote the incorporation of storm water management practices into agricultural drainage development for the combined reasons of soil erosion control, water quality improvement and flow control; and

- given the limited amount of information on the extent of existing flooding and the possibility that areas that would benefit from reduced flooding may not be that large, engineering works along the Sauble River between the Tara Wetland and the bedrock outcrop channel constriction to alleviate flooding should not be undertaken unless an assessment of the economic benefits and environmental consequences justifies such works.

5.0 REFERENCES

Dickinson, W.T. 1976. Seasonal Variability of Rainfall Extremes, Atmosphere. Vol. 14, No. 4.

Ecologistics Limited. 1984. Sauble River Watershed Drainage Study. Report for the Sauble Valley Conservation Authority.

Hogg, W.D. 1980. Time Distribution of Short Duration Storm Rainfall in Canada. Atmospheric Environment Service, Downsview.

Hogg, W.D. 1982. Distribution of Rainfall with Time: Design Considerations. Presented to A.G.U. Chapman Conference on Rainfall Rates. Atmospheric Environment Service, Downsview.

James F. MacLaren Ltd. 1979. Report on Hydrologic Model Study Humber, Don and Rouge Rivers, Highland, Duff in, Petticoat and Carruthers Creek. Report for the Metro Toronto and Region Conservation Authority.

Williams, J.R. and R.W. Hann, Jr. 1973. HYMO: Problem-Oriented Computer Language for Hydrologic Modelling, Users Manual. U.S. Dept. of Agriculture, ARS-5-9.