STORMWATER RUNOFF STUDY AT TORONTO INTERNATIONAL AIRPORT

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Gentlemen,

Stormwater Runoff Study
at Toronto International Airport

In March 1976, the Environmental Protection Service of Fisheries and Environment Canada, through the Department of Supply and Services, executed an agreement with this firm to carry out a comprehensive study of stormwater runoff contamination problems at Toronto International Airport. The study involved: an extensive monitoring program of stormwater runoff quantity and quality characteristics on three selected catchment areas at the airport; calibration and verification of the Stormwater Management Model (SWMM) and Storage, Treatment and Overflow Model (STORM) based on results of the monitoring program; comparison of statistical methods with the simulation approach for predicting stormwater runoff quality; assessment of the effects of airport operational activities on stormwater runoff quantity and quality; and, development of a stormwater runoff management strategy.

The principal observations, conclusions and recommendations of this study have been summarized below for convenience.

Observations and Conclusions

1. Stormwater runoff hydrographs were recorded on numerous low, medium and high intensity rainfall events on the three catchment areas assigned for monitoring. Verification of SWMM was accomplished

and increasing accuracy with increasing rainfall intensity was demonstrated.

Calibration of SWMM in future airport studies in general will not be necessary except in very detailed applications. The model is well suited to the prediction of peak flows for use in design of storm drainage sewers or stormwater management facilities and to the simulation of complete hydrographs for use in the assessment of the effect on runoff flows of alternative airport development plans or runoff control strategies.

2. Several runoff hydrographs for snowmelt and rain-on-snow events were also recorded during the study. Application of SWMM and STORM showed that the models tend to overpredict the peak runoff rate. However, the total runoff volume was estimated with reasonable accuracy by both models.

As STORM operates on an hourly time step, several years of runoff data can be simulated in a relatively short computer processing time. The model is therefore particularly applicable to studies involving the assessment of stormwater runoff management alternatives.

3. Stormwater runoff pollutographs were defined for a total of 31 events from the three catchment areas. Composite samples were prepared on an additional 50 runoff events and grab samples were collected on another 29 events. All samples were analysed for pH, five-day biochemical oxygen demand (BOD) and suspended solids (SS). In addition, all samples collected during the winter months were analysed for total Kjeldahl nitrogen (TKN) and several samples were also analysed for nitrite nitrogen, nitrate nitrogen, ammonia nitrogen, orthophosphate and total phosphorus.

An evaluation of the analytical data indicated that the contamination of stormwater runoff at the airport was most significant during the winter period, approximately between mid-November to mid-May. Airport activities, including aircraft deicing using glycol based deicer fluids and airfield deicing with urea, were identified as being the principal pollutant sources. Jet fuel spillage was also found to be an important environmental concern although the analytical program was not designed to monitor for this pollutant.

4. Simulation of stormwater runoff pollutographs over the summer and fall period, using the SWMM Generalized Quality Model, demonstrated that the model can predict BOD and SS concentration and mass emission profiles with reasonable accuracy. The rate of pollutant accumulation, however, demonstrated noticeable variability between storm events on each catchment area. The pollutant accumulation rate was also found to vary between the catchment areas, reflecting on differences in land use and level of activity in the respective catchments.

   For future applications at other airports, calibration of the model will be required to define the rate of pollutant accumulation on each major catchment area. Once sufficient data has been collected on other airport catchment areas, it may be possible to define the expected range in pollutant accumulation rates so that the model can be applied without further calibration.

5. The structure of the SWMM quality model does not allow for proper simulation of the effect of deicing agents on the pollutant load in winter runoff events as the model incorporates the assumption of a uniform rate of pollutant accumulation during the antecedent dry period. However, the model can be used for predictive purposes by specifying as input to the model the equivalent pollutant loading from deicing agents applied during the antecedent period prior to each runoff event.

6. Statistical models were found to be applicable for predicting runoff BOD and SS pollutographs over the summer and fall periods, although not as accurately as the simulation models. Application of statistical models on winter runoff quality events demonstrated that SS concentrations could be predicted

with an acceptable level of accuracy. Prediction of BOD concentration levels, however, was found to be unsatisfactory.

The statistical models developed in this study can be applied to predicting runoff quality at Toronto International Airport provided the values selected for the input variables fall within the range specified in the report. However, the models are not considered to be directly transferable to other airports.

7. Aircraft deicing using glycol based deicer fluids was found to be the most significant source of stormwater runoff contamination at Toronto International Airport. High levels of BOD were recorded in runoff collected from the apron areas at Terminals 1 and 2 throughout the winter months. Snow removed from the aprons also was found to contain substantial BOD levels.

Management strategies considered in this study included collection and treatment of contaminated surface runoff from the aprons and snow dump piles as well as centralization of the deicing operation to allow recovery and recycle of deicer fluid. The latter alternative has not found wide acceptance among the airlines and airport operating authority. This is due to the high costs involved and operational constraints imposed with a centralized deicing facility.

Collection and treatment of surface runoff requires the interception and storage of runoff from approximately 80 acres around Terminal 1 and 105 acres around Terminal 2. Treatment would be most effectively provided through discharge to the Regional Municipality of Peel sanitary trunk sewer for treatment at the Lakeview Water Pollution Control Plant. Negotiations with the Regional Municipality of Peel and the Ontario Ministry of the Environment are required to obtain an agreement for discharge to the regional system.

8. Airfield deicing using urea was shown to contribute to high nitrogen levels in runoff from the runways. It was estimated that 50 percent or more of the urea

applied is carried off in surface runoff with the majority of the nitrogen loading entering Etobicoke Creek. Nitrogen levels in Etobicoke Creek were not found to increase noticeably although this observation was based on analysis of a very limited amount of receiving water quality data. The remainder of the urea is removed with snow to the grassy areas bordering the runways and does not appear to present any serious environmental problems with respect to either contamination of groundwater or overloading the soil nitrogen utilization capacity.

It was concluded that management of contaminated surface runoff from the airfield is not required. Additional monitoring of receiving water quality is necessary to confirm the above conclusion. In addition, a monitoring program may be required to confirm observations regarding the groundwater and soil regimes opposite the runways.

9. Jet fuel spillage occurs mainly on the apron areas of the terminals and was found to be significant in terms of both frequency and quantity of fuel spilled. The majority of these spills were washed off the apron areas into the storm sewer system with no further treatment provided.

Improved procedures are required for managing fuel spills. As most of the fuel spills can be classified as small spills, it was concluded that clean-up of these spills would be most effectively carried out using an adsorbing material. Large spills on the apron areas present a serious fire hazard and therefore are most effectively managed by washoff into the sewer system. Provisions to collect and treat runoff from the apron storm sewers will be required to ensure adequate environmental protection. Alternatively, large spills could be cleaned up using a vacuum type pick-up device, however, the applicability of this method requires further investigation.

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Recommendations

1. Monitoring of the quality of Etobicoke Creek as it enters and exits the airport property is recommended to more clearly define the effect of urea washoff from the airfield on the receiving water quality. It is proposed that sampling be carried out only during the winter months over one season and that the samples be analysed for total Kjeldahl nitrogen and ammonia nitrogen.

2. Studies currently being undertaken elsewhere in Canada on the fate of urea used for airfield de-icing should be reviewed upon completion to establish whether monitoring of the groundwater and soil regimes at Toronto International Aiprort is required.

3. It is recommended that the Emergency Services Group at Toronto International Airport institute procedures for clean-up of small category fuel spills using an adsorbing material. Field testing of adsorbing materials is also recommended in order to select a material which will best suit this application.

4. Investigation of vacuum type pick-up devices is proposed to determine their suitability for clean-up of large fuel spills and the possible elimination of downstream oil removal facilities.

5. Facilities to intercept and store runoff contaminated as a result of aircraft deicing on the apron areas of Terminals 1 and 2 are recommended as detailed in the report. In summary, the facilities are designed to store runoff between the period of mid-November to mid-May with pumpout to the Regional Municipality of Peel sanitary sewer system for treatment at the Lakeview Water Pollution Control Plant. The facilities are sized to provide storage for approximately 95 percent of the runoff volume expected over an average winter with emptying of the facilities occurring between runoff events in order to distribute the loading on the treatment plant. In the summer months the facilities would be operated on a flow through basis to provide environmental protection against large fuel spills.

Separate storage facilities are recommended for the Terminal 1 and 2 drainage areas. Each facility incorporates solids separation to prevent solids build-up in the storage tanks. Oil separation within the storage tanks has also been provided for removal of spilled fuels. This provision can be eliminated should it be demonstrated in recommendation number 4 that the facilities are not necessary. The capital cost of the proposed facilities was estimated to equal $5,030,000, exclusive of engineering, contract administration, land and legal costs.

6. Prior to a final commitment to the above recommendation, it is suggested that Transport Canada undertake a detailed comparative evaluation of constructing a centralized deicing facility versus the proposed stormwater management facilities.

Acknowledgements

In concluding, we wish to express our appreciation to the participating members of the Steering Committee for their direction and guidance, and to the many employees throughout the airport complex, without whose assistance this report might not have been completed.

All of which is respectfully submitted,

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SECTION 1

INTRODUCTION

INTRODUCTION 1

1.1 Purpose of Study

Airport operations and expansions, and the construction of new airport complexes present a potential environmental hazard to the surrounding area. The airshed, land, and watersheds that surround an airport may be adversely affected by a variety of pollutants which are directly associated with activities related to all airports. In recognition of this situation, Fisheries and Environment Canada has initiated a number of studies at Federal Facilities which include various airports across Canada to identify environmental problems and to develop management systems.

During 1974-75, James F. MacLaren Limited carried out a study, on behalf of Fisheries and Environment Canada, to determine the magnitude of various environmental problems at Toronto International Airport. One objective of that study was to identify the origins and analyze the general characteristics of wastes entering the airport storm drainage system via stormwater runoff and to assess major pollutants entering the airport property from external sources.

At the conclusion of the above study it was recommended that:

"(i) Further monitoring be undertaken at Toronto International Airport on selected drainage areas to more clearly define the runoff hydrographs and pollutographs...

(ii) Refinement of the Storm Water Management Model (SWMM) and the Storage Treatment and Overflow Model (STORM) be undertaken following collection of the runoff quantity and quality data discussed in (i) above.

(iii) Assessment of storage and treatment requirements be carried out using the models discussed in (ii) above as management and design tools."

In March 1976, James F. MacLaren Limited entered into an agreement with the Department of Supply and Services on behalf of Fisheries and Environment Canada to carry out a further study at Toronto International Airport, which largely followed the above recommendations.

1.2 Terms of Reference

The objectives of the study, as defined in the terms of reference, were as follows:

A. To determine the effect of airports and associated airport operational activities on the quantity and quality of stormwater runoff.

B. To identify important considerations in the design and operation of airport drainage systems.

C. To clearly define runoff hydrographs and pollutographs for selected drainage areas at Toronto International Airport.

D. To refine SWMM and STORM stormwater runoff computer models relative to Toronto International Airport.

E. To define the purposefulness of the SWMM and STORM models as applied to existing and prospective Canadian airports.

F. To identify and assess drainage, storage and treatment alternatives for the management of stormwater runoff at Toronto International Airport, utilizing the SWMM and STORM models in the process.

G. To recommend a system of runoff management at Toronto International Airport and to discuss the protection afforded the receiving environment as a result of implementation of such a scheme.

H. To develop an implementation program for runoff management, including time table, estimates of resources required, and capital and operating costs.

I. To submit the final report to the Environmental Protection Service, Fisheries and Environment Canada.

The detailed work statements for the study are given in Appendix A.

SECTION 2

STORMWATER RUNOFF AND AIRPORT OPERATIONS MONITORING PROGRAMS

STORMWATER RUNOFF AND AIRPORT OPERATIONS MONITORING PROGRAMS 2

2.1 Selection of Runoff Areas

In the previous study of environmental problems at Toronto International Airport (Ref. 1), - also referred to herein as TIA - major storm water drainage areas were identified using available subsurface drainage plans, topographical maps, aerial photographs, and visual field surveys. In delineating drainage areas, the degree of subdivision was based on satisfying several basic criteria:

(i) identifying land use activities typical to an airport drainage scheme;

(ii) identifying drainage areas which were distinct entities;

(iii) establishing major areas with one principal storm water discharge sewer or ditch; and

(iv) determining areas which were suitable for establishing storm water sampling stations.

Using these criteria, several major drainage catchment areas were identified. Catchment areas K, M, and S, shown on Figure 2.1 were found to be most representative of the diverse nature of land use activities and airport operations. Because the pollutant loading in storm water runoff was also the highest from these three areas, they were selected for

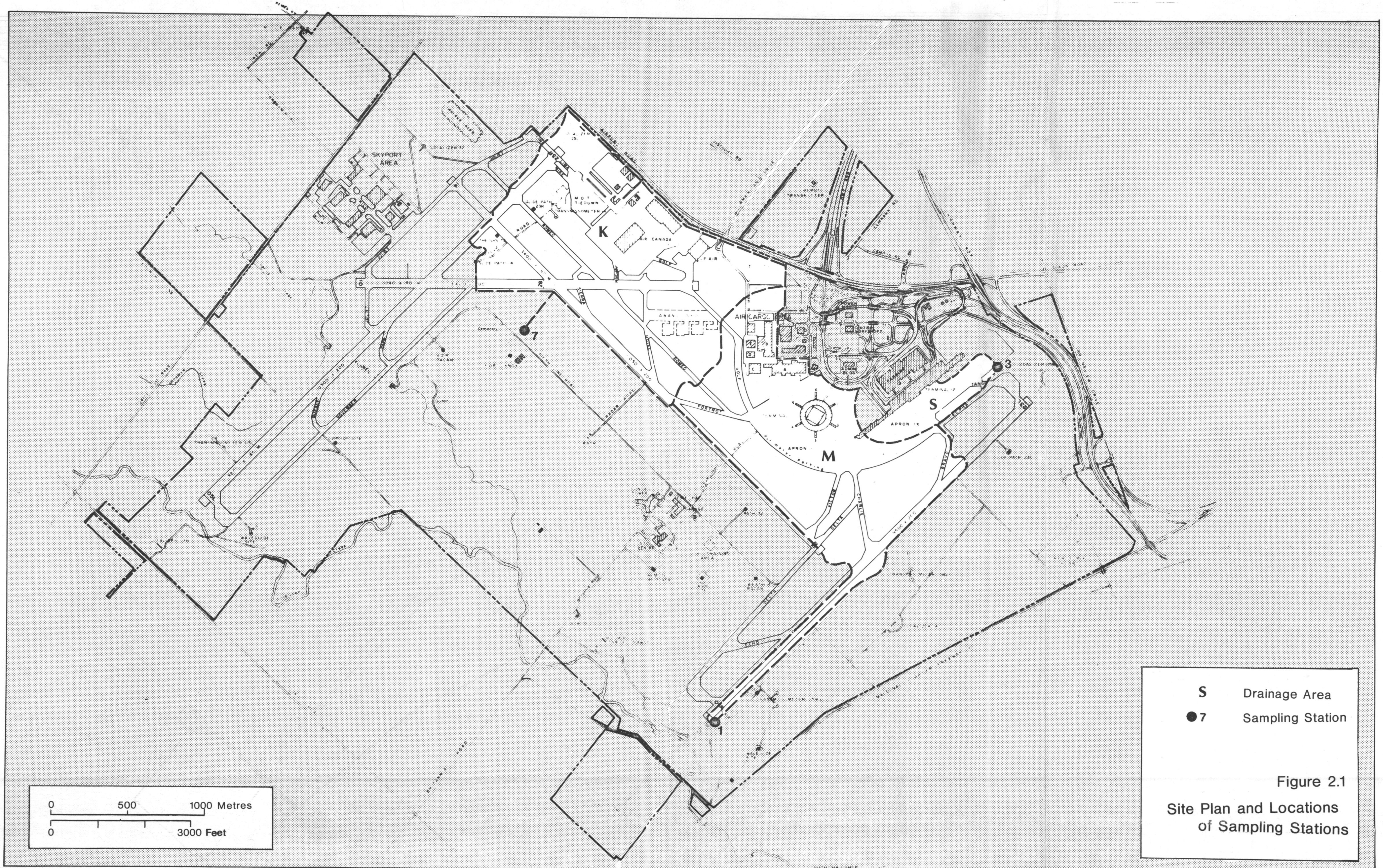

Figure 2.1

Site Plan and Locations of Sampling Stations

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a more extensive storm water runoff monitoring and sampling program in the current study.

The three catchment areas are described below:

Catchment Area K: contains a total area of approximately 409 acres of which 58 percent (239 acres) is open grassy area and 42 percent (170 acres) consists of paved areas and building rooftops, mainly of Air Canada, Wardair and CP Air aircraft maintenance facilities. The outfall sewer from the area is located near a storage facility commonly referred to as Fort Knox and is located in the Etobicoke Creek watershed. A second outfall sewer is planned in this area in the near future and will increase the catchment to include the Air Cargo area. Details of the proposed changes to the drainage system are contained in a report by Proctor and Redfern Limited (Ref. 2).

Catchment Area M: has a clearly defined drainage area of approximately 399 acres, containing the apron area and a portion of the building facilities at Terminal 1, the Air Cargo area west of the Customs buildings, the new parking lot north of the Air Cargo area, runways, taxiways and grassy areas. Land use in area M comprises approximately 12.8 percent (51 acres) commercial, 21.8 percent (87 acres) industrial and 65.4 percent (261 acres) open or grassy area. Runoff from the area is carried through a closed pipe system to a 72-inch diameter outfall. The runways and taxiways are drained with perforated piping used to stabilize the groundwater table and also to handle storm runoff from these areas. The perforated piping is connected to the main drainage sewer. The outfall is located on Etobicoke Creek, about 1/4 mile north of the Macdonald-Cartier Freeway (Highway 401). Upon implementation of proposed alterations to the drainage system in area K as recommended by Proctor and Redfern Limited (Ref. 2), drainage from the Air Cargo area which currently contributes to area M runoff will be directed to a second outfall in area K.

Catchment Area S: drains the apron area on the southerly side of Terminal 2 plus the grassy area between the apron and taxiway Alpha. The catchment has a total drainage area of 57 acres consisting of 47 acres of paved area and 10 acres of grassy area. The corresponding land use classification equals approximately 82.5 percent industrial and 17.5 percent open area. Runoff is conveyed through a sewer system to a 78 inch diameter outfall sewer with discharge to Mimico Creek.

2.2 Stormwater Runoff Quantity and Quality Monitoring

2.2.1 Selection of Sampling Sites

During the previous study at TIA (Ref. 1), it was established that the storm drainage systems in catchment areas K, M, and S are highly integrated. As a result there are only a few suitable sampling sites and these are generally on the outfall sewers. Therefore, the monitoring equipment was installed at or near the sites selected in the previous study (i.e., Site 1 for Area M; Site 3 for Area S; and Site 7 for Area K), as shown on Figure 2.1. Sites 1 and 3 were relocated to manholes a short distance from the original sites; while Site 7 was essentially unchanged.

2.2.2 Monitoring Equipment

The monitoring equipment initially installed at the three sites consisted of:

(i) A Manning T-1000 Dipper Transmitter and Rustrak Recorder at Site 7;

(ii) Channelogger Flowmeters and Level Recorders at Sites 1 and 3;

(iii) Manning T-4000 Portable Samplers at all three sites.

In the latter stages of the monitoring program the Manning T-1000 Dipper Transmitter and Rustrak Recorder at Site 7 were replaced with a Channelogger Flowmeter and Level Recorder.

The Manning dipper features flow measurement through sensing of the water surface level which is plotted against time on a recorder. The Channelogger flowmeter and level recorder traces the water level by measuring differential change in the bubble back pressure. These flow measurement units were connected to the samplers with activation of the latter automatically initiated when runoff in the respective sewers reached a depth of approximately one inch. In essence, this meant that all rainfall and snowmelt events of any significance were sampled.

The Manning T-4000 portable samplers used in this project contained 24 individual 500 millilitre sample bottles for the collection of discrete samples. The equipment offers considerable flexibility in the selection of the sampling interval, ranging from a minimum of 1/16 hour to several hours. This feature allowed the sampling frequency to be adjusted as required to characterize runoff quality from short duration, high intensity runoff events in the summer months as well as long duration, low intensity runoff events during the winter period.

The flow measuring and sampling equipment was maintained on a routine basis to ensure that the equipment was kept in continuous operating condition. Back-up equipment was used to replace malfunctioning units which proved to occur fairly frequently. Freeze-up of the equipment during the winter months proved to be an on-going problem even though the equipment was housed in heated and insulated enclosures.

2.2.3 Monitoring Program Design

Monitoring of storm runoff events was carried out at Sites 1, 3 and 7 over a 13-month period, from March 1, 1976 to March 31, 1977. Discrete samples were collected at preselected time intervals over the storm events. The time interval for sample collection was selected in each instance to monitor over the peak interval of the runoff event during the summer months, and over long duration runoff events during the winter months. For each drainage area, the time interval was also varied depending upon the size and surface coverage of the drainage area.

While discrete samples were collected on most runoff events, not all discrete samples were analyzed due to cost considerations. Rather, discrete samples were analyzed only on selected runoff events. The selection of these events was based on consideration of differences in the runoff intensity and the antecedent dry period in order to characterize runoff pollutographs for a variety of conditions.

For the discrete sampling profiles, the first three or four samples were analyzed individually to characterize runoff quality during the peak interval of the pollutant loading. Over the remainder of each event, the individual samples were combined in groups of two or three discrete samples and composited on a flow proportional basis for analysis.

Composite samples were prepared on all other storm events and involved the proportioning of all discrete samples into one sample per event in accordance with the recorded flow. Grab samples were collected during periods of low flow, particularly during the winter.

The number of discrete profiles, composite and grab samples obtained at each site is given in Table 2.1. A total of 31 discrete sampling profiles, 50 composite samples and 29 grab samples were collected from the three sites over the duration of the program.

All samples were analyzed for pH, suspended solids (SS) and five-day biochemical oxygen demand (BOD) while samples collected during the winter months were also analyzed for total Kjeldahl nitrogen (TKN). In addition, the analytical program was expanded in the latter stages to include analysis of samples from Site 1 for orthophosphate, total phosphorus, nitrite nitrogen, nitrate nitrogen and ammonia nitrogen. These parameters were selected to characterize the effect of aircraft deicer (a glycol based fluid) and airfield deicer (urea) upon the runoff quality. Both types of deicing compounds are used in the area draining to Site 1. All analyses were performed in accordance with the test procedures outlined in the Thirteenth Edition of Standard Methods for the Examination of Water and Wastewater (Ref. 3).

2.3 Airport Operations Monitoring

Reporting procedures for gathering data on airport operations were established in the former TIA study (Ref. 1). These procedures were reinstituted and consisted primarily of

TABLE 2-1

TOTAL NUMBER OF RUNOFF EVENTS SAMPLED DURING STUDY PERIOD

Monitoring Site No.	Number of Events Monitored per Sample Type		
	Discrete Profiles	Composite Samples	Grab Samples
1	14	13	9
3	9	16	9
7	8	21	11

providing various organizations with prepared forms for recording data on the frequency, quantity, location, and, where applicable, clean-up procedures employed for activities identified as having detrimental effects on stormwater run-off quality. The following activities were monitored throughout the study period: urea application by Transport Canada field maintenance staff; aircraft deicer application by airlines and airline service agencies; sand and salt application by Transport Canada field maintenance staff and private contractors; and, fuel spills as recorded by the Emergency Services Group and Consolidated Aviation Fueling.

2.4 Collection of Meteorological Data

Meteorological data required for characterization of precipitation-runoff processes were obtained from the Atmospheric Environment Service (AES) station on the airport site and included:

(i) rainfall data, in the form of continuous rain gauge records for complete definition of storm hyetographs (intensity-time patterns), and hourly rainfall records for assembly of a continuous precipitation record;

(ii) snowfall data, recorded on a six-hour basis, and daily depth and water equivalent of snow cover for determination of snowpack depth and daily snowmelt rates;

(iii) temperature, recorded on an hourly basis, used as input to the runoff models for calculating hourly snowmelt rates and the corresponding runoff hydrographs.

The data collected for events occurring during the study period were used primarily for calibration of the SWMM and STORM runoff models. Since the events occurring during this period could not encompass the complete range of climate conditions in terms of rainfall intensities, length of dry periods, etc., existing meteorological data over a multi-year period were assembled and analyzed. These data were used for determining long-term airport runoff characteristics.

References (Section 2)

1. "A Study of Environmental Problems at Toronto International Airport". Report to Environment Canada by James F. MacLaren Limited, July, 1975.

2. "Storm Drainage Study of Area-3". Report to Transport Canada by Proctor and Redfern Limited, August, 1975.

3. "Thirteenth Edition of Standard Methods for the Examination of Water and Wastewater". Prepared and published jointly by the American Public Health Association, American Water Works Association and Water Pollution Control Federation, 1971.

SECTION 3

STORMWATER RUNOFF MODELLING

STORMWATER RUNOFF MODELLING 3

3.1 Model Selection

3.1.1 Quantity Models

Application of the Environmental Protection Agency's Stormwater Management Model (SWMM) (Ref. 1) in a study at Toronto International Airport in 1975 by James F. MacLaren Limited (Ref. 2), indicated that the model was capable of accurately simulating airport runoff flows from low intensity storms. However, calibration of SWMM on medium to high intensity storms was not possible as no significant rainfall events were recorded during that study.

One of the principal objectives of the current study therefore involved verifying the accuracy of SWMM for the simulation of runoff from high intensity rainstorms. In setting this objective, it was recognized that if SWMM proved to accurately simulate runoff flows for all conditions, then it could be a valuable tool in the design of drainage systems and environmental control facilities at proposed airports as well as for extensions to existing airport facilities. Several high intensity storms were recorded during the current study and consequently a complete verification of SWMM was possible.

In addition to SWMM, application of the Storage, Treatment and Overflow Model (STORM) (Ref. 3) has demonstrated that this model is an appropriate tool for the continuous simulation of runoff over periods of several years. This aspect is considered to be particularly useful in the sizing of runoff storage and treatment facilities.

Only a limited amount of work on simulation of runoff flows using STORM was attempted in the current study as work undertaken by Proctor and Redfern Limited and James F. MacLaren Limited (Ref. 5) demonstrated the adequacy of this model. Two STORM simulations are discussed in this section of the report.

3.1.2 Quality Models

Initial attempts at the simulation of pollutant concentrations in airport runoff using the SWMM model in the 1975 study (Ref. 2) indicated that the model offered potential for simulating runoff quality at Canadian airports during the summer or warm weather months.* Further investigation into the simulation of the BOD and suspended solids pollutographs was set as one of the objectives of the current study therefore, as it was recognized that the extent of costly sample collection and analysis in future airport studies potentially could be greatly reduced.

Three versions of SWMM were tested in initial runoff quality simulations during this study. The application of Version V of SWMM (Ref. 4) resulted in a reasonable simulation of BOD concentrations, but the simulations of SS levels were poor. Attempts to improve the latter detracted from the accuracy of BOD simulation. This difficulty is attributed to the fact that in this version of SWMM, the ratio of BOD to SS composition is fixed for each of the five land use categories

* Summer or warm weather months are defined as the period between approximately mid-May and mid-November.

accepted by the model. The latest version of the model, SWMM VI (Ref. 4) allows the user to specify the BOD:SS ratio and is therefore potentially more flexible than its predecessor. However, application of SWMM VI indicated, at the time of writing, that there are inconsistencies in the quality subroutines in the model that preclude the simulation of BOD profiles.

Eventually, runoff quality simulations were conducted using the SWMM Generalized Quality Model (GQM) (Ref. 5). This model uses exactly the same equations and computational sequence as employed in the above models. However, the user may alter a greater number of program variables in order to achieve an acceptable calibration. Since the GQM version requires an input hydrograph as a basis for quality simulations, flows simulated using the SWMM V quantity model were used for this purpose. SWMM quality simulations incorporating application of the GQM produced fairly reasonable results as discussed in subsequent sub-sections. A detailed discussion on the SWMM Generalized Quality Model may be found in the report prepared by Proctor and Redfern Limited and James F. MacLaren Limited (Ref. 5).

3.2 Quantity Simulation

3.2.1 SWMM Quantity Simulations for Summer Conditions

The results of SWMM quantity simulations for several medium to high intensity rainstorms on flows from drainage areas M, S and K, having areas of 399, 57 and 409 acres respectively, are considered below. Details of the model calibration are not presented as the sensitivity of SWMM variables and their use in calibration is covered in detail in other reports (Ref. 1, 4, 5). In addition to the discussion of recorded and simulated flows, the results of several other simulations are presented in summary form.

Figure 3.1

The rainstorm presented in this figure exhibits a hyetograph (rainfall histogram) that is almost a unit pulse. The simulated hydrograph for flow from drainage area M responds slightly more quickly to this pulse than does the measured flow. The recorded instantaneous peak flow equals approximately 14 cfs while the simulated peak flow, averaged over the time step for simulation of 5 minutes, is about 11.5 cfs. The simulated falling limb of the hydrograph follows the recorded curve very closely, demonstrating clearly the ability of SWMM to generate very realistic flow responses.

Figure 3.2

The medium intensity rainfall event shown on Figure 3.2 has a longer duration than the one presented above on Figure 3.1. Consequently, the recorded peak flow from drainage area M of 22 cfs is higher than the 14 cfs value measured on the previous event. Once again, it is noted that the initial portion of the recorded hydrograph lags the simulated flow by a few minutes. The measured hydrograph rises vertically to about 20 cfs in contrast to the slightly inclined simulated rising limb. The peak simulated flow however, is within about 1 cfs of the recorded value. The falling limb is well simulated with the exception of a second peak which does not appear in the recorded flow. This anomaly also appears later in Figure 3.5 for drainage area S. An adequate explanation is not readily apparent in either case.

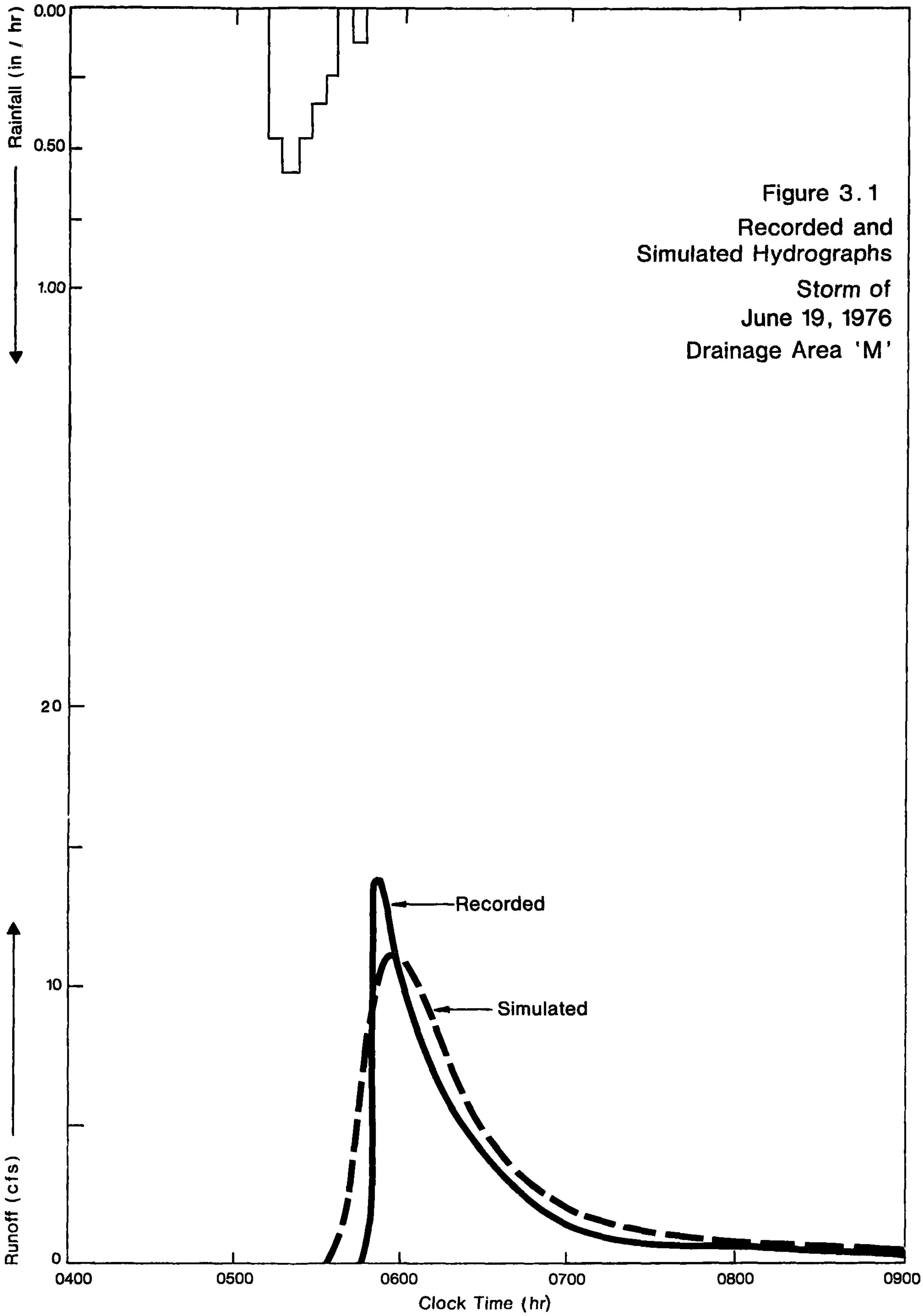


Figure 3.1
Recorded and
Simulated Hydrographs
Storm of
June 19, 1976
Drainage Area 'M'
Rainfall (in / hr)
0.00
0.50
1.00
20
10
0
Runoff (cfs)
Recorded
Simulated
0400
0500
0600
0700
0800
0900
Clock Time (hr)

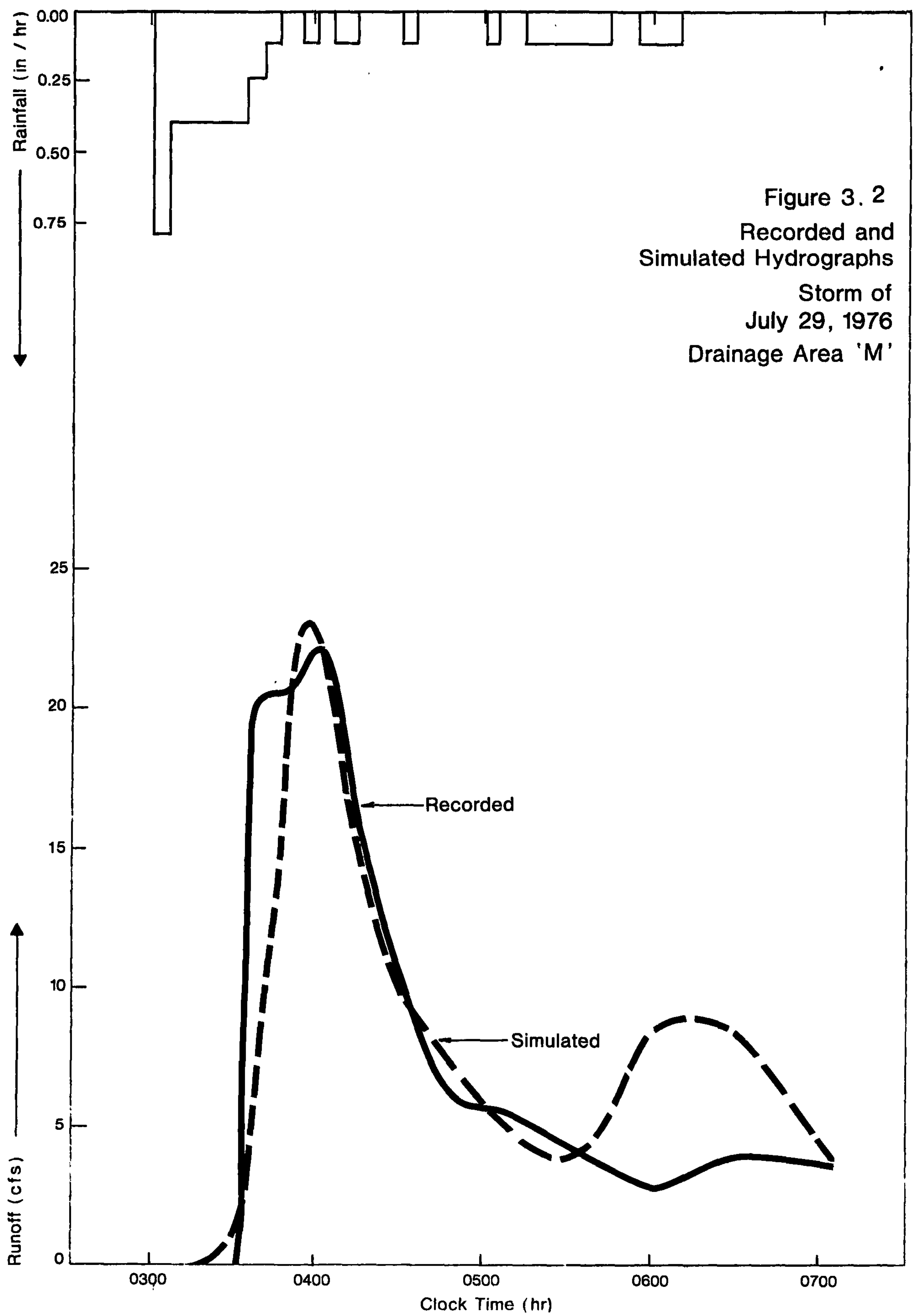


Figure 3.2
Recorded and
Simulated Hydrographs
Storm of
July 29, 1976
Drainage Area 'M'

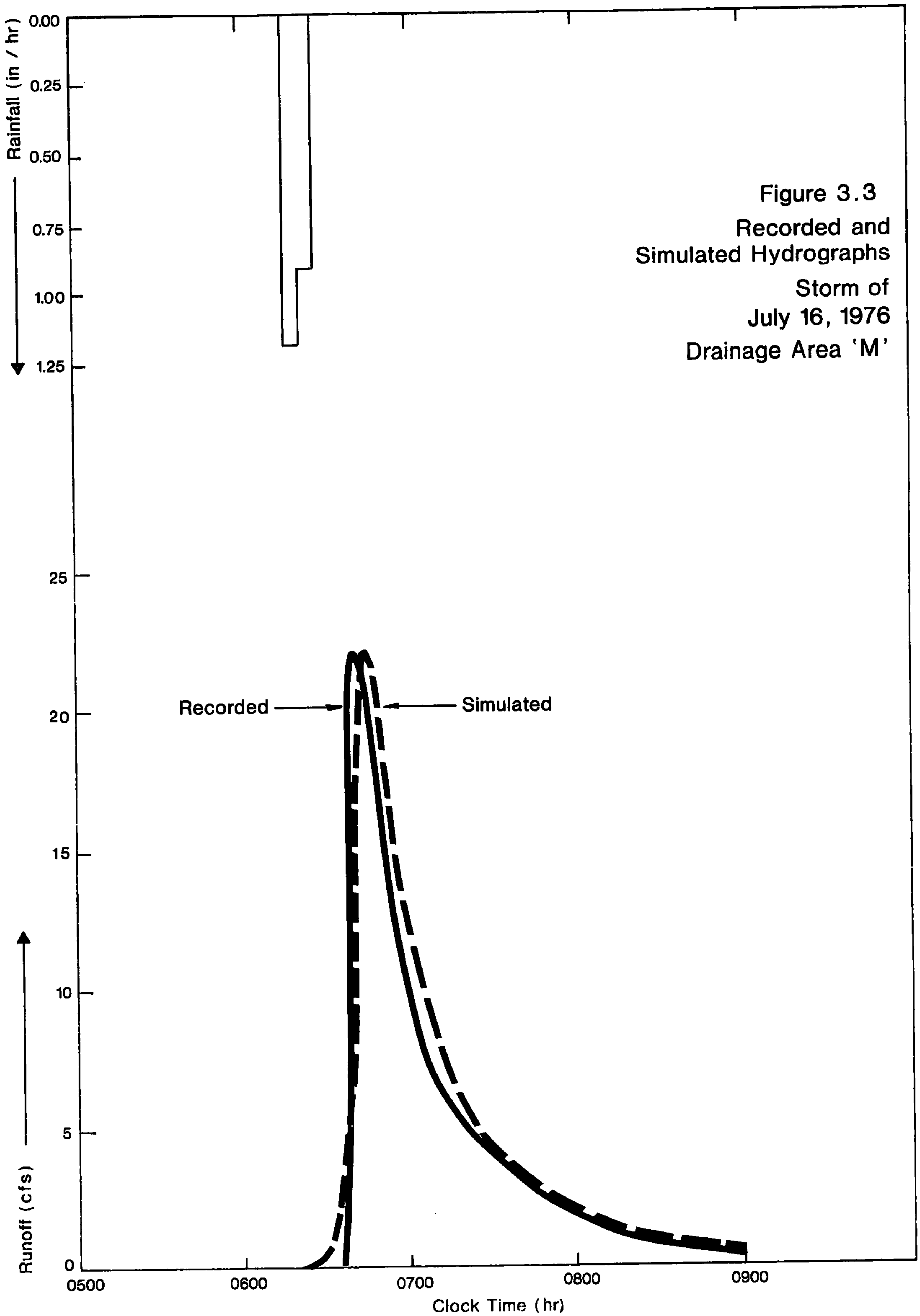


Figure 3.3
Recorded and Simulated Hydrographs
Storm of July 16, 1976
Drainage Area 'M'

Figure 3.3

Figure 3.3 presents the third of the storms evaluated in detail for drainage area M. The rainfall event is of the unit pulse type similar to that considered in the first example. Of particular note is the excellent accord shown between simulated and recorded flows. The event clearly demonstrates the increasing accuracy of SWMM at higher intensity storms. The result is not unexpected for high intensity rainstorms, as any errors in the estimation of depression storage and infiltration at the start of the event are nullified by the greater runoff volumes.

Figure 3.4

This figure presents the first of three events discussed for drainage area S. It is noted that with exception of an inconsistency of about 2 cfs between the recorded and simulated peak flows, the recorded hydrograph is well duplicated by SWMM. This factor is not considered to be a serious error at the relatively low flow involved since the remainder of the recorded flow is well reproduced.

Figure 3.5

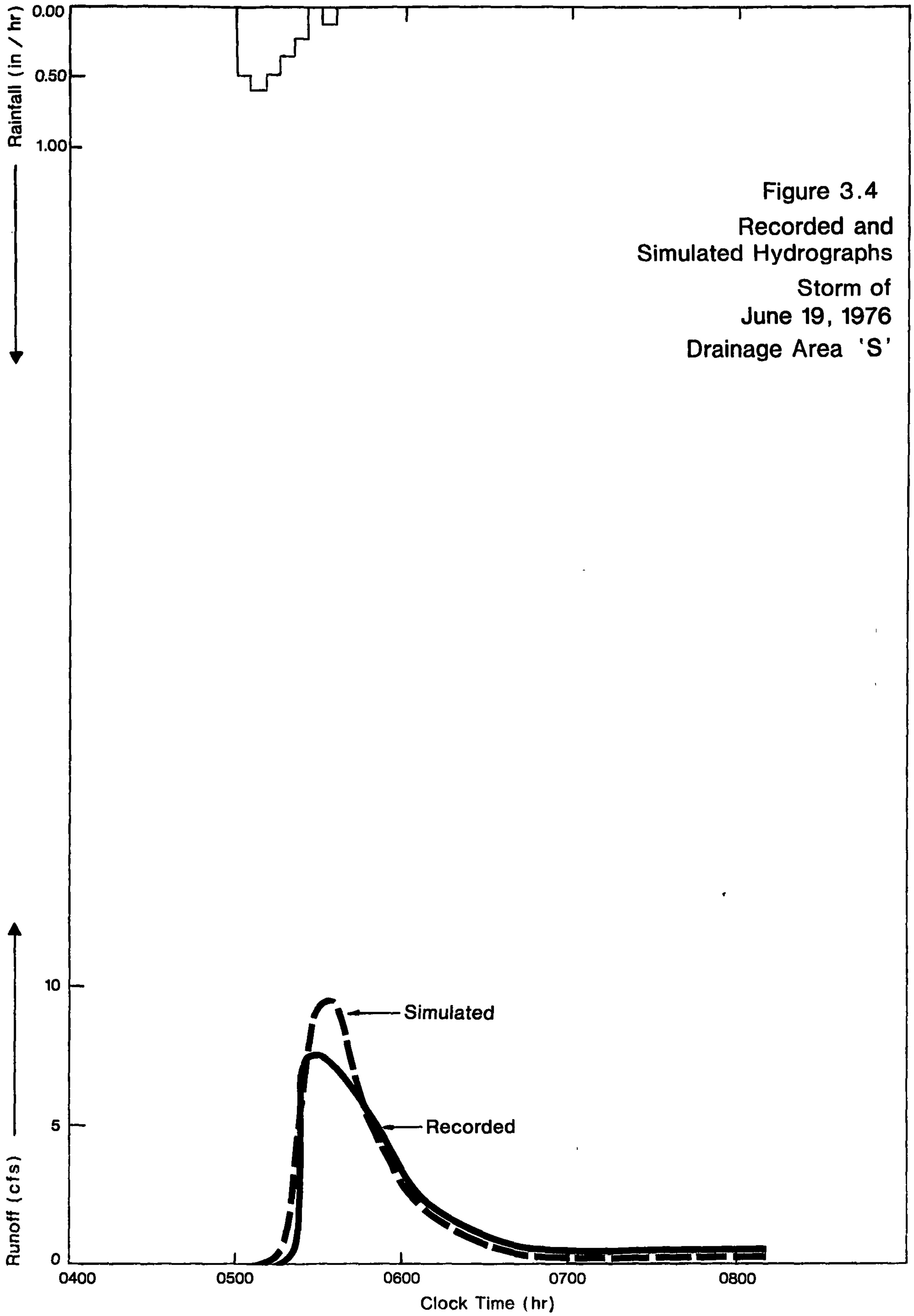
The simulation shown in Figure 3.5 is generally acceptable over the first hour of runoff in that the rising limb and peak flow are reasonably well simulated. However, the recorded flow remains higher than the simulated flow for a considerable period of time after the peak. The retarded falling limb in the recorded flow appears anomalous, especially when compared with the flow recorded in the larger drainage area M for the same event, as shown on Figure 3.2. A further irregularity in this event is the second peak simulated by SWMM and not reflected in the measurements. The second simulated peak occurs in response to a steady low intensity rainfall over the latter part of the event and thus the flow response appears reasonable. An adequate explanation for the inconsistencies noted above is not apparent as several factors could be responsible.

Figure 3.6

The simulation presented in this figure on area S is for an extremely high intensity, short duration event. The results indicate good agreement in peak flows with both the recorded and simulated peaks equalling 56 cfs (i.e. approximately 1 cfs of runoff per acre). A discrepancy is noted between the recorded and simulated falling limbs, but in general the total volumes under the two hydrographs correspond.

Figure 3.7

The curves on Figure 3.7 indicate one of the potential benefits associated with the use of SWMM. The effect of the high intensity storm (discussed above for drainage area S) in drainage area K caused the recording instrument to overshoot its strip chart. The SWMM simulation closely follows the recorded rising limb and goes on to predict a peak flow of about 115 cfs for this event (i.e. approximately 0.3 cfs runoff per acre). The falling limb of the simulated hydrograph appears to drop very rapidly in comparison to its measured counterpart. This inconsistency may be due to either the failure of SWMM to accurately simulate residual runoff from the substantial grassed area in this catchment or to a recorder malfunction following the overshooting of the chart.


Rainfall (in / hr)
0.00
0.50
1.00
Figure 3.4
Recorded and
Simulated Hydrographs
Storm of
June 19, 1976
Drainage Area 'S'
Runoff (cfs)
10
5
0
Simulated
Recorded
0400
0500
0600
0700
0800
Clock Time (hr)

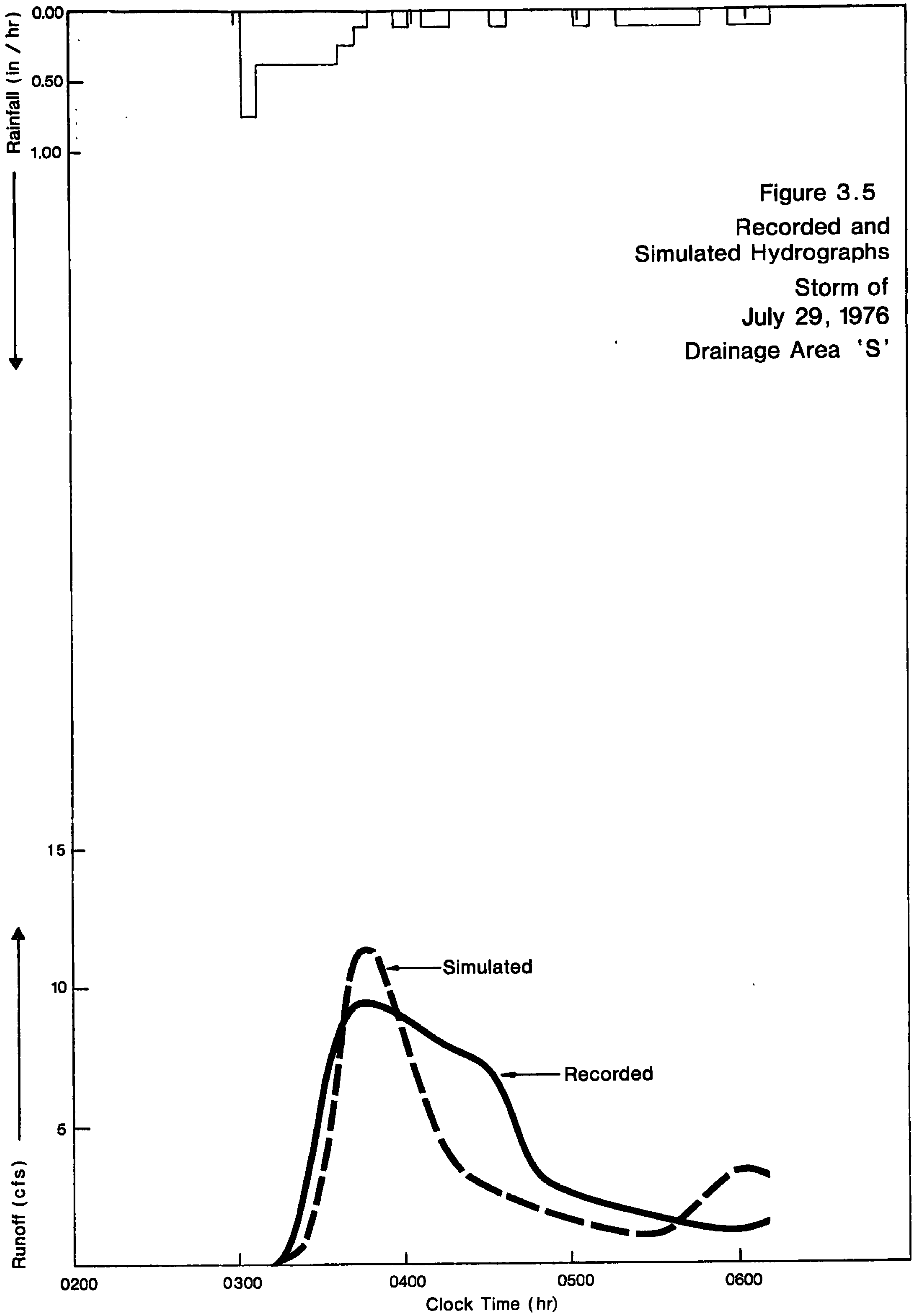


Figure 3.5
Recorded and Simulated Hydrographs
Storm of July 29, 1976
Drainage Area 'S'

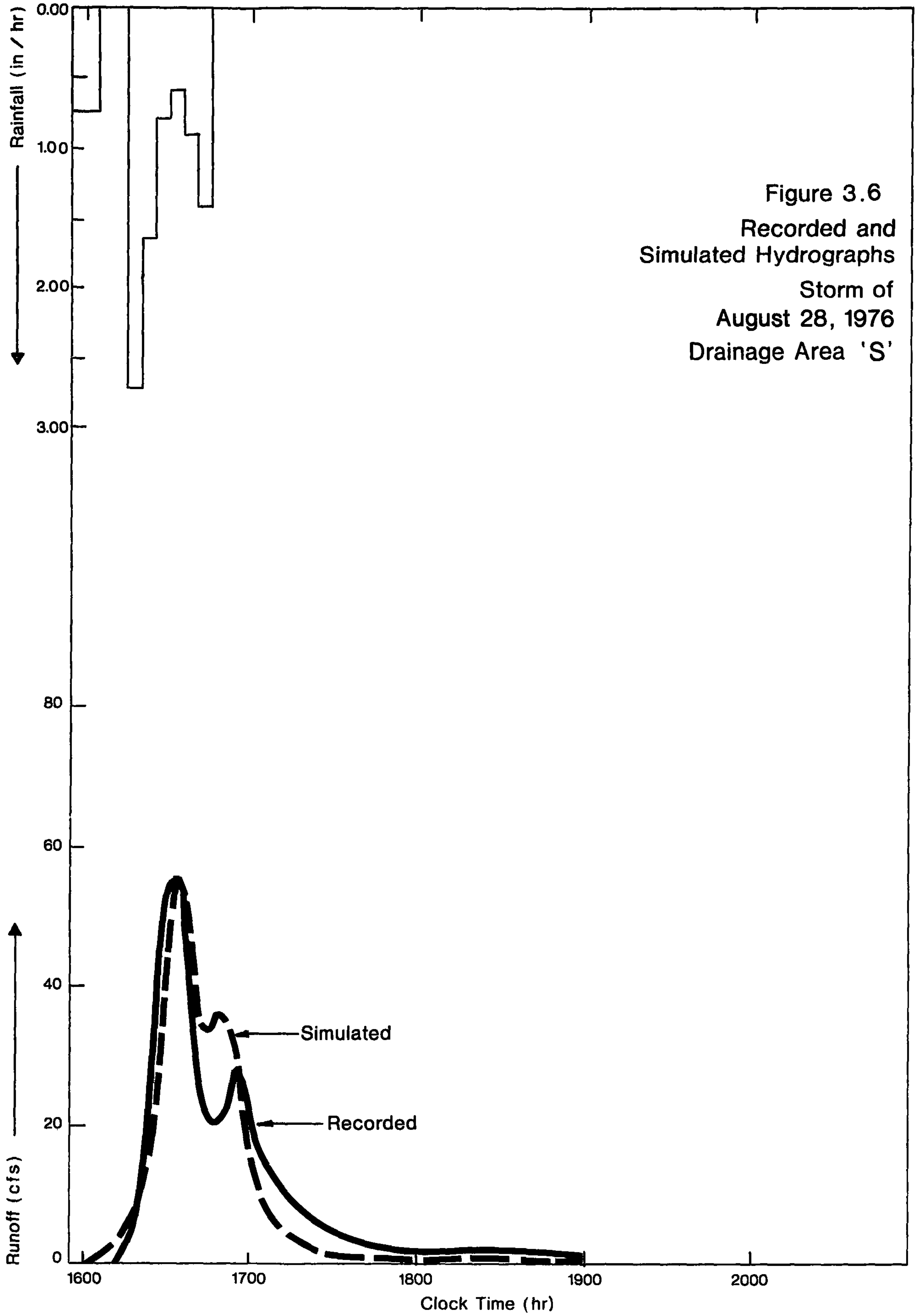


Figure 3.6
Recorded and Simulated Hydrographs
Storm of August 28, 1976
Drainage Area 'S'

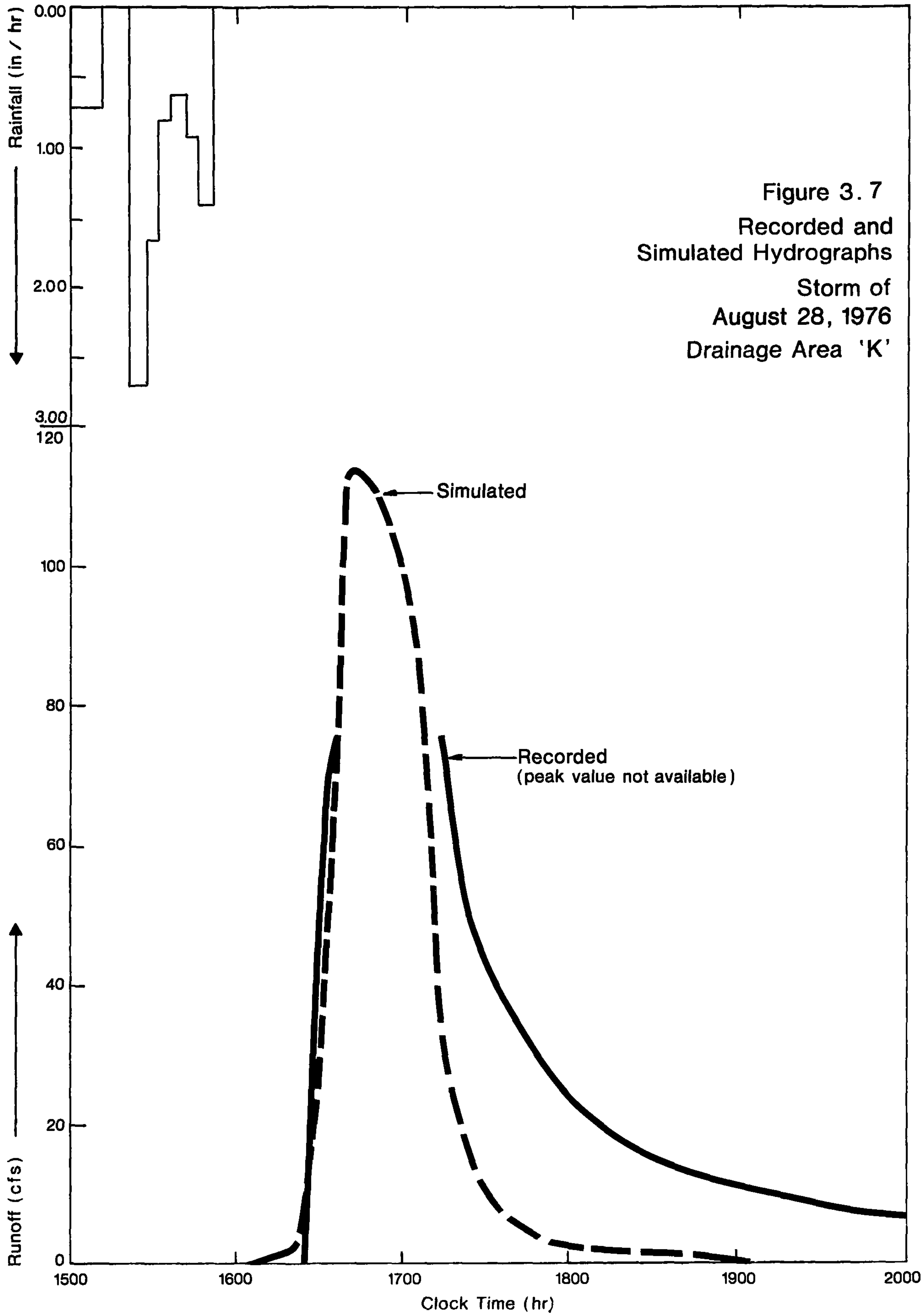


Figure 3. 7
Recorded and Simulated Hydrographs
Storm of August 28, 1976
Drainage Area 'K'
Rainfall (in / hr)
0.00
1.00
2.00
3.00
120
100
80
60
40
20
0
Runoff (cfs)
Simulated
Recorded
(peak value not available)
1500
1600
1700
1800
1900
2000
Clock Time (hr)

Table 3.1

A summary of all SWMM quantity simulations carried out in this study (excepting those for which comparable recorded data were incomplete) is presented in Table 3.1. The summary indicates that SWMM is generally capable of reproducing measured peak flow and the timing to peak flow with a high level of accuracy. As demonstrated by the preceding detailed comparisons of recorded and simulated hydrographs, the overall flow response is also reasonably well reproduced by SWMM.

Table 3.2

Table 3.2 summarizes the values of the variables used in the quantity simulations. As will be noted, calibration of SWMM for quantity simulations is quite straight forward, with only the value of depression storage for impervious areas being varied between simulations. These changes are necessary in order to accurately reflect antecedent conditions, that is, to account for changes in depression storage which varies depending on the antecedent dry period and whether or not the ground is frozen.

3.2.2 SWMM Quantity Simulations for Snowmelt Conditions

The previous discussion has dealt specifically with SWMM quantity simulations for runoff occurring during the warm weather months. In addition, the SWMM quantity model is capable of simulating snowmelt runoff. The snowmelt routines of SWMM were calibrated for winter conditions at the airport in a recent study undertaken by Proctor and Redfern Limited and James F. MacLaren Limited (Ref. 5). Thus only a brief summary of results of two simulations are discussed.

TABLE 3.1

SUMMARY OF SWMM QUANTITY SIMULATIONS

Drainage Area	Storm Date 1976	Recorded Peak Flow (cfs)	Computed Peak Flow: Recorded Peak Flow	Computed Time to Peak Flow: Recorded Time to Peak Flow
M	June 19	13.9	1.18	1.30
	July 16	22.2	1.06	1.20
	July 29	22.2	1.06	1.00
S	April 15(1)	23.5	1.05	1.00
	April 15(2)	10.0	1.25	0.95
	May 11	4.7	0.84	1.33
	June 13	64.0	1.38	1.00
	June 19	7.5	1.26	1.20
	July 29	9.5	1.21	1.00
	August 28	56.0	1.00	1.00
K	March 12	13.5	1.11	1.08
	March 31	12.2	1.26	0.97
	April 15(1)	35.0	1.40	1.00
	April 15(2)	21.0	1.06	1.00
	April 25	23.2	0.82	1.03
	July 29	18.2	1.22	1.00

Drainage Area	Peak Flow Ratio: Mean	Peak Flow Ratio: Standard Deviation	Time to Peak Ratio: Mean	Time to Peak Ratio: Standard Deviation
M	1.10	0.069	1.17	0.15
S	1.14	0.19	1.07	0.14
K	1.15	0.20	1.01	0.038

TABLE 3.2

SUMMARY OF SWMM QUANTITY CALIBRATION DATA

Drainage Area	Percent Impervious Area With Zero Depression Storage	Minimum/Maximum Infiltration Rates (in/hr)		Impervious and Pervious Area Roughness Coefficients		Depression Storage (in)	
		Minimum	Maximum	Impervious Area	Pervious Area	Impervious Area	Pervious Area
M	25	0.5	3	.013	.25	.062-.125	.184
S	25	0.5	3	.013	.25	.022-.062	.184
K	25	0.5	3	.013	.25	.062-.125	.184

Figures 3.8 and 3.9

Runoff hydrographs are presented in Figures 3.8 and 3.9 for two consecutive events occurring on March 15 and 16, 1975. For the event on March 15, there is an obvious phase shift of about two hours between the recorded and simulated hydrographs. Apart from this factor, however, the model produces a very realistic hydrograph with the peak flow and total runoff volume agreeing reasonably well with the recorded values. The total volume under the simulated curves equals 171,800 cubic feet versus 143,100 cubic feet under the recorded curve.

The timing of runoff on the March 16 events is quite well simulated, but the simulated peak flow is considerably higher than the recorded peak flow. The recorded flow, however, remains relatively high during the declining hours. Consequently, the total runoff volume is well predicted equalling 101,800 cubic feet under the simulated curve versus a recorded volume of 104,300 cubic feet.

3.2.3 STORM Quantity Simulations

STORM is a fairly simple runoff simulation model operating on an hourly time step in comparison with SWMM which uses 5 or 10 minute time steps. Details on the STORM program and the application of this model on runoff simulations may be found elsewhere (Ref. 3, 5).

Two examples of STORM quantity simulations are considered briefly below.

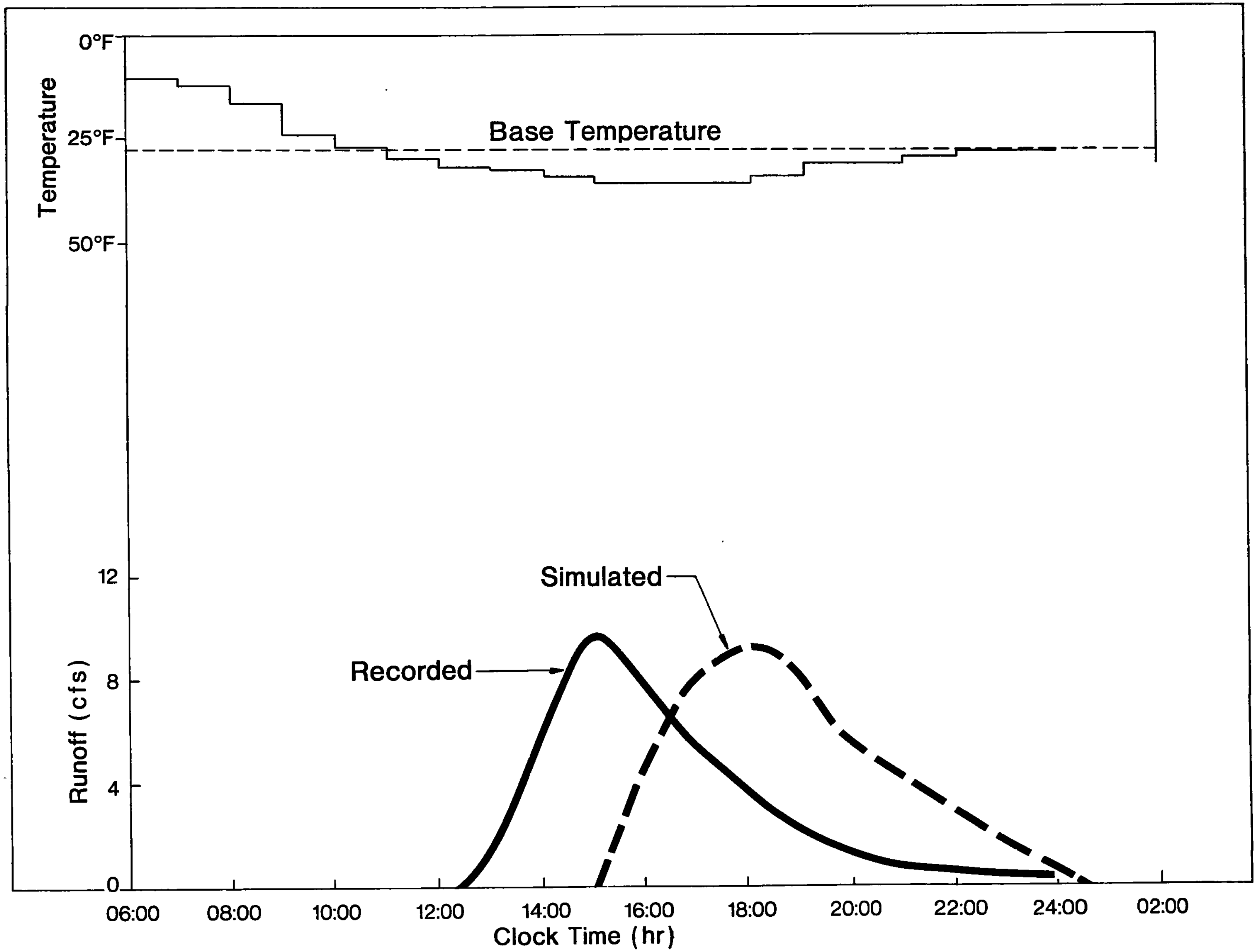


Figure 3.8 Recorded and Simulated Hydrographs, Drainage Area 'M' - Snowmelt, March 15, 1975

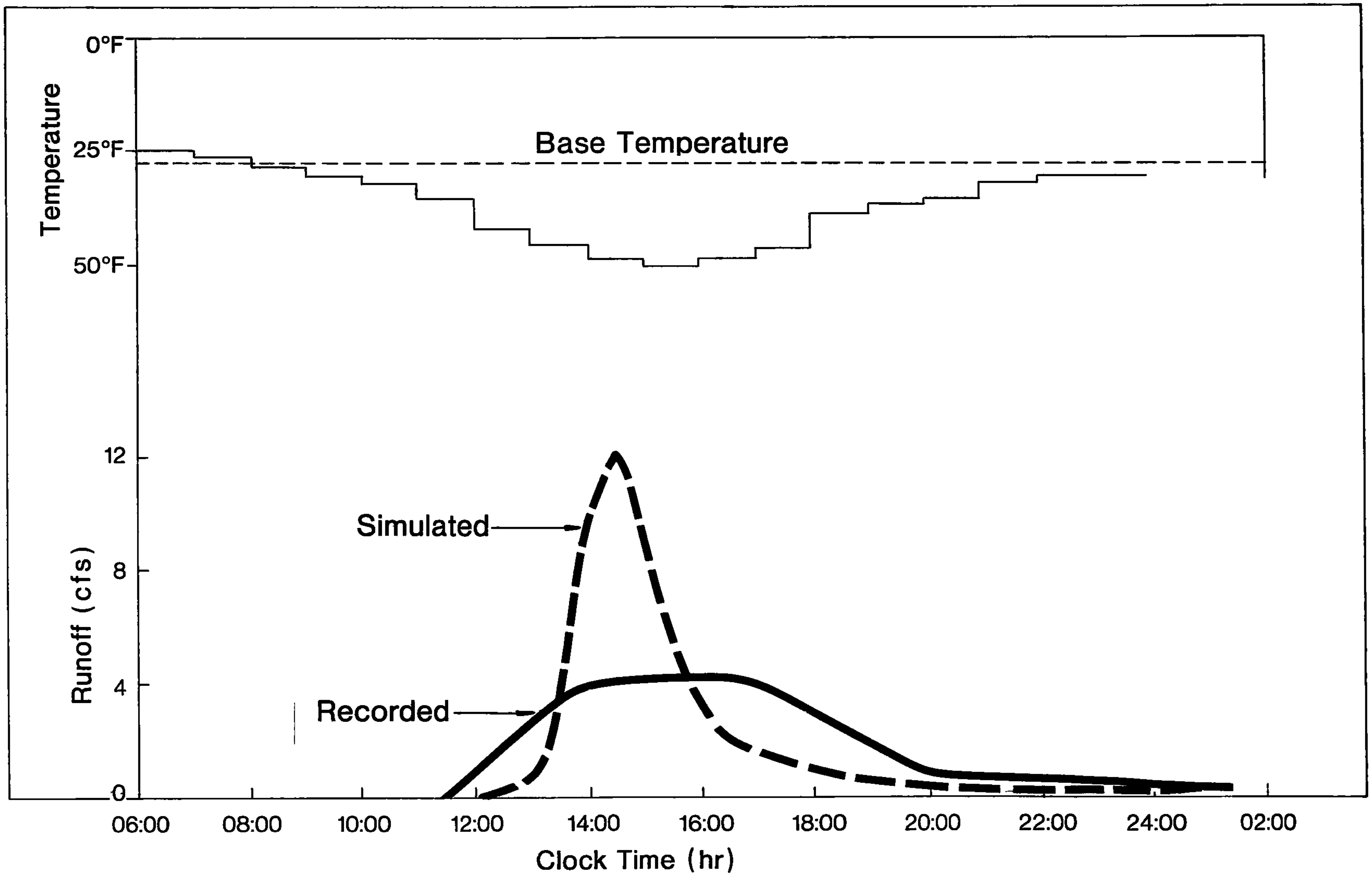


Figure 3.9 Recorded and Simulated Hydrographs, Drainage Area 'M' - Snowmelt, March 16, 1975

Figure 3.10

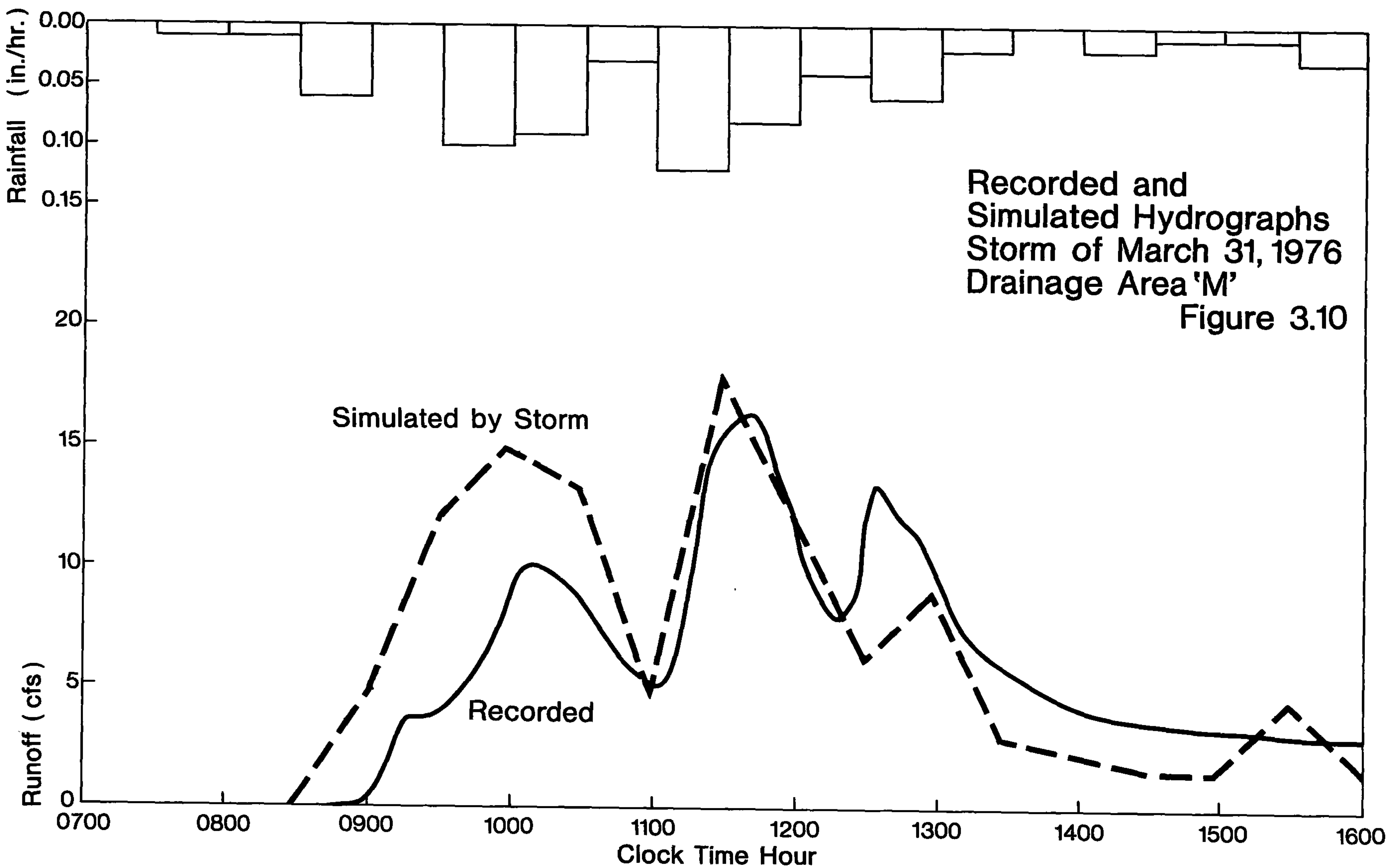
The general shape of the recorded runoff hydrograph for this long duration, low intensity storm is well reproduced by STORM. There is a tendency for the predicted peaks in the early stages of the event to precede the measured peaks, but the total runoff volumes under the two curves are approximately equal.

Figure 3.11

The particular event presented in Figure 3.11 consisted of a combination of snowmelt and rainfall runoff. (Note that the hyetograph is for rainfall only). The model tends to overestimate the first peak of the runoff event and simulated flows remain higher than recorded flows over most of the event. However, the recorded falling limb extends for a longer time than the simulated counterpart. This feature somewhat offsets the degree to which the model overestimates the total volume of runoff.

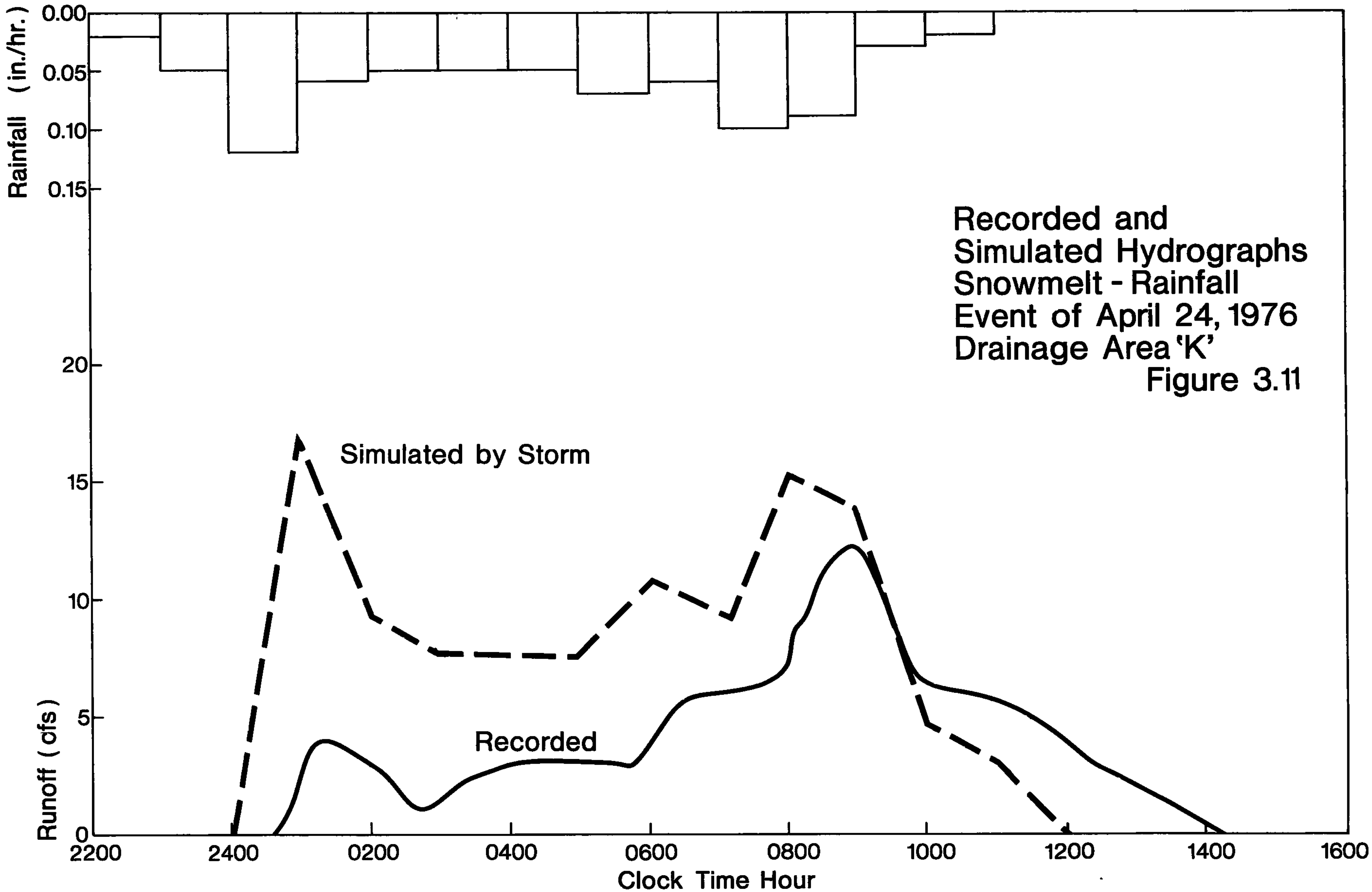
3.2.4 Summary Discussion on SWMM and STORM Quantity Simulations

The preceding examples have indicated that SWMM is capable of accurately simulating stormwater runoff from medium and high intensity rainfall events, as well as from low intensity events as established in the 1975 study (Ref. 2). Indeed, accuracy generally improves with increasing rainfall intensity as errors in estimating the initial depression storage are nullified by the large runoff volumes. It can be concluded therefore, that SWMM is well suited to the simulation of stormwater runoff at airport facilities.



Recorded and Simulated Hydrographs Storm of March 31, 1976 Drainage Area 'M'

Figure 3.10


Rainfall (in./hr.)
0.00
0.05
0.10
0.15
Recorded and
Simulated Hydrographs
Snowmelt - Rainfall
Event of April 24, 1976
Drainage Area 'K'
Figure 3.11
20
15
10
5
0
Simulated by Storm
Recorded
Runoff (cfs)
2200
2400
0200
0400
0600
0800
1000
1200
1400
1600
Clock Time Hour

Application of SWMM over traditional methods offers the advantage in that peak flows can be accurately predicted for use in the design of storm drainage systems. In addition, the model provides complete runoff hydrograph simulations which can be utilized for a variety of purposes including prediction of the effect of airport development on runoff flows for use in planning and environmental impact studies or in defining design conditions for runoff control measures.

Snowmelt runoff events can also be simulated using SWMM to a reasonable level of accuracy with respect to total runoff volumes. However, peak snowmelt flows may be overestimated.

In addition to using SWMM, rain-on-snow and rainfall only events can be simulated using STORM. As this model operates on an hourly time step, in contrast with SWMM which operates on 5 or 10 minute time steps, the peak flows are simulated to a lesser degree of accuracy. Nevertheless, total runoff volumes are estimated reasonably well with STORM. In addition, several years runoff data can be simulated in a relatively short computer processing time. Thus in projects involving the assessment of stormwater runoff management systems, STORM is well suited for screening of alternative systems.

3.3 Quality Simulation

3.3.1 Generalized Quality Model Features

The SWMM Generalized Quality Model (GQM) was selected for runoff quality simulation following initial testing of two other SWMM quality sub-routines as the GQM offers the advantage in that pollutographs for biochemical oxygen demand (BOD) and suspended solids (SS) are calibrated separately. Since the GQM uses exactly the same computational sequence as in the other versions of SWMM, the following brief discussion applies equally to any model using the SWMM algorithm.

In the SWMM quality routines, dust and dirt are considered to accumulate over the catchment surface at a uniform daily rate, dependent on land use. The percentage of specific pollutants (e.g. BOD) contained in the dust and dirt determines the total amount of pollutants available for wash-off during a runoff event. Sweeping or cleaning of the catchment surface results in a reduction in the accumulated pollutants in direct proportion to the specified efficiency of the equipment. One final factor influencing the available pollutant load is the concentration of pollutants in catch-basins. The pollutant load available for wash-off during an event can be determined therefore, by adjusting the magnitude of any of the processes considered above.

The amount of pollutant removed from the surface is computed in the quality routine by an exponential decay equation operating on a time step basis. The amount washed off in each time step is assumed to be proportional to the amount remaining at the beginning of the time step. In addition, the rate of wash-off is assumed to be controlled by the runoff rate in each time step and a wash-off exponent, b. The equation is given as follows:

$$P_{OFF} = P_O(1-e^{-br\Delta t}) \qquad (3.1)$$

where:
- Δt = time step
- r = runoff rate
- b = wash-off exponent normally having a value of 4.6
- P_O = available pollutant load on the ground surface at the beginning of time step
- P_{OFF} = amount of pollutant removed from the ground surface during each time step

In a report published in 1976 by Proctor and Redfern Limited and James F. MacLaren Limited (Ref. 5), it was shown that while the application of equation (3.1) generally resulted in an acceptable simulation of BOD concentrations in urban stormwater runoff, it was not always well suited to the simulation of SS levels. Consequently, an optional semi-empirical equation provided in SWMM (Ref. 4) may be used for predicting the SS concentration:

$$P_{OFF} = \frac{P_o}{P_{oi}} \cdot CC \cdot (A.E + B.E^{D}) \qquad (3.2)$$

where:
- P_o = available total pollutant load on the ground surface at the beginning of time step
- P_{oi} = initial pollutant load on the ground surface at the start of storm
- CC = removing coefficient determined by calibration
- A,B,E&D = empirically determined coefficients

In the work described below involving model calibration and verification, equation (3.1) was used for BOD simulation, and equation (3.2) was used for SS simulation.

3.3.2 Generalized Quality Model Calibration

Calibration of the SWMM Generalized Quality Model was undertaken on several stormwater runoff events on each of the three drainage areas monitored during the study. The results of five typical simulations for runoff events recorded on June 19 and July 29, 1976 from drainage areas M and S and on August 28, 1976 from drainage area K are discussed below.

Figure 3.12

The simulated and recorded BOD concentrations correspond closely over the measured period. The simulated curve indicates a pronounced first flush effect resulting from the flushing of catch basins. The first flush effect was not measured on this event due to the time delay involved with initiation of the sampling cycle on the automatic sampling equipment. In addition, it is seen with reference to the recorded and simulated hydrographs presented on Figure 3.1, for the June 19 event on drainage area M, that the rising limb of the measured hydrograph is much steeper than the corresponding simulated hydrograph. This feature implies that the initial catch basin BOD load would be diluted in the actual runoff. The mass emission curves for measured and simulated BOD, shown on Figure 3.12 are nearly identical, demonstrating the close overall agreement between measured and simulated runoff BOD loading.

The simulated peak SS concentration is seen to be of the same order of magnitude as the recorded value, although the former peak is predicted to occur much sooner than the measured peak. The measured SS concentrations are also seen to remain much higher than the simulated concentrations over the latter stages of the runoff event. This phenomenon is presumed to be due to erosion from the grassed zones in drainage area M, a factor which is not accounted for in the model. Inspection of the mass emission pollutographs for SS indicates fairly close agreement between the simulated and measured curves, with exception of the shift in time frame. The curves have similar shapes and the total SS loadings, determined by integrating the areas under the curves, are approximately equal. It is noted, that the high SS concentrations measured over the duration of the runoff event do not greatly affect the shape of the SS pollutograph.

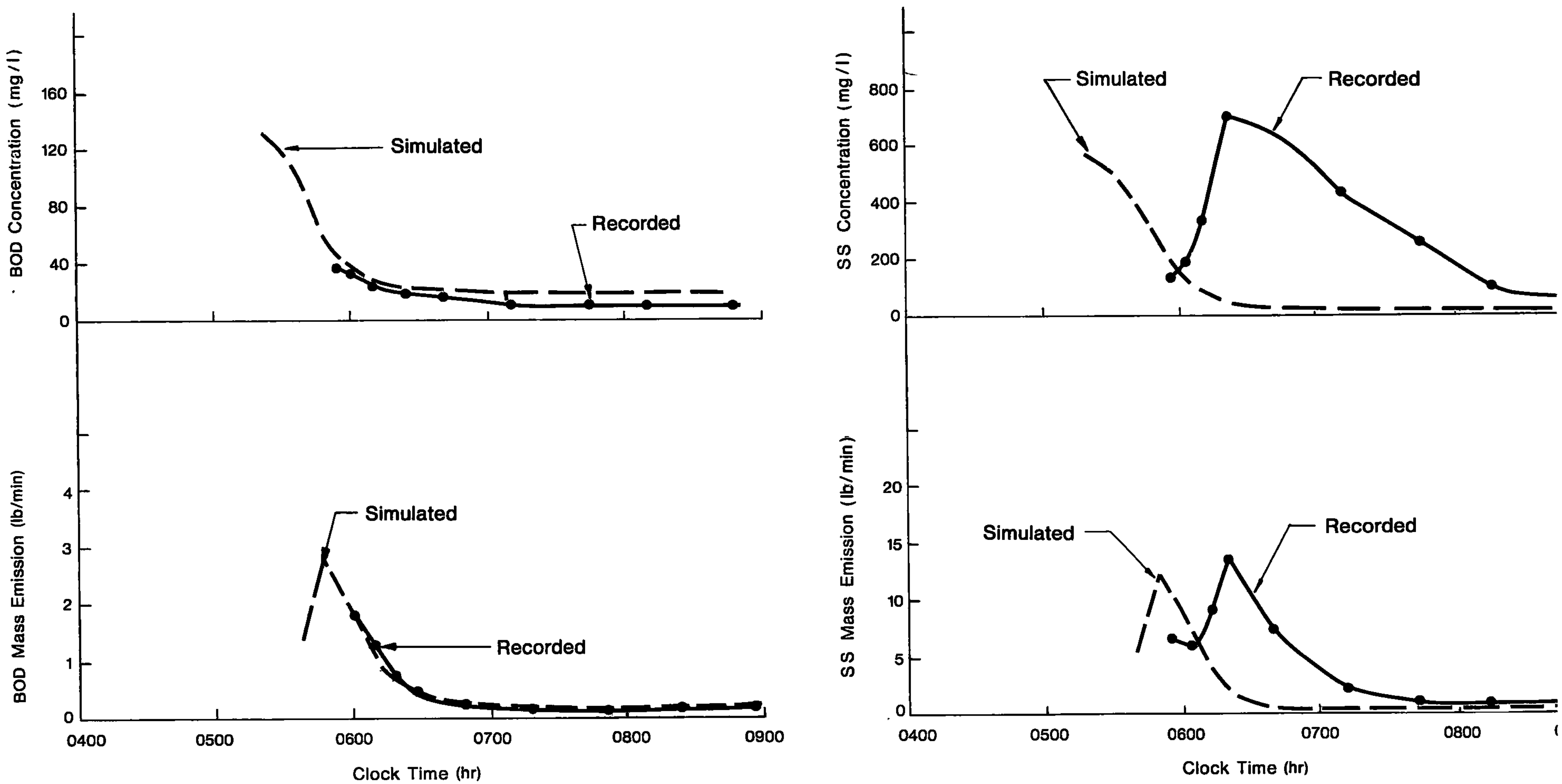


Figure 3.12 Recorded and Simulated Pollutographs Storm of June 19 , 1976 Drainage Area 'M'

Figure 3.13

As in the previous example, the simulated and recorded BOD concentrations are in fairly close agreement. Once again, the first flush effect was not measured due to the lag time involved with initiation of the sampling cycle. In the case of mass emission of BOD, the simulated and recorded curves are in reasonable accord.

The simulated SS concentrations correspond fairly well with the measured concentrations. However, there is a definite phase shift between the curves with the simulated peak occurring earlier. This shift is also apparent in the SS mass pollutographs, although apart from this aspect the simulation is quite accurate.

Figures 3.14 and 3.15

In drainage area S it was frequently possible to measure the first flush effect. The examples presented in Figures 3.14 and 3.15 indicate that the first flush of BOD is well simulated by the model. Both the simulated and recorded BOD concentration plots show two distinct regimes resulting in "L-shaped" curves. Inspection of the simulated and recorded mass BOD pollutographs indicate that the recorded peak is higher in both examples. The higher measured mass peak BOD values may be explained by the fact that the individual sample results represent the average concentration over approximately a 30 second sampling interval, whereas the model predictions are based on the average concentration over 10 minute time steps. Hence, if consecutive recorded values were averaged, the mass recorded pollutographs would correspond more closely to the simulated curves in the two examples presented.

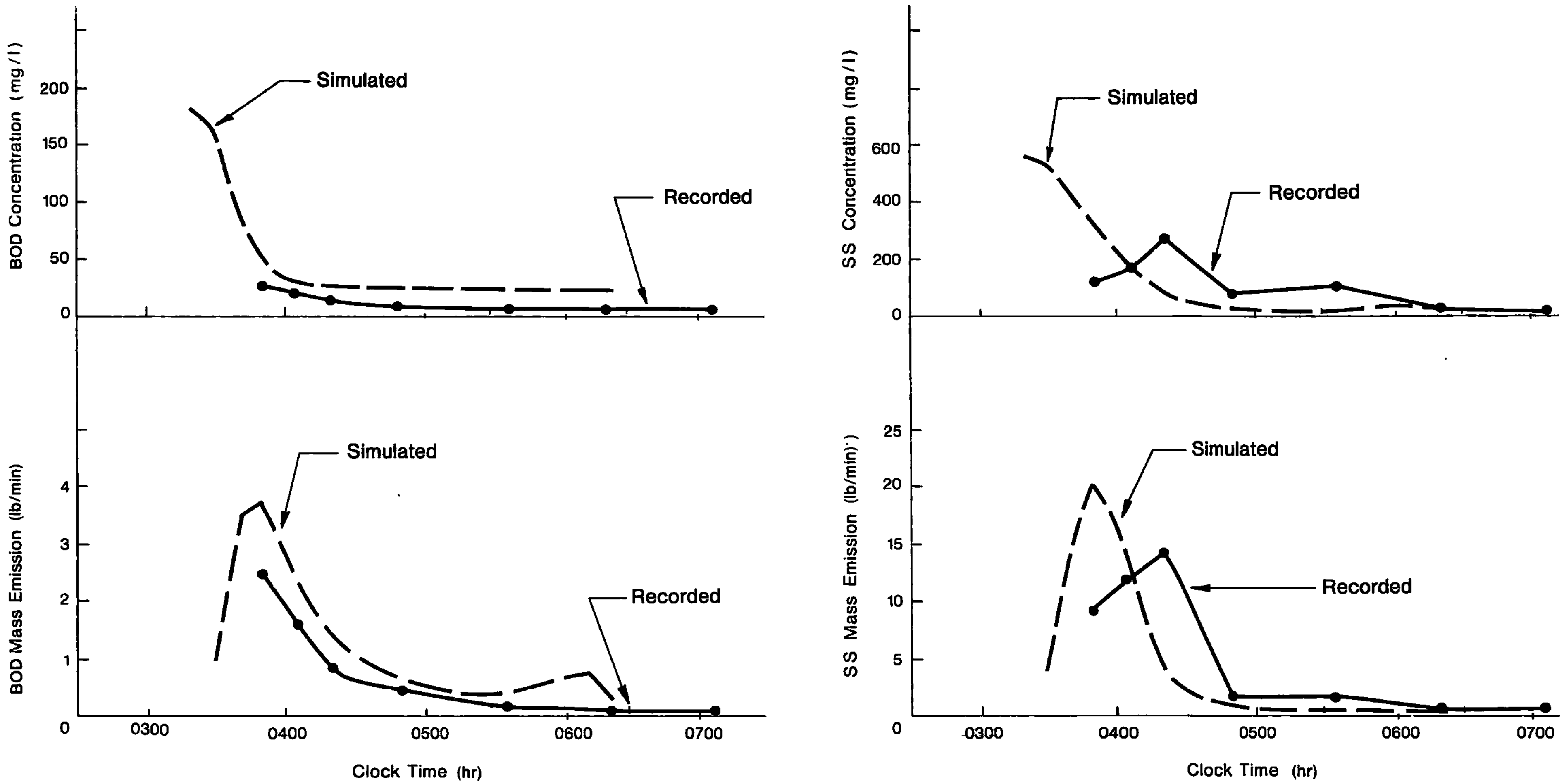


Figure 3.13 Recorded and Simulated Pollutographs Storm of July 29 , 1976 Drainage Area 'M'

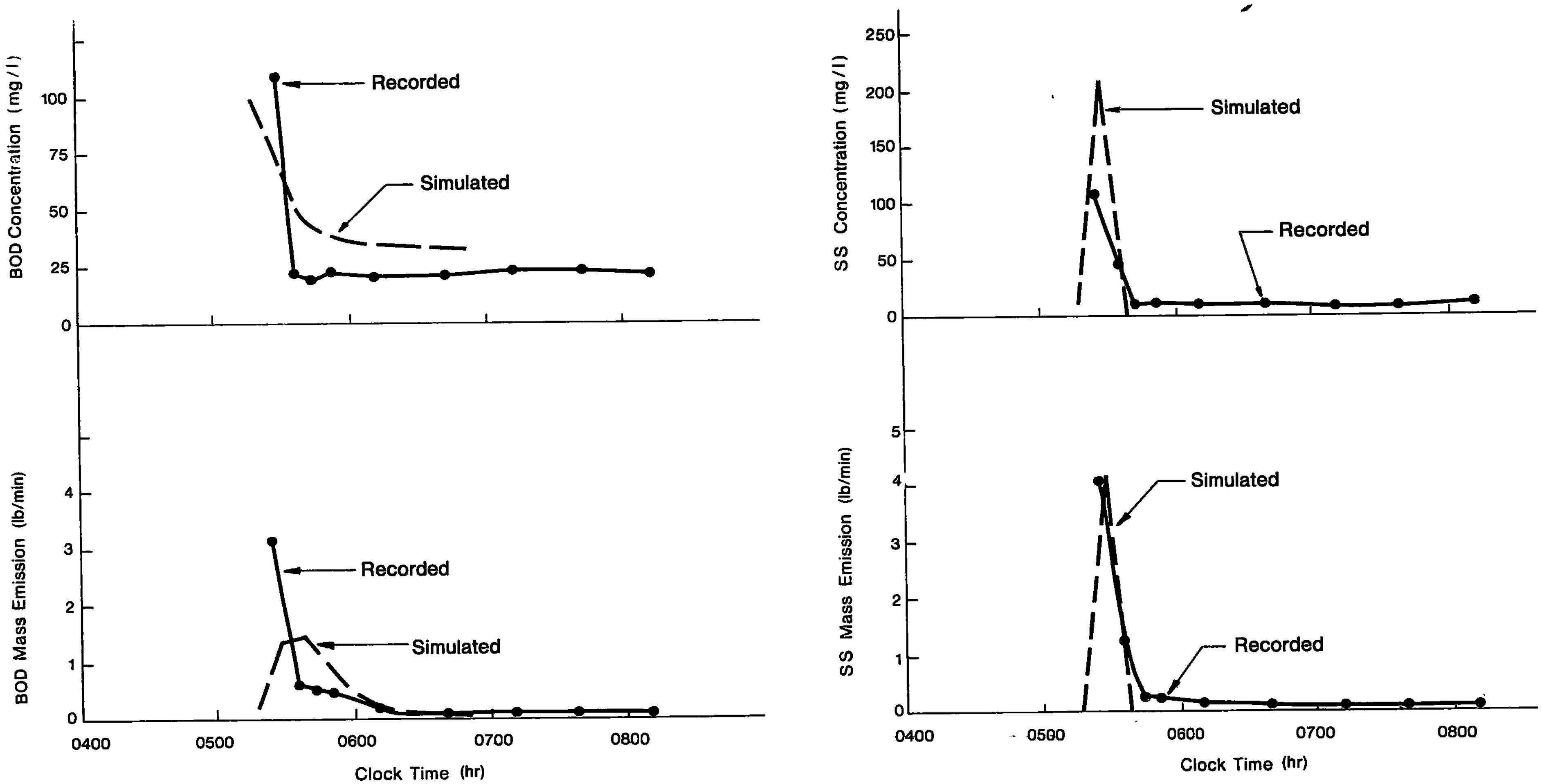


Figure 3.14 Recorded and Simulated Pollutographs Storm of June 19, 1976 Drainage Area 'S'

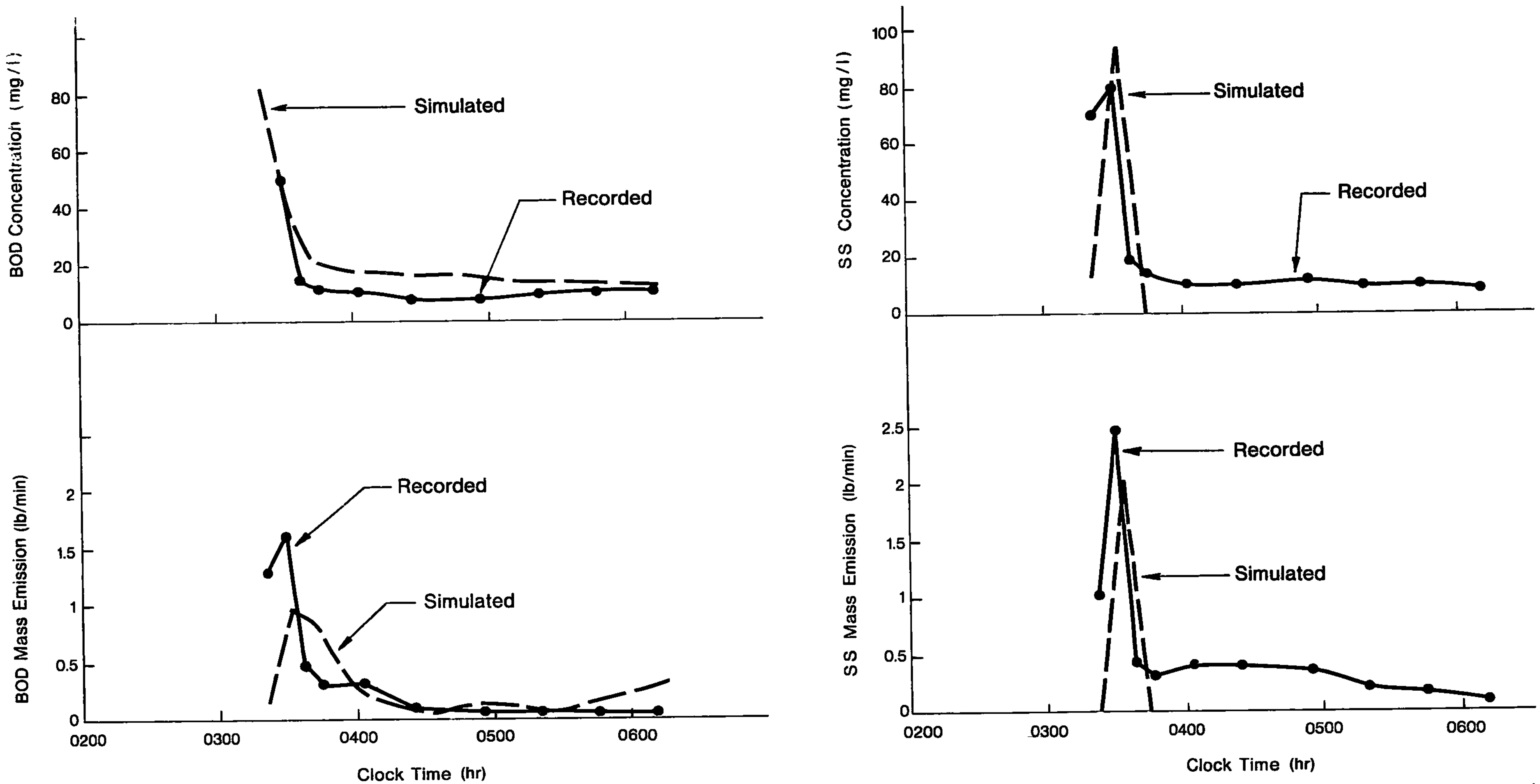


Figure 3.15 Recorded and Simulated Pollutographs Storm of July 29 , 1976 Drainage Area 'S'

The peak simulated SS concentration shown on Figure 3.14 is considerably higher than the recorded value, whereas the simulated and recorded peak values correspond more closely on Figure 3.15. The general shape and timing of the first flush effect however, is well reproduced on both figures. As noted in previous examples, the simulation fails to reproduce the constant low residual SS level. This aspect has little influence on the emission curves as the simulated plots are seen to reproduce the recorded curves very well.

<u>Figure 3.16</u>

The simulated and recorded BOD concentrations are in reasonable accord in this example of a high intensity runoff event from drainage area K. As in the calibrations for area M, the delay involved with initiating the sampling cycle may have resulted in incomplete sampling over the first flush. Otherwise, the recorded and simulated profiles are in reasonable agreement. Mass pollutographs are not presented due to incomplete flow measurements over the duration of the event.

The model simulates the first flush of SS very well in this example with a very close fit on the rising limb of the SS profile. However, the model fails to account for the subsequently high SS levels recorded over the duration of the sampling period. Since the rainfall intensity was extremely high, as demonstrated on Figure 3.7, it is reasonable to attribute the residual SS level to erosion from grassed areas.

<u>Table 3.3</u>

A summary of the values used for calibrating the quality model variables and coefficients on each of the five stormwater

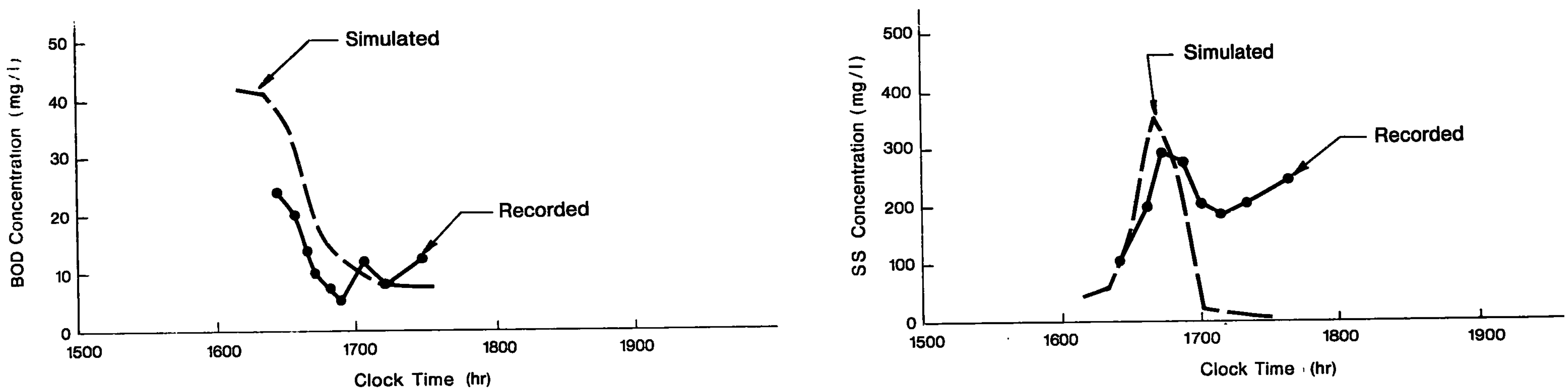


Figure 3.16 Recorded and Simulated Pollutographs Storm of August 28, 1976 Drainage Area 'K'

runoff events discussed above is presented in Table 3.3. From the table, it can be seen that the daily accumulation rate of BOD and SS on the ground surface varies not only between drainage areas but also between storm events on the same drainage area. The initial BOD and SS concentrations in the catch basins also differ considerably between the drainage areas.

Variation in the pollutant accumulation rates between drainage areas is expected as the values reflect on the diversity of land use and airport activity between the areas. For example, drainage area S consists mainly of apron area, where there is a high level of aircraft and support ground service vehicle activity. Hence, the potential for pollutant accumulation on the apron surface from spills of aviation fuel, sanitary aircraft waste, hydraulic fluid and engine oil is high. The significance of these pollutant sources is reflected in the high ratio of BOD to SS for the values presented in Table 3.3 on drainage area S.

Drainage areas M and K on the other hand are much larger areas having a greater diversity of land use. The ratio of BOD to SS is considerably lower in both cases as compared with drainage area S. This factor would seem to indicate that erosion of SS from the grassed areas contributes substantially to the total SS loading in the runoff. The BOD accumulation rates, in particular, is more significant on drainage area M than on drainage area K reflecting on the higher level of activity in area M. It is noted that drainage from area M includes a portion of the air cargo area as well as the apron area around Terminal 1 where there is considerable aircraft and ground service vehicle activity. Area K drainage in contrast originates mainly from around the maintenance hangar facilities, runways, taxiways and grassed areas where the level of activity is much lower.

TABLE 3.3

VARIABLE VALUES USED FOR CALIBRATION OF QUALITY MODEL

Drainage Area	Date 1976	Reference Figure		Daily Pollutant Accumulation Rate in Antecedent Dry Period[1] (lb/acre/day)		Ratio of BOD Accumulation Rate to SS Accumulation Rate	Catch basin Pollutant Concentration (mg/l)		Removing Coefficient[2] CC
		Hydro-graphs	Polluto-graphs	BOD	SS		BOD	SS	
M	June 19	3.1	3.12	0.82	2.22	0.37	180	900	0.45
M	July 29	3.2	3.13	0.59	1.48	0.40	180	900	0.45
S	June 19	3.4	3.14	3.73	3.73	1.00	100	0	0.25
S	July 29	3.5	3.15	0.75	0.19	3.95	100	0	0.25
K	Aug. 28	3.7	3.16	0.41	2.05	0.20	67	40	0.25

1. defined for modelling purposes as the number of antecedent days in which total accumulated rainfall is less than 0.4 in (10 mm).

2. refer to equation (3.2)

The data presented in Table 3.3 also reflects on the variability in pollutant accumulation rates on drainage areas in the airport environment. The values reported on drainage area S for the storm events of June 19 and July 29 particularly emphasize this point. For future predictive work at Toronto International Airport therefore, it will be necessary to base simulations on a range of accumulation rates. It is also doubtful that the values given in Table 3.3 can be used to simulate runoff quality from other airport facilities. Similar investigations at several other airports will be required to determine the general transferability of such information.

With respect to simulation of runoff quality during the winter months, it was found that the dust and dirt approach to pollutant accumulation employed in SWMM is not well suited to the prediction of runoff quality resulting from the application of deicing agents. Consequently, statistical methods were explored as discussed in sub-section 3.4.

3.3.3 Generalized Quality Model Verification

In order to demonstrate the applicability of the calibrated model for simulation of stormwater runoff quality, simulation of BOD and SS pollutographs were undertaken on the storm of July 16 in drainage area M and on the storm of August 28 in drainage area S. No further adjustments or calibrations to the model were attempted to ensure an objective appraisal of the model performance.

Figure 3.17

The simulations presented in Figure 3.17 for the storm event of July 16 were based on the parameter values given in Table

3.3 for the event of July 29 in drainage area M. The simulated and recorded BOD concentrations correspond reasonably well with the simulation giving an estimate of the first flush effect which was partly missed in the field program. The mass emission curves are also in good agreement, especially if consecutive recorded values are averaged.

The initial stage of the simulated SS concentration profile is of the correct order of magnitude. However, the high concentrations measured in the latter part of the event are not accounted for in the simulation. As discussed previously, this discrepancy is felt to be due to failure of the model to account for erosion in grassed areas. Since the simulated concentrations at the time of peak flow, however, are in reasonable agreement with the recorded values, the overall shape of the SS mass emission curve is well simulated.

Figure 3.18

The BOD and SS simulated pollutographs presented in this figure for the runoff event of August 28 in drainage area S were based on the parameter values given in Table 3.3 for the runoff event of June 19 in this area. It is noted that the BOD simulated concentration profile appears to lag behind its recorded counterparts. Since the flow simulation was very accurate, this discrepancy is not readily explained. With the exception of the phase lag, the recorded and simulated BOD concentration and mass emission profiles are in reasonable accord.

The SS concentration simulation is fairly accurate, with the first flush being well reproduced while the low residual levels are ignored. The simulated mass emission curve is

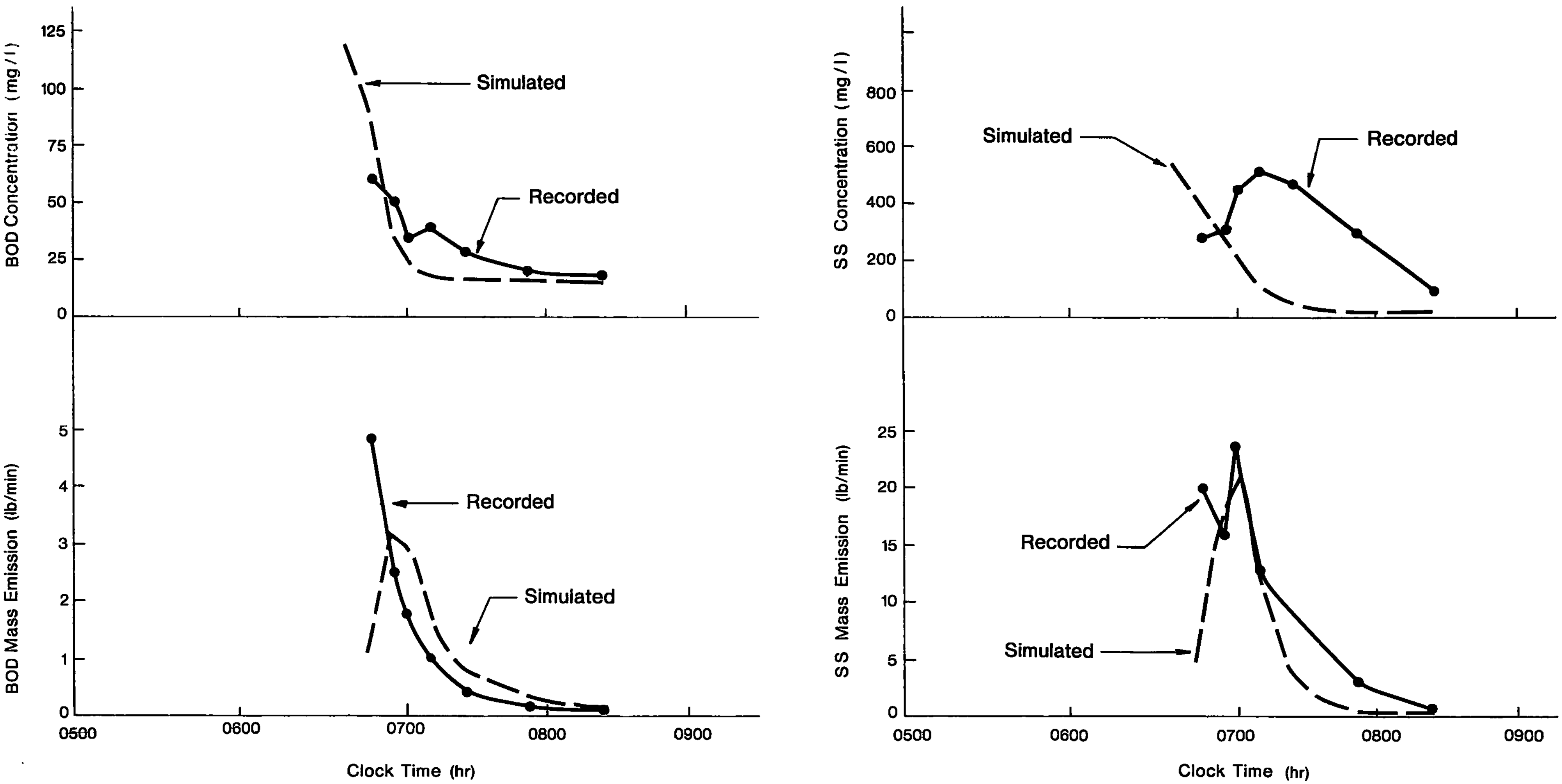


Figure 3.17 Recorded and Simulated Pollutographs Storm of July 16 , 1976 Drainage Area 'M'

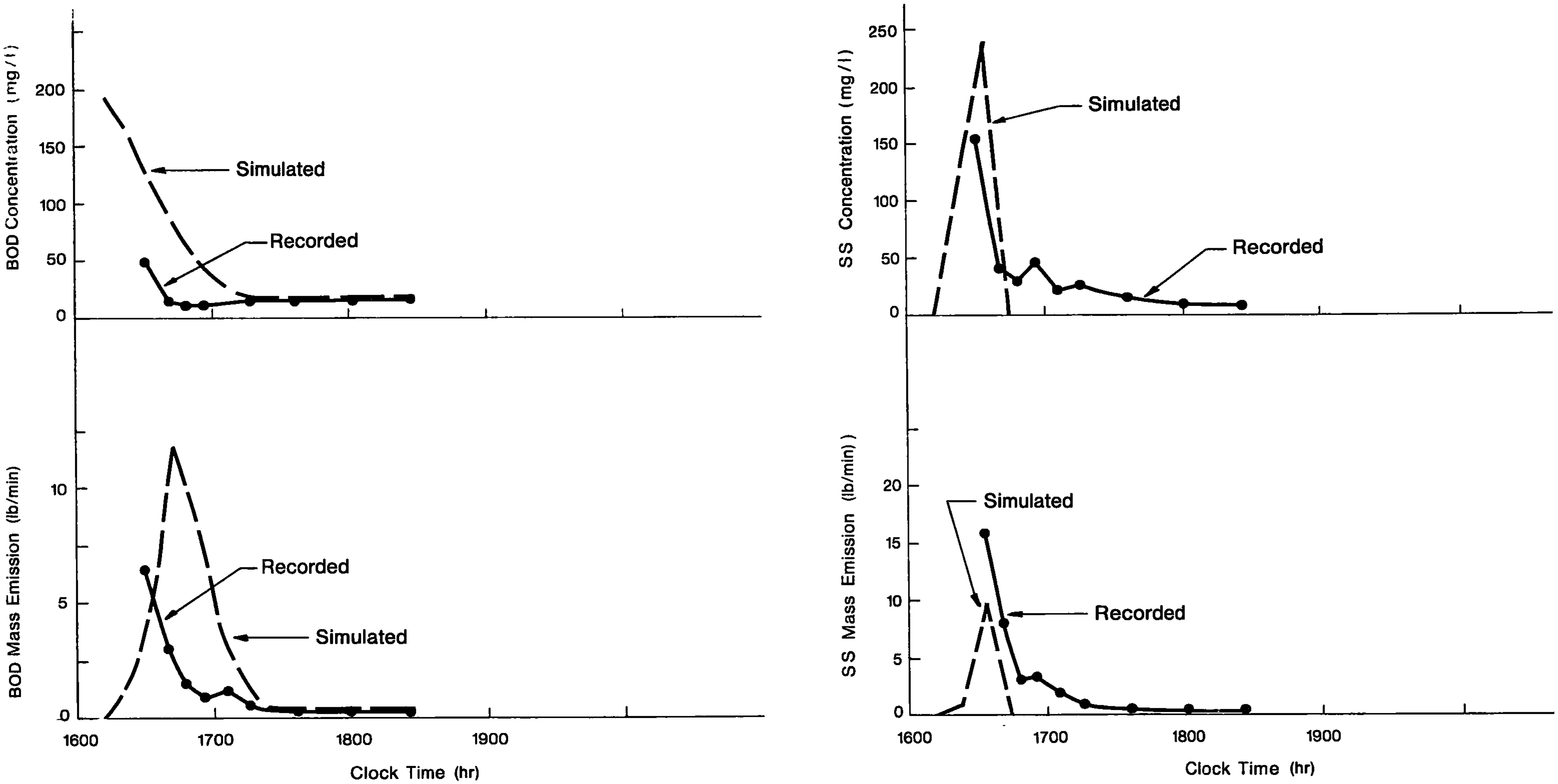


Figure 3.18 Recorded and Simulated Pollutographs Storm of August 28, 1976 Drainage Area 'S'

slightly lower than that computed using the instantaneous recorded concentrations, but the general shape is once again well simulated.

3.3.4 Summary Discussion on Quality Simulation

The work reported in the foregoing sub-sections on calibration and verification of the SWMM Generalized Quality Model has demonstrated the applicability of the model for simulating BOD and SS pollutographs in stormwater runoff from airport catchments during the warm weather months. Simulation of concentration profiles was generally found to be acceptable while reproduction of mass emission curves was usually quite accurate.

The rate of pollutant accumulation, however, showed noticeable variability between storm events on the same catchment area. Furthermore, the pollutant accumulation rate differs between catchment areas and is dependent on the diversity of land use and activity in the areas.

A major implication of the work reported upon herein is that quality modelling can be employed to replace large scale monitoring programs in future airport studies. Sufficient monitoring must be undertaken however, to allow calibration of the model for application at each airport. With further tuning of the model based on the results of additional airport studies, it may then be possible to define the expected range in model variables and coefficients with respect to airport size and level of activity. Application of the model to existing or proposed airport facilities will then be possible without further need for calibration. The model will be particularly useful for predictive purposes in assessing the impact on receiving waters or in evaluating the performance of alternative control strategies.

A limitation of the SWMM quality model is that its current structure does not allow for simulating the effect of deicing agents on the pollutant load in winter runoff. Hence, other methods such as the statistical approach discussed in the following sub-section must be used for predicting runoff quality in the winter months.

3.4 Statistical Modelling

3.4.1 Model Selection and Evaluation

In order to assess the potential for the prediction of pollutant concentrations in stormwater runoff from airports without the application of simulation models, such as SWMM and STORM, several statistical models were examined. The selection of variables to be tested was based on consideration of only those processes that might reasonably be expected to affect pollutant levels and for which the relevant data were readily obtainable. Due to the significant influence of aircraft deicing on runoff water quality during the winter months, the selection of variables was also based on differentiating between those processes which were considered applicable during the summer (warm weather) months and winter (cold weather) months, respectively. A complete listing of variables selected for testing for both summer and winter conditions is presented in Table 3.4.

Of the variables listed in the table, variables x_1, x_2 and x_3 describe the current precipitation event of interest while variables x_4, x_5, x_6, x_7 and x_8 relate to conditions during the antecedent period. These variables were tested in two multiple regression models, the first a multiple linear regression model of the form

$$Y = a_1x_1 + a_2x_2 + \ldots\ldots\ldots\ldots + a_8x_8 + c \qquad (3.3)$$

TABLE 3.4

VARIABLES SELECTED FOR STATISTICAL ANALYSIS

Variable	Definition	Period of Year When Applicable	Units
x_1	. time since start of the storm	summer & winter	minutes
x_2	. precipitation accumulated since the start of the storm	summer & winter	inches
x_3	. average precipitation intensity since the start of the storm	summer & winter	inches/hour
x_4	. number of dry days since the last recorded precipitation	summer & winter	days
x_5	. number of days preceding storm in which total accumulated precipitation is less than one inch	summer only	days
x_6	. total amount of last recorded precipitation	summer & winter	inches
x_7	. amount of aircraft fluid in seven antecedent days	winter only	thousands of gallons
x_8	. snow depth on uncleared ground	winter only	inches

and the second a polynomial regression model written as

$$Y = d(x_1^{b1} \cdot x_2^{b2} \cdot \ldots\ldots\ldots\ldots x_8^{b8}) \quad (3.4)$$

where: Y = the pollutant concentration (mg/l)

$a_1,\ldots,a_8$ and $b_1,\ldots,b_8$ = coefficients of multiple regression

c and d = constants

$x_1,\ldots,x_8$ = the variables defined in Table 3.4

Assessment of the applicability of these models to summer and winter conditions is discussed below:

Summer Conditions

Multiple regression equations were developed for summer conditions from equations (3.3) and (3.4) at different F levels (a statistical measure of significance) inputting data for variables x_1, x_2, x_3, x_4, x_5 and x_6. The procedure involved progressively including variables having a lower correlation with the pollutant concentration being predicted. Table 3.5 summarizes the equations tested, which yielded results significant at a 95 percent F level.

From Table 3.5, it is seen that the polynomial regression equation (3.4b) gave the highest correlation coefficient for BOD concentration. Hence, the BOD concentration in summer runoff can be predicted from the equation

$$BOD(mg/l) = 40.565\ (x_2^{-1.122} \cdot x_3^{0.596} \cdot x_4^{0.831} \cdot x_5^{-0.784} \cdot x_6^{-0.208}) \quad (3.4b)$$

Table 3.5

Equations for Summer Conditions

Pollutant (Y)	No. of Data Points	Variables Included in Final Equation	Form of Equation	Coefficient of Multiple Correlation	Equation Number
BOD	117	x_2, x_4	Linear	0.346	(3.3a)
BOD	100	x_2	Polynomial	0.420	(3.4a)
BOD	100	x_2, x_3, x_4, x_5, x_6	Polynomial	0.711	(3.4b)
SS	117	x_1, x_2, x_6	Linear	0.500	(3.3b)
SS	117	x_3	Linear	0.429	(3.3c)
SS	100	x_2, x_4, x_6	Polynomial	0.370	(3.4c)

The standard error of estimate of equation (3.4b) equals 1.056. Similarly, the highest correlation coefficient for SS concentration is given by the equation

$$SS(mg/l) = -\ 0.385x_1 - 213.700x_2 + 1057.736x_6 + 207.597 \quad (3.3b)$$

having a standard error of estimate of 175.921.

The standard errors of estimate given above represent a range of error such that the value estimated by the regression equation is within this range for about 2 out of 3 samples, and is within twice this range for about 19 out of 20 samples.

Winter Conditions

A similar analysis to that described for summer conditions was conducted for the winter period. In this case, however, two sets of variables were selected for independent evaluation. The first set of variables included x_1, x_2, x_3, x_4, x_6 and x_8 as defined previously in Table 3.4.

Table 3.6 summarizes the equations tested, which yielded results significant at a 95 percent F level. In several cases, BOD values for samples taken in drainage area K were excluded from the analysis, since aircraft are not deiced in the area and consequently concentrations of BOD in winter runoff are generally much lower than those in runoff from drainage areas M and S.

In this analysis equations (3.4d) and (3.4e) resulted in the highest coefficient of multiple correlation for BOD and SS respectively. Hence, the concentration of BOD in winter runoff can be predicted from the equation

Table 3.6

Equations for Winter Conditions

Pollutant (Y)	No. of Data Points	Variables Included in Final Equation	Form of Equation	Coefficient of Multiple Correlation	Equation Number
BOD	100	x_8	linear	0.485	(3.3d)
BOD	61	x_8	linear	0.712*	(3.3e)
BOD	61	x_1, x_2, x_3	polynomial	0.901*	(3.4d)
SS	100	x_3, x_6	linear	0.419	(3.3f)
SS	100	x_6, x_8	polynomial	0.500	(3.4e)

* indicates omission of drainage area K data

$$\text{BOD (mg/l)} = 1537.788\ (x_1^{-0.163} \cdot x_2^{-1.381} \cdot x_3^{1.214}) \qquad (3.4d)$$

which has a standard error of estimate of 2.054.

For the prediction of SS levels in winter runoff, the equation takes the form

$$\text{SS (mg/l)} = 90.758\ (x_8^{0.096} \cdot x_6^{-0.251}) \qquad (3.4e)$$

having a standard error of estimate of 2.077.

A second set of multiple regression equations was developed from equations (3.3) and (3.4) to test the correlation of BOD levels in winter runoff with variables x_1, x_2, x_3, x_6, x_7 and x_8. In particular, it is noted that variable x_7, the amount of deicer fluid applied during the seven antecedent days, was included in this analysis. A seven day antecedent period was selected to account for accumulation of deicer fluid in the drainage areas and catch basins. In addition, only BOD data collected on runoff from drainage areas M and S were included in the analysis as the influence of aircraft deicing is restricted to these areas at Toronto International Airport.

Only a polynomial form of equation was tested in view of the superiority of this representation in the analysis discussed previously. The resulting equation for predicting the BOD concentration is given by

$$\text{BOD (mg/l)} = 1821.107\ (x_1^{-0.165} \cdot x_2^{-1.272} \cdot x_3^{1.137} \cdot x_7^{0.047}) \qquad (3.4g)$$

having a standard error of estimate of 2.025.

The coefficient of multiple correlation for equation (3.4g) equalled 0.905, which is only marginally higher than that for equation (3.4d). However, because aircraft deicing has been shown to have a definite impact on runoff water quality, equation (3.4g) is considered to give the better representation.

3.4.2 Predictive Uses of Statistical Models

Generally, the use of statistical models is not valid in the predictive mode when the values of the input variables (x_i) differ greatly from those of the sample data used in the formulation. A statistical measure of the spread of the sample data is the standard deviation, s. Based on an analysis of the sample data, it is considered that an acceptable definition of the range of these data is the mean value plus or minus two standard deviations.

Tables 3.7 and 3.8 indicate the range of input variables that may be used with the summer and winter statistical models respectively. Large errors are possible when input variables fall outside these bounds.

3.5 Assessment of Statistical and Simulation Models

3.5.1 Comparison of Models on Selected Runoff Events

A comparative analysis of the statistical and simulation models presented previously for the prediction of runoff quality during both summer and winter conditions was undertaken on selected runoff events.

Table 3.7

Range of Variables for Predictive Use of Summer Models

Input Variable x_i	Mean Value $\bar{x}_i$	Predictive Range $\bar{x}_i \pm 2s$ $(x_i \geq 0)$
x_1	180.5	0-365
x_2	0.333	0-0.76
x_3	0.135	0-0.315
x_4	2.7	0-6
x_5	16.0	6-26
x_6	0.18	0-0.30

where x_1 = time since start of storm, minutes

x_2 = precipitation accumulated since the start of storm, inches

x_3 = average precipitation intensity since the start of the storm, inches/hour

x_4 = number of dry days since the last recorded precipitation, days

x_5 = number of days preceding storm in which total accumulated precipitation is less than one inch, days

x_6 = total amount of last recorded precipitation, inches

Table 3.8

Range of Variables for
Predictive Use of Winter Models

Input Variable x_i	Mean Value $\bar{x}_i$	Predictive Range $\bar{x}_i \pm 2s$ $(x_i \geq 0)$
x_1	128.5	0-458
x_2	0.146	0-0.44
x_3	0.034	0-0.086
x_6	.32	0-0.86
x_7	2.05	0-10.67
x_8	.05	0-0.13

where x_1 = time since start of storm, minutes

x_2 = precipitation accumulated since the start of storm, inches

x_3 = average precipitation intensity since the start of the storm, inches/hour

x_6 = total amount of last recorded precipitation, inches

x_7 = amount of aircraft deicing fluid applied in seven antecedent days, thousands of gallons

x_8 = snow depth on uncleared ground, inches

Summer Runoff Quality

Rainfall and runoff records as well as quality data measured on the storm of October 14, 1974, from drainage area M, during the previous study (Ref. 2) were selected for comparison of the statistical and simulation models in predicting summer runoff quality. This particular event was selected as it introduced a completely new set of data which had not been used in calibration of either model. For the statistical model, equations (3.4b) and (3.3b) were used for predicting BOD and SS concentration profiles respectively. With the GQM simulation model, calibration data presented previously in Table 3.3 for the storm event of July 29, 1976 were used.

The results of the application of statistical and simulation models are shown in Table 3.9. It is seen that both models tend to overpredict the BOD concentration but are generally of the correct order of magnitude. With respect to the SS concentration, the statistical model is seen to overestimate the SS level during the latter stages of the event whereas the SWMM simulation model underestimates the recorded results.

As a measure of the accuracy of the models in predicting runoff pollutant concentrations, the sum of errors was computed between predicted and recorded concentrations as shown in the table. The sum of errors is simply a summation of the absolute value of differences between corresponding measured and predicted results. As can be seen from the table, the sum of errors for both BOD and SS was lowest with the SWMM simulation indicating that this model gave the best overall accuracy.

Table 3.9

Predicted BOD and SS Concentrations
in Stormwater Runoff From the Event of
October 14, 1974
In Drainage Area M

Time from Start of Rainfall (min)	BOD (mg/l)			SS (mg/l)		
	Recorded	Statistical Model	SWMM	Recorded	Statistical Model	SWMM
60	-	56	123	-	213	531
70	-	46	92	-	204	436
80	-	40	48	-	195	310
94.5	11	33	23	148	181	160
124.5	5	26	16	64	165	61
154.5	7	22	15	71	147	23
184.5	7	19	15	69	136	19
214.5	6	17	14	58	120	10
244.5	6	16	13	64	109	4
SUM OF ERRORS	-	91	54	-	384	221

Winter Runoff Quality

The event of March 12, 1975, recorded during the previous study (Ref. 2) on drainage area M was selected for testing of the predictive winter runoff quality models. Equations (3.4g) and (3.4e) were used for the statistical prediction of BOD and SS respectively. The results obtained from the application of these equations are presented in Table 3.10.

For this example, it is seen that there is a very poor reproduction of BOD concentrations over the duration of the recorded runoff event. The SS concentrations, however, agree reasonably well, indicating that equation (3.4e) can be successfully applied for predicting SS levels in winter runoff.

In view of the shortcomings of equation (3.4g) for predicting BOD concentration with time in winter runoff, a further attempt was made to correlate BOD concentration with aircraft deicer usage. In this analysis, a simple linear regression analysis was conducted between composite BOD sample results and deicer usage in the seven day period prior to runoff sampling. These data yielded a correlation coefficient of 0.553. The equation significant at an F level of 95 percent for predicting the average BOD concentration in a winter runoff event is given as follows

$$\text{BOD (mg/l)} = 233x_7 + 296 \qquad (3.5)$$

and has a standard error of estimate of 1.387. In equation (3.5), x_7 represents the amount of aircraft deicer applied in thousands of gallons. The acceptable range of values for this parameter as applied to future predictions is $0 \leq x_7 < 6.74$.

Table 3.10

Statistical Model Prediction of
BOD and SS Concentrations in Runoff From
Rain-on-Snow Event of March 12, 1975

Time from Start of Rainfall (min)	BOD (mg/l)		SS (mg/l)	
	Recorded	Statistical Model	Recorded	Statistical Model
270	1240	207	244	320
300	1310	176	221	320
330	1330	153	233	320
364	1440	135	232	320
394	1280	120	256	320
424	1370	109	283	320
454	1350	100	262	320

Equation (3.5) was tested against the flow composited average BOD concentration for runoff from the March 12, 1975 event in drainage area M. The volume of deicer fluid applied during the 7 days prior to this event was 5.429×10^3 gallons. Therefore, the predicted BOD concentration obtained from equation (3.5) is

$$\text{BOD} = (233 \times 5.429) + 296 = 1561 \text{ mg/l}$$

This value compares quite favourably with the recorded average flow proportioned value* of 1342 mg/l. However, it should be emphasized that the application of a model such as equation (3.5) is liable to result in substantial error, due to the drastic simplification of the complex physical relationships involved.

As discussed previously, SWMM is not well suited to simulating winter runoff quality as the dust and dirt approach used to describe the buildup of pollutants on a catchment surface assumes a uniform rate of accumulation of pollutants in the dry period preceding a storm. The limitations of this approach for the simulation of chemicals applied for deicing were recognized in the development of the SWMM snowmelt model by Proctor and Redfern Limited and James F. MacLaren Limited (Ref. 5). A conclusion of that work was that it is necessary to supply as an input to the model the total amount of deicing agents (salt) applied to an urban catchment prior to the runoff event.

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* This value is slightly different from a value calculated based on the flows presented in the 1975 report (Ref. 2) due to a typographical error in the flow records for that event.

Based on the above consideration and stimulated by the apparent inadequacy of statistical models for predicting winter BOD concentrations, an attempt was made to modify the input to the SWMM, GQM version, to allow winter runoff quality simulation. The rain-on-snow event of March 12, 1975 was again used as a test case for the modified simulation. Instead of calibrating the model to reproduce recorded BOD concentrations, the amount of BOD available at the start of the event was specified as input. This value was determined as the equivalent BOD load contained in the deicer fluid applied on drainage area M in the 7 days prior to the start of the event. A BOD value of 390,000 mg/l was assumed for the deicing fluid consisting of 50 percent water and 50 percent glycol compounds. It was also assumed that 90 percent of the applied BOD loading was retained in the catchment area.

Recorded flow values were used as input to the modified SWMM simulation in this example. In the absence of this data, however, simulation of runoff quantity using the SWMM snowmelt routine would be acceptable as described previously. Table 3.11 presents the recorded and simulated BOD concentrations for the event of March 12, 1975.

As evidenced from the table, the simulated BOD values correspond fairly closely to the measured results. The simulated values show a decreasing concentration with time however, whereas the measured BOD values remained fairly consistent over the duration of the runoff event. Nonetheless, it can be concluded that the "modified-input" SWMM predicts the recorded concentrations with a reasonable degree of accuracy. Moreover, the cumulative mass emission of pounds of BOD is estimated very accurately over the sampling period.

Table 3.11

SWMM Simulation of BOD Concentration in Runoff from the Rain-on-Snow Event of March 12, 1975, on Drainage Area M

Clock Time (hr, min)	Recorded Flow* (cfs)	BOD (mg/l)		Cumulative BOD Mass Emission (lb)	
		Recorded	Simulated	Recorded	Simulated
01:30	1.0	1240	1727	-	-
02:00	1.4	1310	1590	172	229
02:30	3.4	1330	1432	528	631
02:34	4.0	1310	1406	601	716
03:04	4.7	1440	1211	1274	1357
03:34	4.6	1280	1016	1985	1937
04:04	4.4	1370	895	2656	2678
04:34	4.5	1350	837	3337	3112

* Note that these are the correct flows. Values given in the 1975 report (Ref. 2) are incorrect due to a typographical error.

3.5.2 Summary Discussion on Model Application

A detailed analysis of both simulation and statistical models for the prediction of stormwater runoff quantity and/or quality from an airport environment has been presented in previous sub-sections of this report. Only a brief summary discussion on the applicability of these models therefore is presented below.

Quantity Modelling

The work undertaken in this study on quantity modelling was specifically oriented to the calibration and verification of simulation models, as previous work had demonstrated the general applicability of these models in the reproduction of runoff hydrographs. The results presented herein have shown that the simulation approach of SWMM is entirely applicable to the prediction of stormwater runoff from airport facilities. Runoff hydrographs from low, medium and high intensity rainfall events were found to be well reproduced; increasing in accuracy with increasing rainfall intensity. Calibration of SWMM was also found to be very straightforward and may not be necessary at all except in very detailed applications.

Simulation of runoff from snowmelt and rain-on-snow events using either SWMM or STORM was found to be less reliable with respect to reproduction of the hydrographs. However, the total runoff volumes were estimated fairly accurately by both models. In addition, it was shown that STORM can be applied to predict the total runoff volume for rainfall events but does not reproduce runoff hydrographs nearly as accurately as SWMM.

In summary, the superiority of the simulation modelling approach for the prediction of runoff from airport property has been demonstrated. In particular, SWMM can be used to accurately predict the shape of the runoff hydrograph for any design storm event. This information will be especially useful in the design of stormwater drainage and management systems at existing and future airport facilities.

In addition, the simulation model STORM will also prove to be a valuable tool in the design of stormwater management systems. The advantage of this model is that several years meteorological data can be processed in a relatively short computer processing time providing a continuous record of the total runoff volume for all storm events. Such data is required for assessing alternative storage and treatment strategies.

Quality Modelling - Summer Conditions

The examples discussed previously demonstrate that it is possible to calibrate the quality routines of SWMM in order to reproduce recorded pollutant concentrations within a reasonable degree of accuracy. The analysis indicates that although dust and dirt may not accumulate at a uniform rate, it is possible to obtain a credible verification of the model based on a small number of measured events. In view of the normal variation observed with respect to the rate of pollutant accumulation in the airport environment, alternative model calibrations can be used to predict an expected range of pollutant emissions.

The statistical models developed in this study also appear capable of predicting pollutant concentrations in runoff to an acceptable level of accuracy when used within the specified range of input conditions. However, statistical models are known to be less "transferable" than simulation models as the former models cannot take into account changes in physical conditions between airports (such as land use, ground slope, etc.) whereas simulation models explicitly account for such variations. Consequently, the statistical models described in this report may be of little direct use at other airports, except where conditions are very similar to those at Toronto International Airport.

In view of the greater generality of quality simulation models and of the relatively small amount of field data required to commence predictive work, it is considered that these models are more useful for studies at airport facilities than statistical models. A further advantage of the simulation approach is the ability to conduct quantity and quality simulations using the same model.

Quality Modelling - Winter Conditions

The dust and dirt approach of the SWMM quality routine has been shown in previous work to be inappropriate for the simulation of runoff quality influenced by the periodic addition of deicing agents. A conclusion of that work was that it is necessary to provide as input to the model, the total amount of deicing agent applied on the catchment during the antecedent period prior to a runoff event. Consequently, a modified simulation was undertaken in this study to evaluate the appropriateness of this approach.

The results of the modified SWMM simulation indicates that the BOD content in winter runoff from a catchment at an airport where aircraft deicing is carried out can be fairly accurately simulated. Hence, this approach would seem to be appropriate for future simulation work at other airports.

The statistical models developed for predicting BOD concentrations in winter runoff were generally found to produce unsatisfactory results. However, the suspended solids model was shown to predict the pollutant concentration with an acceptable level of accuracy. Hence, the suspended solids statistical model can be used for predictive purposes at Toronto International Airport. As previously noted regarding the statistical approach, the SS model may have little direct application at other airports.

References (Section 3)

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SECTION 4

STORMWATER RUNOFF MANAGEMENT ALTERNATIVES

STORMWATER RUNOFF MANAGEMENT ALTERNATIVES 4

4.1 Stormwater Runoff Quality Characteristics

4.1.1 Quality Monitoring Program

All runoff quality data collected during the monitoring period from March 1, 1976 to March 31, 1977 is presented in Appendix D. The analytical program consisted of measuring the pH value, five-day biochemical oxygen demand (BOD) and suspended solids (SS) concentrations on all samples collected as well as the total Kjeldahl nitrogen (TKN) levels on samples collected during the winter months. In addition, the program was expanded late in the project to include measurement of the orthophosphate, total phosphorous, nitrite nitrogen, nitrate nitrogen and ammonia nitrogen concentrations on samples collected at Site 1 draining catchment area M.

The sampling program consisted of the collection of grab and composite samples in addition to discrete samples on selected runoff events from each site. The significance of the runoff quality data from each of the three catchment areas follows.

4.1.2 Stormwater Runoff Quality at Site 1

Summer and Fall Conditions

Storm runoff from catchment area M contained fairly high concentrations of suspended solids. During several storm events, concentrations greater than 500 mg/l occurred, and in about 65 percent of all samples a level of 100 mg/l was exceeded. The peak suspended solids concentration was 1011 mg/l, recorded on August 28, 1976. As discussed in Section 3, the high suspended solids levels are attributable to erosion in the open or grassy areas.

The organic content of the runoff was generally quite low with approximately 70 percent of the BOD values less than 25 mg/l. The highest BOD concentrations occurred during a runoff event on October 6, 1976, when values of 153, 150, 106, 61 and 106 mg/l were recorded on five consecutive discrete samples.

Values of pH ranged from 6.9 to 8.3.

Winter and Spring Conditions

Concentrations of suspended solids in drainage from catchment area M were somewhat lower in the winter and spring than during the summer and fall. A concentration of 500 mg/l was exceeded on only two occasions, and a level of 100 mg/l was exceeded in about 50 percent of all samples. A peak concentration of 532 mg/l was recorded on March 27, 1976.

The organic content of runoff increased greatly during the winter and spring. BOD values of less than 50 mg/l were measured in only about 15 percent of all samples. Samples from several runoff events had values greater than 1000 mg/l, with a peak of 16,400 mg/l occurring on March 19, 1976. These high BOD values resulted from the use of glycol compound based aircraft deicer fluids. As discussed in subsection 4.2.2, a substantial portion of the applied deicer fluid enters the apron area drainage systems.

The TKN content of runoff from catchment area M was high throughout the winter. Values greater than 100 mg/l were measured in samples from several runoff events, with a peak value of 195 mg/l occurring on January 26, 1977. The predominant source of Kjeldahl nitrogen has been attributed to urea used for deicing runways, taxiways, and aprons within the catchment area. Contamination of runoff by urea is more fully discussed in sub-section 4.2.1.

Values of pH ranged from 6.6 to 9.1.

During the later part of the winter of 1977, the analytical program was expanded to include orthophosphate, total phosphorus, nitrite nitrogen, nitrate nitrogen, and ammonia nitrogen. Most recorded values of orthophosphate were within the range of 0.01 to 0.17 mg/l. The highest level equalled 6.4 mg/l measured on a grab sample collected on January 26, 1977. Total phosphorus concentrations were generally in the range of 0.50 to 1.68 mg/l. During a runoff event of December 20, 1976, discrete samples had levels of 2.28, 4.98, 3.10, and 3.60 mg/l. The peak value recorded was 11 mg/l, occurring on January 26, 1977.

Nitrite and nitrate nitrogen concentrations were generally quite low. Nitrite levels were less than 0.05 mg/l in all but two samples, and a nitrate concentration of 0.5 mg/l was exceeded only twice.

Ammonia nitrogen levels were quite high, being greater than 10 mg/l in almost all samples, and reaching a peak of 72 mg/l on two consecutive discrete samples on the runoff event of December 20, 1976, and 84 mg/l on a grab sample taken on January 26, 1977.

4.1.3 Stormwater Runoff Quality at Site 3

Summer and Fall Conditions

The quality of runoff samples collected from catchment area S was considered to be representative of that resulting from airport activities associated with an apron area since most of the flow to this catchment area originated from Terminal 2 apron drainage system.

Suspended solids concentrations ranged from 4 to 315 mg/l during the summer and fall, but were less than 100 mg/l in about 90 percent of all samples.

BOD concentrations were also quite low. Most samples were in the range of 10 to 30 mg/l with a peak value of 310 mg/l being measured on a discrete sampling event on June 13, 1976.

The pH of samples ranged from 6.6 to 8.5.

Winter and Spring Conditions

Suspended solids concentrations were quite high during winter and spring, particularly in March, April and early May, 1976, when most recorded values were greater than 200 mg/l and a peak of 1102 mg/l occurred. Samples taken in the period from November, 1976 to March, 1977 generally had levels less than 100 mg/l.

BOD concentrations were very high, dropping below 100 mg/l on only two samples. During a runoff event on March 12, 1976, all discrete samples had BOD values greater than 5000 mg/l. A peak of 58,750 mg/l was measured on a grab sample taken on January 26, 1977. As mentioned in the discussion for catchment area M, these high BOD concentrations can be attributed to aircraft deicer fluid entering the runoff from area S.

TKN concentrations were generally high due to the presence of nitrogen compounds in the aircraft deicer fluid and the use of urea for airfield deicing. Values of TKN were greater than 10 mg/l in all but two samples, and a peak of 522 mg/l was measured on a grab sample taken on January 26, 1977.

A few grab samples obtained during February and March, 1977, were analysed for ammonia nitrogen. Values ranged from 5.05 to 32.2 mg/l.

The pH ranged from 6.5 to 8.6.

4.1.4 Stormwater Runoff Quality at Site 7

Summer and Fall Conditions

Suspended solids concentrations in runoff from catchment area K varied greatly, ranging from 14 to 282 mg/l. Samples from several events had levels greater than 100 mg/l, while several others had levels less than 50 mg/l.

BOD concentrations were less than 55 mg/l in all cases except on July 6, 1976 when a peak of 111 mg/l occurred.

The pH ranged from 7.0 to 7.9.

Winter and Spring Conditions

Suspended solids concentrations also varied greatly during the winter and spring, ranging from 3 to 2296 mg/l. Many samples had levels greater than 100 mg/l, but there were also several samples with values less than 100 mg/l.

BOD concentrations ranged from 7 to 1100 mg/l, but in most cases were less than 50 mg/l. The high BOD of 1100 mg/l is attributable to fire fighting foam entering the runoff following a training exercise at the CP Air hangar. The runoff in catchment area K thus does not appear to have been influenced significantly by aircraft deicer fluid, as in areas M and S.

TKN concentrations were generally fairly high, with most samples in the range of 15 to 50 mg/l. The peak concentration measured was 59 mg/l. Again, the use of urea for airfield deicing has been identified as the principal source of nitrogen in runoff from area K.

In February and March, 1977, three grab samples were analyzed for ammonia nitrogen and the concentrations ranged from 4.92 to 8.64 mg/l.

The pH ranged from 7.0 to 9.3.

4.2 Stormwater Runoff Contamination Problems

4.2.1 Airfield Deicing Activities

Maintenance of the runways, apron areas and service roads at the airport is the responsibility of Transport Canada. The services provided include removal of snow and ice which in general is accomplished using a fleet of snow plows, sweepers and blowers. Urea is also used as a deicing or anti-icing agent, particularly on the runways where it is essential to keep the pavement bare for safety reasons. In general, urea is used only when ice has formed on the runway surface.
On occasion, urea is applied to the runways as an anti-icing agent when freezing rain is predicted by the weather station.

Urea is the principal deicing agent used on the airfield due to its non-corrosiveness to aircraft bodies. Most of the urea used is applied to the runways, with application on the taxiways and aprons practiced only under extreme weather conditions. At other times sand is used on these areas.

Salt (sodium chloride) is applied to the terminal and service roads maintained by Transport Canada. All other tenants on the airport complex are responsible for their own snow removal, which is generally performed by private contractors.

Typical annual quantities of deicer and sand usage by Transport Canada, based on 1970 to 1977 data, were reported as follows: urea - 100 tons, salt - 400 tons and sand - 3000 tons.

Commercial grade urea ($CO(NH_2)_2$), used for deicing, is 99 percent pure, containing 46.3 percent nitrogen on a weight basis. Upon contact with water, urea hydrolyzes according to the following reaction:

$$CO(NH_2)_2 + H_2O \rightarrow NH_2COONH_4 \rightarrow CO_2 + 2NH_3$$

resulting in the formation of carbon dioxide and ammonia-nitrogen. The rate at which this proceeds however, is strongly temperature dependent.

The fate of nitrogen in the urea applied to runways is of interest in evaluating potential environmental problems resulting from airfield deicing practices. There are three major routes by which nitrogen will leave the runways.

(i) Volatolization to the atmosphere. This is a potentially significant pathway.

(ii) Dissolution in water with urea or ammonium-nitrogen being carried off in surface runoff.

(iii) Removal with snow to grassed areas bordering the runways. The nitrogen reaching the soil as ammonium-nitrogen (NH_4^+) is very resistant to leaching by water as it adheres to minerals, clays and colloids in the soil. Bacterial activity subsequently transforms the ammonium form of nitrogen to the nitrate (NO_3^-) form. When nitrogen reaches this stage in its cycle it becomes subject to three fates:

(a) consumption by plants

(b) leaching and transport by water moving through the soil

(c) decomposition to gaseous forms of nitrogen which return to the atmosphere.

Of the pathways, two are particularly important to the possibility of excess nitrogen in runoff or groundwater:

(i) dissolution following application with ammonium-nitrogen or undissociated urea being carried off in surface runoff

(ii) leaching and transport of nitrate-nitrogen in groundwater.

In 1971-72, a study was carried out at Penticton, Nisku (Edmonton), and Calgary airports to evaluate the fate of nitrogen from urea application on runways and to assess the potential contribution of this nitrogen source to local lake eutrophication (Ref. 1). Soil samples were taken at sites bordering the runways and two types of analysis were performed:

(i) the standard farm soil fertility analysis,

(ii) non-routine analyses, including NH_4^+, total exchange capacity (TEC), total N, organic matter, sodium, potassium, calcium and magnesium.

Based on the results of these analyses the study concluded that:

"1. No indications were found that nitrogen is moving from the airports as runoff or in ground waters in significant amounts.

2. Grass response to urea added as a fertilizer in comparison with ammonium nitrate suggests some loss of urea nitrogen to the atmosphere.

3. Notable increases in soil organic matter can account for sizeable immobilization of nitrogen in the soil.

4. By increasing soil organic matter, grass bordering runways is utilizing urea nitrogen that might otherwise accumulate to undesirable levels with pollution potentials.

5. The urea used at these airports as an anti-icing agent does not appear to be contributing to impaired water quality."

During the winters of 1974-75 and 1976-77, samples of runoff from the airfield at Toronto International Airport were analyzed for total Kjeldahl nitrogen (TKN) content, as well as other parameters. The TKN analyses were performed to determine the effect of airfield deicing activities on surface runoff quality. The results of these analyses suggest that a substantial portion of the urea nitrogen loading is being removed from the runways in surface runoff. This observation is contrary to the conclusion of the above-noted study (Ref. 1) and may be a reflection on the local climatic conditions at Toronto International Airport.

As an example, on March 12, 1975, 4 tons of urea containing approximately 3700 pounds of nitrogen was applied to runway 05R-23L prior to a rain-on-snow event. Since approximately 59 percent of the runway lies in area M, drainage from this portion of the runway was monitored at Site 1. Calculation of the nitrogen loading in the runoff recorded at Site 1 on March 12 and 13 was estimated based on data presented in Table 4.1 and Figure 4.1. The estimated nitrogen loading in the runoff from that portion of runway 05R-23L draining to Site 1 equalled 1390 lb. Assuming that a proportional amount of nitrogen was carried in runoff from the remaining portion of runway 05R-23L, the total nitrogen loading in runoff from the entire runway would equal 2360 pounds, or 64 percent of the total nitrogen loading applied. The probability that this high a proportion of the nitrogen loading would appear in runoff immediately following application is unlikely under most weather conditions. The example cited above was conducive to rapid wash-off as urea was applied just prior to a rainfall event. Water quality data collected at all three sites (reported in Appendix D) however, indicates that nitrogen was being continuously removed over the duration of the winter and spring periods. This observation suggests that some portion of the nitrogen loading removed with snow

TABLE 4.1

Estimated Nitrogen Loading in Runoff Event of March 12th and 13th, 1975, from Catchment Area 'M'

Time Interval (min)	TKN Average Concentration Over Time Interval (mg/l)	Average Flowrate Over Time Interval (cfs)	Nitrogen Loading (lb)
30	139	1.2	18.8
30	204	2.4	55.1
4	226	3.6	12.2
30	189	4.35	92.4
30	155	4.65	80.9
30	141	4.5	71.2
30	135	4.45	67.5
60	124	4.75	132.3
60	112	5.4	135.9
60	102	6.4	146.7
60	93	6.75	141.0
60	84	5.75	108.5
60	75	5.0	84.2
60	68	4.75	72.6
60	60	4.15	55.9
60	53	3.4	40.5
60	47	2.6	27.4
60	41	1.95	18.0
60	35	1.45	11.4
60	29	1.0	6.5
60	24	.7	3.8
60	20	.52	2.3
60	15	.45	1.5
60	11	.45	1.1
60	10	.45	1.0

TOTAL NITROGEN LOADING = 1388.7 lb

TOTAL RUNOFF VOLUME = 1,503,700 gallons

AVERAGE NITROGEN CONCENTRATION = 92.4 mg/l

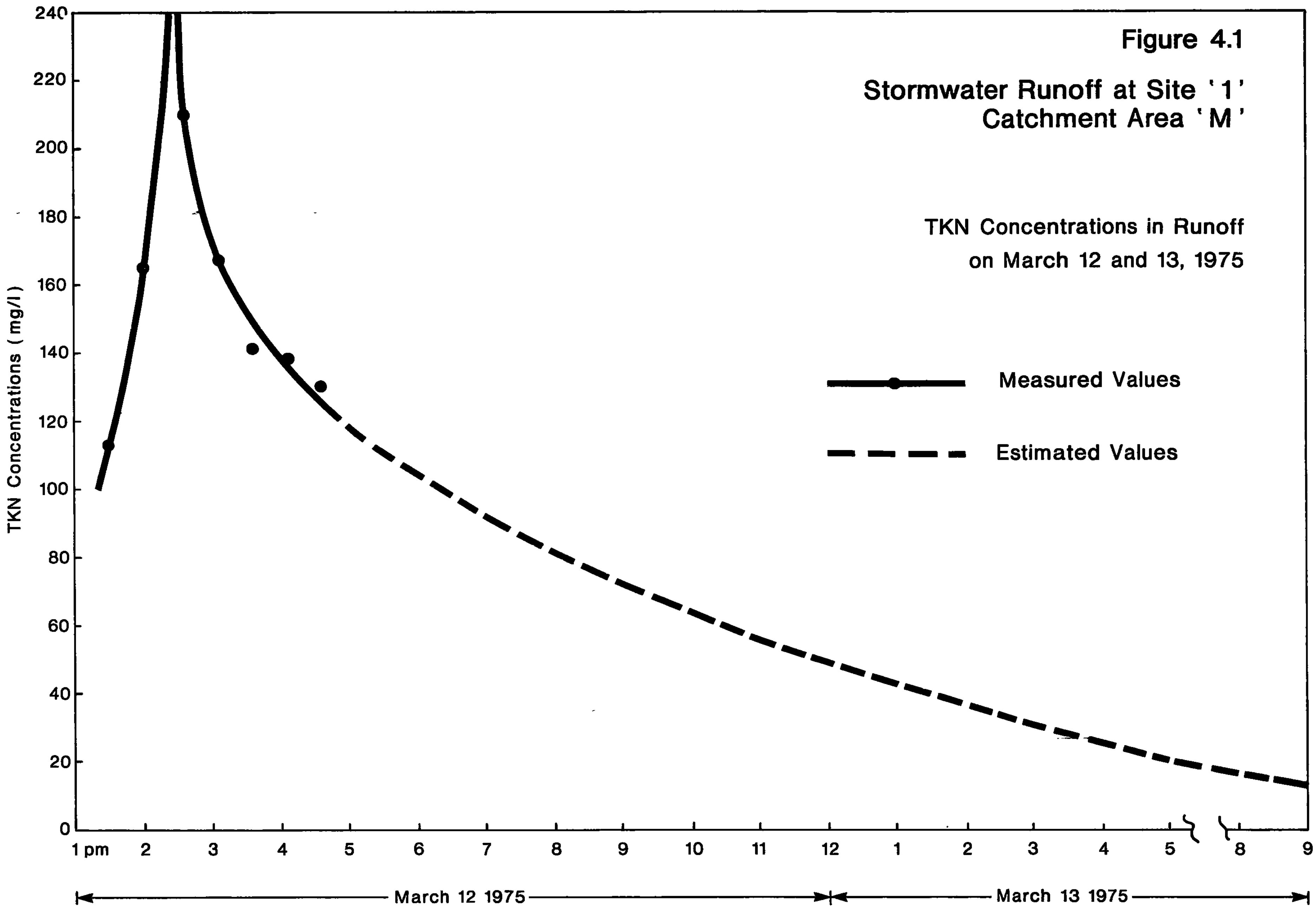


Figure 4.1
Stormwater Runoff at Site '1'
Catchment Area 'M'
TKN Concentrations in Runoff
on March 12 and 13, 1975
Measured Values
Estimated Values
TKN Concentrations (mg/l)
240
220
200
180
160
140
120
100
80
60
40
20
0
1 pm
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
8
9
March 12 1975
March 13 1975

to the grassy area boundaring the runways will be carried with runoff during snowmelt.

As the current study did not include analysis of soil or groundwater samples, it was not possible to attempt a nitrogen balance or to assess the potential for groundwater contamination through nitrate nitrogen leaching and transport. However, an estimate can be made of the maximum rate of nitrogen application to the grassed areas bordering the runways. Assuming that snow is thrown over a 100 foot wide strip along both sides of all three runways, the use of 100 tons of urea per year would result in a nitrogen application rate of 500 lb/acre, provided that no nitrogen was lost to the atmosphere or in runoff. Since it has been shown that a substantial portion of the nitrogen is lost through runoff, at least under certain weather conditions, the actual application rate would be much less than the maximum and perhaps more in the order of one-half of the maximum rate or 250 lb/acre. As a point of comparison, recommended nitrogen application rates for various crops are as follows (Ref. 2):

Corn	200 lb N/acre or less
Oats, Barley, Timothy	100 lb N/acre or less
Grasses	15-180 lb N/acre

In the study at Penticton, Nisku, and Calgary airports (Ref. 1), it was concluded that nitrogen application rates in the order of 250-350 lb/acre did not result in contamination of groundwaters. Nevertheless, the following recommendations were made:

"1. In order to avoid eventually overloading the N utilization capacity of the grass acreage within 100' of the runways, snow from the runways should be extended over more acreage. This could be done by double or triple plowing.

2. If (1) above is not practical, the grass could be harvested on the area bordering runways and disposed of as grass feed for livestock. This is a common dairy system of animal feeding (zero-pasture) and equipment is available for mowing and transport. Harvesting would remove much of the applied N.

3. Soil tests should be used for future monitoring."

Since the estimated nitrogen application rate to grassed areas at TIA is similar to the rates at Penticton, Nisku, and Calgary, it is unlikely that a significant amount of nitrogen is moving from the soil into the groundwater. However, analysis of soil and groundwater samples from areas bordering the runways is recommended in order to confirm or disprove this conclusion. In the interim, consideration might be given to the practices recommended above for ensuring that the nitrogen utilization capacity of the grass is not overloaded.

With respect to the nitrogen loading in stormwater runoff, assuming that 50 percent of the total nitrogen applied in the form of urea enters the surface drainage system, a total loading of approximately 23 tons of nitrogen would be carried in the runoff during an average winter. A major portion of this nitrogen loading is carried through the storm drainage system discharging to Etobicoke Creek with the remaining portion entering Mimico Creek.

As monitoring of receiving water quality was not included in the terms of reference for this study, a thorough analysis of the impact of airport activities on the receiving waters could not be attempted. However, a limited amount of quality data was collected during the former study on Etobicoke Creek (Ref. 7). The average concentration of total Kjeldhal nitrogen on four grab samples collected between February 20 and April 2, 1975, equalled 1.11 mg/ℓ and 2.11 mg/ℓ respectively on Etobicoke Creek as it enters and exits the airport property. This increase of 1.0 mg/ℓ in TKN in Etobicoke Creek has been attributed to the nitrogen loading carried in runoff contaminated from the spreading of digested sludge on a parcel of land on the airport property as well as the application of urea on the airfield. The relative contribution of these two nitrogen sources to the increased nitrogen levels measured in Etobicoke Creek cannot be accurately estimated as only a portion of the total runoff volume from the airport property was monitored. Data collected on the runoff event of March 12, 1975, however, indicates a nitrogen loading of 1920 pounds from a portion of the grassy area on which digested sludge was applied as compared to a nitrogen loading of 1390 pounds from a portion of runway 05R-23L on which urea was applied. As demonstrated by the above comparison, both the spreading of digested sludge and the application of urea contributed significantly to the total nitrogen loading discharged to Etobicoke Creek.

While the analysis presented above demonstrates that certain operations on the airport property contributes to raising the nitrogen concentration in Etobicoke Creek, the overall increase in TKN was generally found to be equal or less than 1 mg/ℓ. Similar results were found on two sets of grab samples collected during March, 1977 as reported in Appendix D. In addition, a review of water quality data reported by the Ontario Ministry of the Environment on Etobicoke Creek at Derry Road East, upstream of the airport property, and at Burnhamthorpe Road downstream of the airport property indicates no significant difference in the nitrogen content. The average concentration of total Kjeldhal nitrogen and ammonia nitrogen on seven grab samples collected on corresponding days during 1976 equalled 0.781 and 0.077 mg/ℓ respectively at the Derry Road East station as compared to 0.794 and 0.077 mg/ℓ respectively at the Burnhamthorpe Road station. Based on this very limited analysis therefore, it would appear that airfield deicing does not alter the water quality of Etobicoke Creek to a great degree. A more detailed sampling and analyses program is required to confirm the above conclusion.

The nitrogen loading carried in runoff from the airport property eventually reaches Lake Ontario through Etobicoke and Mimico Creeks. As a note of comparison, the yearly nitrogen loading to Lake Ontario from all sources was estimated to equal approximately 190,000 tons during 1974 (Ref. 3). Given the comparatively small nitrogen loading from Toronto International Airport, equalling only 0.012 percent of the total nitrogen loading on Lake Ontario, it can be seen that the airfield deicing operation does not contribute significantly to the total nitrogen loading on the lake.

4.2.2 Aircraft Deicing

Aircraft deicing commonly involves spray application of a heated deicing fluid to the aircraft. The deicing fluids generally used are a mixture of water and glycol compounds which are heated to approximately 82°C (180°F) before application. The heated fluid serves to melt the ice and snow while the glycol content prevents any further ice formation on the aircraft.

Aircraft deicing at TIA is currently performed at the gate positions of Terminals 1 and 2 by the ground staff of the respective airlines using mobile ground equipment. Two types of deicing fluids are used by the airlines, manufactured in Canada by Dow Chemical of Canada Limited and Union Carbide

Canada Limited respectively. The composition and quality characteristics of the deicer fluids is given in Table 4.2. The Dow product is supplied in the diluted form whereas the Carbide product contains only a small amount of water. The latter product is diluted to approximately 50 percent water content before application, hence the solution as used has similar composition and quality characteristics as the Dow product. The most significant features of the deicing fluids are the high TOC and BOD concentrations which are due to the presence of glycol compounds, principally ethylene glycol and propylene glycol. The inhibitor packages consist mainly of thickening agents and trace amounts of anti-foaming agents, corrosion inhibitors and wetting agents.

A summary of reported deicer fluid usage for three consecutive winter periods by all operators of aircraft deicing equipment is presented in Table 4.3. A record of daily usage over the period between March 1, 1976 to March 31, 1977 is given in Appendix B.

As indicated by the data in Table 4.3, the total quantity of deicer fluid used over the past three winters has shown a marked reduction. This reduction may be due in part to variations in the weather conditions between these periods. However, improved operating procedures aimed at reducing deicer fluid consumption were introduced and likely had a significant effect. Both cost and environmental considerations prompted the introduction of these procedures.

As suggested by the high BOD content and large quantity of deicer fluids used, any contamination of surface drainage with these fluids can cause severe pollution. In fact, the results of work undertaken at other airports (Ref. 4,5) as well as the findings of this study, have shown that aircraft deicing operations are one of the most significant non-point pollution sources at an airport. The main factors contribu-

TABLE 4.2

COMPOSITION AND QUALITY CHARACTERISTICS OF AIRCRAFT DEICER FLUIDS

COMPOSITION	DOW	UCAR
Water	50%	5%
Ethylene glycol	32%	56%
Propylene glycol	16%	38%
Inhibitor package	2%	1%

QUALITY CHARACTERISTICS		
TOC (mg/l)	261,000	460,000
BOD_5 (mg/l)	360,000 - 420,000	710,000 - 800,000
pH	8.8	8.7

TABLE 4.3

QUANTITY OF DEICER FLUID APPLIED DURING THREE CONSECUTIVE WINTER PERIODS

Aircraft Deicer Operators	Quantity Applied (Imperial Gallons) 1974/75	1975/76	1976/77+
Air Canada	152930	84120	56610
CP Air	17265	8350	29838
General Aviation	33464	42119	14869
Wardair	4260	N.D.*	2445
North Central	1027	405**	2310
Great Lakes	620	N.D.*	N.D.*
TOTAL	209,566	134,994	106,072

* No Data (N.D.)

** Approximate

\+ Does not include April and May, 1977 deicer usage.

ting to the contamination of surface drainage are: the dispersed nature of the operation over the apron area which precludes easy isolation of the pollution source; the high percentage of deicer fluid washed off the aircraft onto the apron; and, the high organic content of the deicer fluid. It has been estimated that less than 20 percent of the deicer fluid applied remains on an aircraft (Ref. 6) although this figure will vary substantially depending upon the mode of application and surface temperatures.

Results of the current study indicate that deicer fluid reaching the apron area follows one or all of three pathways:

(i) it enters the storm sewer system directly through surface runoff. Field observations and grab samples taken during low runoff periods following aircraft deicing indicated that deicer fluid was reaching the storm drainage system directly.

(ii) it is retained on the apron area and washed off during subsequent storm runoff events. All runoff samples collected during the winter months were found to contain significant BOD concentrations indicating that deicer fluid was being retained on the drainage area.

(iii) it is removed from the apron surface during snow removal operations. Samples of snow collected from the snow dump located in the grassy area opposite Terminal 1 and between taxiways Fox Trot and Victor were found to contain high BOD levels. Samples taken from the top and bottom of the snow pile on January 26, 1977 were found to contain 9,200 and 53,600 mg/l of BOD, respectively. A second set of samples collected on February 2, 1977, from another location in the same dump area measured 2,500 and 4,350 mg/l of BOD on samples taken from the top and bottom of the pile, respectively.

The amount of deicer fluid removed from the apron areas during snow removal operations is unknown. However, as snow removal generally is undertaken prior to commencement of aircraft deicing activities, particularly following a heavy snowfall, it is probable that only a small percentage of the total deicer fluid applied is removed with the snow.

Regardless of which of the above routes the deicer fluid follows it ultimately reaches the receiving waters, as the drainage system from the apron and surrounding areas at Terminals 1 and 2 discharge directly to Etobicoke and Mimico Creeks respectively. The total BOD loading reaching the receiving waters during the past three winter seasons, therefore, has equalled approximately 654,000, 421,000 and 331,000 pounds during 1974/1975, 1975/1976 and 1976/1977 respectively. The above figures were estimated based on an average BOD concentration of 390,000 mg/l for the deicer fluid and an assumed washoff rate from the aircraft of 80 percent of the total fluid applied.

As a means of comparison, the estimated BOD loadings given above are equivalent to the annual BOD loading from a population of 5,000 to 10,000 persons, assuming a BOD contribution of 0.17 pounds per capita per day. It is apparent therefore that runoff contaminated through aircraft deicing carries a substantial BOD loading.

4.2.3 Fueling and Defueling Operations

Fuel for all aircraft operating from both terminals is provided by Consolidated Aviation Fueling. The jet fuels, JP1 and JP4, are stored in tanks both above and below grade elevation at the tank farm located on the airport property. The fuels are delivered from these tanks through buried pipe to distribution headers around each terminal. A normal fueling operation involves connecting a fuel truck to a distribution hydrant and pumping the fuel on board the aircraft. Occasionally, an aircraft must be defueled and a fuel truck is used to remove and contain the unloaded fuel. Operating regulations require that the fuel removed from an aircraft must be loaded back on the the same aircraft.

Fuel spills occur frequently on the apron areas even though precautions are taken to prevent these occurrences. Airport operating regulations require that all spill occurrences be recorded and monthly summary reports are prepared by Consolidated Aviation Fueling. In addition, spills of any significance are reported immediately to the Emergency Services Group for appropriate action. This generally involves washing the spilled fuel into the nearest catchment basin. In some cases sand or other dry adsorption materials are used. Reports of these spill events as well as others reported occurring elsewhere on the airport complex, are also maintained by the Emergency Services Group.

There are other miscellaneous sources of fuel losses on the apron areas, such as from the fuel hydrants, as a result of improper hose coupling and drainage from the hoses during uncoupling. The hydrants are situated in concrete chambers below the apron level and are subject to flooding during rain storms. In order to gain access to the hydrants, it is necessary to pump out the chamber contents. In these cases the contents, which are a mixture of jet fuel and water, are normally discharged onto the apron surface.

A summary of fuel spill reports prepared by Emergency Services Group is presented in Appendix C. The records indicate that most reported fuel spills occur on the apron areas of Terminals 1 and 2. In total, there were 132 spills between March 6, 1976 and April 9, 1977, resulting in an estimated loss of 3,060 gallons of jet fuel (excluding a major spill at the Consolidated Aviation Fueling tank farm). Based on these figures, the average quantity of spilled fuel equalled approximately 23 gallons, ranging from 1 to 100 gallons per spill. In comparison, there were 106 reported spills between May 1, 1974 and April 9, 1975, having an estimated total fuel loss of 1,825 gallons for an equivalent average spill quantity of 17 gallons.

As noted previously, fuel spills occurring on the apron areas of the terminals are generally washed into the storm sewer systems. Since the sewers are not equipped with oil separators, all fuel losses subsequently reach either Etobicoke or Mimico Creeks.

4.3 Identification of Management Alternatives

4.3.1 Scope of Problem

Monitoring of stormwater runoff quality on three principal catchment areas at Toronto International Airport has shown that contamination of runoff results mainly from non-point source airport activities. Specifically, these contamination sources include:

(i) urea hydrolysis and washoff from the airfield areas, particularly the runways, following the application of urea as an anti-icing or deicing agent;

(ii) aircraft deicer fluid runoff onto the apron areas while aircraft are being deiced at the gate areas prior to departure; and,

(iii) jet fuel spillage onto the apron areas while fueling and defueling aircraft.

In addition to the above sources, the high level of activity around the terminal facilities enhances the rate of accumulation of organic and suspended matter. As a result, the first flush of runoff from the apron areas during the summer and fall period can contain upwards of 100 to 300 mg/l of BOD. However, the BOD concentration generally decreases very rapidly with increasing flow to less than 25 mg/l. Suspended solids concentrations were also found to demonstrate a very similar pattern to the BOD concentration profiles.

Development of a stormwater management strategy for Toronto International Airport therefore, mainly involves the control of pollutant loadings from the apron areas. The principal exception to the above, notwithstanding recommendations put forth in the 1975 study (Ref. 7) regarding the management of point source pollution problems, is the contamination of surface runoff from the runways as a result of airfield deicing using urea.

4.3.2 Airfield Deicer Management Alternatives

Runoff from the runways during the winter months has been shown to contain fairly high nitrogen levels as a result of using urea for deicing purposes. Since it is essential to maintain the runways free of ice for safety reasons, elimination of urea usage is not a practical consideration. Furthermore, there are few suitable substitutes which are non-corrosive to aircraft bodies and will provide the required level of freeze protection.

Alternatively, management of runway runoff during the winter season could involve collection of the runoff for subsequent treatment to remove the nitrogen content. This approach would require the interception of runway runoff which is collected at catch basins located on the asphalt shoulders and is transported through perforated piping to numerous points of discharge throughout the airport property. Interception of these drainage systems would require the installation of several miles of collection sewers as well as storage, pumping and treatment facilities. A disadvantage of this alternative is that only a portion of the total runoff nitrogen loading would be collected for treatment as it has been estimated previously that approximately 50 percent of the urea applied to runways is picked up during snow removal operations and spread on the bordering grassy areas. It can be expected therefore that some portion of this nitrogen loading will be carried in overland runoff to the receiving waters during snow melt conditions.

In view of the foregoing considerations, it was concluded that collection and treatment of runway runoff would represent a very costly solution which would not effectively eliminate the nitrogen loading on the receiving waters. For these reasons, this alternative was found to be an impractical solution. Furthermore, it was shown previously that the nitrogen loading discharged to Etobicoke Creek as a result of urea usage does not appear to substantially alter the nitrogen concentration in this receiving water. It would appear therefore, that urea usage does not present a serious environment problem although additional monitoring on the receiving water is recommended to confirm this conclusion.

As a final management alternative, it is recommended that urea usage be closely monitored and controlled to ensure that excessive quantities are not applied. By closely controlling urea usage, the amount of urea potentially entering the surface runoff will be directly reduced thus minimizing the nitrogen loading on the receiving waters.

It should be noted that the conclusions made above are specific to Toronto International Airport. Work currently being undertaken at other airports in Western Canada indicates that the nitrogen loading on receiving waters resulting from urea usage for airfield deicing may be a significant source of this nutrient. Hence, it will be necessary to undertake site specific investigations at each airport to determine if management of stormwater runoff contaminated through airfield deicing is required.

4.3.3 Fuel Spill Management Alternatives

Spillage of aircraft fuel onto the apron area has previously been shown to be significant both in terms of frequency and quantity. Current operating procedures generally involve washdown of the spilled fuel into the nearest catch basin, although some small fuel spills are neutralized using a dry adsorbing substance.

The above observations are consistent with the findings of a recent study undertaken by the U.S. Department of Defence (Ref. 8) in which was concluded that:

"a. The frequency of occurrence and quantities of fuel associated with aircraft fuel spills within the DOD are significant both in terms of lost fuel and potential impact upon the environment.

b. Fueling and defueling spills can be best categorized into two groups. The first may be considered as "small" and the second as "other".

c. The present technique of water-washdown used in the majority of those cases for neutralizing "small" fuel spills is inefficient in terms of fire department resources employed and unacceptable in terms of the environmental impact."

With respect to the management of these fuel spills, that study also concluded that:

"d. "Small" category fuel spills are best neutralized by the use of dry adsorbing techniques employing either granular or mat-like products. The residual materials should be removed by trained personnel (e.g., fire department) and properly disposed of to eliminate any further potential fire or environmental hazards.

e. "Other" category fuel spills are best neutralized by the flush method using water supplemented, as required, with either foaming or other fire suppressing agents. For those installations where a central ramp service area drainage collection system exists, the volumes of wastes discharged from such activities should be held and treated prior to release into the environment. For those installations where no such collection system exists, consideration should be given to the possibility of picking up (removing) the fuel-water mixture using such devices as wet-vacs and providing subsequent adequate treatment prior to discharge into the environment."

The above management alternatives for neutralizing fuel spills are equally applicable to Toronto International Airport. It is recommended therefore that:

(i) small fuel spills not presenting a fire hazard be treated using an adsorbing material. As there are several types of adsorbing materials available on the market for such use, the Emergency Services Group should undertake testing to establish which material(s) best suit their requirements.

(ii) fuel spills presenting a fire hazard continue to be washed off the apron area into the storm sewer using water supplemented, as required, with fire suppressing agents. Provisions to collect and treat the contaminated runoff are also recommended as discussed in sub-section 4.4.

(iii) the use of such devices as wet-vacs be investigated as an alternative method for managing large fuel spills rather than washing the spilled fuel into the storm sewer system as recommended in item ii) above. While this approach would provide a more positive means for managing the larger fuel spills, further investigation is required into operational aspects as well as the adequacy of protection provided against fire hazards. In addition, consideration must be given to the fact that a portion of a fuel spill may gain direct access to the storm sewer before clean-up measures can be enacted. Provision of in-line collection facilities in the storm sewer system may still be warranted where this condition exists.

4.3.4 Aircraft Deicing Management Alternatives

In investigating waste management alternatives for controlling or minimizing contamination of surface runoff from the aircraft deicing activity, three basic alternatives were identified for consideration. These include:

(i) using another type of deicer fluid which is non-damaging to the environment and yet satisfies other operational requirements;

(ii) collecting and treating contaminated surface runoff for discharge of the treated effluent; and,

(iii) developing a centralized deicing pad, collecting and processing the pad drainage for recycle of recovered deicer fluid.

A discussion of the viability of these alternative management schemes follows.

Deicer Fluid Options

Various studies have been performed to identify deicer fluids to replace the glycol type fluids now commonly used. Criteria of importance to the selection of a replacement deicer fluid are as follows: it must have minimal environmental impact since a significant fraction of the quantity applied is lost with surface runoff; it must be non-corrosive to the aircraft; and, it must have good deicing properties. To date, no such deicer fluid has been discovered which satisfies these criteria. The glycol based fluids are the only ones which have found wide acceptance among the airlines.

Numerous investigations are reportedly being undertaken by the airlines aimed at reducing deicer fluid usage. These investigations include: varying the glycol content of the deicer depending upon weather conditions; and, washing aircraft initially with a hot water spray to remove the snow cover followed by a final washing using deicer fluid to prevent subsequent freezing. In this regard, it is reported that Air Canada have equipped one truck to carry out testing at Toronto International Airport during the upcoming winter season.

While there are numerous operational procedures to be resolved, it is anticipated that aircraft deicer fluid usage can be reduced substantially. Such questions as whether or not icing problems will be encountered on the apron areas must first be answered however, before a full commitment is made to revising current operating procedures.

Surface Runoff Treatment

Various investigations have been conducted into treating glycol materials both from deicing applications (Ref. 9,10) and from industrial wastewaters. Systems studied have included the broad range of physical, chemical and biological processes. The latter type processes have been found to be the most applicable and effective means for treating the glycol based fluids. Such chemical and physical processes as ozonation and activated carbon adsorption have been found to be totally ineffective in treating glycol wastes.

With respect to biological treatment, a study was recently carried out by Environment Canada (Ref. 10) to investigate the feasibility of treating deicer fluid in combination with domestic sewage using the activated sludge process. The results showed that the process was capable of producing an effluent having less than 20 mg/l of BOD and 25 mg/l of suspended solids at a biomass loading of 0.15 kilogram BOD per kilogram of mixed liquor suspended solids per day. Filamentous growth was found to present operating problems at higher organic loading rates and at the low temperatures. However, the BOD contribution of deicer fluid to the total BOD loadings in these experiments varied from 0.5 to 4.9 times the BOD contribution from the municipal sewage. At BOD ratios considerably lower than 0.5, it is not expected that filamentous growth would not present as serious an operating problem with the activated sludge system as was experienced with the experimental system.

Application of the biological concept for treatment of contaminated runoff at the airport could potentially be handled by either of two schemes, namely; construction of a biological treatment system on-site, or collection and discharge to the Regional Municipality of Peel sanitary sewer system for treatment at the Lakeview Water Pollution Control Plant.

The principal limitation pertaining to the development of an on-site treatment system is the fact that a biological system must have a continuous feed source in order to maintain an active biomass. Since contaminated surface runoff from the apron areas occurs only following snowmelt or rainstorms and only during the winter months, it would not be possible to maintain an effective biological treatment system. At best, it would be necessary to collect all domestic type wastes on the airport property for treatment in the system in order to maintain a base loading. Contaminated runoff would then have to be collected, stored and released slowly to the treatment system. The viability of such a scheme is highly questionable however, due to wide variations in BOD loading which would be encountered.

The second scheme involving collection of contaminated runoff for discharge to the Regional Municipality of Peel sanitary sewer system and treatment at the Ontario Ministry of the Environment operated Lakeview Water Pollution Control Plant was identified as a potentially viable alternative. Preliminary discussions with the region indicate that consideration would be given to such a scheme provided:

(i) that contaminated runoff is collected and stored for release to the sanitary sewer during low flow periods. Bypassing is currently necessary at the Lakeview Plant during high flow periods which coincide with storm runoff events.

(ii) that release of contaminated runoff be controlled in order to distribute the loading on the treatment system and not overload the plant.

(iii) that the contaminated runoff is discharged to the 72 inch diameter trunk sewer passing through the airport property in the Etobicoke Creek Valley.

Implementation of this alternative therefore would require interception of those storm sewers carrying contaminated runoff and storage of the runoff for controlled discharge to the sanitary sewer system during low flow conditions.

Recovery and Recycle of Deicer Fluid

Another potential solution for eliminating contamination of surface runoff and the receiving waters involves centralizing the deicing operation at one location where the deicer fluid can be recovered and processed for reuse. This scheme would not only minimize the environmental impact of aircraft deicing but may also offer the potential advantage of reducing operating costs through recovery and reuse.

The principal features of the centralized deicing facility include: an extensive pad area on which the deicing operation is carried out; receiving and storage facilities for virgin deicer fluid; collection and storage facilities for containment of the contaminated surface drainage; recovery facilities to reclaim deicer fluid from the surface drainage; and, finally, the deicer application equipment. While a properly designed pad facility could contain most of the deicer washed off the aircraft, some losses are expected. Reported figures on estimated glycol recovery for the centralized deicing facilities at Charles de Gaulle Airport in Paris, France, and Mirabel International Airport in Montreal, Quebec, vary between 70 and 80 percent (Ref. 11). Collection and treatment of contaminated runoff from around a centralized deicing facility must therefore be provided.

While a centralized deicing facility offers the advantage of containing and minimizing a significant pollution problem the alternative is also beset by several disadvantages. These include: a high capital investment estimated at approximately $6,500,000 for a two position facility (excluding the cost of glycol recovery equipment); flight delays during peak hours of aircraft movement; high operating costs for distillation of excess water from the collected runoff; and, the requirement to collect contaminated runoff from an area beyond the deicing pad for treatment.

Furthermore, in light of current investigations into means of reducing deicer fluid usage, the practicability of a centralized facility is somewhat questionable. Until answers are put forth in response to the many questionable areas, however, a centralized deicing facility must be considered a potentially viable alternative.

4.4 Stormwater Management Facilities

4.4.1 Identification of Management Alternatives

From an evaluation of stormwater contamination problems and management alternatives as discussed in previous sub-sections it was established;

(i) that aircraft deicing represents the most serious stormwater contamination problem at the airport. Collection and treatment of the apron and snow dump area runoffs is required during the winter and spring periods therefore, for removal of the high BOD content. Alternatively, management of apron drainage will not be necessary if it is determined that a centralized deicing facility represents a more economical and practical solution. Further investigation into the applicability of a centralized deicing facility for Toronto International Airport by Transport Canada personnel is recommended based on their experience with the installation at Mirabel International Airport. In addition, the results of work to be undertaken by Air Canada during the upcoming winter season on field investigations into means of reducing deicer fluid usage must be taken into consideration in the overall analysis;

(ii) that jet fuel spillage represents the second most significant stormwater contamination problem. Provisions for treatment of apron area runoff to separate spilled fuels will be required unless methods for managing fuel spills on the apron are enacted. Treatment of small fuel spills using a dry adsorbing material is recommended nevertheless, as this approach is the most effective means of mitigating potential environmental damage.

With respect to the treatment of these contaminated runoff streams several alternatives were investigated including:

(i) provision of a multi-purpose facility which would serve as a holding facility for storage of winter runoff as well as effect oil and solids separation. The collected winter runoff would subsequently be released to the regional sanitary sewer system for treatment at the Lakeview Water Pollution Control Plant. The facility would also be operated as a flow through system during the summer and fall to provide oil and solids separation; and,

(ii) provision of in-line oil and solids separation facilities on the drainage sewers from the apron areas with off-stream storage facilities for holding winter runoff for subsequent release to the municipal sewerage system.

From a preliminary evaluation it was determined that a multi-purpose facility would be the most cost effective and therefore was selected for further analysis. In addition, the options of providing separate or combined facilities for storing runoff from the apron areas of Terminals 1 and 2 were also considered. However, it soon became evident that the separate facilities would be more satisfactory from an operations viewpoint and would also minimize construction requirements for large diameter storm sewers.

Analysis of the storm sewer systems to identify possible points of interception indicated that, in general, it is necessary to treat runoff from large areas. Those areas identified for interception of stormwater runoff (see Figure

4.6 enclosed in a pocket at the back of the report) include: all of the apron area around Terminal 1; the apron area on the south side of the Air Cargo area; all of the apron area on the southerly and easterly sides of Terminal 2; as well as, the area drained by the closest storm sewer to Terminal 2 on the northwesterly side. The total area from which runoff would be collected at Terminals 1 and 2 equal 80 and 105 acres respectively.

Specifically excluded from the areas identified for interception are the grassy areas opposite Terminal 1 where snow removed from the aprons is currently dumped. These areas were excluded as future use of these areas as dump sites is uncertain. Airport development plans reportedly have allowed for the extension of taxiway Romeo around the outer edge of the Terminal 1 apron. It has also been suggested that snow melting equipment may be employed on the apron areas. If snow dumping is continued in the future, then it is recommended that the dump area be suitably graded and drained so that the contaminated runoff can be collected and discharged to one or both of the proposed storage facilities.

4.4.2 Proposed Management Facilities

Storage Facilities

In order to establish the size of the storage facilities required to contain runoff between the period from November 16 and May 15, five years meterological data was processed using the model STORM. From this computer output data, it was determined that there are an average of 42 runoff events per winter yielding a total average seasonal runoff volume from the apron areas equal to 10.35 inches of equivalent rainfall for an average of 0.246 inches per event. Further analysis of the simulated runoff data indicated that there were several runoff events in the range of 0.50 to 0.84 inches of equivalent rainfall and a limited number of events of much greater magnitude. The maximum simulated runoff event equalled 1.93 inches.

Since sizing the multi-purpose storage facilities to contain the largest expected runoff event would clearly result in an excessive expenditure of capital, the data was further evaluated to establish the optimum design basis. From this analysis, it was found that sizing the storage facilities on the basis of runoff volume of 0.84 inches (i.e. 0.84 inches ÷ 12 inches/foot x no. of acres x 43,560 square feet/acre = cubic feet of storage volume required) will allow the collection of approximately 95 percent of the total winter runoff. The runoff volume from 39 out of 42 events would be collected in total from treatment with by-passing occurring only on the remaining three events.

In order to ensure that peak flow from all expected runoff events over the design period receive treatment, it is proposed that the inlet and outlet works be designed to pass the peak flow from a 1 in 2 year return period storm. Flows in excess of the 1 in 2 year return storm would be by-passed at the interceptor facilities shown on Figure 4.4 and 4.6.

For the Terminal 1 drainage area, the peak flow for a 1 in 2 year storm, was computed using SWMM to equal 175 cfs, as shown in Figure 4.2. This flow is greater than the capacity of the existing sewer system, which is estimated to equal 100 cfs. Therefore, the allowable peak flow rate for the Terminal 1 facility was set at 100 cfs. It is believed that surcharging is occurring in the sewer system when the peak flow exceeds 100 cfs. Prior to detailed design of the stormwater management facilities further sewer analysis should be performed to determine the significance of the

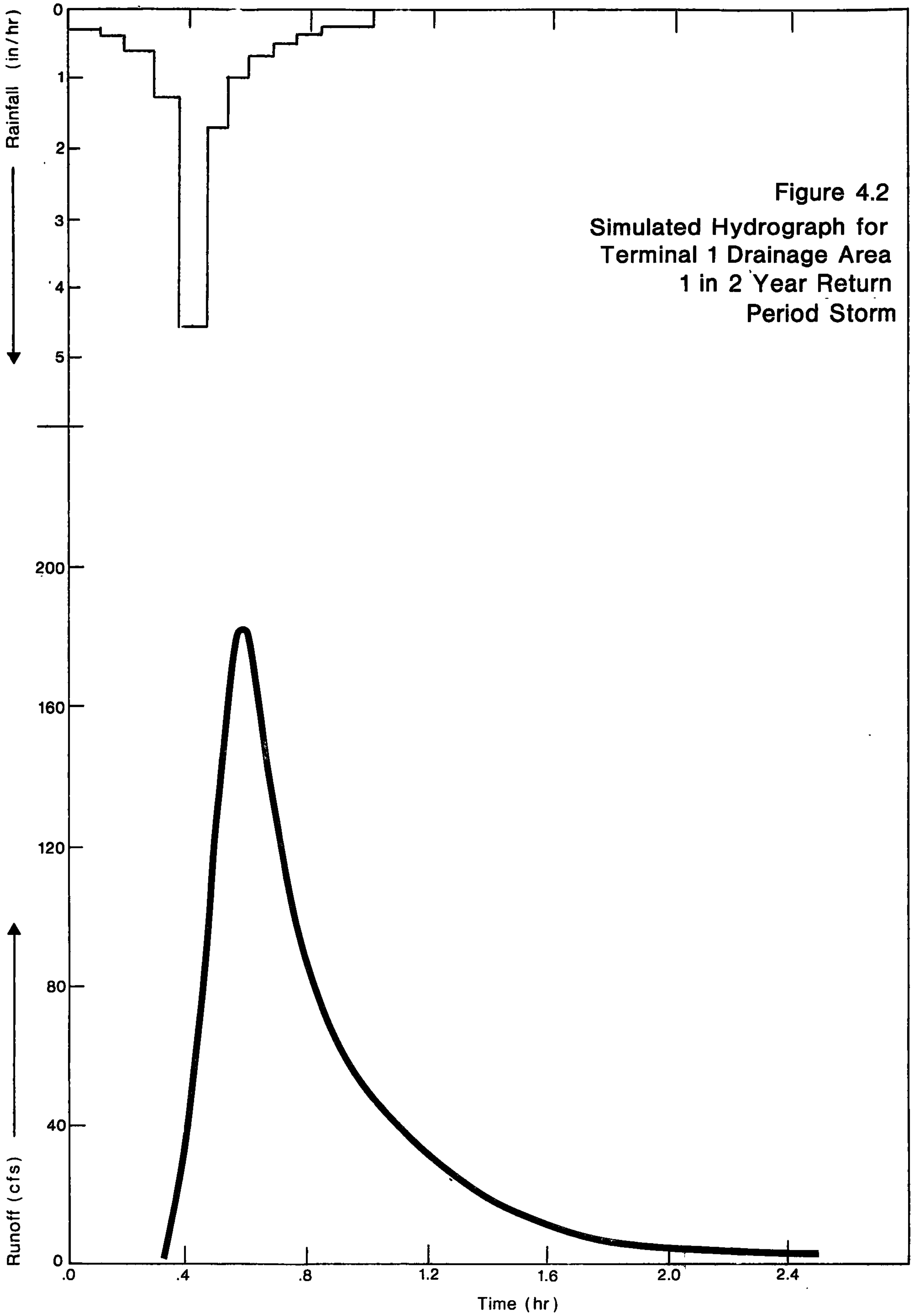


Figure 4.2
Simulated Hydrograph for Terminal 1 Drainage Area 1 in 2 Year Return Period Storm

surcharging problem and if corrective measures are warranted.

For the Terminal 2 drainage area, the peak flow for a 1 in 2 year storm computed using SWMM was found to equal 180 cfs, as shown in Figure 4.3, which is within the capacity of the existing sewer system.

Withdrawal from the storage facilities will be accomplished by means of variable speed pumps with discharge to the regional sanitary trunk sewer as shown on Figure 4.6 (enclosed at the back of the report). From an analysis of pump out time requirements, it was established that a peak pump out rate equal to 0.01 cfs per acre is required to ensure that the storage facilities are emptied within a reasonable time period. A full storage tank could be emptied in approximately 3.5 days at the peak pump out rate. However, it is proposed that the pump out rate be decreased as the storage tank volume lowers. This will allow distribution of the loading on the sewage treatment plant over a longer period of time and thus optimize performance of that system. In addition to the above design features, it is proposed that the storage facilities be operated as flow through systems during the summer and fall months to achieve oil separation on drainage from the apron areas.

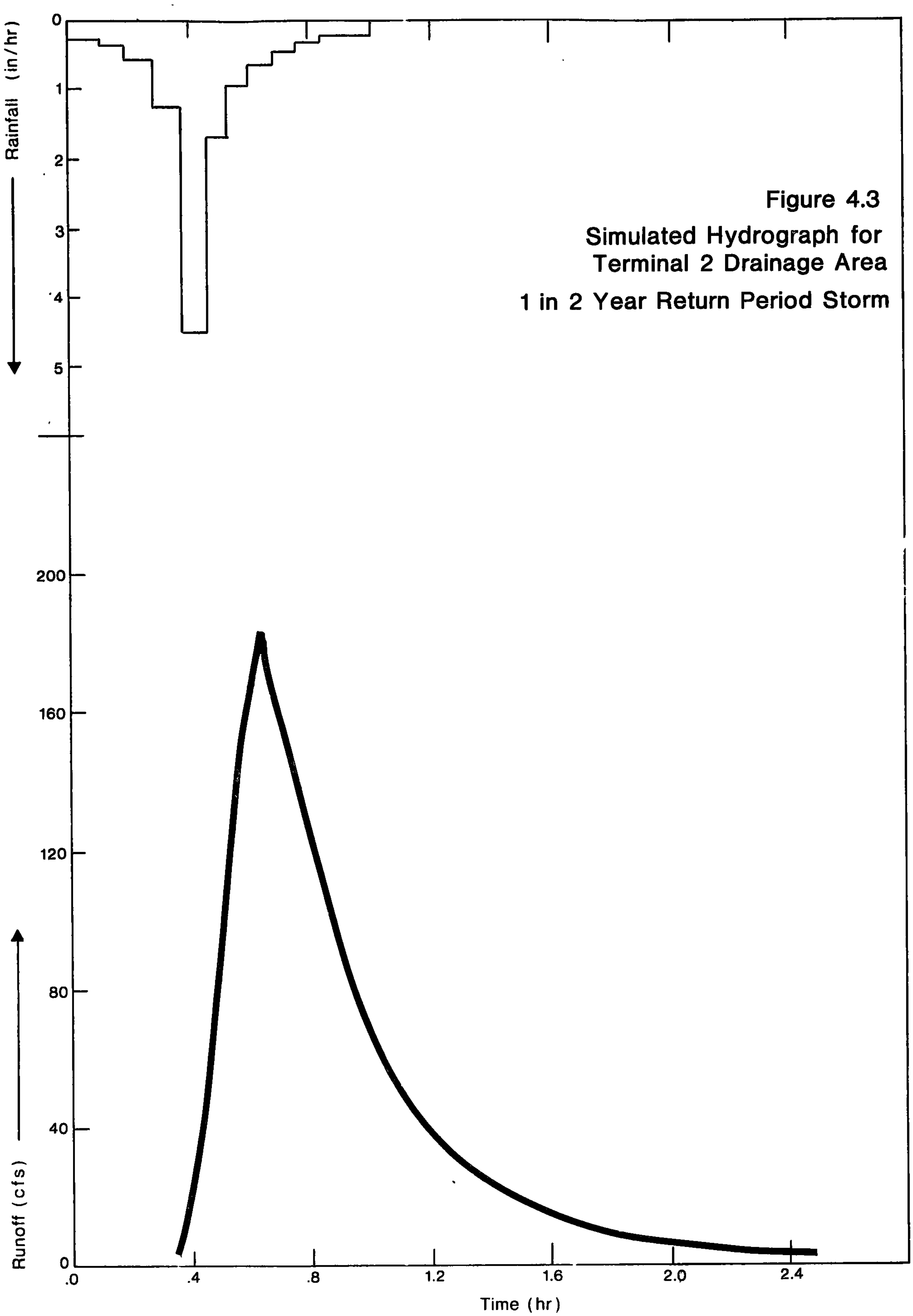
Design details for the respective storage facilities are therefore as follows:

Terminal 1:	Runoff Area	80 acres
	Storage Capacity	245,000 cubic feet
	Allowable Peak Flow Entering Facility	100 cfs
	Pump out Capacity	0.8 cfs

Figure 4.3

Simulated Hydrograph for Terminal 2 Drainage Area

1 in 2 Year Return Period Storm



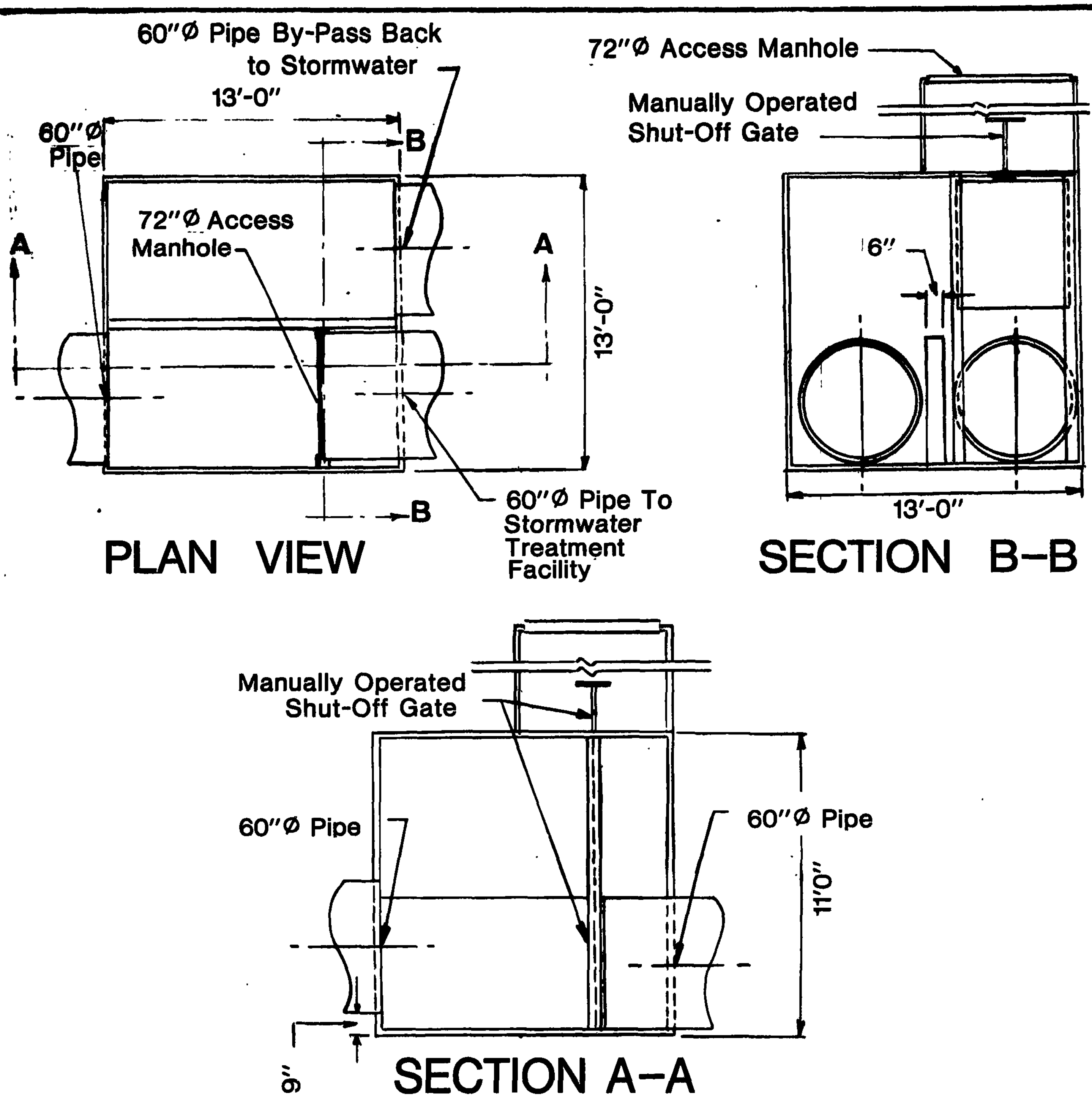
Terminal 2:	Runoff Area	105 acres
	Storage Capacity	320,000 cubic feet
	Allowable Peak Flow Entering Facility	180 cfs
	Pump out Capacity	1.05 cfs

Ancillary Facilities and Operational Aspects

Installation of the stormwater management facilities will require new sewers, as well as the rerouting of some existing sewers. Proposed locations for the new and rerouted sewers and the stormwater facilities are shown in Figure 4.6.

Flow to each facility will be controlled by interceptor manholes similar to the one shown on Figure 4.4 for the Terminal 2 drainage area. This structure will ensure that only the maximum allowable flow will enter the facility. Any excess will overflow the dividing wall within the structure and enter the bypass sewer with connection to the existing storm sewer system. The underflow baffle in the interceptor manholes has been provided to retain floating oil during peak flow conditions.

The storage/treatment facility proposed for Terminal 2 is illustrated in Figure 4.5 (enclosed in the pocket at the back of the report). A similar facility would be installed at Terminal 1. It is proposed that the flow entering each facility will first pass through a tilted plate separator to remove grit and sand. This treatment step is recommended in order to avoid the accumulation of grit and sand within the storage tank. It will also enhance the agglomeration of emulsified oil thus improving performance of the subsequent oil separation chamber. Grit and sand removed in the tilted plate separator will be allowed to accumulate in a bottom hopper from which it will be periodically withdrawn. The



TYPICAL STORMWATER INTERCEPTOR FACILITY

JAMES F. MacLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS & SCIENTISTS
WINDSOR · LONDON · WATERLOO · TORONTO

DATE: AUGUST, 1977 | FIG. No. 4.4

bottom hopper would be provided with an auger cross collector, or other suitable device, feeding the suction side of a pump which would lift the grit and sand to ground elevation. The grit and sand slurry would then be dewatered in a grit concentrator with supernatant return to the influent manhole. Dewatered grit would be loaded unto a dump truck and hauled away to a landfill site.

Sizing of the tilted plate separator for the Terminal 2 facility was based on a design flow of 75 cfs. Analysis of runoff data for the five year simulation period showed that greater than 90 percent of the runoff events had peak flows of less than 75 cfs and for this reason is proposed as a reasonable design basis. For those runoff events having greater peak flows, the tilted plate separator would operate at reduced efficiency resulting in carry over of solids to the oil separator chamber. A similar sized facility would be provided at Terminal 1.

The effluent from the plate separator will enter a jet fuel/glycol separation chamber occupying a portion of the storage tank. Jet fuel, glycol and other oils floating on the surface will be skimmed off and directed to a storage tank. The treated contents of the separation chamber will then overflow a dividing wall and enter the remaining portion of the storage facility.

Sizing of the oil separation chamber was based on providing effective treatment to flows up to 30 cfs. This design flow was selected on the basis that jet fuel retained on the apron surface and within the sewer system will normally be carried with the initial runoff flush before peak flows are reached. In addition, analysis of the five years of simulated runoff data indicated that a high percentage of the runoff events had peak flows of less than 30 cfs.

Normal operation of the storage facility, including the oil separation chamber, will involve pump out of the tank contents during the winter months with discharge to the sanitary trunk sewer located in the Etobicoke Creek Valley for treatment at the Lakeview Water Pollution Control Plant. Under this mode of operation, the separation chamber will usually be empty prior to a runoff event. Hence, this chamber will serve to hold a majority of the runoff occurring during the winter period and allow for more efficient separation of glycol and jet fuel. Pump out will occur only during dry periods between each runoff period for reasons outlined previously. It is also proposed that the pump out rate be decreased as the storage tank water level is lowered in order to distribute the loading on the treatment plant.

During the summer months the storage facilities will operate as flow through basins to provide oil separation. The effluent from the facilities will be directed back to a nearby storm sewer via the basin overflow outlets.

Costs and Implementation Schedule

Capital cost estimates for the stormwater management facilities were developed based on such items as:

(i) construction of the storage basins;
(ii) construction of the interception facilities;
(iii) laying of new sewers;
(iv) rerouting of existing sewers;
(v) construction in a restricted area.

The estimated capital costs related to ENR (Toronto) Construction Cost Index of 2700 are as follows:

Storm sewers, intercept manholes and sanitary sewers	$1,185,000
Terminal 1 storage facility	1,860,000
Terminal 2 storage facility	1,985,000
Total Cost	$5,030,000

These costs exclude engineering, contract administration, escalation allowance, land and legal costs.

It is estimated that an 18 to 24 month period will be required for design and construction of the proposed facilities. Negotiations with the Regional Municipality of Peel and the Ontario Ministry of the Environment must be entered into first however, to obtain agreement for discharge to the regional sewer system.

Operating costs for the recommended multi-purpose storage and treatment facilities for Terminals 1 and 2 will include such items as removal and disposal of solids from the plate separation portion of the facilities; removal and disposal of the contents of the fuel skimming storage tanks; operation of the pumping units; as well as, regular maintenance on the tanks and associated mechanical equipment. In addition, an agreement must be entered into with the Regional Municipality of Peel for discharge of runoff during the winter period to the regional sewerage system. Under this agreement the operating authority (i.e. Transport Canada) will be assessed a sewer use charge based on the volume of waste water discharged to the sewer system, which currently equals $720 per million gallons, as well as, a BOD surcharge which currently carries a cost equivalent to $440 per million gallons (Ref. 12). For an average winter runoff volume of 10.35 inches from 185 acres of apron area, the base charge will equal approximately $31,000 per year. The BOD surcharge assuming an average winter usage of 100,000 gallons of deicer fluid (i.e. 50:50 solution) and a BOD concentration of 390,000 mg/l for the deicer fluid will equal an additional $15,000 per year. The total sewer use charge payable to the Region therefore will be in the order of $45,000 to $50,000 per year.

4.5 Recommended Methodology for Stormwater Management at Canadian Airports

This study provides the basis of a methodology for stormwater management at Canadian airports. Simulation of runoff events and identification and quantification of significant pollutant loadings are the key components of this methodology.

The usefulness of the simulation models SWMM and STORM in designing stormwater management facilities has been clearly demonstrated. SWMM can be used to accurately predict the shape of the runoff hydrograph for any design storm event. Calibration of SWMM was found to be very straightforward and may not be necessary at all except in very detailed applications.

STORM was also shown to be a valuable tool in the design of stormwater management systems. STORM can provide a continuous record of total runoff volumes for all storm events over a period of several years at a reasonable cost. Such data are required for assessing alternative storage and treatment systems.

Simulation of runoff hydrographs from snowmelt and rain-on-snow events using either SWMM or STORM was found to be less accurate. However, total runoff volumes were estimated fairly accurately by both models.

Quality simulations using SWMM can reproduce BOD and suspended solids concentrations under summer conditions within a reasonable degree of accuracy. However, the concentrations of these pollutants under summer conditions are not the major concern related to stormwater management. The primary purpose for this type of simulation would be in assessing the impact of stormwater discharges on receiving waters.

The major stormwater pollutants resulting from airport operations are contamination of surface runoff resulting from the application of aircraft deicer fluids and spillage of jet fuel. In developing a stormwater management plan for an airport, it is therefore necessary to identify areas where significant contamination from these sources is likely to occur, to determine the pollutant loading from each source, and to design drainage and sewer systems to isolate runoff from the identified areas. At Toronto International Airport, fuel spills and application of deicer fluids occur on the apron areas near the terminals. The storm sewers serving these areas are integrated with sewers serving other areas. Thus, the most highly contaminated stormwater cannot be isolated for separate treatment.

The BOD concentration in winter runoff from a catchment where aircraft deicing is carried out can be fairly accurately simulated using a modified version of the SWMM quality routine. No work was attempted on simulating the effects of fuel spills.

In summary, the hydraulic characteristics of runoff events can be well simulated using either SWMM or STORM for the purpose of developing a stormwater management plan. The models require little calibration and should be widely applicable to other airports in Canada. The quality routine of SWMM is also widely applicable for quality modelling, although calibration is required at each airport. Runoff quality data should be collected on a minimum of three storm events for each significant drainage area in order to identify the expected range in pollutant accumulation rates.

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APPENDIX A

STATEMENT OF WORK

STATEMENT OF WORK (as taken from Terms of Reference)

The study and preparation of the report will be executed in accordance with the following:

A. Airport Operation and the Effects on Stormwater Runoff

1. Identify and discuss point and non-point sources of contamination of stormwater runoff at Canadian airports, including information on the nature of sources, types of pollutants, relative importance of pollutants from each source, and pollutant loadings related to natural and operational factors.

B. Existing Stormwater Management Systems

1. Define basic objectives and concerns in stormwater collection systems as applied to existing Canadian airports and discuss the manner in which existing system design concepts reflect these objectives.

2. Discuss the effects of existing stormwater collection systems at airports on physical and chemical characteristics of runoff water.

3. Discuss measures which have been incorporated into the design of stormwater collection systems which afford protection to the receiving environment.

C. Runoff Hydrographs and Pollutographs

1. Review all available runoff data for selected drainage areas at Toronto International Airport.

2. Conduct an in-depth stormwater runoff monitoring program on selected drainage areas within the Toronto International Airport complex. Selected drainage areas, as defined in a previous study, include:

   (i) CATCHMENT AREA K: one of the largest single catchments having a total area of approximately 495 acres of which 52 percent is level, grassy area and 48 percent consists of paved areas and building rooftops, mainly of Air Canada and Wardair aircraft maintenance facilities. External drainage enters this area through culverts under Airport Road. The extent of the external drainage area has not been clearly defined at present. The outfall from the area is located near a storage facility commonly referred to as Fort Knox and is located in the Etobicoke Creek water shed.

   (ii) CATCHMENT AREA M: a clearly defined drainage area of approximately 399 acres, containing the apron area and a portion of the building facilities at Terminal 1, runways, taxiways and grassy area. Runoff from building, apron and grassy areas is carried through a closed pipe system to a 72-inch diameter outfall. The runways and taxiways are drained with perforated piping used to stabilize the groundwater table and also to handle storm runoff from these areas. The perforated piping is connected to the main drainage sewer. The outfall is located on Etobicoke Creek about 1/4 mile north of the MacDonald Cartier Freeway (Highway 401).

(iii) CATCHMENT AREA S: an area draining the apron at Terminal 2, virtually impervious, storm runoff quality representative of the characteristic activities carried out of the aprons. The drainage area contains 57 acres with only a small fraction of grassy area. Runoff is conveyed through a closed pipe system which discharges into an open ditch flowing towards Mimico Creek.

3. Assign monitoring stations at strategic locations throughout selected drainage areas for the purpose of defining the nature and relative importance of each pollutant.

4. Equip each monitoring station with a 24-hour recording flow meter and automatic sampler (supplied by EPS). The accuracy of the flow meter shall be within the range of $\pm$ 10 percent of the daily flow volume. The automatic sampler shall be installed at the same point as the flow meter. Initiation of sampling intervals and frequency of sample collection will be such that statistically reliable data may be presented for various climatic conditions and airport activities incurred during the study period.

5. Record climatic conditions precisely including storm intensity (centimeters per hour), storm duration, storm inception, length of dry period between storm, ambient temperatures, depth and water equivalent of snowcover, amount of snow melt per day.

6. Report airport activity in selected drainage areas precisely. Airport activities may include, but are not limited to, daily aircraft movements, fire training exercises, the incidence of accidents such as fires, fuel spills, industrial spills, aircraft sanitary waste spills, etc. The method and volume of chemical required for the cleanup of accidental spills, as well as the specific location of the incident, shall be recorded.

7. Record incidents of application of pesticides in the selected open areas. Indicate the method of application, the application rate, and the total volume of pesticide applied.

8. Monitor the use of deicing agents, both for aircraft and runway deicing. Application rates in gallons per day and tons per day respectively shall be recorded, along with indication of the application site and prevailing climatic conditions.

9. Continue the monitoring and recording program for a minimum period of 40 major storm events. (A storm event shall be interpreted as a period of precipitation with a rainfall intensity of 13 millimeters/hour (0.5 inches/hour).

10. Utilizing information recorded in a previous study, as well as data collected from the monitoring of selected drainage areas at Toronto International Airport, correlate, by means of hydrographs, pollutographs and hyetographs, stormwater flow, BOD, SS, rainfall intensity and duration and snowmelt.

11. Determine and illustrate by means of statistical analysis and/or graphical display, the correlation between quantity of stormwater runoff and the following:

    (i) total area drained, topographic features, surficial soil characteristics, hydrogeological characteristics

    (ii) storm duration and intensity

    (iii) length of dry period between storms

    (iv) ambient temperature

    (v) depth and water equivalent of snowcover

    (vi) amount of snow-melt per day

    (vii) airport operations (including accidental spills, etc).

12. Determine and illustrate by means of statistical analysis and/or graphical display, the correlation between quality of stormwater runoff and the following:

    (i) total area drained, topographic features, surficial soil characteristics, hydrogeologic characteristics

    (ii) storm duration and intensity

    (iii) length of dry period between storms

(iv) ambient temperatures

(v) depth and water equivalent of snowcover

(vi) amount of snow-melt per day

(vii) airport operations (including accidental spills, etc).

D. Storm Water Management Model (SWMM) and Storage, Treatment and Overflow Model (STORM) Refinement

1. Apply the SWMM and STORM computer models to the three selected drainage areas at Toronto International Airport.

2. Utilizing information and data collected in a previous study at Toronto International Airport, calibrate the runoff models for the selected drainage areas at Toronto International Airport.

3. Refine the SWMM and STORM models following the collection of runoff quantity and quality data, as discussed previously.

4. Discuss the accuracy and confidence limit of the SWMM and STORM models and compare predicted quantity and quality runoff characteristics with actual measurements for storms of various intensities and durations at Toronto International Airports.

E. Stormwater Management Models for Airports

1. Define the purposefulness of SWMM and STORM models for use in design, construction and operation of runoff drainage systems at Canadian airports.

2. Outline the nature and extent of investigations which must be undertaken at each airport site prior to calibration and subsequent utilization of the SWMM and STORM models.

F. Stormwater Management Alternatives at Toronto International Airport

1. Outline the present procedures and equipment utilized by airport personnel during various airport activities in the selected drainage areas and discuss the manner in which these activities affect runoff water.

2. Utilizing the SWMM and STORM models as management and design tools, identify and assess drainage storage and treatment alternatives for stormwater runoff that will meet the present and future needs at Toronto International Airport.

G. Development of a Plan for Stormwater Management

1. Recommend a preferred type of drainage, storage and treatment system for stormwater runoff at Toronto International Airport which will meet present and future requirements, and all applicable guidelines and regulations.

2. Justify the recommended type of runoff management system and discuss the protection it will afford to the environment.

3. Outline capital and operating costs to be expected resources utilized and equipment and operating personnel required.

H. Development of Implementation Program

1. Develop an implementation program for the airport including timetable, and steps to be followed to bring about a smooth transition from the existing management system to the newly developed plan.

APPENDIX B

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: March 1976

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2	12108	1061	3413			16582
3	6993	930	2693			10616
4		324	25			349
5			253			253
6			459			459
7		91			75	166
8						
9						
10	1884	622	361			2867
11	72	30	228			330
12	982	571	608			2161
13	1913		678			2591
14	37	89				126
15	26					26
16	2904	537	676			4117
17			153			153
18	2810	400	213			3423
19	900	258	83			1241
20						
21						
22			75			75
23						
24						
25						
26						
27						
28						
29						
30						
31						
TOTAL (gal.)	30629	4913	9918		75	45535

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: April 1976

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25	1972		4275			6247
26	1797		2165			3962
27						
28						
29						
30						
31						
TOTAL (gal.)	3769		6440			10209

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: May 1976

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2						
3						
4						
5						
6						
7	683	45	650			1378
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
TOTAL (gal.)	683	45	650			1378

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: November 1976

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2						
3						
4		62	220		175	457
5		96	276			372
6						
7						
8		69				69
9		446	150			596
10						
11						
12		10		170		180
13		20			100	120
14						
15		91			25	116
16		824				824
17						
18						
19						
20		60				60
21						
22	410	208				618
23						
24						
25	858	169	320			1347
26						
27						
28						
29						
30						
31						
TOTAL (gal.)	1268	2055	966	170	300	4759

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: December 1976

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1	1958	53				2011
2						
3		204				204
4	5325		1453		250	7028
5	45					45
6	122	23				145
7	2512	1941	291		200	4944
8						
9			250			250
10						
11						
12	773	50	15		35	873
13						
14						
15						
16	359	67				426
17	3875	1020	1236		125	6256
18						
19	465	121				586
20						
21						
22						
23	338	139	50			527
24	22	65				87
25	1402	128	135			1665
26	679	225	160			1064
27	1557		1010		250	2817
28		268	150	50		468
29	914	293	40			1247
30			10			10
31	250	89			25	364
TOTAL (gal.)	20596	4686	1080	50	805	31017

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: January 1977

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1		339	146			485
2						
3		12	35			47
4	595	777	58			1430
5						
6		1105	315			1420
7	900	52		475	100	1527
8		36				36
9						
10	224		121		10	355
11	143					143
12						
13	104		225			329
14	1730	1803	1274		50	4857
15		266	66			332
16		14				14
17	16	31	75		50	172
18		25				25
19		150				150
20	82					82
21						
22		49				49
23						
24	2193	473	731		25	3422
25	2556	946	148	300		3950
26	79	31				110
27		692			40	732
28	1230	510				1740
29						
30						
31						
TOTAL (gal.)	9852	7311	3194	775	275	21407

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: February 1977

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2		120	73			193
3	250	280	38			568
4	46	759	50			855
5		30				30
6						
7						
8	116	20				136
9	20	70	30			120
10		2280	78	450	150	2958
11			6			6
12	465		9			474
13		20			150	170
14						
15						
16		99				99
17						
18			5			5
19		35	84		30	149
20		75	9			84
21		76	5			81
22						
23	5970	1038	688		190	7886
24	1122	416	30	450	150	2168
25	1027	355	223		40	1645
26					25	25
27	3752	2467	2243	500		8962
28	392	25	25			442
29						
30						
31						
TOTAL (gal.)	13160	8165	3596	1400	735	27056

MONTHLY AIRCRAFT DEICER FLUID CONSUMPTION

Month: March 1977

Date	Air Canada	C.P. Air	General Aviation	Wardair	North Central Airlines	Total
1						
2						
3						
4	424	180	120		45	769
5						
6						
7						
8	422				25	447
9		97				97
10			15			15
11			14			14
12						
13						
14						
15						
16	32		100			132
17			200			200
18	2529	957	1152			4638
19			257			257
20	2675	1731	17	50		4473
21	162	285			20	467
22	5490	4371	360			10221
23						
24						
25			14			14
26						
27			27			27
28						
29						
30						
31						
TOTAL (gal.)	11734	7621	2276	50	90	21771

APPENDIX C

FUEL SPILL REPORT

FUEL SPILL REPORT

Month: March 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure: Water (gallons)	Handling Procedure: Sand (Tons)	Handling Procedure: Other
6	-	1	24	(50'x50')	-	-	Used	-
8	13:32	2	71	10	JP4	250	-	-
19	19:32	2	91	25	JP4	1000	-	-
24	-	1	22	5-6	-	Used	-	-
24	-	1	52	5	-	Used	-	-
24	19:32	1	22	30-45	JP4	1500	-	-
26	03:24	1	63	1	JP1	-	-	Speed Dry
27	09:09	1	52	10	JP1	500	-	-
TOTAL: 8 Spills				102		3250	-	Used

Month: April 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
4	09:16	1	53	10	JP4	500	-	-
7	11:48	Sky Port Area		500	Aircraft Gas	6000	7.2	-
9	-	2	71	(3'x4')	-	Used	-	-
9	18:51	2	73	5	JP1	200	-	-
10	01:21	Ramp Area Con-solidated Parking		30	JP4	4000	-	-
10	08:45	Air Canada Cargo Gas Pumps		10	Gas	500	-	-
10	09:09	2	85	10	JP4	500	-	-
10	-	Fuel Centre		5	-	Used	-	-
11	17:21	2	103	50	JP4	2000	-	-
17	18:21	2	71	10-15	JP4	550	-	-
20	18:41	2	93	5	JP1	100	-	-
23	01:50	2	83&85	5	Reg. Gas	500	-	-
TOTAL 12 Spills				645		14850	7.2	-

FUEL SPILL REPORT

Month: May 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure: Water (gallons)	Sand (Tons)	Other
8	12:23	1	52	10	JP1	2500	-	-
9	09:18	1	55	10	JP1	1000	-	-
9	-	1	52	20	-	Used	-	-
15	14:50	2	72	20	JP4	500	-	-
29	07:45	2	73	10-15	JP4	800	-	-
31	16:55	1	61	10	JP1	400	-	-
31	-	1	61	5	-	Used	-	-
TOTAL:	7 Spills			90		5200	-	-

Month: June 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
2	07:39	1	42	10	JP1	1000	-	-
2	-	1	43	5	-	Used	-	-
8	12:18	1	52	5-8	JP4	500	-	-
13	18:43	1	23	10	JP1	500	-	-
14	02:00	South Ramp	10	65-75	JP4	2800	-	-
14	22:15	2	79	3	JP4	500	-	-
14	22:47	2	103	100	-	4000	-	-
16	14:12	2	103	20	JP4	800	-	-
16	21:04	2	103	25	JP4	2000	-	-
17	18:22	1	24	10	JP1	1000	-	-
17	-	1	23	10	-	Used	-	-
17	22:59	2	103	250-300	JP4	6000	-	-
23	16:58	1	21	20	JP1	800	-	-
27	21:19	1	11	15	JP1	400	-	-
TOTAL:	14 Spills			610		20300	-	-

FUEL SPILL REPORT

Month: July 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure: Water (gallons)	Handling Procedure: Sand (Tons)	Handling Procedure: Other
3	19:05	2	87	10	Gas	Used	-	-
6	12:22	1	51	10-15	JP1	1000	-	-
7	-	1	34	(4')	-	Used	-	-
7	-	1	51	(10')	-	Used	-	-
7	17:55	1	Finger 3	15	JP1	500	-	-
8	09:05	2	85	10	JP1	750	-	-
11	09:30	1	32	25	JP1	1000	-	-
11	-	1	42	(8')	-	Used	-	-
13	-	2	91	(50')	-	Used	-	-
14	15:33	2	76	25	JP4	500	-	-
16	19:37	2	101	15-20	Jet B	500	-	-
16	-	2	103	(6')	-	Used	-	-
17	04:22	2	Departure Ramp	20	Auto Gas	1000	-	-
18	18:28	2	103	20-30	Jet B	1000	-	-
TOTAL:	14 Spills			170		6250	Used	-

Month: August 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
4	-	1	32	(2')	-	-	-	Speed Dry
6	-	2	103	(10')	-	Used	-	-
15	-	Tank Farm		(10')	-	Used	-	Speed Dry
21	10:40	1	44	10	JP4	700	-	-
23	03:41	1	21	10	JP4	1000	-	-
29	21:08	1	14	30	JP4	1000	-	-
TOTAL:	6 Spills			50		2700	-	Used

FUEL SPILL REPORT

Month: September 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure Water (gallons)	Handling Procedure Sand (Tons)	Handling Procedure Other
6	17:10	2	103	50	JP1	1500	-	-
18	20:44	2	81	20-30	JP1	800	-	-
18	20:44	2	89	5	JP1	500	-	-
21	17:26	1	43	15	JP1	500	-	-
22	14:05	1	42	10-15	JP4	500	-	-
28	14:21	Air Canada Cargo Hanger		40-50	Hydraulic Fluid	-	2	-
TOTAL:	6 Spills			165		3800	2	-

Month: October 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
3	07:41	1	13	2	JP1	500	-	-
3	18:21	2	91	20	JP4	1500	-	-
4	07:59	1	14	5	JP1	300	-	-
9	10:24	1	21	10	JP1	500	-	-
9	20:48	2	73	10	JP4	300	-	-
9	21:46	1	54	10	JP1	300	-	-
9	-	1	52	(6')	-	Used	-	-
16	21:35	2	89	10	JP4	300	-	-
18	16:51	2	97	25	JP1	300	-	-
28	22:26	1	34			500	-	-
TOTAL:	10 Spills			92		4500	-	-

FUEL SPILL REPORT

Month: November 1976

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure: Water (gallons)	Handling Procedure: Sand (Tons)	Handling Procedure: Other
9	07:53	2	83	20	JP1	-	2	Speed Dry
9	21:55	2	103	25	JP4	500	1	-
17	01:09	1	44	(40'x50')	Hydraulic Fluid	-	1	-
19	08:53	1	South Hold	10	JP1	500	-	-
19	09:18	Button of Runway 14		30	JP4	1000	-	-
20	09:23	2	76	15	JP1	Used	-	-
TOTAL: 6 Spills				100		2000	4	Used
Month: December 1976								
2	09:22	2	74	10	JP4	-	2	-
7	21:48	Consolidated Fuel Farm		65	Octane	-	5	-
9	02:02	Cargo Area	4	5	JP4	-	-	Speed Dry
11	16:24	2	72	15-20	JP4	-	6	-
15	08:33	1	51	25	JP4	500	-	-
15	17:01	1	51	2	JP1	-	-	Speed Dry
16	20:52	2	93B		JP4	1000	-	-
21	15:58	West Ramp (Customs Area)		10	JP4	-	1	-
22	09:30	2	83	10		-	1	-
24	10:06	1	21	30	Hydraulic Fluid	-	3.5	-
30	18:33	1	44	40	JP1	-	15	-
TOTAL: 11 Spills				217		1500	33.5	Used

FUEL SPILL REPORT

Month: January 1977

						Handling Procedure		
Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
5	12:26	1	52	10	JP1	-	-	Speed Dry
7	19:03	1	64	10	JP4	-	1	Speed Dry
9	17:31	2	85	15	JP4	-	1	Speed Dry
12	09:23	1	53	30	JP1	-	2	-
15	14:27	1	61	20	JP4	-	1	-
15	19:42	2	73	20	JP1	-	2	-
18	02:43	2	76	25	JP4	-	1	-
22	10:34	1	61	20	JP1	-	-	Speed Dry
22	13:13	2	72	25	JP4	-	5	-
23	09:33	1	51	10	JP1	-	-	Speed Dry
23	10:46	1	51	20	JP1	-	-	Speed Dry
23	12:44	1	52	50	JP1	1000	3	-
25	06:10	2	75	100	JP4	1000	4	-
29	09:20	1	61	15	JP1	-	1	-
29	22:18	2	72	5	JP4	-	-	Speed Dry
TOTAL:	15 Spills			375		2000	21	Used

FUEL SPILL REPORT

Month: February 1977

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure Water (gallons)	Handling Procedure Sand (Tons)	Handling Procedure Other
2	19:04	2	83	75	JP4	-	5	Speed Dry
4	19:09	1	12	20	JP4	500	2	-
4	20:39	2	103	15	JP4	-	2	Speed Dry
9	02:13	2	72	40	JP4	2000	1	-
9	04:44	1	Gas Pumps	20	Gas	-	-	Speed Dry
16	08:59	1	53	15	JP4	-	-	Speed Dry
27	16:46	2	76	50	JP4	2000	-	-
28	06:41	2	91A	10	JP1	500	2	-
TOTAL: 8 Spills				245		5000	12	-

FUEL SPILL REPORT

Month: March 1977

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Handling Procedure: Water (gallons)	Sand (Tons)	Other
5	14:01	1	51	20	JP4	500	-	-
6	13:56	1	24	8	Motor Oil	-	-	Speed Dry
9	08:54	Sky Charter		30	JP2	1500	-	-
13	07:31	1	12	15	Jet B	500	-	-
17	08:44	2	74	5	Jet 1	500	-	-
17	09:22	2	74	20	Jet 1	1000	-	-
19	00:35	Consolidated Fuel Farm		11453	JP4	-	15	-
23	16:51	1	54	10	Jet A	200	-	-
29	20:42	1	51	20	JP1	700	-	-
31	01:49	2	76	12	Diesel	600	-	-
TOTAL:	10 Spills			11593		5500	15	-

Month: April 1977

Date	Time	Terminal	Gate	Spill Quantity (gallons)	Type Fuel	Water (gallons)	Sand (Tons)	Other
3	03:24	Air Canada Gas Pumps		15	Gas	1000	-	-
3	08:06	Gate South	6	20	JP1	500	-	-
6	17:04	1	52	4	JP1	200	-	-
6	17:52	1	51	10	JP4	100	-	-
9	08:49	1	61	10	JP1	500	-	-
TOTAL:	5 Spills			59		2300	-	-

APPENDIX D

RUNOFF QUALITY DATA

RUNOFF QUALITY DATA

A complete tabulation of the data obtained from the runoff sampling program is provided in this section. The location of the sampling stations are identified in Figure 2-1 in the main report. The sample type numbers indicate the mode of sampling i.e. 1) grab sample, 2) composite sample, 3) discrete sample. The code numbers given have been taken from the "NAQUADAT" Dictionary (National Water Quality Data Bank), which are designed to identify the analytical method used for determining a given parameter. Reference is made to Appendix E for recorded runoff volumes at time of sampling.

Code Numbers for Analytical Determinations

NAQUADAT Parameter Code No.	Parameter Name	Unit
000002	Time	Hr, Min
110301	pH	pH Units
110401	Suspended Solids (SS)	mg/l
108202	Biochemical Oxygen Demand (BOD)	mg/l
107001	Total Kjeldahl Nitrogen (TKN)	mg/l (N)
115260	Orthophosphate	mg/l (P)
115407	Total Phosphorus	mg/l (P)
107206	Nitrite	mg/l (N)
107302	Nitrate	mg/l (N)
107554	Ammonia	mg/l (N)

RUNOFF QUALITY DATA

SITE 1, AREA M

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 04	2		7.9	205	1260	11.9
76 03 12	2		8.7	97	1880	416
76 03 19	3	10:05	7.3	162	16400	25.6
		10:08	7.2	230	15900	129
		10:12	7.2	310	10400	23.1
		10:16	7.2	332	10300	39.9
		10:20	7.1	238	10500	19.7
		10:27	7.2	196	10300	27.1
		10:35	7.2	196	6430	27.7
		10:42	7.2	224	3050	28.6
		10:50	7.3	222	1910	29.3
		10:57	7.4	210	3100	26.8
		11:05	7.3	194	1310	29.3
		11:12	7.3	160	1280	26.8
		11:20	7.3	166	1040	16.6

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 19	3	11:27	7.3	136	1110	13.0
76 03 24	2		7.6	61	293	61
76 03 27	3	15:12	7.8	56	165	
		15:27	7.8	196	655	
		15:42	7.8	253	240	
		16:04	7.8	532	111	
		16:34	7.9	327	91	
		17:12	7.9	242	106	
		17:57	7.9	147	120	
		18:42	7.9	87	132	
		19:34	8.0	65	134	
		20:34	8.0	60	131	
76 03 31	3	10:07	7.4	29	120	
		10:22	7.1	69	420	
		10:37	7.1	187	113	
		10:52	7.3	231	135	
		11:14	7.3	180	67	
		11:44	7.4	212	54	
		12:14	7.4	195	85	

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 31	3	12:52	7.4	310	63	
		13:37	7.4	216	93	
		14:29	7.3	86	101	
		15:29	7.4	249	135	
76 04 15	2		7.5	508	20	
76 04 24	3	00:22	7.9	99	430	
		00:37	7.9	95	345	
		00:52	7.8	75	260	
		01:22	7.8	89	138	
		02:07	7.8	106	158	
		02:52	8.0	198	58	
		03:44	8.1	135	46	
		04:44	8.0	48	43	
		05:44	8.0	56	61	
76 04 26	2		8.0	87	205	
76 05 07	2		7.9	16	48	
76 05 11	3	06:55	7.3	166	1260	
		07:03	7.2	83	304	
		07:11	7.3	70	132	

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 05 11		07:31	7.3	107	117	
		08:03	7.3	51	104	
		08:35	7.3	43	102	
		09:07	7.4	46	97	
		09:35	7.4	34	94	
76 06 01	2		7.7	626	18	
76 06 19	3	05:55	7.1	152	39	
		06:03	7.2	175	38	
		06:11	7.2	315	25	
		06:19	7.3	687	24	
		06:39	7.5	644	17	
		07:11	7.6	447	14	
	3	07:43	7.5	244	10	
		08:15	7.4	82	12	
		08:47	7.4	49	11	
76 07 16	3	06:45	6.9	288	68	
		06:53	7.3	312	51	
		07:01	7.2	448	35	
		07:09	7.4	516	39	
		07:25	7.5	480	24	

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 06 16		07:53	7.6	306	20	
		08:25	7.5	98	18	
76 07 29	3	03:50	6.9	121	29	
		04:05	7.5	160	20	
		04:20	7.7	281	15	
		04:50	7.2	68	10	
		05:35	7.5	103	7	
		06:20	7.4	17	4	
		07:12	7.4	18	6	
		08:12	7.5	13	4	
		09:05	7.5	10	5	
76 08 13	3	15:27	8.0	874	26	
		15:42	8.2	779	11	
		15:57	8.2	916	16	
		16:12	8.2	476	13	
		16:42	8.1	341	10	
		17:27	7.9	309	11	
		18:12	7.9	142	9	
		18:57	7.8	111	7	
		19:50	7.7	87	9	
		20:42	7.7	64	8	

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 08 28	3	16:57	7.4	371	49	
		17:12	7.8	1011	18	
		17:27	7.7	466	14	
		17:42	7.5	323	19	
		18:12	7.6	189	11	
		19:04	7.5	80	8	
76 09 01	2		7.5	907	28	
76 09 10	2		7.4	269	34	
76 10 06	3	17:22	7.9	340	153	
		17:37	7.6	188	150	
		17:52	7.7	370	106	
		18:29	8.0	60	61	
		19:40	7.7	146	106	
		19:55	8.3	50	25	
		20:10	8.1	16	18	
		20:48	8.0	46	17	
		21:48	7.9	36	23	
		22:25	7.7	60	22	
		22:40	7.8	148	38	
		23:18	7.8	88	19	

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 10 14	2		8.0	11	12	
76 10 21	2		7.8	26	23	
76 12 20	3	06:40	8.8	204	495	100
76 12 20	3	06:55	8.7	436	340	94
76 12 20	3	07:10	8.6	416	118	84
76 12 20	3	07:25	7.5	348	60	66
76 12 20	3	07:55	7.3	204	43	38
76 12 20	3	08:40	6.9	144	43	31
76 12 20	3	09:35	7.0	172	36	22
76 12 20	3	10:20	7.0	156	28	14
76 12 20	3	11:12	7.0	104	60	14
76 12 20	3	12:12	7.0	88	78	13
77 01 26	1		7.4	7.5	14250	195
77 02 02	1		7.7	52	575	54.9
77 02 09	1		7.0	77	315	9.87
77 02 16	1		7.3	33	690	37.5
77 02 22	1		7.3	66	285	22.6
77 03 01	1		9.1	136	525	123
77 03 09	1		6.9	24	187	4.02
77 03 10	2		6.8	68	40	5.62

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
77 03 12	3	14:04	7.1	37	164	7.90
77 03 12	3	14:19	7.2	44	69	6.32
77 03 12	3	14:34	7.1	31	58	5.30
77 03 12	3	14:49	7.1	50	42	4.66
77 03 12	3	15:04	6.8	69	27	4.22
77 03 12	3	15:19	7.0	134	20	4.16
77 03 12	3	15:34	7.0	5.7	21	3.84
77 03 12	3	15:39	6.7	79	21	4.09
77 03 23	1		7.3	29	770	9.3
77 03 30	2		6.6	159	1000	7.42
77 03 30	1		7.1	33	168	6.71

RUNOFF QUALITY DATA

SITE 1, AREA M

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	ORTHO-PHOSPHATE 115260	TOTAL PHOSPHORUS 115407	NITRITE 107206	NITRATE 107302	AMMONIA 107554
76 12 20	3	06:40	<0.05	2.28	0.03	0.40	72
76 12 20	3	06:55	0.06	4.98	0.03	0.35	72
76 12 20	3	07:10	0.06	3.10	0.02	0.35	69
76 12 20	3	07:25	0.98*	3.60	0.03	0.35	47
76 12 20	3	07:55	0.17	1.55	0.02	0.40	23
76 12 20	3	08:40	0.69*	1.68	0.02	0.35	21
76 12 20	3	09:35	0.16	1.08	0.02	0.50	19
76 12 20	3	10:20	<0.05	0.82	0.03	0.35	14
76 12 20	3	11:12	<0.05	1.14	0.04	0.35	12
76 12 20	3	12:12	0.11	1.20	0.02	0.55	13
77 1 26	1		6.4	11	0.02	0.29	84.4
77 2 02	1		0.06	0.94	0.92	0.01	4.59
77 2 09	1		0.04	1.54	0.08	0.65	2.19
77 2 16	1		0.12	1.00	0.011	0.16	26.8
77 2 22	1		0.04	0.74	0.006	0.13	14.0
77 3 01	1		0.17	1.62	0.024	0.19	44.9

* Confirmed result

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	ORTHO-PHOSPHATE 115260	TOTAL PHOSPHORUS 115407	NITRITE 107206	NITRATE 107302	AMMONIA 107554
77 3 09	1		0.02	0.57	<0.002	0.16	3.99
77 3 10	2		<0.01	0.57	0.002	0.13	3.47
77 3 12	3	14:04	1.21	1.94	0.006	0.24	-
77 3 12	3	14:19	0.05	0.58	0.009	0.19	-
77 3 12	3	14:34	0.03	0.50	0.005	0.18	-
77 3 12	3	14:49	<0.01	0.68	0.003	0.11	-
77 3 12	3	15:04	<0.01	0.54	0.006	0.11	-
77 3 12	3	15:19	0.01	0.82	0.003	0.08	-
77 3 12	3	15:34	0.01	0.65	0.003	0.12	-
77 3 12	3	15:49	0.39	1.37	0.006	0.11	-

RUNOFF QUALITY DATA

SITE 3, AREA S

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 04	2		8.6	547	21200	53
76 03 12	3	14:58	7.9	243	8900	39.2
		15:09	7.9	267	5600	29.6
		15:20	7.7	209	5430	29.6
		15:31	7.6	663	5700	27.6
		15:43	7.7	578	7600	29.4
		15:54	7.8	683	9500	31.3
		16:06	7.7	304	5900	35.6
		16:17	7.6	729	5150	35.6
76 03 16	2		7.7	160	19800	43.3
76 04 15	2		7.4	300	22	
76 05 02	3	19:29	7.7	1102	590	
		19:34	7.6	676	675	
		19:39	7.6	51	705	
		19:44	7.1	140	1100	
		19:54	7.3	84	1100	
		20:04	7.1	64	305	
		20:24	7.1	48	230	
		20:39	7.2	54	280	

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 05 02		20:59	7.3	45	330	
		21:19	7.2	55	415	
76 05 06	2		7.2	28	940	
76 05 07	2		7.3	13	340	
76 05 11	3	06:08	7.1	56	1050	
	3	06:16	7.6	87	1140	
		06:24	7.6	75	2330	
		06:36	7.6	63	700	
		06:56	7.3	35	210	
		07:24	7.2	74	182	
		07:56	7.3	25	167	
		08:28	7.4	32	242	
		09:00	7.6	41	304	
76 06 13	3	21:27	7.3	315	310	
		21:35	7.1	129	22	
		21:42	7.1	60	12	
		21:50	7.1	57	18	
		22:05	7.1	42	14	
		22:27	7.0	46	17	
		22:50	6.9	16	11	
		23:12	6.9	14	16	
		23:38	7.1	20	17	

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 06 19	3	05:27	6.9	113	112	
		05:35	7.0	46	23	
		05:42	6.8	21	20	
76 06 19	3	05:50	6.6	23	24	
		06:09	6.8	17	21	
		06:39	6.8	15	23	
		07:09	6.9	14	24	
		07:39	6.9	15	24	
		08:09	7.0	19	24	
76 06 30	2		7.7	20	18	
76 07 07	2		6.6	28	23	
76 07 10	2		6.9	15	22	
76 07 16	3	06:22	7.2	184	60	
		06:30	7.1	60	30	
		06:38	6.8	48	28	
		06:46	7.0	30	47	
		07:05	6.8	30	22	
		07:38	6.9	12	22	
		08.10	6.9	12	26	
76 07 29	3	03:27	7.1	69	82	
		03:35	6.9	78	52	
		03:43	6.8	17	16	

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 07 29	3	03:51	6.7	13	12	
		04:07	6.6	11	11	
		04:31	6.6	8	8	
		04:55	6.8	12	9	
		05:19	6.8	9	10	
		05:47	6.9	9	12	
		06:15	7.0	9	13	
76 08 28	3	16:26	7.1	155	51	
		16:34	6.8	40	14	
		16:42	6.9	28	11	
		16:50	6.9	44	11	
		16:58	6.9	20	12	
		17:10	6.9	23	13	
		17:30	6.9	13	12	
		17:54	7.0	7	13	
	3	18:18	7.1	9	13	
76 09 01	2		7.0	104	24	
76 09 10	2		7.1	73	28	
76 09 26	2		7.2	29	16	

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 10 06	3	16:37	7.3	104	64	
		16:45	7.1	62	45	
		16:52	7.1	66	40	
		17:00	7.2	94	38	
		17:15	7.4	44	17	
		17:37	6.9	28	24	
		18:00	7.1	8	19	
		18:26	7.2	10	29	
		18:56	7.2	4	24	
		19:15	7.0	6	25	
		19:22	7.4	22	20	
		19:30	7.4	56	49	
76 10 21	2		7.8	19	33	
76 10 22	2		8.5	21	37	
76 11 26	2		7.0	89	420	
77 01 26	1		7.7	672	58750	522
77 02 02	1		8.2	-	470	43.1
77 02 16	1		7.4	38	5450	115
77 02 22	1		7.5	26	1275	26.5
77 03 01	1		7.0	92	775	34.4

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
77 03 09	1		6.5	69	1350	5.32
77 03 10	2		6.5	79	1675	11.8
77 03 12	1		7.5	23	19	6.35
77 03 23	1		7.3	89	1550	11.7
77 03 30	2		6.6	85	1238	14.2
77 03 30	1		7.3	39	375	11.9

RUNOFF QUALITY DATA

SITE 3, AREA S

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	ORTHO-PHOSPHATE 115260	TOTAL PHOSPHORUS 115407	NITRITE 107206	NITRATE 107302	AMMONIA 107554
77 02 02	1		-	-	-	-	5.05
77 02 16	1		-	-	-	-	32.3
77 02 22	1		-	-	-	-	13.9
77 03 01	1		-	-	-	-	9.08

RUNOFF QUALITY DATA

SITE 7, AREA K

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 04	3	08:40	7.6	121	36	43
		08:47	7.6	130	35	46
		08:55	7.6	142	52	46
		09:06	7.6	131	34	59
		09:17	7.6	91	37	53
		09:28	7.6	101	40	53
		09:40	7.6	109	32	48
		09:51	7.6	127	41	40
		10:02	7.6	136	47	45
76 03 12	3	17:11	7.7	80	32	32.2
		17:18	7.6	50	27	29.5
		17:26	7.7	43	25	29.7
		17:33	7.8	43	24	29.8
		17:48	7.7	41	24	30.6
		18:03	7.6	26	19	30.3
		18:18	7.6	29	21	31.9

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 12	3	18:33	7.7	32	21	31.3
		18:48	7.8	37	17	32.2
76 03 19	3	10:37	7.4	156	25	10.4
		10:44	7.4	130	23	16.1
		10:52	7.4	110	24	19.1
		10:59	7.4	84	27	20.0
		11:14	7.5	68	22	19.1
		11:29	7.5	122	24	17.3
		11:44	7.4	92	28	16.5
		11:59	7.4	42	21	15.0
		12:21	7.4	32	20	15.6
		12:44	7.5	40	20	14.1
		13:06	7.5	42	21	9.9
		13:29	7.5	52	22	8.1
76 03 25	2		7.7	34	15	34
76 03 26	1		7.7	10	7	10
76 03 27	2		7.8	138	20	
76 03 31	3	10:13	7.3	76	13	
		10:28	7.6	93	5	
		10:43	7.7	92	2	

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 03 31	3	11:13	7.6	72	2	
		11:58	7.5	78	6	
		12:43	7.5	70	3	
		13:35	7.6	75	2	
		14:35	7.5	71	5	
		15:35	7.6	92	2	
76 04 15	2		7.4	462	23	
76 04 15	2		7.7	196	12	
76 04 24	3	01:01	7.8	55	24	
		01:16	7.8	68	24	
		01:31	7.8	62	13	
		02:01	7.9	41	12	
		02:46	7.9	25	11	
		03:31	8.0	15	11	
		04:23	8.0	13	12	
		05:23	8.1	9	11	
		06:23	8.1	17	7	
76 04 26	3	13:33	8.0	61	8	
		13:48	8.1	23	10	
		14:03	8.1	19	10	

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 04 26	3	14:18	8.1	22	9	
		15:03	8.2	24	9	
		15:48	8.2	19	9	
		16:33	8.1	33	9	
		17:33	8.2	39	7	
		18:33	8.2	23	7	
76 05 02	2		7.6	90	18	
76 05 06	2		7.5	35	13	
76 05 07	2		8.0	12	11	
76 05 11	2		7.7	26	16	
76 06 01	2		7.2	143	13	
76 07 06	1		7.4	16	111	
76 07 10	2		7.4	20	7	
76 07 29	2		7.0	127	34	
76 08 12	2		7.8	26	7	
76 08 28	3	16:32	7.5	104	25	
		16:40	7.3	196	21	
		16:47	7.3	282	11	
		16:55	7.3	270	8	
		17:02	7.4	202	6	

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 08 28	3	17:10	7.3	176	13	
		17:21	7.4	196	9	
		17:40	7.5	240	13	
76 09 01	2		7.4	121	17	
76 09 10	2		7.3	48	13	
76 09 26	2		7.4	32	11	
76 10 06	2		7.5	32	55	
76 10 14	2		7.8	48	7	
76 10 19	2		7.9	14	17	
76 10 21	2		7.6	34	17	
76 11 26	2		7.3	33	105	
76 11 26	2		7.2	50	100	
76 12 20	3		7.2	128	43	41
76 12 20	3		7.1	66	39	36
76 12 20	3		7.0	82	39	28
76 12 20	3		7.1	30	39	21
76 12 20	3		7.6	202	38	20
76 12 20	3		7.3	144	39	14
76 12 20	3		7.1	90	13	10

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	pH 110301	SS 110401	BOD 108202	TKN 107001
76 12 20	3		7.0	68	15	8.7
76 12 20	3		7.2	66	9	6.3
76 12 20	3		7.3	22	9	6.1
77 01 26	1		7.2	122	175	18.9
77 02 02	1		8.0	10	170	6.5
77 02 16	1		7.5	8	14	20.4
77 02 22	1		7.5	25	40	7.26
77 03 01	1		7.0	2296	1100	33.1
77 03 09	1		7.2	23	24	3.80
77 03 12	1		9.3	10	520	28.5
77 03 23	1		7.4	4	9	3.46
77 03 30	1		7.6	3	11	2.06

RUNOFF QUALITY DATA

SITE 7, AREA K

DATE YR/MN/DY	SAMPLE TYPE	TIME HR MIN 000002	ORTHO-PHOSPHATE 115260	TOTAL PHOSPHORUS 115407	NITRITE 107206	NITRATE 107302	AMMONIA 107554
77 02 16	1		-	-	-	-	6.34
77 02 22	1		-	-	-	-	4.92
77 03 01	1		-	-	-	-	8.64

MISCELLANEOUS QUALITY DATA

DATE YR/MN/DY	SAMPLE DESCRIPTION	pH 110301	SS 110401	BOD 108202	AMMONIA 107554	TKN 107001	TOTAL PHOSPHORUS 115407
77 01 26	Top of Snowpile Opposite Terminal 1	7.2	2748	9200	-	176	-
77 01 26	Bottom of Snowpile Opposite Terminal 1	6.9	149	53600	-	540	-
77 02 02	Top of Snowpile Opposite Terminal 1	8.1	-	2500	7.1	126	-
77 02 02	Bottom of Snowpile Opposite Terminal 1	7.6	-	4350	12.7	96	-
77 02 02	Snow Sample near Site 3	8.2	-	470	5.0	43	-
77 02 02	Snow Sample near Site 7	8.0	10	170	-	6.5	-
77 02 02	Snow Sample Opposite Runway 05R	8.4	-	938	4.4	29.7	-
77 02 02	Aircraft Deicing Fluid of 40:60 Mix	7.9	-	365000	3.8	6.2	1200

MISCELLANEOUS QUALITY DATA

DATE YR/MN/DY	SAMPLE DESCRIPTION	pH 110301	SS 110401	BOD 108202	TKN 107001
77 03 01	Etobicoke Creek, North of Airport	7.7	26	21	7.48
77 03 01	Etobicoke Creek, South of Airport	7.8	27	11	7.92
77 03 09	Etobicoke Creek, North of Airport	7.0	328	14	4.24
77 03 09	Etobicoke Creek, South of Airport	7.2	973	160	5.12

MISCELLANEOUS QUALITY DATA

DATE YR/MN/DY	SAMPLE DESCRIPTION	ORTHO-PHOSPHATE P	TOTAL PHOSPHORUS P	NITRITE N	NITRATE N	AMMONIA N
77 03 01	Etobicoke Creek, North of Airport	0.22	0.43	0.135	1.96	4.87
77 03 01	Etobicoke Creek, South of Airport	0.21	0.43	0.112	1.90	3.01
77 03 09	Etobicoke Creek, North of Airport	0.28	0.94	0.060	0.81	1.83
77 03 09	Etobicoke Creek, South of Airport	0.24	2.02	0.040	0.53	1.72

APPENDIX E

RECORDED RUNOFF QUANTITY DATA

APPENDIX E

RECORDED RUNOFF QUANTITY DATA

SITE 1, AREA M

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 03 19	10:07	0.54
	10:15	0.54
	10:22	0.76
	10:30	0.98
	10:41	0.98
	10:56	1.20
	11:11	1.45
	11:26	1.7
	11:41	2.0
	11:56	2.7
	12:11	3.0
	12:26	3.7
	12:41	5.3
	12:56	7.4
	13:30	13.5
	14:00	20.0
	14:30	25.0
	15:00	23.5
	16:00	18.0
	18:00	9.6
	20:00	4.1
	22:00	2.0
76 03 27	15:12	4.5
	15:27	4.5
	15:42	4.1
	16:04	4.9
	16:34	3.0
	17:12	1.7
	17:57	1.2
	18:42	0.76
	19:34	0.76
	20:34	0.31
76 03 31	10:07	1.2
	10:22	2.0
	10:37	3.0
	10:52	3.7
	11:14	3.7
	11:44	6.3

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 03 31	12:14	9.8
	12:52	9.2
	13:36	6.3
	14:29	8.6
	15:29	15.5
	16:00	11.1
	18:00	8.6
	20:00	4.5
	24:00	3.0
76 04 01	04:00	3.0
	08:00	1.2
	12:00	0.76
76 04 25	00:22	1.5
	00:37	3.9
	00:52	5.3
	01:22	6.3
	02:07	4.5
	02:52	3.7
	03:44	5.3
	04:44	4.9
	05:44	4.9
	07:00	8.2
	09:00	15.5
	11:00	11.4
	13:00	9.5
	15:00	4.1
	16:00	9.5
	17:00	17.0
	19:00	8.2
	21:00	9.5
	23:00	5.0
76 04 26	01:00	4.9
	05:00	3.5
76 05 11	06:57	5.0
	07:05	5.3
	07:13	5.3
	07:33	5.0
	08:05	3.7
	08:37	2.3
	09:09	1.2
	09:37	0.54
	10:00	0.20
	11:00	0.09

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 06 19	05:55	11.7
	06:03	9.2
	06:11	7.4
	06:19	5.8
	06:39	3.7
	07:11	1.5
	07:43	0.76
	08:15	0.76
	08:47	0.31
	10:00	0.31
	11:00	3.0
	12:00	17.1
	12:30	34.5
	13:00	13.1
	14:00	5.3
	16:00	1.2
	18:00	0.2
76 07 16	06:45	22.2
	06:52	13.9
	07:00	9.8
	07:07	7.4
	07:22	4.5
	07:49	2.3
	08:21	0.76
	09:00	0.20
	09:30	0.10
76 07 29	03:50	20.5
	04:05	21.3
	04:20	13.9
	04:50	6.3
	05:35	3.7
	06:20	3.0
	07:12	3.0
	08:12	4.1
	09:05	12.4
	10:00	7.4
	11:00	3.0
	12:00	1.7
76 08 13	15:27	59.6
	15:42	21.4
	15:57	9.8
	16:12	7.4
	16:42	4.5
	17:27	9.8
	18:12	7.4

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 08 13	18:57	4.5
	19:50	3.0
	20:42	1.4
	22:00	0.31
	23:00	0.11
	24:00	0.08
76 08 28	16:57	>91.6
	17:12	>91.6
	17:27	>91.6
	17:42	46.5
	18:12	15.5
	19:04	5.8
	20:00	3.0
	21:00	1.0
	22:00	0.2
76 10 06	17:22	3.3
	17:37	2.3
	17:52	1.7
	18:29	0.76
	19:40	9.8
	19:55	9.8
	20:10	6.3
	20:48	3.3
	21:48	0.76
	22:25	11.1
	22:40	8.6
	23:18	3.7
76 10 07	00:18	3.3
	01:18	0.76
	02:18	0.20
	03:18	0.11
76 12 20	06:40	0.76
	06:55	9.8
	07:10	12.4
	07:25	16.3
	07:55	16.3
	08:40	8.6
	09:35	10.5
	10:20	13.9
	11:12	7.4
	12:12	4.9
	13:12	3.7
	14:12	3.0

SITE 1, AREA M (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 12 20	15:12	1.7
	16:12	0.76
	17:12	0.25
77 03 12	14:26	0.20
	14:49	0.20
	15:19	0.20
	16:04	0.26
	16:56	0.26
	17:56	0.20
	18:48	0.76
	19:33	1.70
	21:33	1.5
	23:33	44.1
77 03 13	02:33	34.5
	04:33	15.5
	06:33	4.5
	08:33	3.7
	14:33	1.7
	18:33	0.76

APPENDIX E

RECORDED RUNOFF QUANTITY DATA

SITE 3, AREA S

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 03 12	14:58	1.2
	15:20	1.5
	15:43	1.5
	16:05	1.4
	16:28	1.2
	16:51	1.8
	17:13	3.6
	17:35	2.9
	18:00	2.2
	19:00	1.2
	21:00	1.2
	22:00	9.5
	23:00	8.5
	24:00	2.9
76 03 13	02:00	1.2
	04:00	1.5
	08:00	0.7
76 05 02	19:34	0.24
	19:39	0.24
	19:44	2.7
	19:51	4.0
	20:04	4.8
	20:19	4.8
	20:34	2.7
	20:51	1.5
	21:11	2.1
	21:29	13.2
	22:00	8.8
	23:00	2.1
	24:00	0.3
76 05 03	01:00	0.2
76 05 11	06:08	0.64
	06:16	1.2
	06:24	2.7
	06:36	4.9
	06:56	4.9
	07:24	3.5
	07:56	2.0

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 05 11	08:28	0.93
	09:00	0.30
	10:00	0.13
	11:00	0.10
76 06 13	21:27	25.3
	21:35	56.4
	21:42	53.5
	21:50	17.5
	21:57	10.2
	22:12	5.3
	22:35	1.8
	22:57	0.64
	23:24	0.24
	24:00	0.13
76 06 14	00:30	0.10
76 06 19	05:27	7.5
	05:35	7.5
	05:42	6.3
	05:50	4.9
	06:09	2.1
	06:39	0.9
	07:09	0.6
	07:39	0.6
	08:09	0.4
	09:00	0.4
	10:00	1.5
	11:00	6.9
	12:00	8.8
	13:00	3.5
	14:00	0.9
	15:00	0.24
76 07 16	06:22	9.5
	06:30	8.8
	06:38	6.9
	06:48	6.3
	07:06	3.1
	07:38	0.93
	08:10	0.35
	08:30	0.24
	09:00	0.13
76 07 29	03:27	3.5
	03:35	7.5
	03:43	9.5
	03:51	9.5

SITE 3, AREA S (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 07 29	04:07	8.8
	04:31	6.3
	04:55	2.7
	05:19	1.5
	05:47	1.5
	06:19	2.1
	07:00	2.1
	08:00	0.93
	09:00	5.3
	10:00	5.3
	11:00	1.2
	12:00	0.3
	13:00	0.2
76 08 28	16:26	35.7
	16:34	54.9
	16:42	28.5
	16:50	22.2
	16:58	24.2
	17:10	10.2
	17:30	5.3
	17:54	1.5
	18:18	0.35
	19:00	0.2
	20:00	0.1
76 10 06	16:37	5.3
	16:45	5.8
	16:52	4.4
	17:00	3.5
	17:15	2.4
	17:37	1.8
	18:00	0.93
	18:26	0.35
	18:56	0.30
	19:15	0.93
	19:22	11.7
	19:30	10.2
	20:00	4.4
	22:00	8.8
	23:00	2.1
	24:00	2.1
76 10 07	01:00	0.3

APPENDIX E

RECORDED RUNOFF QUANTITY DATA

SITE 7, AREA K

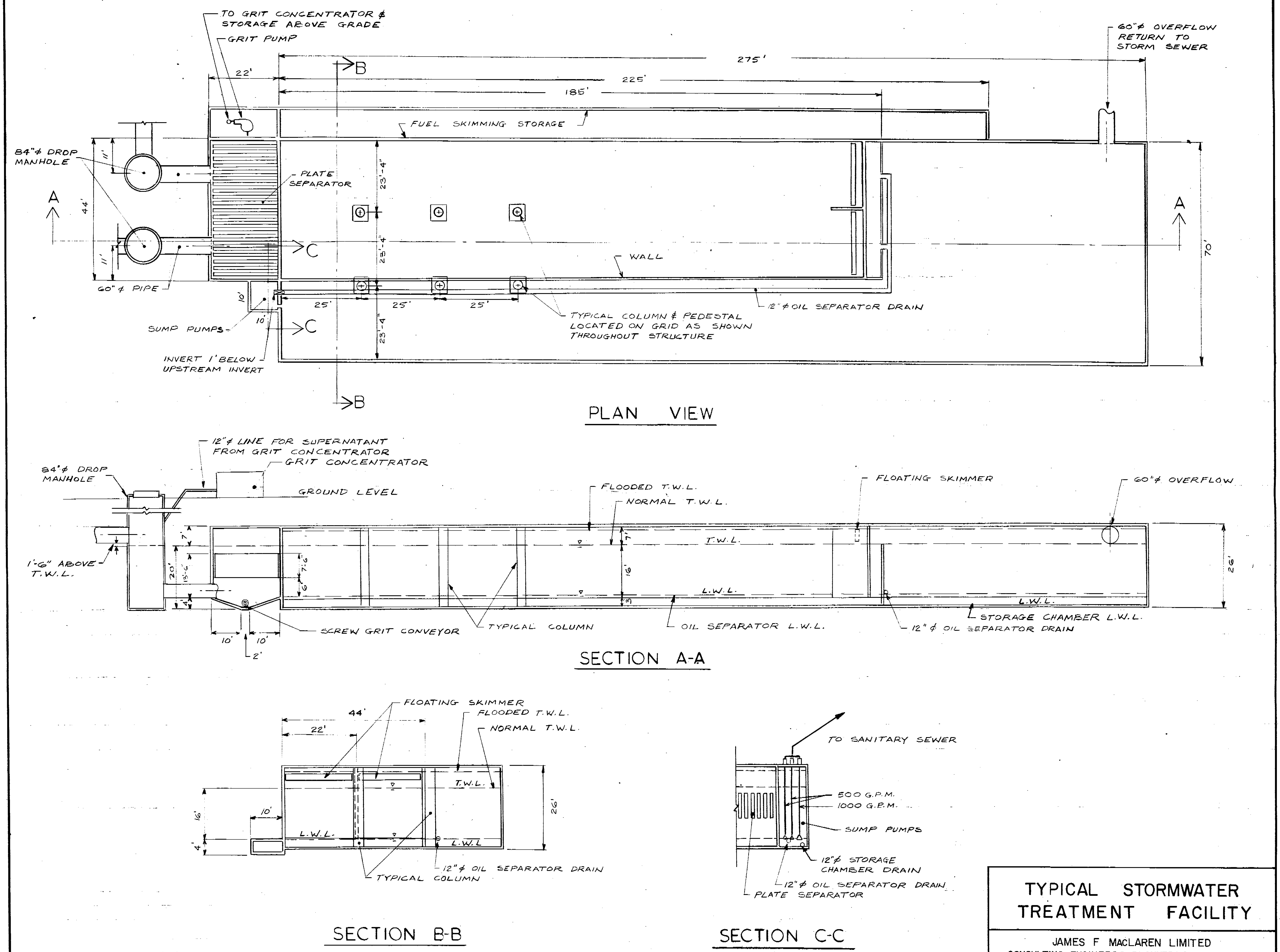
DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 03 04	08:47	1.45
	08:55	2.40
	09:02	1.80
	09:13	1.45
	09:25	1.45
	09:36	1.25
	09:47	1.25
	09:58	1.00
	10:09	1.00
	12:00	0.65
	14:00	0.47
	16:00	0.15
	17:00	1.45
	17:30	0.65
	18:00	0.30
	20:00	0.15
76 03 12	22:00	1.25
	22:07	4.2
	22:15	10.0
	22:22	20.0
	22:33	30.5
	22:48	37.8
	23:03	37.8
	23:18	24.5
	23:33	21.6
	24:00	11.6
76 03 13	01:00	10.5
	02:30	11.2
	04:00	9.0
	08:00	4.2
76 03 19	10:44	2.20
	10:52	2.20
	10:59	1.80
	11:07	1.0
	11:18	0.74
	11:33	0.56
	11:48	0.56
	12:03	0.56
	12:22	0.92
	12:44	2.40

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 03 19	13:07	5.0
	13:29	9.0
	14:00	11.1
	15:00	15.0
	16:00	12.8
	18:00	9.8
	20:00	5.0
	24:00	2.1
76 03 20	02:00	1.4
	06:00	0.92
76 03 31	10:13	0.74
	10:28	0.92
	10:43	0.92
	11:13	3.5
	11:58	10.5
	12:43	8.0
	13:35	2.8
	14:35	12.0
	15:35	9.0
	16:00	5.9
	17:00	10.3
	18:00	5.0
	20:00	2.8
	24:00	2.5
76 04 01	04:00	0.92
	08:00	0.15
76 04 25	01:01	2.4
	01:16	4.2
	01:31	3.9
	02:01	3.5
	02:46	0.92
	03:31	2.4
	04:23	3.1
	05:23	3.1
	06:23	6.3
	08:00	7.0
	09:00	12.2
	10:00	6.3
	12:00	3.6
	14:00	1.0
	15:00	2.8
	16:00	23.2
	17:00	9.4
	18:00	6.9
	20:00	2.6
	24:00	4.9

SITE 7, AREA K (Cont'd)

DATE YR/MN/DY	CLOCK TIME	FLOWRATE cfs
76 04 26	11:48	1.2
	12:03	1.4
	12:18	1.9
	12:48	1.9
	13:33	3.5
	14:18	5.9
	15:10	8.0
	16:10	9.0
	17:10	6.9
	18:00	5.9
	20:00	2.1
	22:00	0.74
	24:00	0.40
76 08 28	16:32	>78.4
	16:40	>78.4
	16:47	>78.4
	16:55	>78.4
	17:02	>78.4
	17:10	63.0
	17:21	44.3
	17:40	29.5
	18:30	16.3
	19:00	11.0
	20:00	7.2
	21:00	4.5
	22:00	3.4
	24:00	2.3
76 08 29	02:00	1.6
	04:00	1.1



TYPICAL STORMWATER TREATMENT FACILITY

JAMES F MACLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS & SCIENTISTS
WINDSOR · LONDON · WATERLOO · TORONTO

DATE: OCTOBER, 1977 | FIG. No. 4.5

LOCATION OF PROPOSED STORMWATER MANAGEMENT FACILITIES
JAMES F. MacLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS & SCIENTISTS
WINDSOR·LONDON·WATERLOO·TORONTO
DATE: AUGUST, 1977
FIG. No. 4.6
LEGEND
EXISTING MANHOLE
NEW MANHOLE
STORMWATER INTERCEPTOR FACILITY
EXISTING SEWER
NEW SEWER
BOUNDARY OF DRAINAGE AREA
TO MIMCO CREEK
STORMWATER STORAGE FACILITY
OVERFLOW SEWER
BY-PASS
SANITARY DISCHARGE SEWER
EXTENDED APRON
PROPOSED APRON EXTENSION
TERMINAL 2 EXTENSION
PARKING AREA
PARKING GARAGE (UNDER CONST.)
PARKING GARAGE (COMPLETE)
TERMINAL 2
TERMINAL TWO DRAINAGE AREA
NEW ROADWAY (UNDER CONSTRUCTION OR COMPLETED)
AIRPORT ROAD
WORKSHOPS & POWER HOUSE
ADMINISTRATION
TERMINAL 1
TERMINAL ONE DRAINAGE AREA
CARGO AREA
PARKING AREA
STORMWATER STORAGE FACILITY
OVERFLOW SEWER
HIGHWAY 401
TO ETOBICOKE CR. SEWER TRUNK
SCALE
400 0 400 800 1200 FT.