WMC INTERNATIONAL LTD.
MELIADINE WEST GOLD PROJECT
WATER BALANCE STUDY
1998 DATA REPORT

Submitted To:

WMC International Ltd.

Nepean, Ontario

Submitted By:

AGRA Earth & Environmental Limited

Calgary, Alberta

December 1998

CW1525.00

V:\Calgary
WR&CP\PROJECT\CW\1525\Report\1998\R_BH1120.WPD

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

PAGE

TABLE OF CONTENTS (cont'd)

PAGE

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (cont'd)

PAGE

LIST OF FIGURES (cont'd)

TABLE OF CONTENTS (cont'd)

PAGE

LIST OF FIGURES (cont'd)

APPENDICES

ACKNOWLEDGEMENTS

The writer would like to acknowledge the contributions and assistance of the following individuals towards the collection, interpretation and analysis of the data and the preparation of this report:

- Mr. Ben Hubert, WMC's environmental consultant coordinator, for advice and guidan in the planning of the field program and the reporting of the results.

- Mr. Alan Sexton and the other WMC camp staff who provided and coordinated transportation and logistics to facilitate timely execution of the field program.

- Mr. Tyler MacKinnon of WMC who provided the digital base map data.

- Mr. Dustin Fredlund and Mr. Kelly Owlijoot, the student field staff hired by WMC, for their dedication to the field data collection program.

- Mr. Murray Jones and Mr. Wade Hanna of the Water Survey of Canada for their assistance in the practical and technical details of the field data collection program.

EXECUTIVE SUMMARY

Introduction

AGRA Earth & Environmental Limited (AEE) was retained by WMC International Limited (WMC) early in 1997 to conduct a two year water balance study for the Meliadine West Gold Project. The purpose of the water balance study is to provide measurements of the water balance components of snow melt, rainfall, evaporation, evapotranspiration and runoff in the Meliadine River Basin and selected sub-basins, with the intention of providing a tool to plan for and monitor mine operations and closure.

This document reports the results of work carried out during the 1998 field season. The data collected in 1997 were presented in the 1997 Data Report issued in March 1998.

The project area is located within the basin of Meliadine Lake about 30 km northwest of Rankin Inlet on the western edge of Hudson Bay. The Meliadine Basin is within the zon of continuous permafrost. The terrain is dominated by glacial landforms consisting of drumlins of glacial till, eskers consisting of gravels and sands and numerous shallow lak and ponds. Meliadine Lake discharges into the Meliadine River which discharges into Hudson Bay just north of Rankin Inlet. A secondary outlet allows some discharge from Meliadine Lake into the adjacent Diana River Basin to the west. The area where mine development is considered most likely is located on a peninsula jutting into Meliadine La

The 1998 work program included measurement of discharges of Meliadine Lake, the Meliadine River and the adjacent Diana River; measuring discharges from lakes in the su basins of the peninsula area expected to be affected by gold mine development; monitor lake levels; measuring pre-melt snowpack water equivalent, measuring evaporation and evaluating the relative magnitudes of the principal basin inputs, losses and yields withi the context of regional and historical climate and runoff data. Rainfall, temperature and other climate data for the project area were collected and provided by WMC.

Hydrometric monitoring was conducted in 1998 at the following stations:

The four main river discharge monitoring stations established in 1997 were reactivated:

- Meliadine River at the outlet of Meliadine Lake.
- West outlet of Meliadine Lake (discharging into the Diana River basin).
- Meliadine River near the mouth.
- Diana River near Rankin Inlet.

In addition, the four lake level monitoring stations established on the main lakes in 1997 were also re-established:

C Meliadine Lake near Rankin Inlet (automated station)
C Meliadine Lake at Meliadine Camp (staff gauge/direct water level survey)
C Diana Lake (staff gauge/direct water level survey)
C Peter Lake (staff gauge/direct water level survey)

Seven lake outlet stations were operated in the Meliadine Lake peninsula area; fou of these were sites operated in 1997, and three sites were at new locations.

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1998 hydrologic year (October '97 through September '98) was a moderately wet year. The observed tot precipitation of 339 mm was almost twice the total 1997 precipitation of 172 mm, and 13 percent higher than the 17 year annual average. The 1998 wet year conditions were preceded by four continuous years of below average precipitation, of which the precedir year of 1996-97 was the driest on record.

The historical runoff data for the Diana River parallels the historical climate data, but wit an over-year lag effect. The measured yield for 1998 for the Diana is 203 mm, which wa 8 percent above the 9 year annual mean of 188 mm. However the ratio of 1998 runoff t precipitation (Rankin Inlet) is only 0.60, well below the average of 0.65, due to the lag effect of the preceding very dry year. A reverse effect occurred in 1997, when the runoff ratio was 0.78, due to the effect of the preceding wetter year.

Meliadine and Diana Basins

The total 1998 runoff for the Meliadine Lake basin is estimated to be 147 mm over the catchment area of 569 km^2. This includes about 11 mm of runoff estimated to have occurred through the winter prior to the spring snowmelt. That volume appears to be converted to ice in the downstream basin, as the Meliadine River at the mouth is frozen during the winter and does not discharge. About 30 mm or 20 percent of the total 1998 Meliadine Lake runoff was discharged through the west outlet into the Diana River basin via Peter Lake. The remaining 117 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged a nominal 128 mm of runoff in 1998 bas on the total catchment area of 796 km^2. In effect however, when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet, the 1998 runoff becomes 149 mm, which agrees closely with that of Meliadine Lake.

The Diana River 1998 yield of 203 mm becomes 191 mm when the diversion in from Meliadine Lake is deducted. The latter value is about 28 percent higher than the yields f the Meliadine Lake and River basins. Diana River yields are expected to be higher than Meliadine Basin yields because greater proportional evaporative loss occurs in the latter, a direct consequence of the fact that Meliadine Lake represents 20 percent of the total catchment, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment. In addition, higher precipitation appears to have occurred in the Diana Basin 1998.

For the 1998 hydrologic year the ratio of runoff to precipitation (Rankin Inlet) for the Meliadine River basin was 0.43, which is very similar to the runoff ratio of 0.45 for 1997 That suggests that over-year storage does not appear to be a significant factor in Meliac Basin yields.

Meliadine Lake Peninsula Basins

The main components of the water balance for seven peninsula basins were measured f the 1998 season. The runoff yields for five of the six Basin A and B stations showed a h degree of consistency, ranging from 140 mm to 150 mm, with a weighted mean value o 148 mm. That result is practically identical with the overall yield of 147 mm for the Meliadine Lake basin. The comparatively low yield of 113 mm for the Lake B7 basin is considered to be due to snowmelt runoff volume not measured at the start of runoff. Th somewhat lower yield of 136 mm for the Basin D station is considered to reflect the significantly higher lake surface evaporation losses in Basin D.

Basin storage over the May through September season increased for all basins. The weighted average increase for Basins A and B equals 14 mm. An additional storage increase of about 30 to 40 mm is estimated to have occurred in the first half of October 1997, due to runoff from heavy precipitation observed at that time. The principal mechanism for basin storage is the retention capacity of basin lakes and ponds.

The average 1998 ratio of runoff to total precipitation (defined as the spring snow water equivalent plus the season's rainfall observed at the Meliadine Camp station) equals 0.54. The 1997 reported average of 0.44, when adjusted by reducing the 1997 over-estimate of snow water equivalent, becomes 0.54 as well.

In 1998, snowmelt and rainfall each contributed about 50 percent of the total precipitation input. Basin outflows averaged 54 percent of the total precipitation input. Some 31 percent of precipitation was lost by evaporation and 10 percent by evapotranspiration. An average of 5 percent of precipitation went into basin storage. In terms of the precipitation components, it is estimated that about 95 percent of the snowmelt and perhaps 10 percent of the rainfall went to runoff, while all the rest was lost to evaporation and evapotranspiration except for about 10 percent of the rainfall which went into basin storage.

All of the peninsula monitored lakes remained essentially at or above their zero outflow levels, although periods of very low flow occurred. All lakes rose above their zero outflo levels in September in response to rainfall.

The various differences and inconsistencies noted in the 1997 data are assessed on the basis of the 1998 results to have been due largely to incomplete and inaccurate measurements. The 1998 data indicate a high degree of similarity in the hydrologic characteristics of the peninsula basins.

Reliability of Results

The accuracy of the 1997 monitoring data was affected by undesirable characteristics at most of the basin lake outlets and by the movement of benchmarks at the monitoring sites. These difficulties were largely corrected for the 1998 field work, resulting in much better and more reliable data. The fact that 1998 was a moderately wet year also helped to reduce the sensitivity of the results to inaccuracies in the estimates and approximations of some portions of the water balance components.

Recommendations

Recommendations are made in the report for some further improvements in methodology, if monitoring is to be continued in future years.

1.0 INTRODUCTION

1.1 BACKGROUND

WMC International Limited has been conducting a gold exploration program near Meliadine Lake in Nunavut since 1995. The quality of the results have indicated that development of a gold mine could become feasible and that environmental baseline stud should commence. AGRA Earth & Environmental Limited (AEE) was retained by WMC early in 1997 to conduct a two year water balance study for the Meliadine West Gold Project. The project area is located about 30 km northwest of Rankin Inlet on the weste edge of Hudson Bay (see Figure 1.1).

The results of the 1997 data collection program are reported in a previous document by AEE entitled "WMC International Ltd., Meliadine West Gold Project, Water Balance Stud 1997 Data Report", April 1998. The 1997 Data Report provides background information and describes the project area. The present document reports the results of the 1998 da collection program. The present report builds on the 1997 Data Report, and repeats onl limited amount of the background and descriptive information. The present report shou be read in conjunction with the 1997 Data Report.

1.2 SCOPE OF 1998 PROGRAM

The main work components and activities planned and carried out by AEE for the 1998 program are summarized as follows in Table 1.1.

Figure 1.1

TABLE 1.1
1998 Water Balance
Component and Activity Summary

Component	Office Activities	Field Activities
Snow Water Equivalent	C Develop snow distribution terrain map C Select transects C Calculate snow water equivalents	C Conduct snow surveys
Drainage Areas	C Delineate drainage boundaries C Measure areas	C Field verification of drainage boundaries
Flow Monitoring	C Specify and procure Aquadams C Compile and analyze data	C Select new station sites C Place Aquadams C Install stations C Operate stations C Make discharge measurements C Retrieve data C Shut down stations
Lake Level Monitoring	C Compile and analyze data	C Obtain winter ice and water levels C Install staff gauges C Monitor staff gauges C Survey water levels
Precipitation	C Obtain and compile precipitation data	
Evaporation	C Compile and analyze data	C Install evaporation pan C Operate pan C Shut down pan
Evapotranspiration	C Obtain climate station data C Estimate evapotranspiration	

WMC installed and operated a climate station to monitor precipitation, temperature, relative humidity, net radiation, soil temperature and wind data. These data provided essential inputs to the water balance study.

A parallel fisheries and water quality program was carried out by RL&L Environmental Services Ltd. of Edmonton.

2.0 1998 WORK PROGRAM

2.1 DETAILED WORK PLAN

The detailed work plan for the 1998 season was developed on the basis of continuing th monitoring work started in 1997, with various changes and additions as recommended the 1997 Data Report. Monitoring was carried out in both main lakes and rivers and in t smaller lake basins located in the Meliadine Lake peninsula where the majority of the exploration work is occurring. Monitoring of the peninsula basins was focussed in 1998 Basins A and B, as those basins are considered the likely area of future development. Th work carried out is summarized in the following sections.

2.2 DIGITAL MAP BASE

A new digital map base was developed for the peninsula area by WMC based on 1:10 0 scale aerial photography taken in July 1997. The mapping was produced in multiple sheets at a scale of 1:5000, with 1 metre contours referenced to the NAD 83 coordinate system. This was a major improvement in terms of defining the watershed topography, determining drainage basin boundaries, and providing a detailed base for GIS analysis o the terrain for snow distribution classification within the peninsula basins.

The map base for the 1997 Data Report was based on 1:50 000 scale NTS topographic maps with 10 metre contours, referenced to the NAD 27 coordinate system. To convert the NAD 27 coordinates referred to in the 1997 Data Report to NAD 83 coordinates as u in the present report, the following adjustments are applicable.

Northing:	NAD 27	+	233 m = NAD 83
Easting:	NAD 27	!	002 m = NAD 83

2.3 SNOW SURVEYS

Snow surveys were carried out in peninsula basins A and B in the period May 5 to May 1998. Snow depth and density were sampled along 10 transects over a total distance o 6600 metres. Snow distribution terrain units were identified using GIS technology appli to the new digital map base. The snow survey data were then integrated into the GIS model to calculate the total water equivalent for the snowpack in each study basin.

2.4 HYDROMETRIC MONITORING

2.4.1 General

AEE subcontracted with the Water Survey of Canada (WSC), Yellowknife, to provide services for the selection, procurement and installation of the hydrometric equipment, to assist with operation and shut down of the stations, and associated tasks. All WSC services were carried out under the supervision of Murray Jones, Supervisor, Nunavut Area, WSC, Yellowknife. All equipment and instrumentation used and the methods and procedures used for data collection and data handling, generally conformed to WSC standards.

The principal activities involved in the hydrometric monitoring program and the associat schedule, are as follows:

Pre-Season Ice and Water Levels	May 7 - 8
Installation and Startup	June 4 - 12
Operation - Inspection	Weekly throughout June - September
Operation - Discharge Measurement	Monthly throughout June - September
Seasonal Shut-Down	September 21 - 25
Data Compilation and Analysis	October through November

2.4.2 Main River Flow Monitoring

The four main river flow monitoring stations established in 1997 were continued:

- Diana River near Rankin Inlet.
- Meliadine River at the outlet of Meliadine Lake.
- Meliadine River near the mouth.
- West outlet of Meliadine Lake (discharging into the Diana River basin).

The locations of the main river monitoring stations are shown on Figure 2.1.

2.4.3 Main Lake Level Monitoring

The six lake level monitoring stations established on the main lakes in 1997 were continued:

- Meliadine Lake near Rankin Inlet (automated station)
- Meliadine Lake at Meliadine Camp (staff gauge/direct water level survey)
- Meliadine Lake at main outlet (staff gauge/direct water level survey)
- Meliadine Lake at west outlet (staff gauge/direct water level survey)
- Diana Lake (staff gauge/direct water level survey)
- Peter Lake (staff gauge/direct water level survey)

The staff gauges at the two Meliadine Lake outlets correspond to the flow monitoring stations at the same locations.

Staff gauge readings were used less than in 1997, as it was found that accurate reading were difficult to obtain when wind was present, which it usually was. Instead, direct water levels (DWL) were obtained by level survey from the local benchmarks, whenever possible.

Figure 2.1

The automated station on Meliadine Lake provided a continuous record of water levels, which were used as part of the data required to calculate outflows from the two Meliadi Lake outlets.

The locations of the lake level monitoring stations are shown on Figure 2.1.

2.4.4 Peninsula Basin Monitoring

Four of the five monitoring stations operated in 1997 were continued in 1998, and three new stations added. A total of seven station were thus operated in 1998. All except on of the 1998 stations are located in Basins A and B. The locations are shown in Figure 2

Two stations are located in Basin A; these stations are the same as those operated in Basin A in 1997. Four stations are located in Basin B; one continued from 1997 (Outlet Lake B4/Newy Lake) and three new stations. Two of the new stations are located on outlets of lakes (B5 and B7) upstream of Lake B4, and one downstream at the outlet of Basin B to Meliadine Lake. Note that the latter station is designated B2-ML, i.e., as the outlet of Lake B2 into Meliadine Lake, as Lake B1 is a very small pond which functions essentially as a widening of the Lake B2 outlet channel. Similarly, the station at the outl of Lake B4 is designated station B4-2, as Lake B3 is essentially a widening of the lake outlet channel.

The 1997 station G2-1 (Outlet of Control Lake) was discontinued as the 1997 monitoring results for this station were of poor quality due to the small size of the lake and basin, ea cessation of outflow, and poorly defined discharge rating curve. Station D5-4 (Outlet of Lake D5) was retained as a control station outside of Basins A and B.

Lake identification numbers are based on the scheme developed by RL&L Environmental Services Ltd. in 1997. To avoid confusion, this scheme has been retained, even though some additional lakes have been added, and others deleted from the basins, based on th new mapping.

Hydraulic characteristics at some of the lake outlets were identified in the 1997 Data Report
as being problematic for accurate monitoring, due to the potential for a significant fractio of flow to occur outside the channel at higher flows. Such conditions were identified at the outlets of Lakes B7, B5 and A6. Overbank flows at these outlets were restricted by placing sections of flexible rubber dam (Aquadams) at critical locations at the start of the runoff.

Photos of the stations are provided in the Photo section at the end of this report.

Figure 2.2

2.4.5 Drainage Areas

Main River Basins and Lakes

Drainage areas for the main river flow monitoring stations are summarized in Table 2.1. These areas are unchanged from those measured from 1:50 000 and 1:250 000 scale topographic mapping and used in the 1997 Data Report. The table includes identificatio of the directly connected main lake area upstream of the monitoring station, as well as a estimate of the area of the other lakes in the basin. That area is estimated at 25 percent the total basin area after deducting the area of the directly connected main lake area. Th value of 25 percent was obtained from detailed lake and land surface area measurement of the peninsula basins. The purpose of identifying lake area is to facilitate hydrologic comparison of the basins as well as to permit assessment of the effect of lake evaporatio on the basin yield and water balance.

TABLE 2.1
Main River Basin and Lake Areas in km^2

Basin Station	Land Surface	Directly Connected Lake Surface	Other Lake Surface (Estimated)	Total Lake Surface	Total Area
Meliadine River at Meliadine Lake Outlet	334	114	121	235	569
Meliadine River Tributary Basin	157	17	53	70	227
Meliadine River at Mouth	491	131	174	305	796
Diana River near Rankin Inlet	948	217	315	532	1480

Peninsula Monitored Basins and Lakes

The drainage boundaries of the peninsula basins and sub-basins monitored in 1998 wer delineated using the new map base, augmented by field inspection and verification of uncertain areas. The delineated areas were then measured in AutoCAD from the new m base, and are reported in Table 2.2. The table includes the following breakdown of area for each monitoring site:

C land surface area
C surface area of the monitored lake
C surface area and number of other lakes upstream of the monitored lake
C total area of lake surfaces
C total area of sub-basin
C ratio of lake area to total area

The table lists the values for each of the above area categories for the monitored sub-ba for the total basin including all other upstream monitoring sites if any, and for the total basin upstream of the monitored lake itself. The breakdown of basin areas facilitates hydrologic comparison between basins and permits assessment of the effect of lake evaporation on the basin yield and water balance.

TABLE 2.2
Peninsula Monitored Basin and Lake Areas

Monitoring Station	Basin	Land Surface (ha)	Monitored Lake Surface (ha)	Other Lakes		Total Lake Surface (ha)	Total Area (ha)	Ratio of Lake to Total Area
				Surface (ha)	Number			
Lake A6	Sub-Basin	457.64	54.54	137.08	49	191.62	649.26	0.295
	Upstream Basin	457.64				137.08	594.72	0.230
Lake A1	Sub-basin	250.43	16.29	23.15	35	39.44	289.87	0.136
	Total Basin	708.07	16.29	214.77	85	231.06	939.13	0.246
	Upstream Basin	708.07				214.77	922.84	0.233
Lake B7	Sub-Basin	197.55	58.10	7.03	25	65.13	262.68	0.248
	Upstream Basin	197.55				7.03	204.58	0.034
Lake B5	Sub-basin	155.11	55.94	18.34	7	74.28	229.39	0.324
	Total Basin	352.66	55.94	83.47	33	139.41	492.07	0.283
	Upstream Basin	352.66				83.47	436.13	0.191
Lake B4	Sub-basin	1149.57	85.74	309.52	167	395.26	1544.83	0.256
	Total Basin	1502.23	85.74	448.93	201	534.67	2036.9	0.262
	Upstream Basin	1502.23				448.93	1951.16	0.230
Lake B2	Sub-basin	150.60	48.95	18.71	13	67.66	218.26	0.310
	Total Basin	1652.83	48.95	553.38	215	602.33	2255.16	0.267
	Upstream Basin	1652.83				553.38	2206.21	0.251
Lake D5	Sub-Basin	238.35	7.02	123.14	18	130.16	368.51	0.353
	Upstream Basin	238.35				123.14	361.49	0.341

The areas for the sub-basins listed above represent the incremental areas for the sub-basin, not the total areas, which are obtained by adding in the areas of all the upstream sub-basins.

The areas of the four lakes monitored in both 1997 and 1998 (A6, A1, B4, D5) as measured from the new mapping resulted in values from 2 percent to 10 percent higher than the 1997 values. Sub-basin areas also changed from those given in the 1997 Data Report (Table 3.2). The differences in the total areas of sub-basins are listed in Table 2.3

TABLE 2.3
Comparison of Sub-Basin Areas Determined from 1997 and 1998 Mapping

Sub-Basin	Total Area (ha)		1998 Variance	
	1997 Mapping	1998 Mapping	ha	%
Lake A6	586.62	649.26	+62.64	+10.7
Lake A1	275.93	289.87	+13.94	+5.1
Basin A Total	862.55	939.13	+76.58	+8.9
Lake B4 Total	1783.06	2036.90	+253.84	+14.2
Lake B2	274.60	218.26	-56.34	-20.5
Basin B Total	2057.66	2255.16	+197.50	+9.6
Lake D5	357.87	368.51	+10.64	+3.0

Significant changes in drainage area boundaries, based on use of the more accurate mapping, occurred for the following:

- Lake A6 Sub-Basin: A previously excluded area along the northeast edge of the sub-basin was added into the drainage area. The area added has no defined outflow channel, but based on contours and spot elevations is considered to drain into the Lake A6 sub-basin. This change, combined with other minor boundary adjustments, means that the area used in the 1997 Data Report was 9.6 percent too low.

- Lake B4 Sub-Basin: A previously excluded area along the southwest edge of the sub-basin, southwest of Lake B53, was found to drain into the Lake B4 sub-basin and was thus included inside the new boundary. This change, combined with other minor adjustments to the boundary, means that the area used in the 1997 Data Report for the total sub-basin drainage area was 12.5 percent too low.

- Lake B2 Sub-Basin: The Lake B2 sub-basin was not monitored in 1997. Howeve this sub-basin is the most downstream sub-basin within Basin B and thus the tot drainage area of this sub-basin coincides with the total for Basin B, which was listed in the 1997 Data Report. It was found that Lake B41, previously considered part of Basin B, is actually outside the basin. The total area for Basin B is therefor reduced by the excluded area; however, the overall effect of all the changes to the Basin B boundary means that the area used in the 1997 Data Report for Basin B was 8.8 percent too low.

Drainage areas for the other sub-basins (Lake A1, Lake D5) changed less than 5 percent from those reported in the 1997 Data Report.

Table 2.2 indicates that for the peninsula basins, lakes occupy about 26 percent of the to area, on average. This is very close to the 25 percent obtained for the 1997 Data Report This slight difference was not considered significant enough to warrant revising the valu of the main river basin and lake area breakdown (Table 2.1 above) previously given in th 1997 Data Report.

2.5 MELIADINE LAKE OUTLETS CROSS SECTIONS

Cross sections of the main outlet and the west outlet of Meliadine Lake were surveyed o July 7, 1998. The purpose of the surveys was to define the channel geometry of the outlets sufficiently to permit future extension of the discharge rating curves and facilitate the simulation of Meliadine Lake water levels for hypothetical conditions. The survey no and cross section plots are provided in Appendix G.

2.6 EVAPORATION

A Class A evaporation pan was established by AEE at the WMC Camp at Meliadine Lake mid-June and operated to the end of September. The pan data were used to estimate la evaporation losses from the basins.

2.7 EVAPOTRANSPIRATION

Direct measurement of evapotranspiration (ET) was not considered feasible and was not attempted. Calculation of the potential ET using climate data from the climate station at the WMC Camp, as was done for the 1997 Data Report, could not be done in 1998 because of missing climate station data. Instead, ET losses were estimated using the value estimated for 1997, but adjusted for differences in observed 1998 climate and precipitation.

3.0 METEOROLOGICAL DATA

3.1 REGIONAL HISTORICAL PRECIPITATION

The Atmospheric Environment Service (AES) has collected meteorological data at the Rankin Inlet airport since 1981, including rainfall, snowfall and total precipitation. These data were analyzed in the 1997 Data Report on the basis of a hydrologic year. A hydrologic year is defined so as to include essentially all precipitation that contributes to the annual runoff. For the study area, most precipitation occurring after September 30 will fall as snow and accumulate over the winter to contribute to the next calendar year's runoff. Any precipitation falling as rain after September 30 would be expected to freeze into the already fallen snow or into the active layer. The hydrologic year was thus defined to extend from October 1 of the previous year to September 30 of the current year.

Rankin Inlet AES total precipitation data for the 1997-98 hydrologic year is currently available to the end of September 1998; totals for the hydrologic year can therefore be calculated. The total 1997-98 annual observed precipitation, on an hydrologic year basis, is 338.8 mm. This value is 13 percent above the 17-year annual average total precipitation of 299.3 mm. The value for each year of record, the mean, and the ratio of the annual value to the mean are listed in Table 3.1. The data listed in Table 3.1 are shown graphically in Figure 3.1.

The 1997-98 total precipitation was almost twice (1.97) the total of 172.0 mm for the previous year of 1996-97 and was the wettest year since 1990-91. The total of 338.8 mm consisted of 230.7 mm of rainfall and 109.5 mm of snowfall, representing 29 percent higher and 9 percent lower amounts, respectively, then their 17-year averages. Approximately one-third of the annual rainfall fell in the months of October 1997 and May 1998, those amounts are the highest recorded for those months in the period of record.

Updated tabulations of observed monthly and annual rainfall, snowfall, and total precipitation for Rankin Inlet, on both a calendar year and a hydrologic year basis for the period of record, are provided in Appendix B.1.

Figure 3.1

TABLE 3.1
Rankin Inlet Observed Annual Precipitation
by Hydrologic Year (Oct. - Sept.)

Hydrologic Year	Total	Total/Average
81 - 82	271.7	0.91
82 - 83	357.6	1.19
83 - 84	278.4	0.93
84 - 85	369.0	1.23
85 - 86	371.9	1.24
86 - 87	334.7	1.12
87 - 88	216.2	0.72
88 - 89	250.7	0.84
89 - 90	359.8	1.20
90 - 91	387.3	1.29
91 - 92	288.5	0.96
92 - 93	316.1	1.06
93 - 94	207.2	0.69
94 - 95	285.9	0.96
95 - 96	281.8	0.94
96 - 97	172.0	0.57
97 - 98	338.8	1.13
Average	299.3	

3.2 PROJECT SITE CLIMATE DATA

3.2.1 Data Observations

The automated climate station installed in 1997 at the Meliadine Camp by Hubert and Associates Ltd. for WMC International continued operating through 1997 and 1998. The data collected over the season were downloaded at the beginning of October 1998. Station observations included air temperature, soil temperature, humidity, wind speed and direction, rainfall (tipping bucket), and net radiation. Rainfall and soil temperature data collection were started at the beginning of June 1998.

A data loss occurred for a critical 32 day mid-summer period extending from July 7 to August 7, 1998, which affected all data except air temperature. This was similar to a 32 day data loss which occurred in 1997. Fortunately, manual rain gauge observations had been initiated for the 1998 season, which together with the manual rain gauge observations at the evaporation pan, allowed infilling of at least the missing precipitation data.

An evaporation pan was installed at the camp by AEE on June 15, 1998, and observations were made to September 13. The pan was decommissioned for the season at the beginning of October. Rainfall was observed at the pan as part of the evaporation data collection.

3.2.2 Rainfall Data

Rainfall data for the 1998 season were collected by the Meliadine Camp station, using an automated tipping-bucket rain gauge. Daily manual rain gauge observations were also made at this station, as well as at the pan evaporation station located at the Meliadine Camp. In addition, manual rain gauge observations were made at the WMC Peter Lake Camp located about 30 km west of the Meliadine Camp (see Figure 2.1). The AES Rankin Inlet station provided a fifth set of rainfall data. The five sets of data, for the common period of record, are given in Table B.2.1, in Appendix B.2. Note that the manual gauges were not always read each day; however, rainfall for days without readings were generally accumulated until the next reading was taken, as indicated by blanks in the table (as opposed to "m" for missing data). The readings thus provide correct values for the total rainfall.

Comparison of the five data sets is provided in Figure 3.2 as cumulative total rainfall over the period of common record starting on June 16, 1998 and ending September 30, 1998 for each station (except for Peter Lake for which the comparison ends on August 20 due to missing data). The missing Meliadine Camp tipping bucket station data for the period July 7 to August 7 were filled in by taking the average of the two local manual gauge observations for the day, or, the available gauge reading for those days when only one manual gauge was read.

The comparison shows that the three Meliadine Camp stations agree quite closely. The cumulative totals for the comparison period for these three gauges are: Camp tipping bucket gauge 131.2 mm, Camp manual gauge 130.4 mm and evaporation pan manual gauge 137.5 mm. The three gauges also compare reasonably closely to the AES Rankin Inlet station which totalled 145.2 mm for the comparison period. The Peter Lake data deviate strongly from the other station data, showing considerably higher rainfalls throughout the season. Based on the above results, it is concluded that the Camp tipping bucket data, filled in by using the manual gauge data, should be used for the Meliadine West Gold Project water balance for the 1998 season. That data set is given in Table 3.2. The total rainfall for the June 1 to September 30 period is therefore 139.9 mm.

TABLE 3.2
Meliadine West Gold Project
1998 Tipping Bucket Rainfall in mm

Date	June	July	August	September
1	0.0	1.7		1.3
2	0.0	0.0	0.2	0.0
3	0.0	0.0		0.0
4	0.0	0.0	0.0	3.7
5	0.0	0.0		0.2
6	0.0	4.5		2.4
7	0.0	0.0	23.4	0.0
8	0.0	0.0	0.0	1.5
9	0.7	0.0	0.0	3.6
10	2.2	0.0	0.0	0.0
11	0.0	0.0	0.1	0.0
12	3.2	0.0	0.9	0.8
13	2.5	0.0	0.0	0.1
14	0.0		0.0	16.3
15	0.0		0.0	0.7
16	0.0	23.8	0.0	0.0
17	0.0	3.7	0.0	0.0
18	0.0	3.6	0.0	0.0
19	0.4		13.8	0.0
20	0.0		6.3	0.3
21	0.0		0.0	0.1
22	2.2		0.0	0.1
23	0.0	1.6	0.0	0.2
24	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0
26	0.0	7.8	0.0	0.0
27	0.0	0.0	0.9	0.2
28	0.0	0.0	3.8	0.5
29	0.0	0.0	0.3	1.4
30	0.3	0.0	0.2	2.8
31		0.4	7.2	
Total	11.5	47.1	45.1	36.2

Note: Tipping bucket data for July 7 to August 7 estimated from manual gauges.
Blank data = data accumulated to the next date with a data value.

Figure 3.2

As a reference, the available daily rainfall as well as the daily snowfall and daily total precipitation for the Rankin Inlet AES station for 1998 are provided in Appendix B.3. Those data show that 32.4 mm of rain fell in May, of which 30.8 mm fell on May 15. However, since the mean air temperature did not rise above freezing until the beginning of June (see Figure 3.4 below), that rainfall would have been absorbed and frozen into the snow pack. Similarly, rainfall if any after the beginning of October would not be expected to run off but would be accumulated with the snow cover or be frozen into the near surface active layer until the spring of 1999.

3.2.3 Other Data

Besides rainfall, other data recorded at the camp climate station include air temperature, soil temperature, net radiation, humidity and wind speed and direction. Daily values for the hydrologic year for each of these parameters except net radiation are shown on Figures 3.3 through 3.6. An expanded plot of maximum and mean daily wind speed is provided for the June through September field season, in Figure 3.7. Net radiation data were not available due to problems with reduction of the data. Monthly mean values are summarized in Table 3.3.

TABLE 3.3
Meliadine Camp Climate Station
Monthly Data Summary 1997-98

Month	Air Temperature					Mean Soil Temperature (/C)	Mean Humidity (%)	Mean Wind Speed (km/h)
	Extreme[1]		Average[2]		Mean (/C)			
	Max (/C)	Min (/C)	Max (/C)	Min (/C)				
Oct. 1997	5.6	-19.0	-4.8	-9.3	-7.1	-2	93.2	46
Nov. 1997	0.0	-30.6	-13.2	-21.6	-17.4		89.6	35.5
Dec. 1997	-7.4	-39.2	-20.1	-27.2	-23.7	N/A	84.4	44
Jan. 1998	-20.1	-41.4	-33.5	-38.5	-36	N/A	70.8	29.3
Feb. 1998	-4.8	-40.1	-23.4	-33	-28.2	N/A	78.4	36.4
Mar. 1998	-12.0	-38.7	-22.4	-31.8	-27.1	N/A	77.9	33.3
Apr. 1998	5.5	-29.2	-9.3	-19.8	-14.5	N/A	88.5	34.4
May 1998	5.5	-17.2	0.2	-7.4	-3.6	N/A	91.4	45.7
Jun. 1998	18.4	-1.9	11.8	1.7	6.8	3.3	85.6	32.1
Jul. 1998	23.1	5.0	15.5	7.7	11.6	5.8[3]	81.3[3]	42.1[3]
Aug. 1998	25.3	1.7	14.8	7.9	11.4	7.4[4]	89.5[4]	41.3[4]
Sep. 1998	14.3	-0.9	8.3	3.2	5.8	4.4	94.2	36.7

Notes:
1. Extremes for the month.
2. Average of the daily extremes for the month.
3. For period July 1 - 6 only.
4. For period August 8 - 31 only.

Figure 3.3

Figure 3.4

Figure 3.5

Figure 3.6

Figure 3.7

3.2.4 Evaporation

3.2.4.1 Evaporation Measurements

The evaporation pan used for the 1997 season was stored over winter at the camp and re-installed on June 15, 1998 allowing observations to start on June 16 (Photo 38). Observations continued through the season to September 13, 1998; the pan was decommissioned for the season at the beginning of October. Monitoring instructions provided to the operator are attached in Appendix A. The pan evaporation observational data are summarized in Table B.4.1 in Appendix B.4. The cumulative (gross) pan evaporation is shown in Figure 3.8.

The data reported in Table B.4.1 are adjusted data. The raw data included a number of cumulative readings representing periods of several days, some readings with obvious errors such as misplaced decimals, some readings affected by high winds blowing water out of the pan, and a few days with missing data. The periods for which cumulative data were available were adjusted by distributing the end of period reading evenly over the days which had been accumulated, the obvious decimal place errors were corrected, and the missing and wind affected data were estimated by taking an average of the three days preceding and the three days following each gap.

The evaporation for the period prior to June 16 was estimated by assuming that the daily evaporation rate increased linearly from zero on June 1, to 3.5 mm/day on June 15. June 1 is the estimated date on which ice cover on the lakes started to diminish and open water started to appear (see Section 5.6 below on the rate of ice cover melting). The evaporation rate of 3.5 mm/day is the weekly average evaporation rate measured for the first week of observations starting June 16. The total evaporation for the period June 1 to 15 is thus estimated to be 26.3 mm.

Similarly, the evaporation for the period after September 13 was estimated by assuming a linear decrease from a daily value of 2.3 mm for September 14 to zero at the end of September. The total evaporation for the period September 14 to 30 is thus estimated to be 19.7 mm. The total gross evaporation loss for the 1998 season was thus 392.2 mm, with a monthly distribution as shown on Figure 3.9. The largest monthly evaporation occurred in July, when 138.2 mm or 35 percent of the annual total occurred.

3.2.4.2 Net Pan Evaporation

The net pan evaporation for the 1998 season is obtained by subtracting the total precipitation during the season from the gross pan evaporation of 392.2 mm. The precipitation for the period June 1 to September 30, as recorded and estimated for the Meliadine Camp tipping bucket gauge, equals 139.9 mm. The net pan evaporation calculated for the 1998 season thus equals 252.3 mm.
Figure 3.8

Figure 3.9

3.2.4.3 Lake Evaporation

Lake evaporation was estimated from the evaporation pan data using the method adopted by AES (Kohler, Nordenson, and Fox, 1955). That method computes lake evaporation as a function of the pan water temperature, the air temperature, the daily wind run (wind run = wind speed x duration), and the pan evaporation.

The available data allowed computations to be completed for 48 days over the open-water season. The computational method and results are given in Appendix B.5. The pan coefficient found for the period equals 0.82. That value is considerably higher than the pan coefficient of 0.70 adopted for the 1997 season. However, the value of 0.82 is considered reasonable for 1998 because the pan location was changed from the exposed ridge used in 1997 (see 1997 Data Report, Photo 30) to a low-lying site in a wetland adjacent to a lake (Photo 38). At the 1998 location the pan evaporation would be expected to be closer to the actual lake evaporation.

The value of 0.82 applied to the complete season provides a total gross lake evaporation of 321.6 mm. Subtracting the total rainfall of 139.9 mm results in a net lake evaporation of 181.7 mm.

3.2.5 Evapotranspiration

The estimation of evapotranspiration (ET) for the project area using the "GD Relationship" proposed by Granger and Gray (1989), as was done for the 1997 data report was not possible for 1998 due to significant gaps in the Meliadine Camp climate station data. Therefore, a less precise estimate was made based on the 1997 results and adjusted for differences in observed pan evaporation and rainfall availability through the season.

For 1997, the potential ET (i.e., maximum possible) was estimated to be 225 mm, whereas the actual ET was estimated to be 15 percent of the potential amount, or 33.8 mm, due to limitations in transpiring vegetative surfaces, and limited moisture availability.

For 1998, it is estimated that the potential ET was less than the 1997 potential ET by about the same ratio as the gross pan evaporation ratio for the two years, i.e., 392/468 = 0.84. On the other hand, significantly more moisture was available for ET processes for the 1998 season; it is estimated that the ratio of actual to potential ET could be in the order of 0.20 for 1998 conditions. The 1998 value for ET is therefore estimated to be (0.20)(0.84)(225 mm) = 37.8 mm.

4.0 SNOWPACK WATER EQUIVALENT

4.1 METHODS AND EQUIPMENT

The methods and equipment used for the 1998 snow surveys are the same as those used in 1997 and described in the 1997 Data Report, with the following improvements:

- The new 1:5000 mapping with 1-metre contours was used to locate the transects.

- Utah Snow Kits with metric units were used, allowing snow depth readings to be made directly in centimetres.

A total of ten transects were located and surveyed, ranging in length from 300 metres to 1650 metres, in Basins A and B (Photos 1 and 2). The locations are shown in Figure 4.1. A total transect length of 6600 metres was surveyed. The surveys were carried out on May 6 and 7, 1998.

The measured snow depths and densities and the topography traversed by each transect are shown graphically on Figures 4.2 through 4.11. A complete tabulation of the snow survey data are provided on Tables C.1 through C.10 in Appendix C. The tables include the GPS coordinates (referenced to the new mapping NAD 1983 coordinates) for the transect end points as observed in the field. In some cases the transect end points as plotted on Figure 4.1 do not agree exactly with the GPS field points because of the inherent limited accuracy of the GPS units.

4.2 TERRAIN UNITS AND SNOW DISTRIBUTION

Terrain units were identified by examination of the snow survey results relative to the topography as indicated on Figures 4.2 to 4.11. Initially, GIS methods were applied to the snow survey data using the digital mapping to attempt to find correlations between characteristic snow depths and terrain. This attempt did not produce satisfactory results, and a manual approach was used which relied upon visual identification of distinctive patterns of snow depth and topography as plotted on the figures, a knowledge of wind effects on snow deposition, and field experience.

Ten terrain units were identified using the above approach, and for each unit the characteristic 1998 snow depths and densities were determined from the snow survey data. The results are summarized in Table 4.1.

Figure 4.1

Figure 4.2

Figure 4.3

Figure 4.4

Figure 4.5

Figure 4.6

Figure 4.7

Figure 4.8

Figure 4.9

Figure 4.10

Figure 4.11

TABLE 4.1
1998 Terrain Units and Representative Snow Depths, Densities and SWE

Terrain Unit		Snow Course Transect	Start Station	End Station	Depth (cm)		Density (%)		SWE (mm)
No.	Description				Mean	SD[3]	Mean	SD[3]	
1	Lake	1	110	270	17.4	8.0	35.5	0.5	
		2	160	480	15.3	9.9	13.8	9.1	
		3	440	590	13.4	7.9	36.0	1.4	
		3	1230	1470	17.7	13.4	36.6	4.0	
		4	1050	1150	21.3	5.6	37.0	0.0	
		7	0	50	24.5	8.6	34.3	7.1	
		8	200	320	21.9	11.3	35.7	4.7	
		9	0	60	19.1	6.3	32.7	2.1	
		Combined	1270[1]		**18.0**	**10.6**	**30.1**	**11.1**	**54.2**
2	Lake Edges	1	0	100	32.7	20.3	44.8	4.4	
		2	490	540	29.7	12.7	28.0	11.0	
		3	380	430	22.8	9.2	34.0	0.0	
		3	1160	1220	30.9	21.1	29.5	0.5	
		9	70	120	30.3	2.6	36.7	1.2	
		Combined	350[1]		**29.8**	**14.4**	**35.9**	**7.8**	**106.9**
3	Crest	1	330	400	6.6	4.2	37.3	2.4	
		2	0	80	2.4	2.8	4.0	2.0	
		3	730	890	9.9	8.9	38.5	1.6	
		4	230	290	4.6	3.6	33.0	0.0	
		7	170	300	12.7	6.0	22.0	0.0	
		8	0	120	15.6	8.0	30.7	3.9	
		Combined	670[1]		**9.6**	**8.0**	**29.5**	**9.8**	**28.3**
4	Low Slopes (<3%)	2	870	1220	22.2	10.2	11.3	4.2	
		3	1050	1150	10.2	5.7	32.0	2.4	
		5	170	500	28.7	16.0	34.1	4.0	
		6	0	310	28.4	13.9	33.3	4.1	
		6	400	700	27.0	13.7	38.7	2.2	
		9	130	500	29.2	11.5	34.1	5.3	
		Combined	1810[1]		**26.0**	**13.7**	**33.5**	**6.9**	**87.2**
5	NE Slopes (3-8.5%)	calculated from 6 and 8[2]			**23.2**		**30.2**		**70.0**

Terrain Unit		Snow Course Transect	Start Station	End Station	Depth (cm)		Density (%)		SWE (mm)
No.	Description				Mean	SD[3]	Mean	SD[3]	
6	NE Slopes (>8.5%)	1	280	320	74.4	51.9	37.7	1.9	
		2	90	150	48.0	17.4	53.3	13.3	
		3	600	720	43.2	23.8	39.8	2.4	
		3	1480	1530	52.0	21.4	37.8	1.3	
		8	130	190	43.0	9.1	35.7	4.9	
		Combined	370[1]		**49.9**	**28.2**	**40.6**	**8.4**	**202.4**
7	SW Slopes (3-8.5%)	2	550	860	15.1	9.4	11.9	10.2	
		3	0	370	21.6	12.3	39.8	5.4	
		6	320	390	42.9	19.4	34.7	4.8	
		Combined	770[1]		**21.1**	**14.5**	**28.0**	**15.4**	59.0
8	SW Slopes (>8.5%)	3	730	890	39.5	16.6	37.9	2.5	
		8	0	120	56.6	17.7	37.5	4.3	
		Combined	220[1]		**45.4**	**18.9**	**37.7**	**3.5**	**171.1**
9	NW Slopes (>3%)	4	100	220	51.4	23.4	39.4	3.2	
		7	60	160	52.3	24.1	31.8	6.9	
		Combined	240[1]		51.8	23.7	36.0	6.4	186.5
		Adjusted			**90.6**				**326.2**
10	SE Slopes (>3%)	5	0	160	59.6	30.4	39.4	3.3	
		Combined	160		59.6	30.4	39.4	3.3	235.0
		Adjusted			**104.3**				**410.9**

Notes: 1. Total length of transects used to obtain characteristic snow values.
2. Values for Terrain Unit 5 = value for Terrain Unit 7 adjusted by ratio of Unit 6 values to Unit 8 values.
3. SD = standard deviation of sample data.

The table identifies the segments of transects that were used to define the characteristics for each terrain unit. The following points apply to the tabulated data:

C Transect 10 was not used, as the snow survey data did not appear to correlate with the transect topography as shown on Figure 4.11. This is considered to be due to the fact that this transect was located at a skew across the slope and that the snow survey data reflect the effects of adjacent topography.

C 97 percent of the data for Transects 1 through 9 (5860 metres out of a possible 6050 metres) were used to obtain the data in Table 4.1.

- Lake edges were defined as a 60 metres wide band, with 30 metres into the lake and 30 metres along the land around the lake.

- The "lake edge" terrain unit, where lakes are bounded by slopes greater than 3 percent, was suppressed in favour of the slope terrain unit.

- Lake and lake edge terrain units were considered to apply to lakes larger than 1 hectare in area only. Smaller lakes with an area of 1 hectare or less were considered to be part of the "low slope" terrain unit.

- Because of a lack of direct snow survey data, the snow characteristics for terrain unit number 5 (NE Slopes 3 to 8.5 percent) were obtained by adjusting the values found for unit 7 (SW Slopes 3 to 8.5 percent) by the ratio of the unit 6 to unit 8 values.

In addition to the above, the snow depths as initially obtained for terrain units 9 and 10 were adjusted upward by 75 percent because of the following:

- When the terrain unit snow depth values obtained using the above procedure (i.e., the modelled values) were plotted back onto the transects, it was found that the obtained values for terrain units 9 and 10 appeared to be only about half of the observed values. This was a result of selecting transect segments too long to be representative.

- The total weighted snow depth for all transects using the obtained values was about 9 percent below the observed.

The values for terrain units 9 and 10 were thus adjusted so that the total weighted modelled and observed values were equal.

The snow water equivalents (SWE) reported in Table 4.1 are obtained by multiplying the mean snow depth in centimetres by the snow density (expressed as a percent of the density of water).

4.3 SNOWMELT VOLUME AND SNOW WATER EQUIVALENT

The monitored sub-basins were divided into the ten terrain units using the GIS software ARC/INFO. The methodology is given in Appendix C.2. The sub-basins with the distribution of the terrain units for each are shown on Figure 4.12.

The 1998 SWE value characteristic of each terrain unit as reported in Table 4.1 was applied to the area of each terrain unit within each sub-basin to obtain an estimate of the total SWE in the sub-basin. The distribution of SWE values within the sub-basins is shown on Figure 4.13. However, those SWE values represent the total SWE of the snowpack as of the

Figure 4.12

Figure 4.13

date of the snow survey, May 5 to 6, 1998. Precipitation which occurred after the snow survey and which was added to the snowpack prior to snowmelt should be added to those values.

Review of the 1998 climate data (see Section 3) and runoff data (see Section 5) indicates that snowmelt runoff started on June 1. All precipitation prior to June 1 is therefore assumed to have been accumulated in the snowpack. Examination of the Rankin Inlet AES 1998 precipitation data in Appendix B shows that, in the period May 7 to 31, a total of 4.8 cm of snowfall was recorded. It is assumed that this snowfall was not significantly redistributed or sublimated by wind, and that it can be added to the SWE of all transects at a density of 10 percent or 4.8 mm of SWE. In addition to the snowfall, a total rainfall of 32.0 mm was recorded for the same period. Almost all of that rain fell on May 15, during a short warm spell. It is assumed that the rain was absorbed into the snowpack. The total additional SWE to be added for the period May 7 to 31 thus equals 36.8 mm. The results are summarized in Table 4.2.

TABLE 4.2
Sub-Basin 1998 Snow Water Equivalents (SWE)

Basin	Sub-Basin Area (km^2)	SWE mm	Cumulative Basin		Post Survey SWE (mm)	Total SWE (mm)
			Area (km^2)	SWE (mm)		
Lake A6	6.4926	94.2	6.4926	94.2	36.8	131.0
Lake A1	2.8987	109.0	9.3913	98.8	36.8	135.6
Lake B7	2.6268	93.8	2.6268	93.8	36.8	130.6
Lake B5	2.2939	94.7	4.9207	94.2	36.8	131.0
Lake B4	15.4483	98.4	20.369	97.4	36.8	134.2
Lake B2	2.1826	100.9	22.5516	97.7	36.8	134.5
Lake D5	3.6851	98.0	3.6851	98.0	36.8	134.8

The snow water equivalents listed in Table 4.2 represent the volumes of water released by the melting of the snowpack within each sub-basin in the spring of 1998. It is evident that the total SWE values for the cumulative basin at each monitoring site differ by less than 5 percent, indicating a high degree of similarity with respect to snow accumulation characteristics at the basin level.

4.4 COMPARISON WITH 1997 RESULTS

The 1998 hydrologic year snowfall recorded at Rankin Inlet AES up to the time of the May 5 to 6 snow survey totaled 104 mm. That is about 36 percent higher than the 1997 hydrologic year snowfall of 76 mm. However, the SWE values of about 110 mm estimated for Basins A and D in 1997 are higher than the 1998 estimates of about 100 mm. The 1997 SWE values may thus have been too high by a factor of about 50 percent. It is considered that the 1997 SWE values are too high because of inaccurate distribution of the terrain units within the basins as a result of the limited mapping available. For example, the 1998 mapping permitted identification of crest areas, which had very low snow accumulations, while the 1997 work assumed that opposite slopes met at hill crests with no actual crest area. Consequently, too much area was assigned as slopes, with relatively high snow accumulations, resulting in an over-estimate of the overall SWE.

Comparison of the two sets of results for individual transects was not possible because the 1998 transects did not correspond to the 1997 transects. However, two of the terrain units used in 1998 correspond to terrain units used in 1997: lake surfaces and flat areas. Comparison of the 1997 and 1998 values for those units show that the 1998 values are 59 percent and 23 percent higher, respectively, for an average of 41 percent higher, than the 1997 values. Those comparisons therefore correspond to the 36 percent increase in snowfall for 1998 indicated by the climate station data, and support the above hypothesis that the 1997 overestimate of SWE was due not to the snow survey data but to the less detailed mapping then available for interpreting the 1997 data.

5.0 HYDROMETRIC MONITORING RESULTS

5.1 OVERVIEW

Hydrometric data collection consisted of monitoring lake levels, lake outflows and river discharges. Monitoring was conducted of the following:

Meliadine River Basin

Meliadine Lake levels
Meliadine Lake discharge to Meliadine River
Meliadine Lake west discharge to Diana River Basin
Meliadine River discharge at the mouth

Diana River Basin

Diana River discharge near Rankin Inlet
Peter Lake levels
Diana Lake levels

Meliadine Lake Peninsula Basins

Seven peninsula basin lakes - levels and discharges

The station locations and descriptions are provided on standard WSC station description forms, in Appendix D.

Identification of the equipment and methods used, and presentation and discussion of the 1998 monitoring results including comparison with the 1997 monitoring results, are given in the following sections. Photos of the monitoring locations and the monitoring activities are provided in the photo section at the end of this report.

5.2 EQUIPMENT AND METHODS

5.2.1 General

Water level and discharge monitoring were carried out using the same equipment as in 1997, and, in general, the same methods and procedures. The equipment and methods used are described in the 1997 Data Report, with modifications as discussed below.

The planned schedule of hydrometric monitoring activities, a detailed monitoring checklist, and a list of special requirements for the 1998 monitoring season were developed and reviewed with the field staff at the start of the monitoring season. Copies of those documents are provided in Appendix A.

5.2.2 Water Level Observations

For the 1998 program, less reliance was placed on use of the staff gauges to observe water levels at the five main lake manual water level monitoring sites (see section 2.4.3 above), because of difficulty in reading the gauge plate under the typical windy conditions in the region. Instead, direct water level (DWL) observations were made by survey from the local benchmarks whenever feasible. The latter method was used consistently at the Diana Lake station, as no staff gauge was installed there for 1998 due to the disappearance of one of the five staff gauge plates from storage over the 1997-98 winter season.

5.2.3 Discharge Measurements

Discharge measurements were conducted at eleven stations during 1998: three Meliadine Lake outlet and River stations, one Diana River station, and seven peninsula basin stations (see Section 2.4). The discharge at each station was measured from five to seven times during the 1998 season, except for the Diana River station where only two measurements were done as the rating curve for the Diana station is very stable.

5.2.4 Pre-Season Lake Levels and Conditions

The water (and/or ice) levels of all the monitored lakes were surveyed relative to local benchmarks prior to the 1998 runoff season. The measurements were carried out in early May, in conjunction with the snow survey work (Photo 3). Measurements involved augering a hole through the lake ice. Ice thicknesses varied in the range of 1.8 metres to 2.2 metres. Some lakes at the augered locations were found to be shallower than these depths and were thus frozen solid to the bottom. In addition, the conditions at the Meliadine River at the Outlet of Meliadine Lake were observed and a discharge measurement was made (Photo 4).

5.2.5 Vertical Control

Vertical control at the stations was a problem in 1997 due to the gradual shifting (due to ground thawing) of the benchmark(s) used to obtain DWL values during the season. Typically, vertical control at a station is provided by a reference benchmark (usually labelled BM#1) located on the most stable available local feature (usually a bed rock outcrop or a large rock). Two other benchmarks, established at locations more convenient for the season's DWL surveys, are then tied-in to the reference benchmark and used for the year.

In 1997, the movement of the benchmarks used during the season was not tracked adequately as the season progressed, leading to some uncertainty as to the correction factors to apply to the water level record. For the 1998 program, a level circuit (i.e. survey tie-in) of the local benchmarks was typically carried out four times during the season, to better track the shifting of the benchmarks used for the year. For stations where the reference benchmark was routinely used for the DWL surveys, only two level circuits were typically carried out.

In addition, it was attempted to make survey ties from station local benchmarks to a network of benchmarks referenced to geodetic datum, established by WMC for their exploration work. However, after expending considerable effort to locate some of the benchmarks, all except one were found to consist of spikes pushed into the ground, and not fixed to anything solid such as a rock. These were thus of no value as a vertical control reference and were not used. It appears that these benchmarks were established primarily for approximate horizontal control rather than vertical control.

A single WMC benchmark was found to provide a fixed vertical reference, BM 1005. That benchmark consists of a bolt fixed to bedrock, in the vicinity of the Lake A6 outlet station. A level circuit between BM 1005 and BM#3 at the Lake A6 station was run on August 2, 1998. However, the other local reference benchmark at the Lake A6 station was not tied in, and the circuit was not repeated to check on movement relative to BM 1005.

5.2.6 Control of Bypass Flows

In the 1997 Data Report it was estimated that for 1997 conditions at the peninsula basins lake outlet monitoring stations, some discharges bypassed the stations due to overbank flows at high water levels. In order to reduce the errors associated with this situation, especially for the two additional stations in peninsula Basin B, it was decided to install barriers to block potential bypass flows. The potential maximum length of barriers required was estimated from the new contour mapping, the aerial photos, and the 1997 experience to amount to 540 metres.

However, barriers could not be installed on top of the snow covered outlet areas as initial flows could then undermine the barriers and wash them out. Digging out the snow in advance was deemed impractical because of uncertainty in locating the outlets under the snow cover and the excessive manpower requirements. It was thus concluded that barrier placement could only be initiated at the very start of outflow, after snowcover was sufficiently depleted.

An initial plan was developed to use sandbags, however, the logistics and manpower requirements to prepare, transport and place a significant number of sandbags in a relatively short time were problematic. An alternative plan was developed based on using low flexible rubber dams 450 mm high. The dams, known by the trade name of “Aquadams” , were easily transportable to the desired sites where they could be installed by being unrolled and filled with water.

Materials and resources were arranged to allow for placement of up to 540 metres of dams. The locations and maximum lengths planned for placement, and the actual lengths placed and the placement dates, are given in Table 5.1. A small amount of sandbags were used as abutments to anchor the ends of the dams (Photo 13).

TABLE 5.1
1998 Aquadams Planned and Placed

Location	Maximum Planned Length (m)	Actual Placement (m)	Date of Placement
Outlet of Lake B7	120	60	June 9
Outlet of Lake B5	225	45	June 9
Outlet of Lake B4	75	0	
Outlet of Lake B2	75	0	
Outlet of Lake A6	30	30	June 10
Outlet of Lake D5	15	0	
Total	540	135	

Considerably less length of dams were placed than anticipated because of the following factors:

- Limited manpower meant that not everything could be done to the ideal desired. Thus, placement of additional dam lengths to control a diminishing fraction of overbank flows was foregone in order carry out the more important work of establishing and starting up the monitoring stations and carrying out critical initial discharge measurements.

- Discharge from the outlet of Lake B4 was initially confined by snow banks. Subsequently, discharges were measured at a relatively confined downstream location.

- Discharges from the outlet of Lake B2 turned out to be reasonably well confined by the natural downstream channel.

- Discharges from the outlet of Lake A1 were well confined at all stages.

- Some overbank water was noted at the outlet of Lake D5, but no flow velocity was detected.

Surplus lengths of Aquadams were retained on site for future use. Some lengths were used to control drilling fluids around the drill rigs. The Aquadams and associated sandbag abutments were removed on August 23 and stored.

5.3 1998 MONITORING RESULTS

5.3.1 1998 Data Set

Complete data sets were obtained for all monitoring stations with the exception of Meliadine Lake at Meliadine Camp (staff gauge water levels) and the Outlet of Lake A1.

The Meliadine Lake at Meliadine Camp staff gauge, although it is close to the camp and relatively straightforward to read, and although instructions were given for daily readings to be taken, was read only three times during the season. These data are intended to provide a backup for the automatic datalogger station in Meliadine Lake, and to provide a basis for interpreting lake level fluctuations caused by wind. Fortunately, these data were not essential to the program.

At the Outlet of Lake A1 one of the station's connections was accidentally dislodged during the August 13 site inspection, with the result that no subsequent data were collected until the station shutdown visit of September 23. However a good correlation with the Lake A6 data permitted estimation of the missing runoff volume for the season.

Detailed presentation and discussion of the 1998 runoff results are provided in Section 6.3.3 below.

A summary of the data collected at each of the monitoring stations is provided in Appendix E and generally includes the following items:

Site Inspection Summary

A summary of when the station was visited and inspected, the discharge measurements made for the season, the zero outflow elevation of the outlet, the measured DWL water levels and the datalogger water levels, any staff gauge readings, and the adjustments to be made to the datalogger record.

Rating Curve Plot

A plot of the discharge versus water level elevation relationship (rating curve) and the observed data points on which the curve is based. The 1997 data points and rating curve are included where applicable to indicate any changes from 1997.

Water Level Plot

A plot of daily mean water level versus time. The plotted water level values are those listed in the Water Level Table (see below). Superimposed on the plot are the DWL survey observations made during the season. The zero flow elevation is identified which defines the point below which there would be no surface outflow from the lake.

Discharge Plot

A plot of daily discharges versus time. The plotted discharges are those listed in the Discharge Table (see below). Superimposed on the plot are the discharge measurements made during the season. In addition, the observed daily rainfalls for the area are plotted on the figure to show how the station discharge responded to the rainfall inputs.

Water Level Table

A table of daily mean water levels for the period of observations. The tabulated values are those obtained from the datalogger record adjusted by linear interpolation between the adjustment points listed in the Site Inspection Summary.

Discharge Table

A table of daily mean discharges for the period of observation. The discharge for each day is obtained from the adjusted daily water level and the rating curve. The daily water levels are those recorded by the datalogger, adjusted by linear interpolation between adjustment points determined by comparing the discharge measurements to the rating curve. The table also reports maximum, mean and minimum values of discharge, and the monthly and total volume of water discharged.

Gauge History

A history of the vertical control at the station including descriptions and elevations of the benchmarks.

5.3.2 Uncertainties and Sources of Error

Uncertainties and sources of error were involved in the monitoring program, which affected the accuracy of the data and the resulting water balance calculations. These were listed and discussed in the 1997 Data Report. The following discussion identifies improvements that were made and the remaining sources of error.

Vertical Control

Vertical control was much improved over 1997. No significant errors are considered to have been introduced into the data due to vertical control issues in 1998.

Field Staff Human Error

The lead field staff provided by WMC was the same as in 1997, which resulted in improved and more consistent field procedures and record keeping in 1998. Nevertheless, due to competing demands placed on field staff by other field programs, and due to the use of various assistants with differing skill levels during the year, as well as replacement of the lead staff toward the end of the season by less experienced and inadequately trained replacement staff, some errors and omissions occurred. In general, errors were obvious and could be corrected with confidence. Omissions were not of a serious nature, and did not compromise the overall reliability of the 1998 data.

Wind Effects

At some of the stations, the lake water level is measured some distance from the lake outlet (due to the need to locate the bubbler orifice in deeper water). In such cases, wind-induced set up of the lake surface could cause a difference in water level between the orifice location and the outlet, causing actual outflows to be slightly higher or lower than indicated by the observed level. The influence of wind is discussed in connection with specific station results in following sections.

Discharges Bypassing Peninsula Basin Monitoring Stations

It is estimated that due to the placement of barriers, the amount of discharge not measured due to bypassing of peninsula monitoring stations by overbank flows was less than that which may have occurred in 1997. This factor was thus not considered to be a significant source of error for the 1998 data.

Rating Curve Data Scatter

The data points of measured discharge versus water level generally do not describe a smooth line relationship, due in part to the factors listed above, but also due to inherent limits in equipment and measurement accuracy and the variation in other factors such as vegetative growth in the outlet channel which can alter the discharge characteristics.

In general, the rating curves obtained for 1998 are considered to have better accuracy than the 1997 curves. An assessment of the 1998 rating curve quality and accuracy is given in Table 5.2.

As indicated in the table, the rating curves for the outlets of Lake B7 and Lake D5 are assessed as "mediocre". In the case of Lake B7, the rating curve plots as two line segments (see Appendix E, Figure E.12.1), which is not normal. However this is likely due to the fact that the first discharge measurement (plotted as the point labelled "B" for ice conditions) was made before the Aquadams were installed, while the others were made afterward. Photo 14 of the Lake B7 Aquadam installation show that the dams did create some backwater in the lake and thus affected the rating curve relationship. The Aquadam installations at Lakes B5 and A6 appear to not have affected the rating curve relationships (Photos 16 and 32).

The Lake D5 rating curve may be affected by backwater conditions from Lake D4 downstream during low flows. Discussions with field staff concerning conditions at this station indicate that during low water conditions, but with water levels above the "zero flow" level, flow velocities were at times observed to be zero. At other times water appeared to be driven in the upstream direction by the wind. The lack of a clear hydraulic control at the outlet is indicated in Photos 12 and 28.

TABLE 5.2
Rating Curve Accuracy Assessment

Rating Curve Assessment	Estimated Accuracy of Computed Discharges	Station
Excellent	±5%	Diana River Meliadine River near the Mouth
Good	±10%	Meliadine River at Outlet Meliadine Lake Outlet of Lake A6 Outlet of Lake A1 Outlet of Lake B5 Outlet of Lake B4 Outlet of Lake B2
Mediocre	±20%	West Outlet of Meliadine Lake Outlet of Lake B7 Outlet of Lake D5

Estimation of Runoff for Pre-Record and Post-Record Periods

Runoff at the peninsula basins is characterized by a very rapid rise to maximum discharge rates followed by a rapid fall to lower discharges. It was not possible to capture the first few days of runoff, meaning that a sizable fraction of the annual runoff volume was not measured directly and had to be estimated. Similarly, shutdown of the stations before freeze-up required that subsequent runoff had to be estimated.

5.4 PRE-SEASON CONDITIONS

5.4.1 Lake Water Levels

Observed Water Levels

The pre-season water and/or ice levels at all the lake monitoring stations were surveyed on May 7 and 8, 1998. The results are summarized in Table 5.3, together with a comparison of the change from the levels observed at the end of September 1997.

TABLE 5.3
Lake Water and Ice Levels, May 1998

May 1998 Conditions					Comparison of Change September 1997- May 1998					
Date 1998	Lake	Ice Thickness (m)	Ice Level (m)	Water Level (m)	Sept. 1997 Water Level (m)	Water Level Change (m)	Lake Area (km^2)	Volume Change Lake (dam^3)	Volume Change Basin (mm)	Basin Area (km^2)
Main Lakes										
35921	Meliadine	1.97	3.254	3.144	3.154	-0.010	114	-1140	-2	569
35921	Peter	2.19	7.245	7.075	6.936	0.139	177	24603	17	1480
35921	Diana	2.14	6.03	5.85	5.840	0.010	40	400	0	1480
Peninsula Lakes										
35922	Lake A6	1.6	9.218	*9.09*[1]	9.096	-0.006	0.5454	-3		
35922	Lake A1	1.82	9.08	9.060	9.206	-0.146	0.1629	-24		
35922	Lake B7	1.99	7.996	7.846						
35922	Lake B5	2.09	8.539	8.399						
35922	Lake B4	1.0	8.079	*7.999*[1]	7.755	0.244	0.8574	209		
35922	Lake B2	1.90	7.568	7.388						
35922	Lake D5	1.3	8.275	*8.171*[1]	7.975	0.196	0.07	14		

Note: [1] Lake frozen to bottom; equivalent water level assumed = ice level - 0.08 ice thickness

Main Lake Levels and Storage Changes

For the main lake stations, the table shows that the May 1998 Meliadine Lake level was only slightly less (10 mm) than the September 1997 level, while the level of Peter Lake rose by 139 mm and Diana Lake was slightly higher (10 mm) than in September 1997. Converting these water level changes into lake volume and corresponding basin yield changes, as shown on the table, it is seen that Meliadine Lake storage volume was reduced by 2 mm of basin yield, while the combined Peter and Diana Lakes increased in storage volume by an amount equal to 17 mm of basin yield.

To obtain a more complete picture of basin yield over the winter period, the volumes discharged from the lakes between the September 25 and May 7 water level observation dates should be added to the volumes tabulated above. For Meliadine Lake, the discharged volume is estimated below as 7260 dam^3, which corresponds to a basin yield of 13 mm. For the Diana basin, that volume is listed in Table 6.3 of the 1997 Data Report (in the “post-record volume” column) as 14 800 dam^3, which corresponds to a basin yield of 10 mm. The total basin yields for the noted winter period are thus as follows:

Meliadine Lake Basin winter yield = 13 mm - 2 mm = 11 mm
Peter/Diana Lake Basin winter yield = 10 mm +17 mm = 27 mm

Note that 2 mm of the Meliadine Lake basin's 11 mm and 10 mm of the Peter/Diana Lake basin's 27 mm winter basin yields were credited to the 1997 runoff year in the 1997 Data Report (p. 72, Table 6.3 "1997 Runoff Summary", "Post-Record Volume" column).

The winter yields noted above must have been contributed by "runoff" from the lake drainage basins into the lakes after September 25, 1997. It is not known whether this runoff was derived from precipitation received prior to October 1, 1997 and routed through the basins, or whether some or all of the 45.1 mm of rainfall (and/or the 32.4 cm of snowfall) observed for the first half of October 1997 (see 1997 Data Report Table B.3.1) may have contributed to this runoff. For consistency with the assumptions made in this study, i.e., that all precipitation received after September 30 is stored in the basin and contributes to the next year's runoff, it is assumed that the winter yields as noted above were derived from the 1997 hydrologic year ending September 30, 1997.

Peninsula Lake Levels and Storage Changes

For the four peninsula lakes measured in both September 1997 and May 1998, the Lake A6 level remained essentially unchanged, Lake A1 dropped 146 mm, Lake D5 rose by 196 mm and Lake B4 rose by 244 mm. There is no obvious rationale to explain the different responses of the peninsula basin lakes. The factors involved may include differences in the timing of freeze up of the lake inlets and outlets.

Peninsula lake storage changes are not expressed in terms of basin yield, as the value of that term depends on the area of the basin relative to the area of the monitored lake and thus varies considerably among the monitored basins.

5.4.2 Main Basin Station Discharges

Conditions at the Meliadine River at the outlet of Meliadine Lake were observed on May 5 and 7. The outlet was observed to be discharging, with several sections of open channel located near the monitoring site. The discharge was observed to be flowing onto the ice and snow cover downstream. Large areas of icing were observed where the discharge had spread out and frozen over the downstream ice cover (Photos 5 to 7). It was estimated that discharge had probably been continuous through the winter. The discharge was measured on May 7, 1998 to be 0.309 m^3/s. The discharge was measured to be 0.477 m^3/s on the previous September 25, 1997. The May 19, 1997 discharge was measured at 0.600 m^3/s.

The winter discharge from Meliadine Lake over the period September 25, 1997 to May 7, 1998, which corresponds to the period between the last 1997 and first 1998 Meliadine Lake water level measurements, is estimated by assuming that the discharge declined to 0.309 m^3/s by November 30, 1997 and then remained steady through the winter to the start of the 1998 runoff (June 1). The runoff volume for the noted period is thus calculated to be 7260 dam^3.

The West outlet of Meliadine Lake, the Meliadine River near the Mouth, and the Diana River were investigated on May 7, 1998 on the ground, visually and by augering through the ice, and were found to be frozen to the bottom with zero discharge.

5.5 DISCHARGE HYDROGRAPHS

The plots of daily discharge versus time (hydrograph) as obtained from the daily water levels and the rating curve for each station, are given on Figures 5.1 through 5.4 for the three Meliadine basin stations and the Diana River station (the four main basin stations) and on Figures 5.5 through 5.11 for the seven peninsula basin stations. The hydrographs for the four main stations show that the peak discharge was captured at all four. For the seven peninsula stations, only the Lake D5 hydrograph captured the peak. The runoff peak for the other six stations passed too quickly to be captured, even for those stations which were started up within three days of the beginning of first runoff.

Each plot includes the discharge measurements made at the station during the season. The improved methodology of measurements and data reduction computations have resulted in the measured points plotting very close to the calculated hydrographs.

Each hydrograph includes a plot of the daily rainfall amounts recorded by the WMC Camp climate station tipping bucket gauge (with missing data filled in using the manual rain gauges). Inspection of the hydrographs for the four main stations shows that there was a small response to the three larger rainfall events of the season which were in the order of 20 mm. Other irregularities in the hydrographs are largely due to wind effects (see below). The hydrographs for the seven peninsula basins show a very weak response to rainfall. The effect is somewhat more noticeable on the water level plots (see Appendix E). The effect of wind does not appear to be significant, presumably because the peninsula lakes are too small for wind setup to develop.

A common plot of the main basin station hydrographs is shown on Figure 5.12. The two Meliadine Lake outlet hydrographs are very similar because they are derived from a single water level record. However, the general pattern and irregularities due to rain and wind effects are similar for all four, except for the early and rapid rise of the Meliadine River near the Mouth. The latter suggests that start of runoff and the early hydrograph of the Meliadine River near the Mouth is governed by the tributary basin downstream of Meliadine Lake.

A common plot of the seven peninsula basin station hydrographs is shown on Figure 5.13. A similar pattern is evident for all seven stations: a very rapid rise to peak at the beginning of June, followed by a rapid decline over a two to four week period to summer low flows, with

Figure 5.1

Figure 5.2

Figure 5.3

Figure 5.4

Figure 5.5

Figure 5.6

Figure 5.7

Figure 5.8

Figure 5.9

Figure 5.10

Figure 5.11

Figure 5.12

Figure 5.13

a slight increase in flows in September in response to rainfall. An expanded plot of the June runoff period is given in Figure 5.14.

The anomalous response exhibited by the 1997 Lake A1 hydrograph (see 1997 Data Report, Section 6.4 and Figure 6.10), was not evident in 1998. A review of the data for both years showed that the 1997 rating curve was much too flat, giving excessively high discharge for a given water level (see Appendix E, Figure E.11.1). The 1998 results are consistent with the upstream station at Lake A6 as well as the other peninsula basin stations.

5.6. ANNUAL DISCHARGE VOLUME

In order to obtain the total annual discharge for each of the monitoring stations, an estimate needs to be made of the runoff which occurred prior to the start of monitoring (June 4 to 8) and runoff which occurred after monitoring ceased (September 22 to 24).

Estimate of Pre-Monitoring Runoff

The early runoff is estimated to have started at the peninsula basins on June 2, when camp staff reported that water was starting to pond along the edges of the lakes, and the ice cover had started to melt. The length of time required for all the ice cover to melt varied from about two weeks for the smaller ponds to about six weeks for Meliadine Lake. For the main basin stations, runoff was estimated to have started on June 1. Runoff volumes for the pre-measurement period were therefore estimated by assuming zero flow on the day before runoff started and then increasing linearly to the value recorded on the first day of station operation.

The following modifications or additional adjustments were made to obtain the best possible estimates:

- The available information indicates that the Meliadine River at the outlet of Meliadine Lake can be assumed to have discharged continuously throughout the winter. However, the end of September is assumed to typically be the end of the precipitation inputs available for that year's runoff. Therefore all runoff volumes between the end of September 1997 and the start of the 1998 runoff at the beginning of June, are assumed to be drawn from 1997 lake storage. That runoff volume should therefore be credited to the 1997 hydrologic year. However, since the current year's volume cannot be known until the end of May 1999, the current year's results are assumed to apply as a surrogate. Thus, the 1998 pre-monitoring runoff volume is estimated from the 1998 data. It is assumed that the discharge of 0.309 m^3/s measured May 7, 1998 was constant over the time period December 1, 1997 to May 31, 1998, producing a runoff volume of 6303 cubic decametres (dam^3), or 11 mm of basin yield.

Figure 5.14

C Other than the Lake D5 outlet, the hydrographs for the earliest peninsula lake stations, which start on June 5, missed capturing the peak by probably only one day. The Lake B7, B5 and B2 stations were started June 7 or 8, and so missed several days of high flow.

The flow data for all the B Basin stations were reviewed to determine if some of the missing days could be estimated. It was noted that the daily discharge at Lake B2 was approximately the same as the discharge for the preceding day at the upstream station of Lake B4, for which the contributing drainage area is within about 10 percent of that at B2. Two extra days of flow (for June 6 and 7) were thus estimated for the Lake B2 station by lagging the B4 values by one day. The data for the upstream Lakes B5 and B7 did not reveal a clear pattern which would allow extrapolation of the data.

Estimate of Post-Monitoring Runoff

It was estimated that the peninsula basins, as well as the West Outlet of Meliadine Lake, continued to discharge to the end of October. The three other main basin stations were assumed to discharge until the end of November. The runoff volume during the period from the last monitoring day to the cessation of runoff was thus estimated by assuming a linear decrease in discharges over the period.

The discharge for Lake A1 was estimated for the period August 12 to September 23, because of the accidental loss of data collection capability between those dates at that station. The data for Lake A6 and Lake A1 were carefully examined and it was noted that the ratio of the runoff volumes of Lake A1 to Lake A6, for the common period of record June 5 to August 12, was equal to 1.51 and that this was also the ratio of the discharges measured at the two stations for the last day of record, September 23. This ratio was thus applied to the volume recorded at Lake A6 for the missing period to estimate the missing data for Lake A1.

The recorded runoff volumes and the estimated volumes for the pre- and post-monitoring runoff periods are summarized in Table 5.4.

TABLE 5.4
1998 Runoff Summary

Station Name	Catchment Area (km^2)	Period of Record	Measured Volume (dam^3)	Estimated Volume		Total Volume	
				Pre-Record (dam^3)	Post-Record (dam^3)	(dam^3)	(mm)
MAIN BASIN STATIONS							
Meliadine River at Meliadine Lake Outlet	569	June 6-Sept 22	48278	6303	11834	66415	117
West Outlet of Meliadine Lake	569	June 6-Sept 22	15872	121	1125	17118	30
Meliadine Lake Both Outlets	569	June 6-Sept 22	64150	6424	12959	83533	147
Meliadine River near the Mouth - Nominal	796	June 4-Sept 22	80950	2994	18007	101951	128
Meliadine River near the Mouth - Effective	682	June 4-Sept 22	80950	2994	18007	101951	149
Diana River near Rankin Inlet - Nominal	1480	June 6-Sept 22	248111	4190	47693	299994	203
Diana River near Rankin Inlet - Adjusted	1480	June 6-Sept 22	232239	4070	46567	282876	191
PENINSULA STATIONS							
Outlet of Lake A6	6.4926	June 5-Sept 23	677	153	107	937	144
Outlet of Lake A1	9.3913	June 5-Sept 23	1022	165	161	1347	143
Outlet of Lake B7	2.6268	June 7-Sept 24	202	61	35	298	113
Outlet of Lake B5	4.9207	June 7-Sept 24	468	136	86	690	140
Outlet of Lake B4	20.369	June 5-Sept 23	2235	607	202	3043	149
Outlet of Lake B2	22.5516	June 8-Sept 24	1693	1460	222	3375	150
Outlet of Lake D5	3.6851	June 6-Sept 23	340	71	92	502	136

The total volume is reported both in cubic decametres (dam^3) and in mm of depth over the catchment area. Note that 1 dam^3 of runoff volume is equivalent to a yield of 1 mm of runoff depth from a catchment area of 1 km^2. The runoff volumes for 1998 expressed as basin yields are also shown graphically on Figure 5.15.

In Table 5.4 and Figure 5.15, there are two entries for the Meliadine River near the mouth. The first entry (128 mm) gives the "nominal" yield, the second entry (149 mm) gives the "effective" yield. The nominal yield is that obtained by using the full catchment area of 796 km^2 as measured from the mapping. The effective yield is that obtained by using the effective catchment area, i.e., the measured area reduced in proportion to the diversion of Meliadine Lake outflows through the west outlet. The west outlet in 1998 diverted 20 percent of the annual total Meliadine Lake basin runoff, thus representing the runoff from 114 km^2 of that basin. Therefore, the effective catchment area for the Meliadine River near the mouth for 1998 is 796 - 114 = 682 km^2. The resulting effective yield of 149 mm for the Meliadine River near the mouth is essentially the same as the yield of 147 mm obtained for Meliadine Lake (both outlets).

Table 5.4 and Figure 5.15 also contain two entries for the Diana River. The first entry gives the “nominal” yield of 203 mm, as measured. The second entry is an “adjusted” yield based on deducting the volume diverted in from the Meliadine basin through the Meliadine Lake west

Figure 5.15

outlet. The adjusted yield for the Diana River is 191 mm or 6 percent less than the nominal yield. The adjusted yield is about 28 percent higher than the yield of the Meliadine Lake or the Meliadine River basins.

The runoff volumes and yields of the seven peninsula basins show a high degree of consistency, with one another and also with the Meliadine Lake and Meliadine River basin results, in contrast with the divergent results obtained in 1997. The yields fall within a range of 136 mm to 150 mm, except for the low yield of 113 mm for Lake B7. The latter is known to be too low because the first few days of high runoff, which constitute a significant percentage of the annual runoff volume, were not measured. The Lake B5 yield of 140 mm is also known to be low for the same reason. The somewhat lower Lake D5 value of 136 mm is considered to be due to the relatively higher proportion of evaporation losses from Basin D due to its higher proportion of lake area (34 percent) compared to the other basins (20 percent to 25 percent).

5.7 LAKE WATER LEVELS AND STORAGE

5.7.1 Main Lakes

Meliadine Lake levels recorded in 1998 at the datalogger station, at the two lake outlets and at the Meliadine Camp are shown on Figure 5.16. The levels were adjusted to a common datum by fitting the staff gauge and DWL survey observations to the adjusted data logger record. The levels show generally good correlation, with only a few minor isolated discrepancies probably due mostly to the differing effects of wind at the different observation locations.

The effect of wind generally can be detected by comparing the water level fluctuations with periods of strong winds as indicated by the plot of daily mean wind speeds on the alternate axis of Figure 5.16. High winds were recorded around July 15 (by field staff), August 20 and September 15, which correspond to the noticeable water level fluctuations on the same dates. The largest wind induced fluctuation occurred in August and caused the water level at the data logger station to drop by about 0.07 metres for several days.

A comparison of the 1998 water levels of Meliadine Lake with those recorded on Peter Lake and Diana Lake is shown on Figure 5.17. The levels for Peter and Diana Lakes have been adjusted to an arbitrary datum to facilitate comparison. The pattern of rise and decline for Meliadine Lake and Peter Lake are similar. The two lakes both peaked in mid-June. However the rise to peak of Meliadine Lake (418 mm) was only 74 percent of the rise in Peter Lake (563 mm), and the decline after the peak of Meliadine (205 mm) was 54 percent of the Peter Lake decline (379 mm). Both lakes had a net rise in water level for the season of about 0.2 metres.

Figure 5.16

Figure 5.17

Diana Lake peaked about two weeks later than Peter Lake (which is to be expected since Diana Lake is downstream of Peter Lake). Diana Lake rose 1089 mm to peak and then declined 687 mm for a net rise for the season of 402 mm: those values are about twice the Peter Lake values.

The changes in lake levels over the year since September 1997, including the changes in lake storage, expressed as an equivalent depth in millimetres over the total basin area, are summarized in Table 5.5.

TABLE 5.5
Main Lake Levels and Storage Changes 1997 - 1998

Lake	Lake Area (km^2)	Basin Area (km^2)	Water Levels (m)					Lake Storage Changes (mm)			
			September 1997	May 1998	Peak 1998	September 1998	Change 97 - 98	Winter Change	Freshet Gain	Summer Loss	Net Change
Meliadine Lake	114	569	3.154	3.144	3.562	3.357	0.203	-2	84	-41	41
Peter Lake	177	1480	6.936	7.075	7.638	7.259	0.323	17	67	-45	39
Diana Lake	40	1480	5.840	5.850	6.939	6.252	0.412	0	29	-19	11
Diana Basin	217	1480						17	97	-64	50

Table 5.5 shows that all three main lakes gained in storage over the season; this was to be expected as 1997 was an unusually dry year which depleted storage. Meliadine Lake gained less in both water level and storage as an equivalent basin depth than did the Diana Basin lakes.

An estimate of the total seasonal (June 1 to September 22-24, 1998) inflow to each main lake system can be made by summing the net storage change from Table 5.5, the seasonal outflow (the measured plus pre-record volumes from Table 5.4) and the net lake evaporation of 182 mm over the lake surface area. The results are given in Table 5.6. The "upstream basin yield" in the table represents the runoff for the season up to the end of monitoring (September 22-24), from the lake tributary basin (i.e., the total basin area less the main lake surface area

TABLE 5.6
Main Lakes
Lake Inflow Volume 1998

Lake	Lake Area (km^2)	Basin Area	Seasonal Change			Inflow Volume		Outflow as % of Inflow
			Outflow to Sept. 22 (dam^3)	Storage Net Gain (dam^3)	Net Evaporation (dam^3)	Volume (dam^3)	Upstream Basin Yield (mm)	
Meliadine Lake	114	569	70574	24282	20748	115604	254	61
Diana Basin	217	1480	252301	48648	39494	340443	270	74

The upstream basin yields for the two basins differ by only 10 percent. Meliadine Lake retained 39 percent of that inflow, while the two Diana Basin lakes retained only 26 percent.

5.7.2 Peninsula Basin Lakes

Water levels at the seven monitored lakes on the peninsula are compared on Figure 5.18. The levels are shown relative to the zero outflow elevation for each lake. Water levels in general declined in a gradual and similar pattern for all five lakes to the end of August. Levels gradually increased in September in response to precipitation, as indicated on Figure 5.18. The effect of wind on the peninsula lakes does not appear to be significant.

The changes in water level since September 1997 and the corresponding change in storage are summarized in Table 5.7.

TABLE 5.7
Peninsula Basin Lake Levels and Storage Changes 1997 - 1998

Lake	Lake Area (km^2)	Water Levels				Water Level and Storage Changes					
		September 1997 (m)	May 1998 (m)	Peak 1998 (m)	September 1998 (m)	Sept. 97 - May 98		May 98 - Sept. 98		Sept. 97 - Sept. 98	
						Level (m)	Storage (dam^3)	Level (m)	Storage (dam^3)	Level (m)	Storage (dam^3)
Lake A6	0.5454	9.096	9.090	9.511	9.277	-0.006	-3	0.187	102	0.181	99
Lake A1	0.1629	9.206	9.060	9.709	9.394	-0.146	-24	0.334	54	0.188	31
Lake B7	0.5810		7.846	8.196	7.984			0.138	80		
Lake B5	0.5594		8.399	8.723	8.552			0.153	86		
Lake B4	0.8574	7.755	7.999	8.336	7.973	0.244	209	-0.026	-22	0.218	187
Lake B2	0.4895		7.388	7.813	7.533			0.145	71		
Lake D5	0.0702	7.975	8.171	8.319	8.089	0.196	14	-0.082	-6	0.114	8

Table 5.7 does not report changes in storage in terms of equivalent basin depth in millimetres, as the volume storage change in the monitored lake, when distributed over the total basin area, results in very differing depths depending on the ratio of monitored lake area to total basin area, and does not represent a useful index or measure of the changes in the basin.

Figure 5.18

Changes in monitored lake water levels, if reasonably consistent, could be extrapolated to all lakes in a basin to obtain an estimate of basin storage. The net changes in level for the May to September 1998 period for which all the seven basin lakes were monitored, are not entirely consistent. Thus, Lakes A6, A1, B7, B5 and B2 show net water level increases, while Lakes B4 and D5 show net reductions. The net changes for the September 1997 to September 1998 period, are more consistent, but are available only for four of the seven lakes. If it is tentatively assumed that the latter are representative of all the lakes in their respective basins, then the 1997 to 1998 basin storage increase is estimated as per Table 5.8, to be in the range of from 40 mm to 58 mm.

TABLE 5.8
Peninsula Basins
1997 - 1998 Basin Storage Estimate

Basin	Basin Area (km^2)	Total Lake Area (km^2)	Estimated Basin Storage Change		
			September 1997 - September 1998		
			Lake Level Change (m)	Lakes Storage Gain (dam^3)	Basin Storage Gain (mm)
Lake A6	6.4926	1.9162			
Lake A1	9.3913	2.3106	0.185	427	46
Lalke B7	2.6268	0.6513			
Lake B5	4.9207	1.3941			
Lake B4	20.3690	5.3467			
Lake B2	22.5516	6.0233	0.218	1313	58
Lake D5	3.6851	1.3016	0.114	148	40

An estimate of the total seasonal inflow to each peninsula lake can be made by summing the net storage change from Table 5.7, the seasonal outflow (the measured plus pre-record volumes from Table 5.4) and the net lake evaporation of 182 mm over the lake surface area. The results are given in Table 5.9. The "upstream basin yield" in the table represents the runoff for the season up to the end of monitoring (September 22-24), from the lake tributary basin (i.e., the total basin area less the area of the monitored lake).

TABLE 5.9
Peninsula Lakes
Lake Inflow Volume 1998

Lake	Lake Area (km^2)	Basin Area (km^2)	Seasonal Change			Inflow Volume		Outflow as % of Inflow
			Outflow to Sept. 22 (dam^3)	Storage Net Gain (dam^3)	Net Evaporation (dam^3)	Volume (dam^3)	Upstream Basin Yield (mm)	
Lake A6	0.5454	6.4926	830	102.0	99.3	1031	173	80
Lake A1	0.1629	9.3913	1187	54.4	29.6	1271	138	93
Lake B7	0.5810	2.6268	263	80.2	105.7	449	219	59
Lake B5	0.5594	4.9207	604	85.6	101.8	791	181	76
Lake B4	0.8574	20.3690	2842	-22.3	156.0	2975	152	96
Lake B2	0.4895	22.5516	3153	71.0	89.1	3313	150	95
Lake D5	0.0702	3.6851	411	-5.8	12.8	418	116	98

The “upstream basin yields” are seen to generally decrease in the downstream direction in both Basins A and B. This is consistent with the fact that the proportion of lake area to land area is seen to increase in the downstream direction, especially in the Basin B (see Table 2.2), and that lake storage and evaporation volumes are much higher than soil moisture storage and evapotranspiration volumes from land. The highest “upstream basin yield” value of 219 mm for Lake B7, is derived from an upstream basin with only 3 percent of upstream area as lake surface (see Table 2.2). Therefore that value represents runoff from land surface with practically no lake storage or evaporation losses. The low value for lake D5 may be due to the significantly higher proportion of lake surface in its upstream basin (34 percent).

Lakes A1, B4, B2 and D5 released as outflows almost all the inflows from their upstream basins. Lakes A1, B7, and B5 released only 59 percent to 80 percent of their inflows. That difference appears to correspond to relative position within the overall basin, i.e., the farther the lake is downstream, the greater percentage of its inflow is released as outflow. That result is in agreement with basic hydrologic principles in that the fraction of inflow capable of being retained by a given lake storage volume will diminish in proportion to the magnitude of the inflow volume, which in turn varies with the drainage area of the basin.

6.0 BASIN YIELD AND WATER BALANCE

6.1 REGIONAL HISTORICAL YIELDS

Regional historical yields are presented and discussed in detail in the 1997 Data Report. The comparison of the annual Diana River runoff with the Rankin Inlet annual (hydrologic year) precipitation, updated to include the 1998 data, is given in Table 6.1 below.

TABLE 6.1
Historical Regional Precipitation and Runoff

Hydrologic Year	Rankin Inlet Precipitation		Diana River Runoff		Runoff Ratio
	mm	Fraction of Mean	mm	Fraction of Mean	
1989	251	0.87	160	0.85	0.64
1990	360	1.25	196	1.04	0.54
1991	387	1.34	263	1.40	0.68
1992	289	1.00	267	1.42	0.92
1993	316	1.09	184	0.98	0.58
1994	207	0.72	135	0.72	0.65
1995	286	0.99	151	0.80	0.53
1996	282	0.98	---	---	---
1997	172	0.60	134	0.71	0.78
1998	339	1.17	203	1.08	0.60
Mean	289		188		0.65

The precipitation data represent the annual total inputs of accumulated snow starting from the previous October, up to and including the September precipitation for each year (see Section 4.1). The pattern of high and low years of precipitation is seen to be generally similar to the variation of runoff. The data show that 1998 was a year of moderately high precipitation at 17 percent above the 10-year mean. Runoff was also moderately high, at 8 percent above the mean. The ratio of runoff to precipitation is somewhat below the average of 0.65, illustrating the lag effect caused by the preceding very dry year. The data given in Table 6.1 are shown graphically on Figure 6.1.

6.2 1998 BASIN YIELD

6.2.1 Overall Results

The runoff volumes obtained from the 1998 monitoring results as presented in Section 5.6 are summarized in Table 6.2 in terms of the basin yields. The basin yields are based on the measured outflows plus the season's outflows estimated to have occurred prior to the start

Figure 6.1

of monitoring and after the end of monitoring, from the monitored lakes at the downstream ends of the basins. The data in Table 6.2 is shown graphically in Figure 6.2.

TABLE 6.2
1998 Basin Yield Summary

Station Name	Basin Area (km^2)	Basin Yield (mm)
MAIN BASIN STATIONS		
Meliadine River at Meliadine Lake Outlet	569	117
West Outlet of Meliadine Lake	569	30
Meliadine Lake Both Outlets	569	147
Meliadine River near the Mouth - Nominal	796	128
Meliadine River near the Mouth - Effective (1)	682	149
Diana River near Rankin Inlet - Nominal	1480	203
Diana River near Rankin Inlet - Adjusted (2)	1480	191
PENINSULA STATIONS		
Outlet of Lake A6	6.4926	144
Outlet of Lake A1	9.3913	143
Outlet of Lake B7	2.6268	113
Outlet of Lake B5	4.9207	140
Outlet of Lake B4	20.3690	149
Outlet of Lake B2	22.5516	150
Outlet of Lake D5	3.6851	136

Notes: 1. Based on "effective" catchment area to account for Meliadine Lake west outflows.
2. Based on adjusted volume by deduction of Meliadine Lake west outflows.

The main points relating to the tabulated basin yield values are discussed below. Some aspects relating to the above results are presented in Section 5.6 above.

6.2.2 Main Basins

The basin yield of Meliadine Lake (from both outlets) of 147 mm was split 80:20 between the main outlet and the west outlet, respectively. The proportion going to the west outlet increased from 15 percent in 1997 to 20 percent in 1998, due to the differing discharge characteristics of the two outlets which cause the proportion of the total outflow discharged through the west outlet to increase for higher overall Meliadine Lake levels, as predicted in the 1997 Data Report. The "effective" yield of 149 mm for the Meliadine River near the Mouth is essentially the same as the yield of the Meliadine Lake basin.

Figure 6.2

The gross yield of the Diana River of 203 mm when adjusted by subtracting the interbasin transfer from the west outlet of Meliadine Lake, reduced by 6 percent to 191 mm. That adjustment is twice the 1997 adjustment factor of 3 percent. The adjusted yield is some 28 percent higher than the Meliadine Lake and Meliadine River yields. That difference is much less than the 70 percent to 100 percent difference found in 1997. The 1998 difference could be partly explained by the apparent higher precipitation which occurred east of the Rankin Inlet - Meliadine Camp area, as indicated by the Peter Lake precipitation data.

The runoff ratio for Meliadine Lake, using the regional Rankin Inlet precipitation data, was 0.43 for the 1998 and 0.45 for the 1997 hydrologic years. Those results support the 1997 Data Report conclusion that over-year storage appears not to be significant for the Meliadine Basin.

6.2.3 Peninsula Basins

The basin yields for the seven peninsula basins vary from 113 mm to 150 mm. The value of 113 mm for Lake B7 is considered to be lower than the actual due to the fact that the first several days of inflow were missed and could not be adequately estimated. These missed days are considered to represent a significant portion of the total volume for the year. This low value should therefore be discounted as not representative. The remaining six basin values range from 136 mm to 150 mm, and are thus within about 10 percent of one another. The basin yield values of 143 mm for Lake A1 and 150 mm for Lake B2 represent the overall values for Basins A and B, respectively. Those values are also consistent with the values of the upstream stations within each basin.

The Basin A and B values of 142 mm and 150 mm agree closely with the overall Meliadine Lake yield of 147 mm.

Comparison of the 1998 results with the 1997 data suggests that the 1997 inconsistencies in results were not due to differences in hydrologic characteristics, but due to not having been able to start monitoring early enough, with the result that a significant part of the early runoff was missed, with varying impact on the overall yield results for the basins. In addition, the Lake A1 1997 outlet rating curve was incorrect and produced grossly overestimated discharges.

The Lake B7 basin differs from all the other peninsula basins in that the monitored lake is the most upstream lake in its basin, with no other significant lakes upstream of it. Thus, the “upstream basin” area contributing runoff to Lake B7 contains only 3 percent of lake surface, whereas all the other monitoring stations have 19 percent or more of the “upstream basin” as lake surface area (see Table 2.2). Consequently, the value of “upstream basin” yield of 219 mm for Lake B7 (see Table 5.9) is indicative of the yield produced by land surface without the effect of lakes. That value represents about 80 percent of the total precipitation input of 271 mm for the season (spring snowpack SWE of 131 mm plus the June through September rainfall of 140 mm).

6.3 PENINSULA BASINS WATER BALANCE ANALYSIS

6.3.1 Water Balance Equation

A water balance analysis for the peninsula basins has been carried out in order to provide an evaluation of the significance of the main hydrologic inputs to and outputs from each basin and to assess the correctness of the evaluation.

The main components to be considered are as follows:

Snowpack melt input expressed as SWE over the basin	=	SWE
Rainfall input	=	P
Evaporation from lake surfaces	=	E
Evapotranspiration from land surfaces	=	ET
Surface water outflow from the basin	=	O
Basin storage increase	=	B

Basin storage increase B consists of lake storage B_L plus moisture storage in the active layer B_A. The relationship between the water balance components is indicated in the basin schematic shown on Figure 6.3.

Subsurface outflow from the basin, included in the 1997 water balance analysis, is not included in the 1998 analysis, as it is considered that there is inadequate evidence to support its inclusion. The rationale is presented in Appendix F.

The water balance is an expression of the conservation of mass for the water entering and leaving the basin. Basically this is expressed as:

Volume In = Volume Out + Change in Storage

In terms of the components identified above, the equation becomes:

$$(SWE)\,(A_{Land} + A_{Lakes}) + P\,(A_{Land}+A_{Lakes}) - ET\,(A_{Land}) - E\,(A_{Lakes}) = O + B$$

Each of the components is discussed below. The evaluation of most of the components is discussed in previous sections of this report.

6.3.2 Water Balance Components

Catchment Areas

The catchment areas and total basin lake areas are reported in Section 2 and elsewhere. The land area (A_{Land}) is the difference between total basin and total lake areas (A_{Lakes}).

Figure 6.3

Snowpack Melt

The SWE of the snowpack accumulations is based on snow surveys of the spring snowpack and measurement of the snow distribution terrain types within the basins, as reported in Section 4.

Precipitation

The precipitation (P) is the rainfall over the runoff season as recorded at the Meliadine Camp tipping bucket gauge, and equals 140 mm for the 1998 season (Section 3.2.2).

Evaporation

Expressed as gross lake evaporation E, this value equals 322 mm for the 1998 season (Section 3.2.4).

Evapotranspiration

The estimated value of the 1998 ET equals 38 mm (Section 3.2.5).

Basin Storage

The basin storage term functions as the residual term in the water balance and is determined by subtracting the basin outputs (evaporation, evapotranspiration, and outflow) from the inputs (snowmelt SWE and rainfall).

6.3.3 Water Balance Results

The water balance for the 1998 season for each of the seven peninsula basins is summarized in Table 6.3. The weighted mean values for Basins A and B combined are also included. The derivation of the values for the various columns of Table 6.3 is explained in the footnotes to the table.

The values reported in Table 6.3 are reasonably consistent for all basins except for Lake B7. The results for Lake B7 are considered to be unrepresentative because of under-estimation of the annual runoff volume due to missed initial days of runoff.

The results indicate that basin storage increased for all basins in amounts ranging from a low of 3 mm for Lake D5 to a high of 49 mm for Lake B7. The weighted average increase for Basins A and B equals 14 mm. This is less than the values of 40 mm to 60 mm (say 50 mm average) of basin storage increase estimated for the 12 month period September 1997 to September 1998 (see Table 5.8). If the 12 month estimates are correct, an amount of about 35 mm of basin storage must have been acquired prior to the June 1 start of runoff. That

TABLE 6.3
Peninsula Basins 1998 Water Balance

Basin	Basin Area		Measured Outflow		SWE	Snowmelt Volume dam^3	Rainfall dam^3	Gross Lake Evaporation dam^3	Evapo-transpiration dam^3	Snowmelt + Rainfall - Evaporation - ET		Basin Storage Change		Ouflow as Fraction of Precipitation
	Total km^2	Lake km^2	dam^3	mm	mm					dam^3	% of Outflow	dam^3	mm	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lake A6	6.4926	1.9162	937	144	131	847	909	617	173	966	103	30	5	0.53
Lake A1	9.3913	2.3106	1347	143	135	1268	1315	744	268	1571	117	223	24	0.52
Lake B7	2.6268	0.6513	298	113	130	342	368	210	75	426	143	128	49	0.42
Lake B5	4.9207	1.3941	690	140	131	643	689	449	133	750	109	60	12	0.52
Lake B4	20.3690	5.3467	3043	149	134	2719	2852	1722	568	3282	108	238	12	0.55
Lake B2	22.5516	6.0233	3375	150	134	3019	3157	1940	625	3612	107	236	10	0.55
Basin A + B	31.9429	8.3339	4723	148	134	4286	4472	2684	892	5182	110	460	14	0.54
Lake D5	3.6851	1.3016	502	136	138	507	516	419	90	514	102	11	3	0.49

Column 1 = Basin name
Column 2 = Total catchment area of basin
Column 3 = Total lake surface area within basin
Column 4 = Measured plus estimated pre- and post-monitoring outflow volume
Column 5 = Column 4 divided by Column 2
Column 6 = Snow water equivalent (SWE) in spring snowpack
Column 7 = Snowmelt volume obtained from SWE (Column 6) times Column 2
Column 8 = Total season rainfall of 140 mm times Column 2
Column 9 = Gross lake evaporation of 322 mm times Column 3
Column 10 = ET of 38 mm times (Column 2 - Column 3)
Column 11 = Basin inputs less losses = Column 7 + Column 8 - Column 9 - Column 10
Column 12 = Column 11 divided by Column 4
Column 13 = Column 11 - Column 4
Column 14 = Column 13 divided by Column 2
Column 15 = Column 4 divided by (Column 7 + Column 8)

could have possibly occurred in October 1997, when a total of 45.1 mm of rain plus 29.8 cm of snowfall was recorded in the first two weeks of October (see 1997 Data Report Appendix B).

The ratio of outflow to total precipitation is in the range of 0.49 to 0.55 for all basins except Lake B7, with a weighted average of 0.54 for Basins A and B. That is significantly higher than the 1997 average of 0.44. However, if the 1997 ratio is adjusted by reducing the contribution of SWE to two-thirds of that estimated in the 1997 Data Report (see Section 4.4 above), the result equals 0.54 which agrees with the 1998 value.

The magnitudes and relative percentage contributions of the various water balance inputs and outputs for each basin as well as the overall area-weighted mean for Basins A and B as reported in Table 6.3 are shown graphically in Figures 6.4 through 6.11. In general, snowmelt and rainfall each contributed about 50 percent of the total precipitation input. Basin outflows averaged 54 percent of the total precipitation input. Some 31 percent of precipitation was lost by evaporation and 10 percent by evapotranspiration. An average of 5 percent of precipitation went into basin storage.

It is estimated that about 95 percent of the snowmelt and perhaps 10 percent of the rainfall went to runoff, while all the rest was lost to evaporation and evapotranspiration except for about 10 percent of the rainfall which went into basin storage.

Figure 6.4

Figure 6.5

Figure 6.6

Figure 6.7

Figure 6.8

Figure 6.9

Figure 6.10

Figure 6.11

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1998 hydrologic year (October '97 through September '98) was a moderately wet year. The observed total precipitation of 339 mm was almost twice the total 1997 precipitation of 172 mm, and 13 percent higher than the 17 year annual average. The 1998 wet year conditions were preceded by four continuous years of below average precipitation, of which the preceding year of 1996-97 was the driest on record.

The historical runoff data for the Diana River parallels the historical climate data, but with an over-year lag effect. The measured yield for 1998 for the Diana is 203 mm, which was 8 percent above the 9 year annual mean of 188 mm. However the ratio of 1998 runoff to precipitation (Rankin Inlet) is only 0.60, well below the average of 0.65, due to the lag effect of the preceding very dry year. A reverse effect occurred in 1997, when the runoff ratio was 0.78, due to the effect of the preceding wetter year.

Meliadine and Diana Basins

The total 1998 runoff for the Meliadine Lake basin is estimated to be 147 mm over the catchment area of 569 km^2. This includes about 11 mm of runoff estimated to have occurred through the winter prior to the spring snowmelt. That volume appears to be converted to ice in the downstream basin, as the Meliadine River at the mouth is frozen during the winter and does not discharge. About 30 mm or 20 percent of the total 1998 Meliadine Lake runoff was discharged through the west outlet into the Diana River basin via Peter Lake. The remaining 117 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged a nominal 128 mm of runoff in 1998 based on the total catchment area of 796 km^2. In effect however, when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet, the runoff becomes 149 mm, which agrees closely with that of Meliadine Lake.

The Diana River 1998 yield of 203 mm becomes 191 mm when the diversion in from Meliadine Lake is deducted. The latter value is about 28 percent higher than the yields for the Meliadine Lake and River basins. Diana River yields are expected to be higher than Meliadine Basin yields because greater proportional evaporative loss occurs in the latter, as a direct consequence of the fact that Meliadine Lake represents 20 percent of the total catchment, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment. In addition, higher precipitation appears to have occurred in the Diana Basin in 1998.

For the 1998 hydrologic year the ratio of runoff to precipitation (Rankin Inlet) for the Meliadine River basin was 0.43, which is very similar to the runoff ratio of 0.45 for 1997. That suggests that over-year storage does not appear to be a significant factor in Meliadine Basin yields.

Peninsula Basins

The main components of the water balance for seven peninsula basins were measured for the 1998 season. The runoff yields for five of the six Basin A and B stations showed a high degree of consistency, ranging from 140 mm to 150 mm, with a weighted mean value of 148 mm. That result is practically identical with the overall yield of 147 mm for the Meliadine Lake basin. The comparatively low yield of 113 mm for the Lake B7 basin is considered to be due to snowmelt runoff volume not measured at the start of runoff. The somewhat lower yield of 136 mm for the Basin D station is considered to reflect the significantly higher lake surface evaporation losses in Basin D.

Basin storage over the May through September season increased for all basins. The weighted average increase for Basins A and B equals 14 mm. An additional storage increase of about 30 to 40 mm is estimated to have occurred in the first half of October 1997, due to runoff from heavy precipitation observed at that time. The principal mechanism for basin storage is the retention capacity of basin lakes and ponds.

The average 1998 ratio of runoff to total precipitation (defined as the spring snow water equivalent plus the season's rainfall observed at the Meliadine Camp station) equals 0.54. The 1997 reported average of 0.44, when adjusted by reducing the 1997 over-estimate of snow water equivalent, becomes 0.54 as well.

In 1998, snowmelt and rainfall each contributed about 50 percent of the total precipitation input. Basin outflows averaged 54 percent of the total precipitation input. Some 31 percent of precipitation was lost by evaporation and 10 percent by evapotranspiration. An average of 5 percent of precipitation went into basin storage. In terms of the precipitation components, it is estimated that about 95 percent of the snowmelt and perhaps 10 percent of the rainfall went to runoff, while all the rest was lost to evaporation and evapotranspiration except for about 10 percent of the rainfall which went into basin storage.

All of the peninsula monitored lakes remained essentially at or above their zero outflow levels, although periods of very low flow occurred. All lakes rose above their zero outflow levels in September in response to rainfall.

The various differences and inconsistencies noted in the 1997 data are assessed on the basis of the 1998 results to have been due largely to incomplete and inaccurate measurements. The 1998 data indicate a high degree of similarity in the hydrologic characteristics of the peninsula basins.

1998 Field Program

The difficulties encountered during the 1997 field program were largely corrected for the 1998 field work, resulting in much better and more reliable data. The fact that 1998 was a moderately wet year also helped to reduce the sensitivity of the results to inaccuracies in the estimates and approximations of some portions of the water balance components.

7.2 RECOMMENDATIONS

Season Start-Up

The importance of starting discharge monitoring as early as possible is clearly demonstrated by the observed 1998 runoff hydrographs. The discharge peaks very quickly, within a few days of the start of runoff. If monitoring starts after the peak day, the total volume for the year can be noticeably under-estimated, especially for smaller basins with limited upstream lake storage.

The mobilization plan for 1998 included utilization of WMC camp labour to install the Aquadams. However, when the runoff started, that labour was not available and all of the start-up work was done by a single hydrometric field crew. As a result, valuable runoff data was not monitored. It is therefore recommended that sufficient manpower be mobilized at the start of the season for future monitoring work.

If the number of stations to be operated next year is similar to the 1998 program, it is recommended that three field crews be mobilized for start-up. Two crews should be led by the consultant/subconsultant staff (AEE and WSC); the third crew could be led by the WMC field staff person One crew would install Aquadams, the second crew would do water level and discharge measurements and the third crew would start up the monitoring stations

WMC Field Staff Commitment and Training

After the consultant/subconsultant staff left the field, around the middle of July, the quality of the data records and field notes began to deteriorate. Although considerably improved over the 1997 season, the data files for the latter part of this year suffer from missed daily readings and incomplete and at times incorrect notekeeping.

It is recommended that, if the water balance program is continued, the lead field staff be given priority responsibility only for the water balance field work, with assistance given to other programs only if time is available. It is further recommended that a designated assistant be allocated to the water balance program in the same fashion, and that this assistant be retained for the full season so that an experienced substitute is always available.

Continuation of the Lake D5 Monitoring Site

The purpose of the Lake D5 monitoring station is to provide a control station outside Basins A and B where mine development is anticipated. Two characteristics of the D5 basin detract from the suitability of this site as a long term control:

- The Lake D5 basin has 35 percent of its area as lake surface. That results in proportionally higher evaporation losses and reduces the runoff yield from the basin in comparison to the Basin A and B stations which have 25 to 30 percent of their areas as lake surface.

- The Lake D5 outlet rating curve relationship especially at lower discharges appears to be affected by backwater conditions from lake D4 and by wind effects. This results in reduced reliability of the data.

It is therefore recommended that alternate sites for a long term control station be investigated. Alternative sites could be located farther downstream in Basin D, in the eastern part of Basin B east of Lake B4 provided no mining development would occur there, or in the basin located directly west of Lake B7 (Basin E).

Peter Lake Rain Gauge

The manual rain gauge at Peter Lake has identified significant variation in the rainfall pattern over the main lake basin areas. This gauge should be retained for future years. Efforts should be made to have this gauge read daily for the entire season.

8.0 CLOSURE

This report contains hydrometric and climate monitoring data collected in 1998 in the Meliadine and Diana River basins, analysis and interpretation of the data, reassessment of some of the 1997 data, and conclusions and recommendations for future work.

This report has been prepared for the exclusive use of WMC International Limited.

Respectfully submitted,

AGRA Earth & Environmental Limited

Neil van der Gugten, M.A.Sc., P.Eng.
Senior Hydrotechnical Engineer

Reviewed by:

Gary R. E. Beckstead, M.Sc., P.Eng.
Reviewer

PHOTOGRAPHS

1998 FIELD SEASON