**ROY HAMILTON, M.A.Sc., P.Eng.**
1138 Handsworth Road, North Vancouver, B.C.
V7R 2A8 (604) 987-8578

October 28, 1997

North Salt Spring Waterworks District,
761 Upper Ganges Road,
Salt Spring Island, B.C. V8K 1S1

Attn. Mr. Mike Larmour,

Re: Proposed hydrological study of St. Mary Lake

I refer to your letter of October 21, 1997 suggesting some modifications to the terms of reference for the hydrological study; and to our subsequent telephone conversation on October 24, 1997. As you know from our conversation there are a number of items that should be clarified a little more, if possible, before the terms of reference are finalized:

1. I understand that you would like to cover the following two options for the operating range of lake levels, each assuming a fixed spillway elevation without flow control:

a) Operating range from 40.00 m to 41.00 m with spillway elevation at 41.00 m
b) Operating range from 39.50 m to 40.50 m with spillway elevation at 40.50 m

Option a) would provide about 0.5 m of positive storage; that is, storage above the present outlet level of 40.530 m. Option b) would provide no positive storage, which means that there would be no advantage in building an uncontrolled spillway at elevation 40.50 m. This option would, however, approximate current conditions, particularly if a spillway width was assumed that would provide similar discharge characteristics to the natural lake outlet.

A fixed spillway elevation implies limited control of maximum lake levels. The only control would be the width of spillway, plus perhaps what could be discharged through the fisheries flow outlet. A very wide spillway would, of course, result in less surcharge (height of lake surface above spillway). The maximum width of spillway may be governed by dam design considerations and/or outlet configuration.

2. Another option is to set the spillway elevation at or about 40.50 m, and provide gates across the full width of the spillway to control the amount of storage. The gates could be opened wide during high flow months to minimize flooding, and gradually closed in the spring to store water up to 41.00 m (or some other chosen upper limit). The spillway width for this option could be designed to provide improved lake outlet conditions (all gates open) thereby overcoming the problem of an undesired increase in flood heights. This option would require an operator to monitor lake levels and operate the gates, normally the responsibility of the owner of the dam structure.

3. In order to provide scenarios for the various options I would have to assume one or more spillway widths and appropriate discharge coefficients. The engineer who is responsible for the dam design should be able to provide some help with respect to optimum spillway width, discharge coefficients, and stage-discharge characteristics.

4. Fisheries flow requirements need to be fixed for each month of the year because they will be an integral part of all the hydrological calculations. I understand that the Ministry of Environment, Lands and Forests may use the mean annual discharge of Duck Creek at the outlet of St. Mary Lake and certain percentage factors to calculate fishery flow requirements. If so, the mean annual discharge of Duck Creek at the outlet of St. Mary Lake needs to be estimated, and agreed upon, as there are very limited data on Duck Creek flows.

5. In using the term "historical" when referring to lake levels, or other hydrological events, a specific set of years must be specified. In this case, for St. Mary Lake, the historic period I have chosen is 1980 to 1996, inclusive, because data on lake levels, stream flows, and precipitation for this period are most complete. It may be necessary to adjust this set of years slightly if, for example, data for 1996 are not readily available.

6. The Ministry of Environment, Lands and Forests have requested that some storage be provided for future users. It appears to me that you are unlikely to be able to develop more that about 0.5 m of positive storage. If the lake level cannot be held to about 41.0 m (thus providing 0.5 m of positive storage) for some length of time into the spring because of the concerns of lakeside owners the effectiveness of the storage would be reduced.

I believe a little more discussion of the above items and resolution of some of them will lead to improved terms of reference and a better overall study. If you are unable to obtain clarification of monthly fishery flow requirements I can make certain assumptions for my analysis, but the results may have to be revised if the fishery flow requirements are later modified by the Ministry of Environment, Lands and Forests.

If you are unable to obtain clarification from the Ministry as to the amount of storage they want for future users I can also make some assumption for my analysis so that the study can proceed.

I suggest we have another meeting on Salt Spring Island, possibly with your lawyer and dam engineer also in attendance.

Yours truly,

Roy Hamilton

Roy Hamilton

# HYDROLOGY OF ST. MARY LAKE

Prepared for:

**NORTH SALT SPRING WATERWORKS DISTRICT**
761 Upper Ganges Road, Salt Spring Island, B.C., V8K 1S1

By:

**Roy Hamilton, M.A.Sc., P. Eng.**
1138 Handsworth Road
North Vancouver, B.C. V7R 2A8

February, 1998

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# HYDROLOGY OF ST. MARY LAKE

## 1. INTRODUCTION

### 1.1 Purpose

The NSSWD is considering storage on St. Mary Lake to support a licence for an additional 500,000 I.g.p.d. (peak daily demand). The purpose of this study is to provide hydrological information to aid in this process. As the district presently has licenses totalling 505,000 I.g.p.d. this would bring the new total to 1,005,000 I.g.p.d.

A major concern is the effect on lake shore properties of changes in lake levels due to increasing water demand, the requirement for fishery flow releases throughout the year, and the B.C. Ministry of Environment, Lands and Parks requirement to provide storage.

### 1.2 Terms of reference

A. Data on lake levels, Duck Creek flows, water demands, lake evaporation, and precipitation will be analyzed for each month for a number of years of record (1980 to 1996 approximately) to find the relationship that the lake level has had in these recent past years to water demand and precipitation. Watershed runoff factors will be determined. This analysis should provide a good basis for establishing historical (1980 to 1996 approximately) conditions.

B. Several scenarios will be prepared showing how future lake levels would be affected throughout the year by increased water demand, estimated storage requirements, and estimated mandatory fishery flow releases, assuming various spillway elevations at a low dam at the outlet of the lake. Scenarios will be prepared for a very dry year (an approximate 1:50 year event) and a very wet year (an approximate 1:50 year event) as well as for average years. Graphics will be prepared to clearly show for each month of the year the differences between historical lake levels and the estimated future lake levels resulting from each scenario.

C. It is understood that the main options are as follows:

1. Spillway level at 40.5 m with an operating range of lake level down to about 39.5 m.

2. Spillway level at 40.7 m with an operating range of lake level down to about 39.7 m.

3. Spillway level at 41.0 m with an operating range of lake level down to about 40.0 m.

D. Existing data available from the NSSWD and government agencies will be used.

## 2. SUMMARY OF RESULTS

In order to make a comparison between historical lake levels and lake levels created by a low dam at the outlet of St. Mary Lake, an analysis was carried out as follows:

The last 8 water years (88-89 to 95-96) were selected as a recent historical sample. Month end lake levels were then calculated assuming three different spillway elevations: 40.5m, 40.7m, and 41.0m. Calculations were made for both Present Demand and Future Demand. The results are shown in figures 1 to 4. where they are compared with historical lake levels.

Figure 1. With the spillway at elevation 40.5 m. the lake level would be below historical lake levels at all times. The maximum lake levels would be reduced. The minimum lake levels would go lower by about 0.3 m with Present Demand and 0.5m with Future Demand.

Figure 2. With the spillway at elevation 40.7m. and Present Demand the lake level would be approximately the same as the historic levels. The peak water levels would be the same or perhaps a little less. With Future Demand the peak levels would not change significantly but the minimum levels would go to about 0.3 m. below historical levels.

Figure 3. With the spillway at elevation 41.0 the lake level would almost always be above the historic lake level. The lake level would remain above 41.0 for several months every year. Peak levels of at least 41.1 would occur every year.

Figure 4. With the spillway at elevation 41.0 but with a 6 m. wide spillway The peak elevation each year would be slightly less, about 0.06m, but other changes would be insignificant.

In order to determine the effect of a very dry year, occurring about once in 50 years, an analysis was done assuming one year with a precipitation of 574 mm., followed by an average year. Calculations were made for both Present Demand and Future Demand for each of the three spillway elevations. The results are shown in Figure 5.

For all three spillway elevations the Present Demand would result in a small amount of spill in the 1:50 dry year. The Future Demand would result in no spill in the 1:50 dry year. The minimum lake levels under Future Demand are estimated to be 39.41 for spillway at 40.5, 39.61 for spillway at 40.7, and 39.91 for spillway at 41.0.

By the end of the following average year the lake levels would have regained their normal pattern.

In order to determine the effect of a very wet year, a severe three day winter storm of 128mm of rain, occurring about once in 50 years, was assumed to occur when the lake is at its average winter peak level. The results are shown in Figure 6.

For all three spillway elevations the storm caused the water level to rise rapidly, over a 3 day period, to about 0.33 metre (0.275 for a 6m wide spillway) above the normal level and then subside gradually over a period of some days. The estimated maximum lake levels resulting from the storm were as follows:

41.062 m for spillway at 40.5m and 3m wide
41.263 m for spillway at 40.7m and 3m wide
41.562 m for spillway at 41.0m and 3m wide
41.430 m for spillway at 41.0m and 6m wide

The maximum historical month end lake level in the last 8 years was for January 1992. It was 41.272 m. See Figure 1.

wasn't Feb 1992 higher ??

## 3. ORGANIZATION OF THIS REPORT

Sections 1. and 2. of this report, together with Figures 1 to 6, define the purpose of this report and provide a summary of results of the hydrological analysis, and thus may be extracted and used alone, if desired. The following sections provide more details.

The Cusheon Lake Watershed, Section 4, is first investigated in order to derive runoff relationships for use in the analysis of St. Mary Lake Watershed.

The historical data for St. Mary Lake is examined in Section 5. This includes lake outlet conditions, the various water demands, and calculation of monthly water budgets for each water year.

Simulation of several scenarios are then undertaken, as described in Section 6, and the results are discussed.

The appendices include conversion factors, tables, sample budget calculations, and other technical material.

## 4. CUSHEON LAKE WATERSHED

The hydrology of Cusheon Lake Watershed was investigated because there is a complete record of the discharge for Cusheon Creek, whereas there are very sparse data for Duck Creek. Results from the analysis of the Cusheon Lake Watershed were then used for the analysis of St Mary Lake Watershed.

A water budget analysis for Cusheon Lake Watershed was made for each of the water years 1979-80 to 1995-96. A sample is provided in Appendix B 1. The water budget was designed to synthesize a monthly outflow from Cusheon Lake for comparison with the recorded discharge of Cusheon Creek. Adjustments were made to soil water holding capacity (WHC) and infiltration characteristics until an optimal fit was obtained between the synthetic outflow and the recorded discharge.

The table of lake evaporation values used for the analysis is in Appendix C. It is based on data recorded at Saanichton CDA station.

As historical water demand data for the Cusheon Lake Watershed were not available, the water budgets were initially prepared without including water demand and later checked assuming the following:

An average annual demand rate of 50% of the licensed amount for waterworks, domestic and industrial uses, and 100% of the licensed amount for irrigation use.

It was found that the water budgets were not affected appreciably by the amount of water demand because it represents only about 2 % of the net runoff from the watershed.

The soil characteristics that provided the optimal fit to the Cusheon data were adopted for the St Mary Lake water budgets. They were: 200 mm for the water holding capacity; and 80% runoff and 20% infiltration for the land runoff equation.

## 5. ST. MARY LAKE WATERSHED

### 5.1 Lake Outlet

There are very limited discharge data for Duck Creek at the outlet of St. Mary Lake. Discharges were recorded from January to August in 1980, and in the low flow period from April to September in recent years, starting in 1990. The daily discharge data for 1980 was the only data that covered part of the high flow season.

A regression analysis was done using the daily 1980 data and the corresponding lake levels to obtain a stage discharge relationship, Appendix D. Although the stage discharge relationship thus derived may be applicable to 1980 data, it does not provide reliable results for other years because of the variations in lake outlet conditions from year to year due to beaver activity, growth of aquatic vegetation, and human intervention of one kind or another. Nevertheless, the values estimated from the regression equations were used in the budgets as an approximate indication of the discharge of Duck Creek, and as a rough check of the budget calculations.

### 5.2 Water demand

Data on water demand was obtained from the NSSWD, the Capital Regional District and the B.C. Ministry of Environment. Information on licensed quantities was obtained from the 1993 Water Allocation Plan and personal communication with Bruno Blecic of the Ministry of Environment. The estimated water demands are believed to be reasonable estimates for this study, but a detailed review of licences was not made. Water demands were converted to cubic dekametres (dam3) for ease of calculation.

HISTORICAL DEMAND

Historical Demand means the actual water quantity used historically. Of course, the demand has been different each year, and has increased over time. Historical demands were used to calculate watershed runoff for the last 17 years. They were obtained as follows:

NSSWD - from pumping records for the years 1979 to 1996

Other Water Users (Highland and Fernwood WWKS) - from CRD pumping records for the years 1991 to 1996. Years before 1991 were estimated. Other, miscellaneous water users were not included because their effect on the calculations was considered negligible.

Irrigation - from the present irrigation licence for 63 acre feet, assumed to have been in full use since 1979, and distributed as follows: May 10%, June 20%, July 30%, Aug. 30%, Sep. 10%.

PRESENT DEMAND

Present Demand is equal to the Historical Demand plus fishery flow requirements (23.4 dam3 per month = 0.009 m3/s). As with the historical demand, it is different each year.

FUTURE DEMAND

Future Demand was estimated by assuming that the average daily demand would be one half of the licensed quantity for all licences except irrigation. For irrigation it was assumed that the full amount of the licensed quantity would be used and would be distributed as follows: May 10%, June 20%, July 30%, Aug. 30%, Sep. 10%. For purposes of estimating future demand the following licences were assumed to be in effect:

Domestic licences - 14,750 Igpd.
Industrial licences - 19,000 Igpd
WWKS (Highland and Fernwood) licences - 164,000 Igpd.
NSSWD licences - 1,005,000 Igpd. (including a new additional licence for 500,000 Igpd.)
Irrigation licences - 78 acre feet (including a new additional licence for 15 acre feet)

**5.3 Watershed runoff**

Runoff amounts from the St. Mary Lake Watershed for each of the water years 79-80 to 95-96 were calculated using monthly water budgets (see sample in Appendix B2 ). This information was later used in the simulation studies, Section 6.

The soil characteristics that provided the best general fit to the Cusheon data were adopted for the St Mary Lake water budgets. They were: 200 mm for the water holding capacity; and 80% runoff and 20% infiltration for the land runoff equation. The annual runoff factor, the ratio of land runoff (Surplus Moisture) to precipitation, was also calculated and is given in the following table:

| Water Year | Precip., mm | Surplus Moisture, mm | Runoff Factor |
|---|---|---|---|
| 79-80 | 1158.8 | 565.3 | 0.488 |
| 80-81 | 1218.6 | 594.5 | 0.488 |
| 81-82 | 1112.4 | 709.1 | 0.637 |
| 82-83 | 1189.2 | 601.6 | 0.506 |
| 83-84 | 1204.7 | 674.9 | 0.560 |
| 84-85 | 898.4 | 452.8 | 0.504 |
| 85-86 | 887.6 | 408.3 | 0.460 |
| 86-87 | 682.5 | 275.8 | 0.404 |
| 87-88 | 682.5 | 199.1 | 0.292 |
| 88-89 | 739.6 | 300.4 | 0.406 |
| 89-90 | 883.5 | 339.4 | 0.384 |
| 90-91 | 1213.4 | 643.8 | 0.531 |
| 91-92 | 999.5 | 536.4 | 0.537 |
| 92-93 | 831.6 | 319.8 | 0.385 |
| 93-94 | 802.4 | 300.4 | 0.374 |
| 94-95 | 1039.3 | 572.3 | 0.551 |
| 95-96 | 1140.6 | 642.3 | 0.563 |

Lake evaporation values used for the analysis are tabulated in Appendix C. They are based on data recorded at Saanichton CDA station.

The Historical Demand, defined in Section 5.2, was used for the water budgets.

The water budgets also provide estimates of lake outflows. They compare only very approximately with the Duck Creek flows, calculated using the 1980 stage discharge equations. This is not surprising, as explained in Section 5.1.

A mean annual flow for Duck Creek was estimated by averaging the lake outflow over the 17 years of record. It comes to 0.089 $m^3/s$. This value is used in Section 6 to calculate the fishery flow requirement.

# 6. ST. MARY LAKE: SIMULATION STUDIES

## 6.0 General

Lake levels were simulated for three spillway elevations, 40.5m, 40.7m and 41.0m, and then compared with recent historical lake levels. I have assumed in all my calculations that there will be a clear unhindered channel from the main lake body up to the spillway. If the channel width and depth is not sufficient to provide a negligible velocity of approach or if beaver dams or vegetation are allowed to plug or diminish the channel the lake levels will increase and my estimates will not apply.

## 6.1 The 8 year series

In order to compare post dam lake levels with historical lake levels a set of calculations were made for a series of water years. The last 8 years, 88-89 to 95-96, were selected. The following cases were considered:

Case 1. Assumed spillway elevation = 40.5, spillway width = 3 m.
Case 2. Assumed spillway elevation = 40.7, spillway width = 3 m.
Case 3. Assumed spillway elevation = 41.0, spillway width = 3 m.
Case 4. Assumed spillway elevation = 41.0, spillway width = 6 m.

Calculations were made for each case using both Present Demand and Future Demand (see Appendices B3 and B4 for sample calculations). The results are shown in Figures 1 to 4.

RESULTS:

Figures 1 to 4 show the historical lake levels and the lake levels which would have occurred assuming that a dam was in place on September 30, 1988 (see also Appendix E). I will comment on each case:

Case 1. With the spillway at elevation 40.5 m. the lake level would be below historical lake levels at all times. The maximum lake levels would be reduced. The minimum lake levels would go lower by about 0.3 m with Present Demand and 0.5m with Future Demand.

Case 2. With the spillway at elevation 40.7m. and Present Demand the lake level would be approximately the same as the historical levels. The peak water levels would be the same or perhaps a little less. With Future Demand the peak levels would not change significantly but the minimum levels would go to about 0.3 m. below historical levels.

Case 3. With the spillway at elevation 41.0 the lake level would almost always be above the historical lake level. The lake level would remain above 41.0 for several months every year. Peak levels of at least 41.1 would occur every year.

Case 4. With the spillway at elevation 41.0, the same as case 3, but with a 6 m. wide spillway The peak elevation each year would be slightly less, about 0.06m (see Appendix E), but other changes would be insignificant.

With Present Demand, in all cases, the rate at which the lake level drops in the summer and fall would be about the same as historically. With Future Demand, however, the lake level would drop at a faster rate.

### 6.2 The 1:50 dry year

Lake levels were estimated assuming a 1:50 dry water year followed by an average year for the following cases:

Case 1. Spillway elevation = 40.5 m. Present Demand
Case 2. Spillway elevation = 40.5 m. Future Demand
Case 3. Spillway elevation = 40.7 m. Present Demand
Case 4. Spillway elevation = 40.7 m. Future Demand
Case 5. Spillway elevation = 41.0 m. Present Demand
Case 6. Spillway elevation = 41.0 m. Future Demand

For simulation of the 1:50 dry year (see example in appendix F) an annual precipitation value of 574 mm was used. This is based on a frequency analysis of 79 years of data for Saanichton CDA station presented in my 1995 report " Hydrology of Maxwell Lake Water Supply". This value was checked using the Saltspring station data. The estimated 1:50 dry year precipitation for the Saltspring station is 640 mm; when this is adjusted to the St Mary site a value of 570 mm is obtained. This is very close to the value of 574 mm adopted.

An average initial soil stress value of 292.2 mm was used. This is a measure of the dryness of the soil at the end of September and is a carryover from the previous water year. The value of 292.2 mm was obtained from the Cusheon Creek analysis.

The lake evaporation chosen for the analysis was assumed to be the average for the period 76-77 to 95-96.

The starting lake elevation, on Sept 30, was obtained by taking an average of the Sept 30 elevations over the past 8 years, 1989 - 1996, for each case.

The minimum Fisheries Flow was assumed to be 10% of the mean annual flow in Duck Creek immediately below the dam. The mean annual flow, 2810 dam$^3$, was calculated using the results of the analysis of the 17 years of record. For purposes of the water budgets it was assumed that 23.4 dam$^3$ was released every month for fisheries.

281.0 ?

RESULTS

Figure 5 shows the results for each of the three assumed spillway elevations.

Present Demand, cases 1,3,5, would result in a small amount of spill in the 1:50 dry year.

Future demand, cases 2,4,6, would result in no spill in the 1:50 dry year. The minimum fisheries flow would nevertheless be maintained throughout the year.

By the end of the following average year the lake levels would have regained their normal pattern.

The minimum and maximum lake levels during the 1:50 dry year are estimated to be as shown in the following table. Maximum elevations occurred at the end of March, approximately, and minimum elevations occurred at the end of October, approximately.

| Case | Spillway Elev. | Demand | Max lake elev. | Min. Lake elev. |
|---|---|---|---|---|
| 1 | 3 m width 40.5 | Present | 40.535 | 39.885 |
| 2 | 40.5 | Future | 40.256 | 39.409 |
| 3 | 40.7 | Present | 40.735 | 40.085 |
| 4 | 40.7 | Future | 40.456 | 39.609 |
| 5 | 41.0 | Present | 41.034 | 40.385 |
| 6 | 41.0 | Future | 40.756 | 39.909 |

### 6.3 The 1:50 year storm

Lake levels were estimated assuming a 1:50 year storm event. This was done for the following cases:

Case 1. Spillway elevation = 40.5 m, spillway width = 3 metres
Case 2. Spillway elevation = 40.7 m, spillway width = 3 metres
Case 3. Spillway elevation = 41.0 m, spillway width = 3 metres
Case 4. Spillway elevation = 41.0 m, spillway width = 6 metres

I checked the response of the St Mary Lake Watershed to 1:50 year storms of various durations, from one hour to 30 days, and found that the storm of 3 days duration was the most critical. The magnitude of the 3 day 1:50 year storm was obtained from an analysis of storm events at Victoria

International Airport over the last 58 years.

Storm events at the St.Mary and Victoria Airport stations were compared. I found that they occurred on the same dates at both stations but that their magnitude was about 5% less at the St Mary station. I decided to use the Victoria Airport storm values without reduction for the analysis.

The storm was assumed to take place in winter when the lake level would be at an average peak level. This peak level was obtained by averaging the end of month lake levels for the peak month for the past 7 years. The average turned out to be very close to the lake level at the end of December 1990 and this date was used for all cases. Figure 6 shows the results of the analysis for each of the four cases (see Appendix G for sample calculation). The analysis was done for Present Demand only. Future Demand would reduce flood levels only a very minor amount, if at all.

RESULTS

For each of the first three cases the storm caused the water level to rise rapidly, over a 3 day period, to about 0.33 metre above the normal level and then subside gradually over a period of some days. In Case 4, with the 6 m. spillway, the water level rose to 0.275 metre above the normal level.

The estimated maximum lake levels resulting from the storm were as follows:

Case 1. 41.062 m
Case 2. 41.263 m
Case 3. 41.562 m
Case 4. 41.430 m

The maximum month end lake level in the last 8 years occurred at the end of January 1992. It was 41.272 m. Cases 3 and 4 exceed this elevation.

[illegible] ... [illegible] · 13 Nov 98. – Max flood [illegible] for 200 yr
slow ([illegible] greater)
10 m wide spillway. 40.7 crest. [illegible] 41.5
6 m " " " 41.8
3 m " " " 42.0

ST. MARY L[illegible] WATER [illegible]

Assumed spillway elevation = 40.5m., spillway width = 3m.

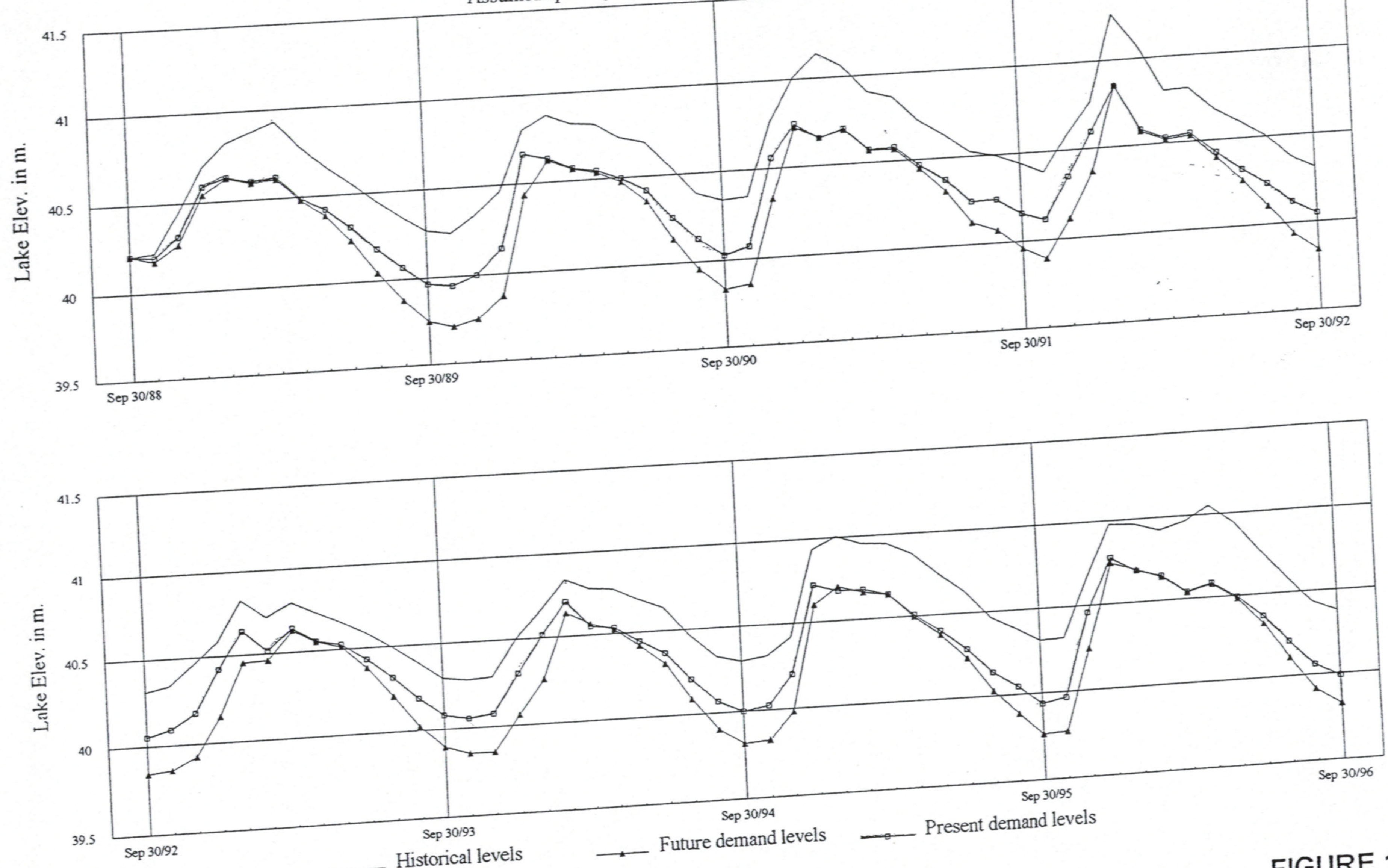


FIGURE 1

series3.wk3

Feb 08, 1998

## ST. MARY LAKE WATER LEVELS

Assumed spillway elevation = 40.7m., spillway width = 3m.

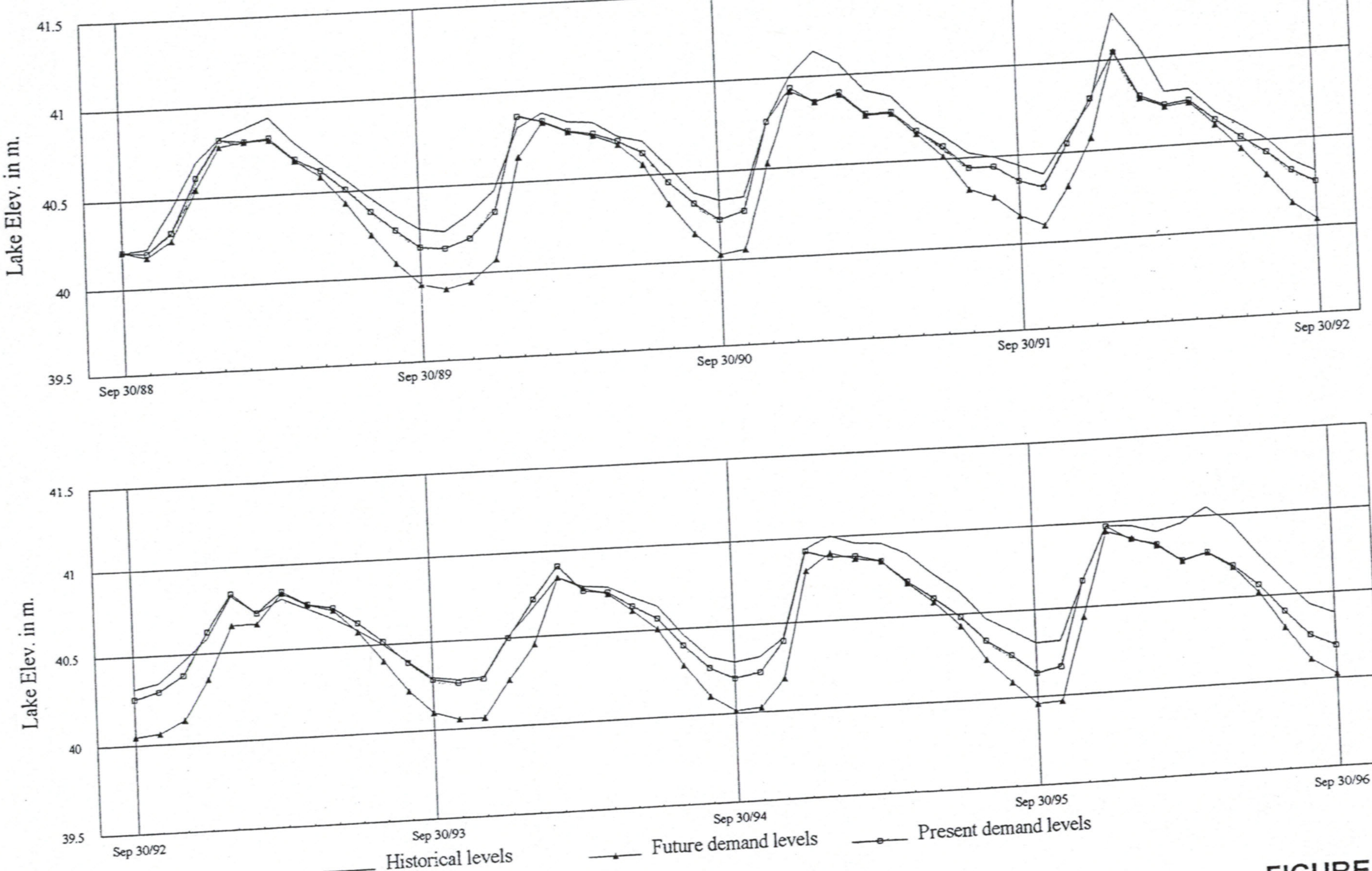


**FIGURE 2**

series2.wk3

Feb 08, 1998

# ST. MARY LAKE WATER LEVELS

Assumed spillway elevation = 41m., spillway width = 6m.

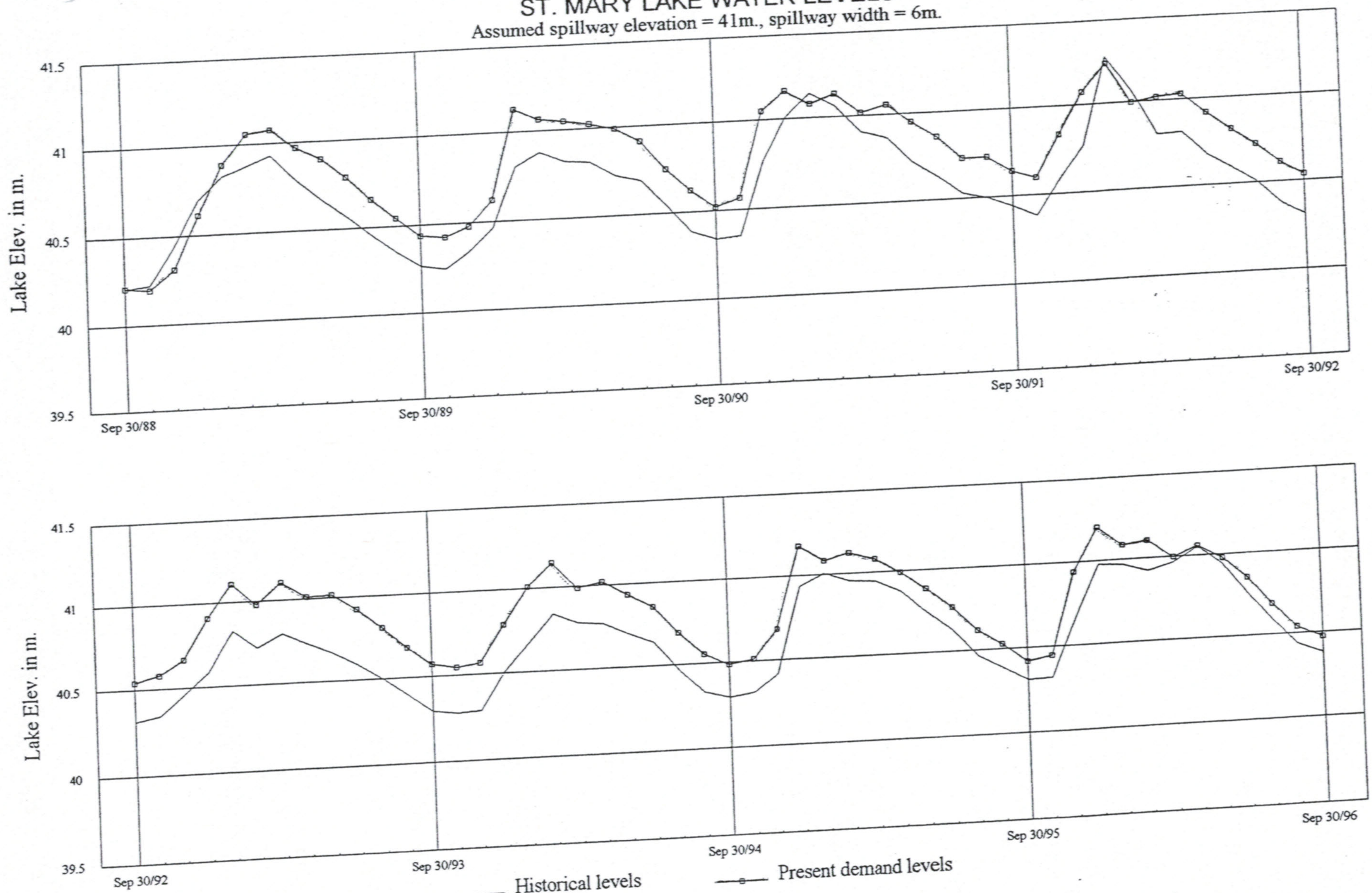


**FIGURE 4**

series4.wk3

Feb 08, 1998

## ST. MARY LAKE WATER LEVELS

Assumed spillway elevation = 41m., spillway width = 3m.

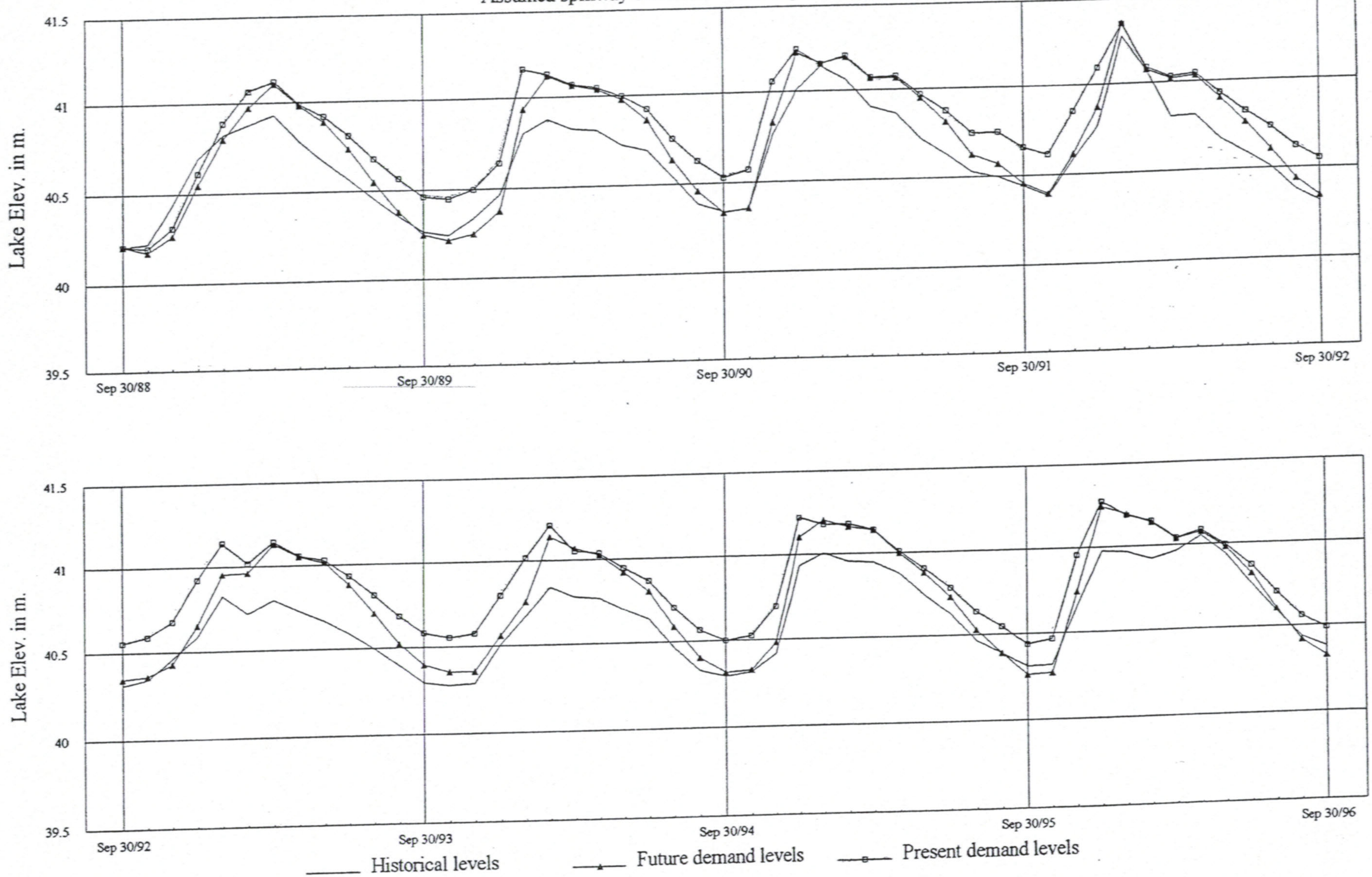


FIGURE 3

series1.wk3

Feb 08, 1998

**FIGURE 5**

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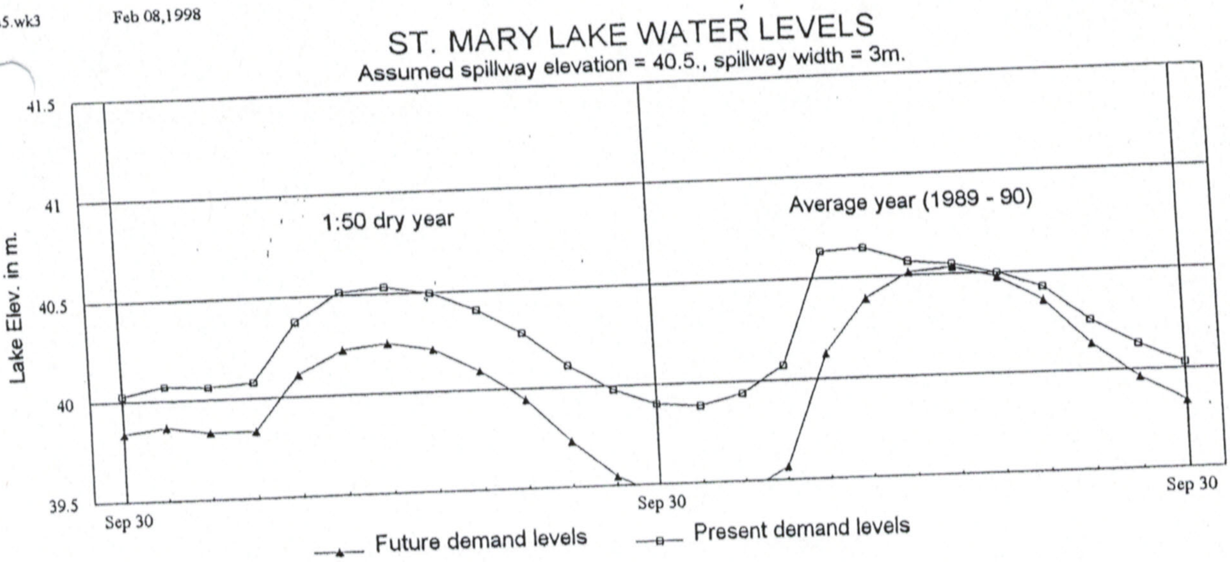
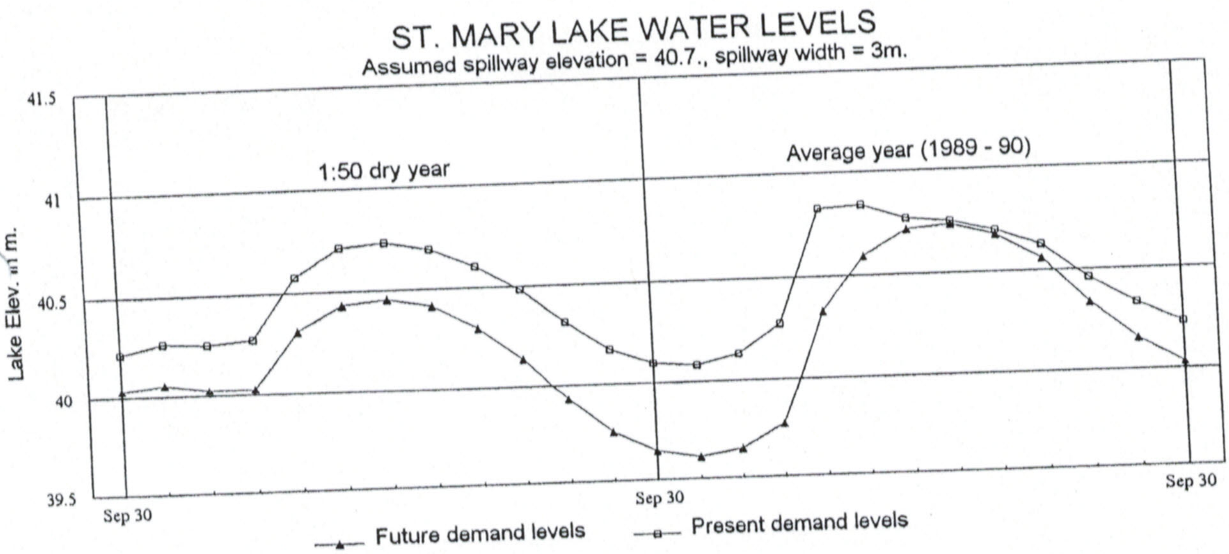
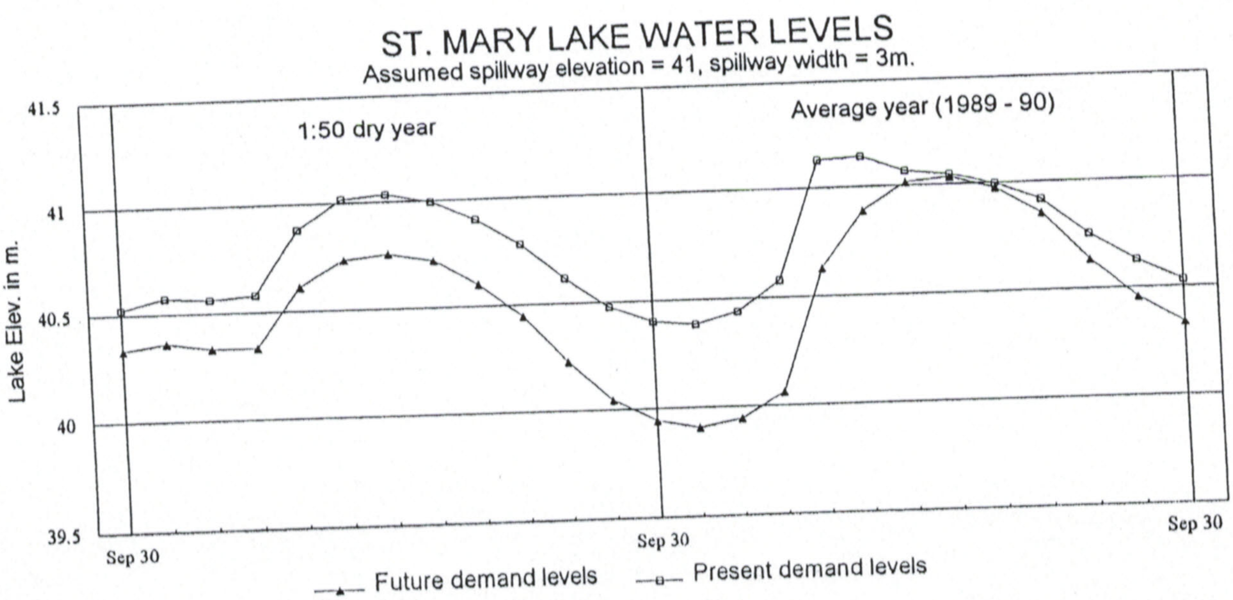
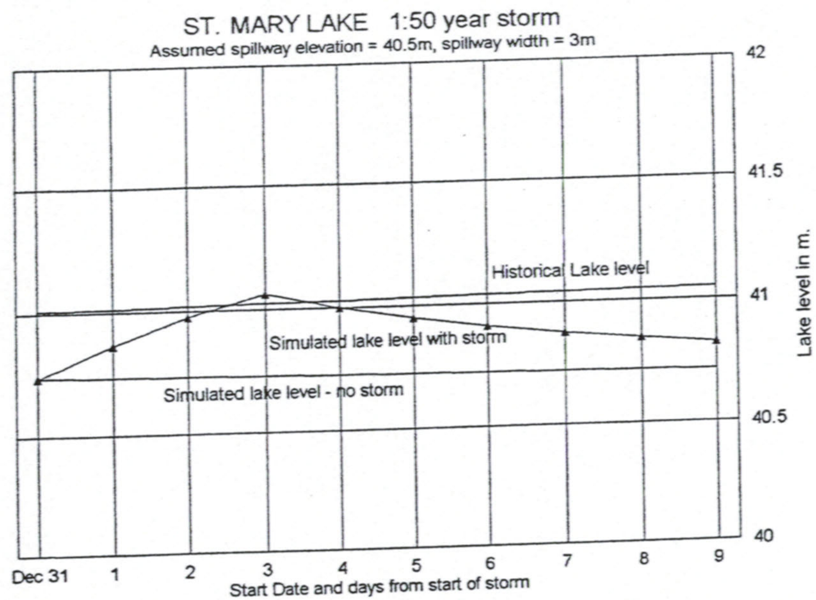
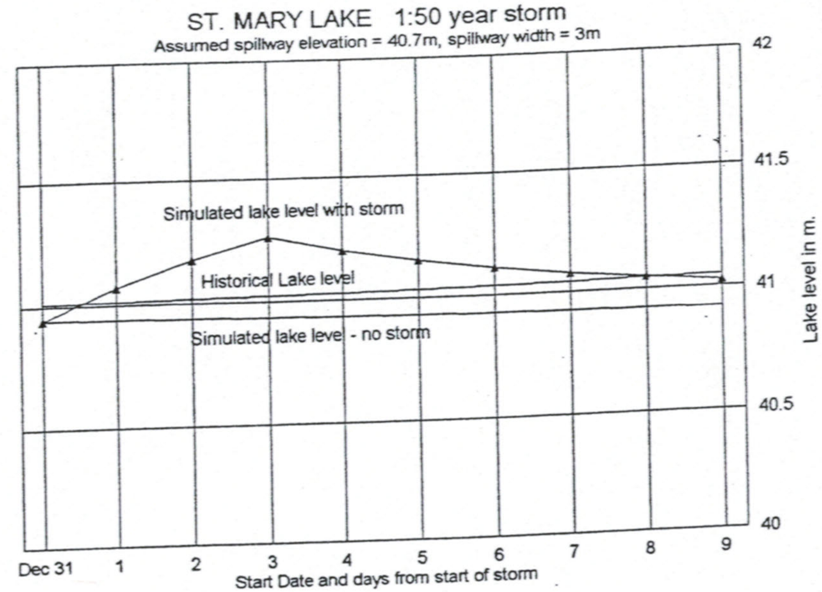
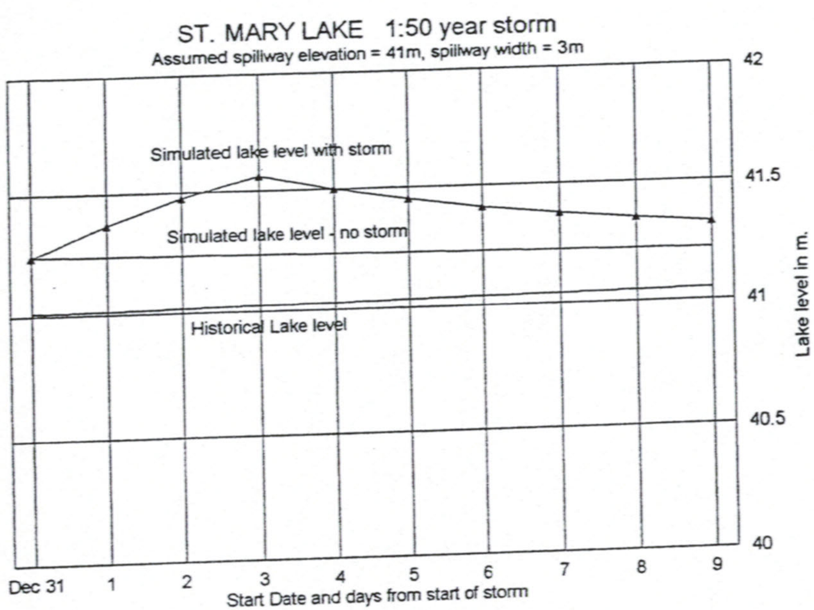




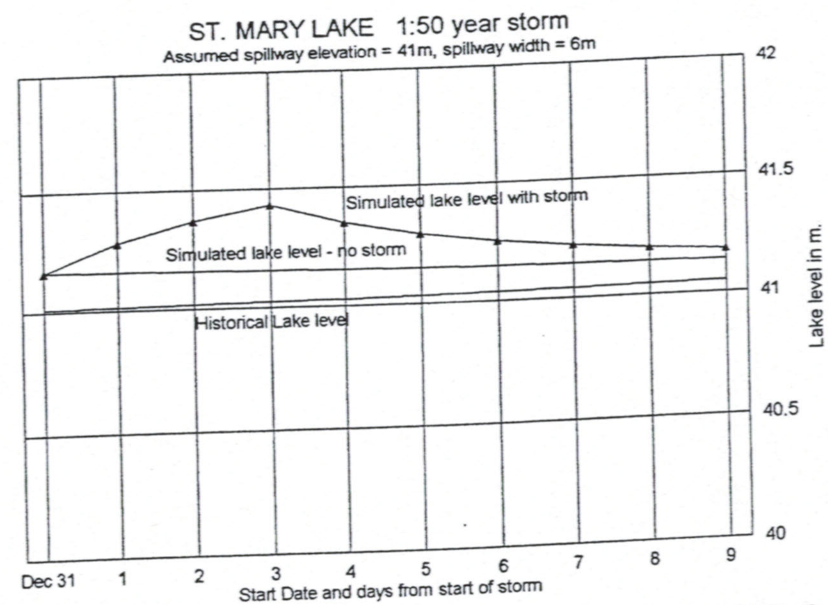
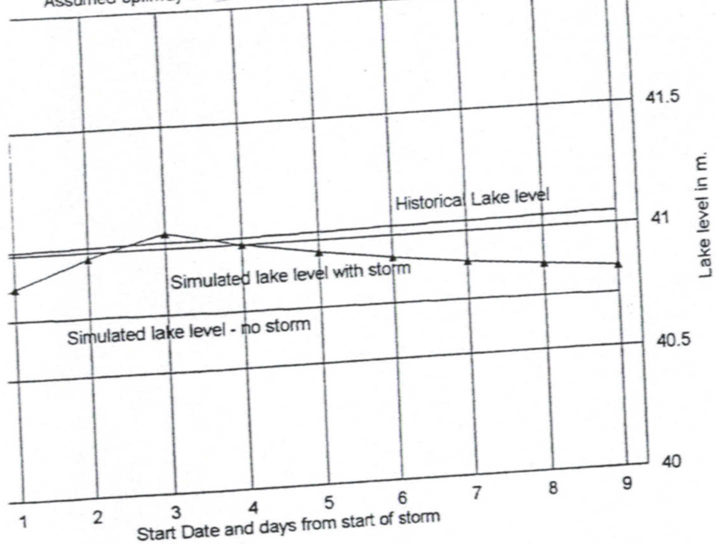
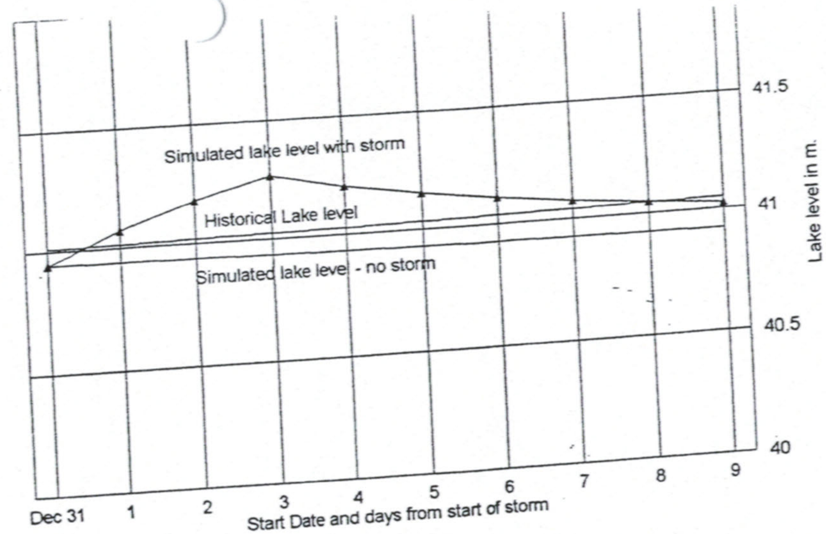




**FIGURE 6**

stormsm.wk3 Feb 08, 1998

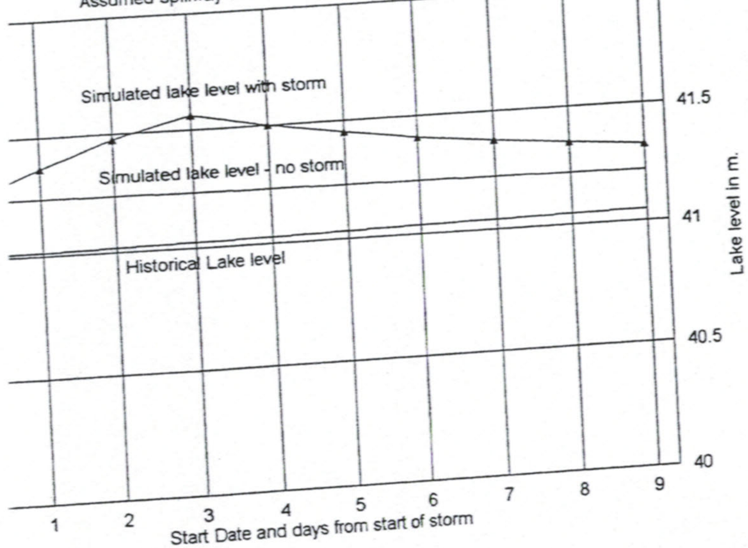
Assumed spillway e... ion = 40.5m, spillway width - 3m




ST. MARY LAKE 1:50 year storm

Assumed spillway elevation = 41m, spillway width = 3m




ST. MARY LAKE 1:50 year storm

Assumed spillway elevation = 41m, spillway width = 6m

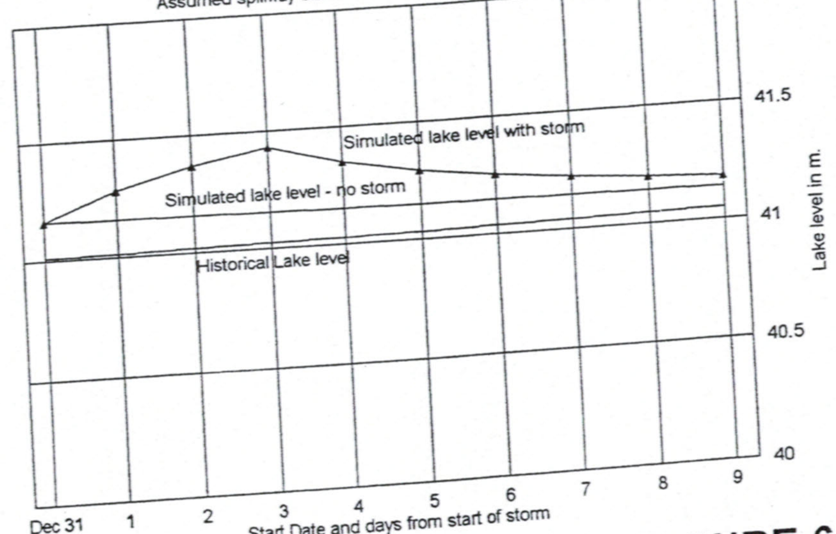



**FIGURE 6**

APPENDIX A

# REAS, COEFFICIENTS, AND CONVERSION FACTORS

**Watershed Area above St. Mary Lake outlet (including lake):** obtained by planimeter from e 1 inch = 1320 feet map prepared in October 1969 by the B.C. Department of Lands, Forests, d Water Resources. The value obtained was 7,203,285 $m^2$ 720.3 Ha vs Grange 2008 A = 690 Ha.

**Area of St. Mary Lake:** obtained by planimeter from the 1 inch = 1320 feet map prepared October 1969 by the B.C. Department of Lands, Forests, and Water Resources. The value obtained was 1,833,973 $m^2$.

**Area versus elevation equation for St. Mary Lake**: derived from a bathymetric plan prepared the B.C. Ministry of Environment, dated Aug 1979. The equation is:

$$A = 11.833\ E - 296.66$$ where A is in hectares and E is in metres.

is equation is applicable from elevation 42.0 m. down to about 39.5 m.

**Storage in St. Mary Lake:** A storage versus elevation curve was derived from a bathymetric in prepared by the B.C. Ministry of Environment, dated Aug 1979. The equation is:

$$S = 1876.055\ E - 60374.455$$ where S is in $dam^3$ and E is in metres.

**Coefficient of discharge for dam spillway:** A metric weir coefficient, M = 1.44 was adopted for the equation $Q = MbH^{1.5}$ where Q is in $m^3/s$. The coefficient M was converted to 124.05 for the equation $Q = MbH^{1.5}$ where Q is in $dam^3/day$. These coefficients apply to a low head broad crested weir. The actual coefficient of a new dam may be a little higher, which would mean that the discharge rate would be slightly greater.

**Conversion Factors:**

metre of depth in the lake = 183.4 $dam^3$ approx.

$dam^3$ = 1,000 $m^3$

,000,000 Igpd = 165.93 $dam^3$ per year

Cusheon Lake Watershed Water Budget

**1989-90**

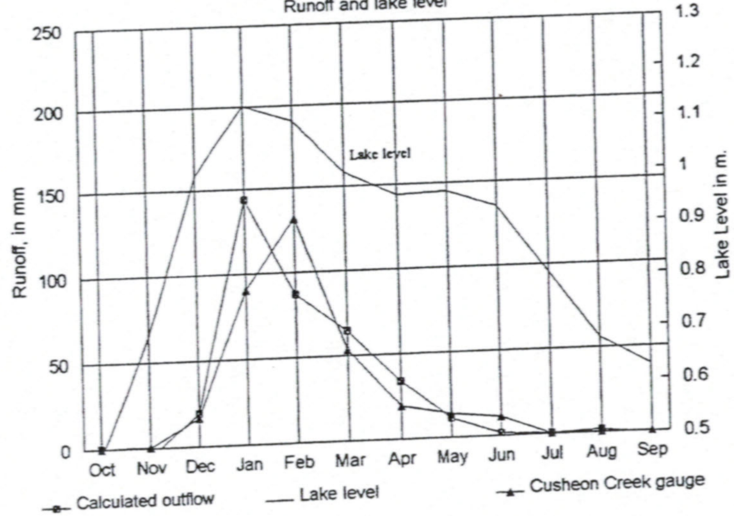
Historical demand

| 1 | 2<br>Days in Month | 3<br>Potential Evap. (PET) | 4<br>Precip. in mm | 5<br>Precip. Minus PET | 6<br>Cumulative Soil Stress | 7<br>Soil Moisture mm | 8<br>Change in soil Storage mm | 9<br>Actual Evap mm | 10<br>Surplus moisture mm | 11<br>Runoff Depth mm | 12<br>Land Runoff dam3 | 13<br>Net Precip into lake dam3 | 14<br>End mo. lake elev. m | 15<br>Change in lake storage dam3 | 16<br>Lake outflow m3/s | 17<br>Lake outflow mm | 18<br>Cusheon Creek Gauge mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 89/90 | 89/90 | | 363.4 | 34.5 | | | 0.0 | | | | 0.48 | | | | |
| Oct | 31 | 45.43 | 52.80 | 7.4 | | 41.9 | 7.4 | 45.4 | -0.1 | -0.1 | -0.46 | 2.06 | 0.48 | 0.42 | 0.000 | 0.1 | 0.00 |
| Nov | 30 | 26.27 | 112.50 | 86.2 | | 128.1 | 86.2 | 26.3 | 0.0 | 0.0 | 0.11 | 24.07 | 0.71 | 62.94 | -0.015 | -4.8 | 0.32 |
| Dec | 31 | 18.60 | 124.20 | 105.6 | | 200.0 | 71.9 | 18.6 | 33.7 | 27.0 | 210.15 | 29.47 | 1.01 | 83.59 | 0.058 | 19.3 | 16.92 |
| Jan | 31 | 16.45 | 194.20 | 177.7 | | 200.0 | 0.0 | 16.5 | 177.7 | 147.6 | 1150.46 | 49.61 | 1.14 | 37.54 | 0.434 | 144.0 | 90.55 |
| Feb | 28 | 11.41 | 82.60 | 71.2 | | 200.0 | 0.0 | 11.4 | 71.2 | 86.5 | 674.03 | 19.87 | 1.11 | -8.93 | 0.291 | 87.0 | 131.82 |
| Mar | 31 | 31.30 | 86.20 | 54.9 | | 200.0 | 0.0 | 31.3 | 54.9 | 61.2 | 477.18 | 15.32 | 1.01 | -28.47 | 0.195 | 64.5 | 53.74 |
| Apr | 30 | 55.64 | 81.40 | 25.8 | | 200.0 | 0.0 | 55.6 | 25.8 | 32.8 | 255.73 | 7.19 | 0.96 | -12.98 | 0.106 | 34.2 | 19.58 |
| May | 31 | 70.72 | 77.40 | 6.7 | | 200.0 | 0.0 | 70.7 | 6.7 | 11.7 | 91.03 | 1.86 | 0.96 | 0.84 | 0.034 | 11.4 | 13.93 |
| Jun | 30 | 94.46 | 45.80 | -48.7 | 48.7 | 157.6 | -42.4 | 88.2 | -0.0 | 2.2 | 17.50 | -13.58 | 0.93 | -8.79 | 0.005 | 1.6 | 11.24 |
| Jul | 31 | 123.96 | 4.00 | -120.0 | 168.6 | 88.3 | -69.3 | 73.3 | 0.0 | 0.4 | 2.95 | -33.48 | 0.81 | -35.59 | 0.002 | 0.6 | 0.33 |
| Aug | 31 | 110.98 | 31.60 | -79.4 | 248.0 | 60.2 | -28.1 | 59.7 | -0.0 | 0.0 | 0.33 | -22.16 | 0.68 | -35.31 | 0.005 | 1.7 | 0.33 |
| Sep | 30 | 80.44 | 10.20 | -70.2 | 318.2 | 42.9 | -17.3 | 27.5 | 0.0 | -0.0 | -0.00 | -19.60 | 0.63 | -14.37 | -0.002 | -0.6 | 0.32 |
| | | 685.7 | 902.9 | | | | | 524.6 | 369.9 | 369.3 | 2879.00 | 60.63 | | | | 359.0 | 339.1 |

Water Holding Capacity (WHC) = 200mm

CUSHEON LAKE WATERSHED

Runoff and lake level




APPENDIX B1

cu89-90r.wk3

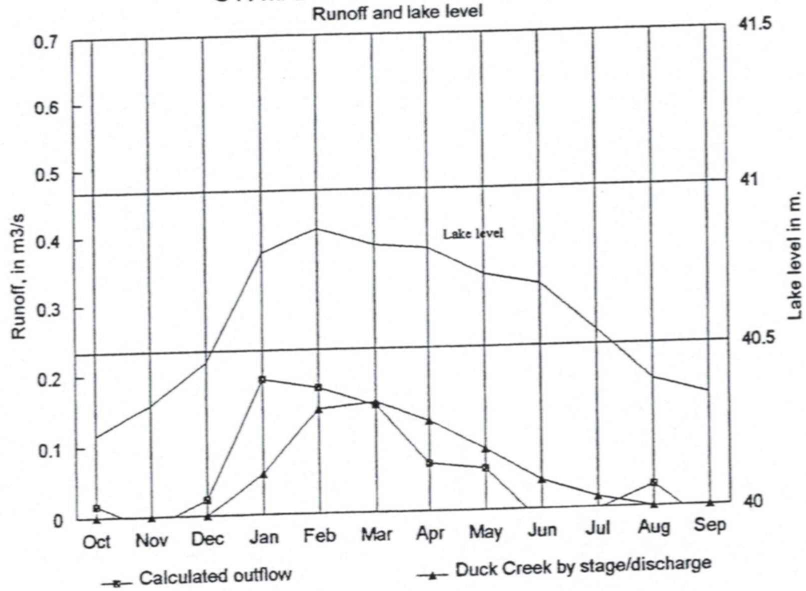
Feb 07,1998

| 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tential Evap. PET) | Precip. | Precip. Minus PET | Cumulativ Soil Stress | Soil Moisture | Change in soil Storage | Actual Evap | Surplus moisture | Runoff Depth | Land Runoff | Net Precip into lake | NSSWD Demand | Other Water Users | Fisheries | Future Users | Irrigation | End mo. lake elev. | Change in lake storage | Lake outflow volume | Lake outflow rate | Duck Creek |
| mm | mm | mm | mm | mm | mm | mm | mm | mm | dam3 | dam3 | dam3 | dam3 (estim) | m3 | m3 | dam3 | m | dam3 | dam3 | m3/s | m3/s |
| | | | 372.9 | 32.9 | | | 0.0 | | | | | | | | | 40.268 | | | | |
| 45.43 | 58.20 | 12.8 | | 45.70 | 12.8 | 45.4 | 0.0 | 0.0 | 0.0 | 23.4 | 20.69 | 2.07 | | | | 40.245 | -42.2 | 42.8 | 0.016 | 0.000 |
| 26.27 | 108.80 | 82.5 | | 128.20 | 82.5 | 26.3 | 0.0 | 0.0 | 0.1 | 151.4 | 21.20 | 2.12 | | | | 40.337 | 168.7 | -40.5 | -0.016 | 0.000 |
| 18.60 | 120.70 | 102.1 | | 200.0 | 71.8 | 18.6 | 30.3 | 24.2 | 130.2 | 187.2 | 18.89 | 1.89 | | | | 40.465 | 234.8 | 61.9 | 0.023 | 0.000 |
| 16.45 | 198.90 | 182.4 | | 200.0 | 0.0 | 16.5 | 182.4 | 150.8 | 809.7 | 334.6 | 15.29 | 1.53 | | | | 40.801 | 616.2 | 511.2 | 0.191 | 0.058 |
| 11.41 | 80.70 | 69.3 | | 200.0 | 0.0 | 11.4 | 69.3 | 85.6 | 459.5 | 127.1 | 15.94 | 1.59 | | | | 40.876 | 137.6 | 431.5 | 0.178 | 0.147 |
| 31.30 | 69.10 | 37.8 | | 200.0 | 0.0 | 31.3 | 37.8 | 47.4 | 254.3 | 69.3 | 15.88 | 1.59 | | | | 40.822 | -99.0 | 405.2 | 0.151 | 0.156 |
| 55.64 | 75.00 | 19.4 | | 200.0 | 0.0 | 55.6 | 19.4 | 24.9 | 133.8 | 35.5 | 15.99 | 1.60 | | | | 40.810 | -22.0 | 173.7 | 0.067 | 0.128 |
| 70.72 | 70.90 | 0.2 | | 200.0 | 0.0 | 70.7 | 0.2 | 4.9 | 26.3 | 0.3 | 17.76 | 1.78 | | | 7.77 | 40.724 | -157.7 | 157.0 | 0.059 | 0.086 |
| 94.46 | 50.90 | -43.6 | 43.6 | 161.6 | -38.4 | 89.3 | 0.0 | 0.9 | 4.8 | -79.9 | 19.78 | 1.98 | | | 15.54 | 40.692 | -58.7 | -53.7 | -0.021 | 0.040 |
| 23.96 | 4.20 | -119.8 | 163.3 | 90.6 | -71.0 | 75.2 | 0.0 | 0.1 | 0.7 | -219.6 | 35.19 | 3.52 | | | 23.31 | 40.543 | -273.3 | -7.7 | -0.003 | 0.016 |
| 10.98 | 31.70 | -79.3 | 242.6 | 61.8 | -28.8 | 60.5 | 0.0 | 0.0 | 0.0 | -145.4 | 33.22 | 3.32 | | | 23.31 | 40.387 | -286.1 | 80.9 | 0.030 | 0.000 |
| 80.44 | 14.40 | -66.0 | 308.6 | 44.9 | -16.9 | 31.3 | 0.0 | 0.0 | 0.0 | -121.1 | 28.43 | 2.84 | | | 7.77 | 40.341 | -84.4 | -75.8 | -0.029 | 0.000 |
| 685.7 | 883.5 | | | | | 532.1 | 339.4 | 338.9 | 1819.3 | 362.8 | 258.3 | 25.8 | | | 77.7 | | | 1686.5 | | |

ding Capacity (WHC) = 200mm

ST. MARY LAKE WATERSHED

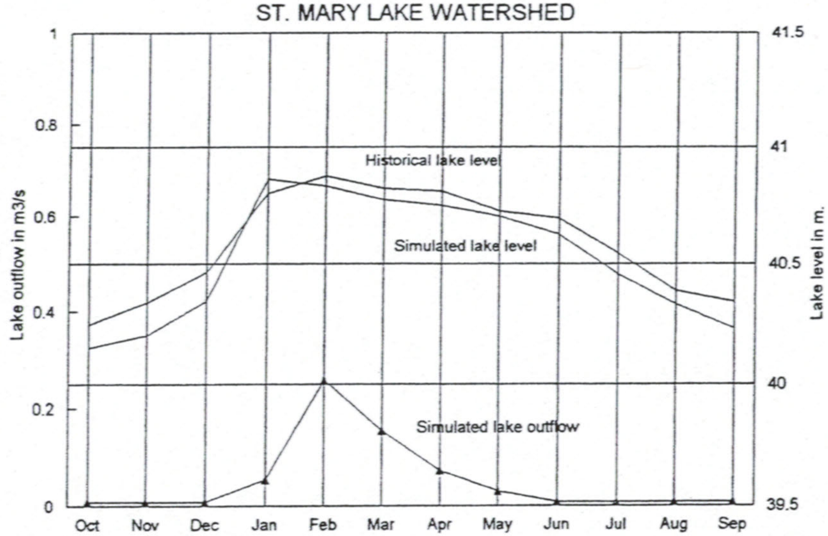
Runoff and lake level




APPENDIX B2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days in Month | Land Runoff | Net Precip into lake | NSSWD Demand | Other Water Users | Fisheries | Irrigation | Net Inflow | Trial lake elev. | Lake spill | Storage Change | Total storage | Lake elev. (Month end) | Lake outflow | Lake outflow | Lake elev. (Historical) |
| | | dam3 | dam3 | dam3 | dam3 | dam3 | dam3 | dam3 | m | dam3 | dam3 | dam3 | m | dam3 | m3/s | m |
| | | | | | | | | End Sept = | 40.163 | | | 14973.54 | | | | |
| Oct | 31 | 0.0 | 23.4 | 20.69 | 7.16 | 23.40 | | -27.83 | | 0.0 | -27.83 | 14945.71 | 40.148 | 23.4 | 0.009 | 40.245 |
| Nov | 30 | 0.1 | 151.4 | 21.20 | 7.85 | 23.40 | | 99.05 | | 0.0 | 99.05 | 15044.76 | 40.201 | 23.4 | 0.009 | 40.337 |
| Dec | 31 | 130.2 | 187.2 | 18.89 | 7.58 | 23.40 | | 267.53 | | 0.0 | 267.53 | 15312.29 | 40.344 | 23.4 | 0.009 | 40.465 |
| Jan | 31 | 809.7 | 334.6 | 15.29 | 8.18 | 23.40 | | 1097.41 | 40.864 | 120.7 | 976.69 | 16288.98 | 40.864 | 144.1 | 0.054 | 40.801 |
| Feb | 28 | 459.5 | 127.1 | 15.94 | 7.69 | 23.40 | | 539.59 | 40.833 | 598.7 | -59.15 | 16229.83 | 40.833 | 622.1 | 0.257 | 40.876 |
| Mar | 31 | 254.3 | 69.3 | 15.88 | 7.49 | 23.40 | | 276.84 | 40.772 | 391.2 | -114.39 | 16115.43 | 40.772 | 414.6 | 0.155 | 40.822 |
| Apr | 30 | 133.8 | 35.5 | 15.99 | 6.35 | 23.40 | | 123.56 | 40.748 | 166.6 | -42.99 | 16072.44 | 40.749 | 190.0 | 0.073 | 40.810 |
| May | 31 | 26.3 | 0.3 | 17.76 | 8.39 | 23.40 | 7.77 | -30.71 | 40.700 | 60.7 | -91.38 | 15981.06 | 40.700 | 84.1 | 0.031 | 40.724 |
| Jun | 30 | 4.8 | -79.9 | 19.78 | 9.64 | 23.40 | 15.54 | -143.47 | | 0.0 | -143.47 | 15837.59 | 40.624 | 23.4 | 0.009 | 40.692 |
| Jul | 31 | 0.7 | -219.6 | 35.19 | 13.40 | 23.40 | 23.31 | -314.25 | | 0.0 | -314.25 | 15523.34 | 40.456 | 23.4 | 0.009 | 40.543 |
| Aug | 31 | 0.0 | -145.4 | 33.22 | 11.78 | 23.40 | 23.31 | -237.11 | | 0.0 | -237.11 | 15286.23 | 40.330 | 23.4 | 0.009 | 40.387 |
| Sep | 30 | 0.0 | -121.1 | 28.43 | 6.82 | 23.40 | 7.77 | -187.54 | | 0.0 | -187.54 | 15098.69 | 40.230 | 23.4 | 0.009 | 40.341 |
| | | 1819.3 | 362.8 | 258.3 | 102.3 | 280.8 | 77.7 | 1463.1 | | 1337.9 | | | | 1618.7 | | |

ST. MARY LAKE WATERSHED

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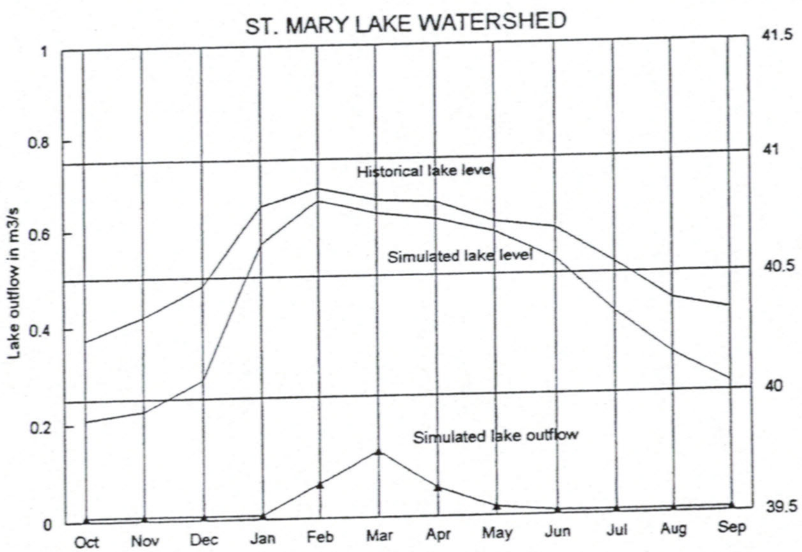
Feb 07, 1998

APPENDIX B3

F[illegible] demand

| 1 | 2<br>Days in Month | 3<br>Land Runoff<br>dam3 | 4<br>Net Precip into lake<br>dam3 | 5<br>NSSWD Demand<br>dam3 | 6<br>Other Water Users<br>dam3 | 7<br>Fisheries<br>dam3 | 8<br>Irrigation<br>dam3 | 9<br>Net Inflow<br>dam3 | 10<br>Trial lake elev.<br>m | 11<br>Lake spill<br>dam3 | 12<br>Storage Change<br>dam3 | 13<br>Total storage<br>dam3 | 14<br>Lake elev. (Month end)<br>m | 15<br>Lake outflow<br>dam3 | 16<br>Lake outflow<br>m3/s | 17<br>Lake elev. (Historical)<br>m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | End Sept = | 39.950 | | | 14573.94 | | | | |
| Oct | 31 | 0.0 | 23.4 | 53.28 | 11.69 | 23.40 | | -64.95 | | 0.0 | -64.95 | 14508.99 | 39.915 | 23.4 | 0.009 | 40.245 |
| Nov | 30 | 0.1 | 151.4 | 51.97 | 11.37 | 23.40 | | 64.77 | | 0.0 | 64.77 | 14573.76 | 39.950 | 23.4 | 0.009 | 40.337 |
| Dec | 31 | 130.2 | 187.2 | 50.97 | 11.38 | 23.40 | | 231.65 | | 0.0 | 231.65 | 14805.41 | 40.073 | 23.4 | 0.009 | 40.465 |
| Jan | 31 | 809.7 | 334.6 | 50.37 | 11.80 | 23.40 | | 1058.71 | | 0.0 | 1058.71 | 15864.12 | 40.638 | 23.4 | 0.009 | 40.801 |
| Feb | 28 | 459.5 | 127.1 | 54.68 | 11.92 | 23.40 | | 496.62 | 40.823 | 149.2 | 347.43 | 16211.55 | 40.823 | 172.6 | 0.071 | 40.876 |
| Mar | 31 | 254.3 | 69.3 | 56.49 | 12.20 | 23.40 | | 231.52 | 40.764 | 342.2 | -110.71 | 16100.84 | 40.764 | 365.6 | 0.137 | 40.822 |
| Apr | 30 | 133.8 | 35.5 | 54.53 | 12.10 | 23.40 | | 79.27 | 40.737 | 130.1 | -50.84 | 16049.99 | 40.737 | 153.5 | 0.059 | 40.810 |
| May | 31 | 26.3 | 0.3 | 60.36 | 14.04 | 23.40 | 9.62 | -80.81 | 40.680 | 26.6 | -107.41 | 15942.59 | 40.680 | 50.0 | 0.019 | 40.724 |
| Jun | 30 | 4.8 | -79.9 | 91.97 | 15.24 | 23.40 | 19.24 | -224.96 | | 0.0 | -224.96 | 15717.63 | 40.560 | 23.4 | 0.009 | 40.692 |
| Jul | 31 | 0.7 | -219.6 | 127.99 | 21.35 | 23.40 | 28.86 | -420.56 | | 0.0 | -420.56 | 15297.07 | 40.335 | 23.4 | 0.009 | 40.543 |
| Aug | 31 | 0.0 | -145.4 | 116.75 | 18.63 | 23.40 | 28.86 | -333.03 | | 0.0 | -333.03 | 14964.04 | 40.158 | 23.4 | 0.009 | 40.387 |
| Sep | 30 | 0.0 | -121.1 | 64.64 | 12.28 | 23.40 | 9.62 | -231.07 | | 0.0 | -231.07 | 14732.97 | 40.035 | 23.4 | 0.009 | 40.341 |
| | | 1819.3 | 362.8 | 834.0 | 164.0 | 280.8 | 96.2 | 807.2 | | 648.1 | | | | 928.9 | | |

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Feb 07, 1998

APPENDIX B4

## ITHLY LAKE EVAPORATION in mm.

ıwaite Equation using Saanichton CDA temperature data

| 76/77 | 77/78 | 78/79 | 79/80 | 80/81 | 81/82 | 82/83 | 83/84 | 84/85 | 85/86 | 86/87 | 87/88 | 88/89 | 89/90 | 90/91 | 91/92 | 92/93 | 93/94 | 94/95 | 95/96 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46.6 | 44.2 | 45.3 | 48.3 | 48.2 | 39.6 | 45.0 | 40.9 | 38.5 | 46.7 | 47.8 | 50.0 | 47.9 | 45.4 | 39.8 | 37.0 | 30.5 | 45.0 | 42.9 | 43.4 | 43.6 |
| 27.6 | 20.9 | 15.1 | 21.6 | 26.1 | 26.5 | 17.3 | 29.1 | 21.4 | 3.6 | 22.8 | 26.5 | 24.0 | 26.3 | 23.6 | 22.0 | 27.3 | 22.0 | 17.9 | 28.1 | 22.5 |
| 20.0 | 12.9 | 8.6 | 20.3 | 18.4 | 12.9 | 14.9 | 4.0 | 5.9 | 8.6 | 16.5 | 11.0 | 17.3 | 18.6 | 4.0 | 13.0 | 13.0 | 13.0 | 13.2 | 14.3 | 13.0 |
| 11.0 | 14.4 | 4.5 | 3.5 | 21.7 | 8.7 | 20.5 | 20.1 | 10.6 | 21.1 | 14.3 | 11.5 | 13.9 | 16.5 | 14.0 | 14.0 | 14.0 | 21.8 | 16.1 | 11.9 | 14.2 |
| 28.3 | 20.9 | 13.0 | 20.1 | 20.1 | 17.0 | 22.4 | 23.5 | 13.8 | 16.9 | 23.7 | 19.2 | 3.3 | 11.4 | 18.0 | 18.0 | 18.0 | 12.1 | 20.3 | 19.0 | 17.9 |
| 29.3 | 35.6 | 35.3 | 28.5 | 37.7 | 28.5 | 37.0 | 40.6 | 28.4 | 39.9 | 34.1 | 29.3 | 24.2 | 31.3 | 32.0 | 32.0 | 32.0 | 34.7 | 30.2 | 34.1 | 32.7 |
| 55.3 | 50.1 | 46.2 | 56.0 | 46.0 | 39.7 | 48.1 | 48.2 | 50.1 | 42.1 | 51.7 | 49.8 | 58.6 | 55.6 | 59.0 | 60.2 | 50.0 | 52.5 | 46.6 | 53.1 | 50.9 |
| 69.6 | 74.5 | 76.8 | 76.6 | 73.2 | 74.7 | 83.4 | 68.2 | 79.3 | 73.4 | 77.3 | 73.6 | 77.6 | 70.7 | 83.7 | 95.4 | 75.0 | 82.3 | 85.9 | 69.1 | 77.0 |
| 100.6 | 107.6 | 93.5 | 91.1 | 85.4 | 107.4 | 95.4 | 93.0 | 98.1 | 96.5 | 98.7 | 94.5 | 102.3 | 94.5 | 85.7 | 110.2 | 96.0 | 91.4 | 104.1 | 96.9 | 97.1 |
| 109.9 | 116.5 | 113.9 | 108.9 | 107.0 | 107.5 | 108.5 | 115.2 | 127.7 | 99.4 | 109.9 | 117.1 | 107.4 | 124.0 | 118.1 | 104.6 | 112.0 | 116.5 | 116.9 | 121.6 | 113.1 |
| 113.3 | 101.5 | 99.8 | 94.7 | 109.5 | 100.0 | 104.3 | 101.8 | 104.5 | 109.4 | 102.3 | 104.8 | 98.6 | 111.0 | 84.3 | 101.7 | 103.0 | 107.6 | 91.5 | 108.9 | 102.6 |
| 69.6 | 67.1 | 80.2 | 71.5 | 72.7 | 78.2 | 69.2 | 71.3 | 72.0 | 72.4 | 78.1 | 70.2 | 80.3 | 80.4 | 59.4 | 64.5 | 74.0 | 78.0 | 80.6 | 69.3 | 73.0 |
| 681.1 | 666.2 | 632.1 | 641.2 | 666.1 | 640.9 | 666.1 | 655.8 | 650.4 | 630.1 | 677.3 | 657.4 | 655.5 | 685.7 | 621.6 | 672.6 | 644.8 | 676.8 | 666.2 | 669.6 | 657.9 |

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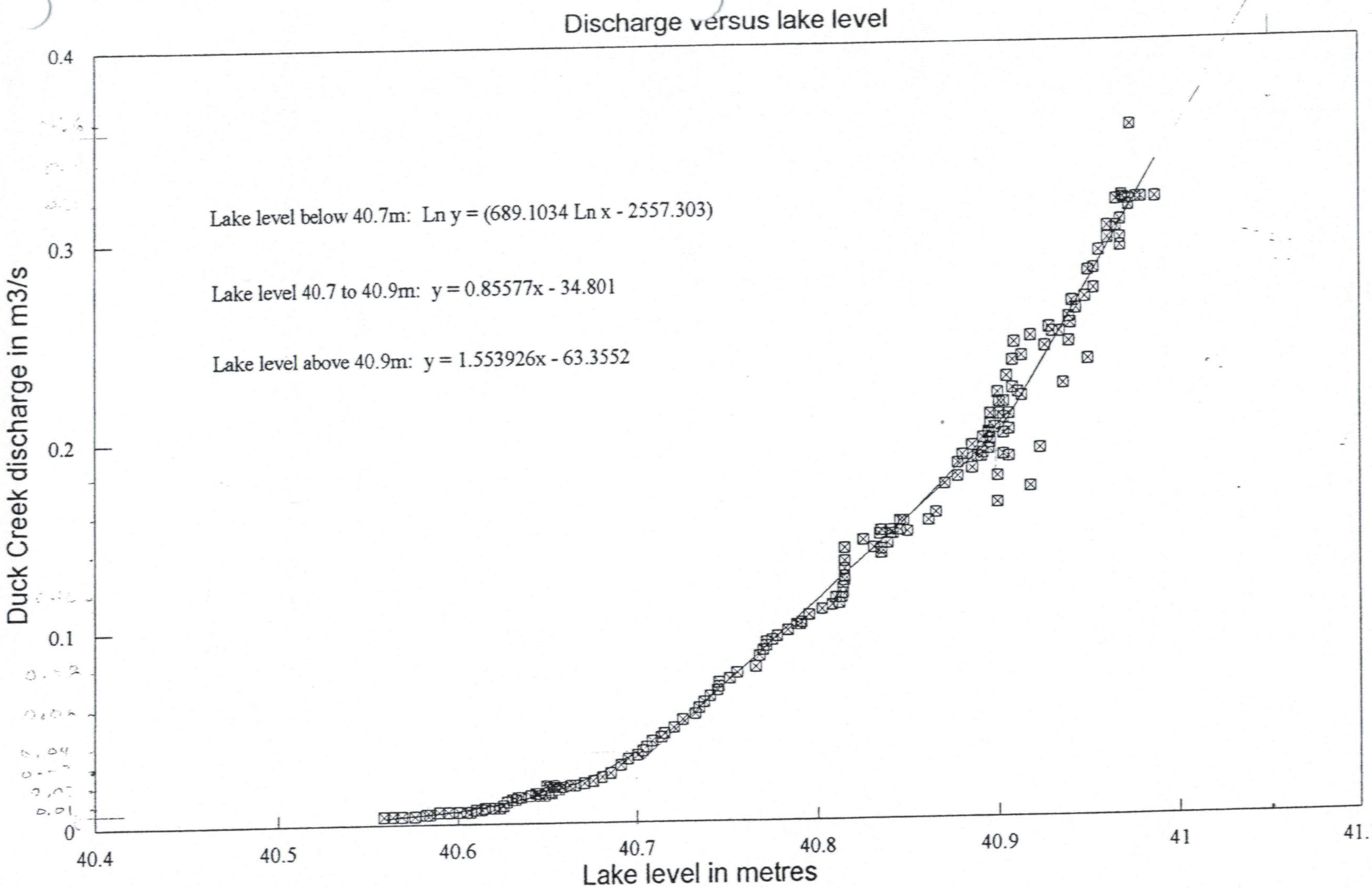
1998

APPENDIX C




# APPENDIX D

regress.wk3

Ref. Pages. - Regression analysis, may be reliable for 1980 ... but not reliable for other years due to ...

# APPENDIX E

**MARY LAKE**

nated elevations for various spillway configurations

**XIMUM LAKE ELEVATIONS**

| | Historical Lake Level | Spillway elev. = 40.5m Spillway width = 3m | | Spillway elev. = 40.7m Spillway width = 3m | | Spillway elev. = 41.0m Spillway width = 3m | | Spillway elev. = 41.0m Spillway width = 6m | |
|---|---|---|---|---|---|---|---|---|---|
| | | Present Demand | Future Demand | Present Demand | Future Demand | Present Demand | Future Demand | Present Demand | Future Demand |
| 8-89 | 40.931 | 40.633 | 40.268 | 40.818 | 40.808 | 41.121 | 41.105 | 41.077 | |
| 9-90 | 40.876 | 40.664 | 40.622 | 40.864 | 40.823 | 41.163 | 41.123 | 41.131 | |
| 0-91 | 41.145 | 40.741 | 40.722 | 40.942 | 40.923 | 41.241 | 41.223 | 41.163 | |
| 1-92 | 41.272 | 40.848 | 40.852 | 41.046 | 41.052 | 41.348 | 41.352 | 41.234 | |
| 2-93 | 40.825 | 40.640 | 40.627 | 40.840 | 40.827 | 41.142 | 41.127 | 41.109 | |
| 3-94 | 40.840 | 40.707 | 40.638 | 40.907 | 40.838 | 41.207 | 41.138 | 41.147 | |
| 4-95 | 41.004 | 40.719 | 40.703 | 40.918 | 40.903 | 41.219 | 41.203 | 41.178 | |
| 5-96 | 41.052 | 40.774 | 40.741 | 40.974 | 40.941 | 41.274 | 41.242 | 41.203 | |

**NIMUM LAKE ELEVATIONS**

| | Historical Lake Level | Spillway elev. = 40.5m Spillway width = 3m | | Spillway elev. = 40.7m Spillway width = 3m | | Spillway elev. = 41.0m Spillway width = 3m | | Spillway elev. = 41.0m Spillway width = 6m | |
|---|---|---|---|---|---|---|---|---|---|
| | | Present Demand | Future Demand | Present Demand | Future Demand | Present Demand | Future Demand | Present Demand | Future Demand |
| 1989 | 40.245 | 39.948 | 39.714 | 40.148 | 39.915 | 40.446 | 40.215 | 40.425 | |
| 1990 | 40.341 | 40.028 | 39.835 | 40.230 | 40.035 | 40.528 | 40.335 | 40.521 | |
| 1991 | 40.386 | 40.116 | 39.898 | 40.314 | 40.098 | 40.616 | 40.398 | 40.598 | |
| 1992 | 40.311 | 40.051 | 39.844 | 40.252 | 40.044 | 40.552 | 40.344 | 40.539 | |
| 1993 | 40.276 | 40.054 | 39.852 | 40.255 | 40.052 | 40.554 | 40.352 | 40.545 | |
| 1994 | 40.291 | 39.998 | 39.814 | 40.197 | 40.014 | 40.498 | 40.314 | 40.485 | |
| 1995 | 40.307 | 39.935 | 39.758 | 40.134 | 39.958 | 40.435 | 40.258 | 40.417 | |

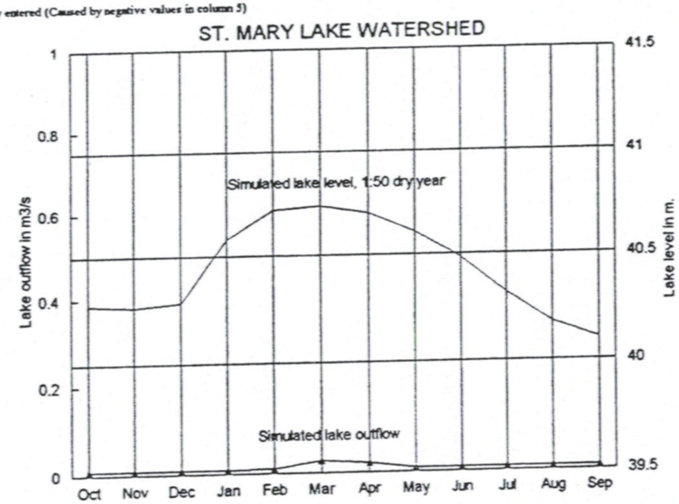
St. MARY LAKE WATERSHED
1:50 dry year precipitation

| | | | |
|---|---|---|---|
| 3.00 | = Spillway width, m. | 40.70 | = Spillway elev. in metres |
| 124.05 | = Discharge coeff. | 15981 | = Total storage at spillway elev. |

1:50 dry yr. Simulation
Present Use

| 1 | 2 Days in Month | 3 Potential Evap. (PET) mm | 4 Precip. mm | 5 Precip. Minus PET mm | 6 Cumulativ Soil Stress mm | 7 Soil Moisture mm | 8 Change in soil Storage mm | 9 Actual Evap mm | 10 Surplus moisture mm | 11 Runoff Depth mm | 12 Land Runoff dam3 | 13 Net Precip into lake dam3 | 14 NSSWD Demand dam3 | 15 Other Water Users dam3 | 16 Fisheries dam3 | 17 Irrigation dam3 | 18 Net Inflow dam3 | 19 Trial lake elev. m | 20 Lake Spill dam3 | 21 Storage Change dam3 | 22 Total storage dam3 | 23 Lake elev. (Month end) m | 24 Lake Outflow dam3 | 25 Lake Outflow m3/s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 292.2 | 48.6 | | | 0.0 | | | | | | | | End Sept = | 40.225 | | | 15089.9 | | | |
| Oct | 31 | 43.6 | 121.45 | 77.8 | | 126.4 | 77.8 | 43.7 | 0.0 | 0.0 | 0.0 | 142.7 | 19.64 | 8.95 | 23.40 | | 90.70 | | 0.0 | 90.70 | 15180.6 | 40.273 | 23.40 | 0.009 |
| Nov | 30 | 22.5 | 38.60 | 16.1 | | 142.50 | 16.1 | 22.5 | 0.0 | 0.0 | 0.1 | 29.6 | 19.15 | 8.71 | 23.40 | | -21.65 | | 0.0 | -21.65 | 15158.9 | 40.262 | 23.40 | 0.009 |
| Dec | 31 | 13.0 | 60.11 | 47.1 | | 189.60 | 47.1 | 13.0 | -0.0 | -0.0 | -0.0 | 86.4 | 18.78 | 8.71 | 23.40 | | 35.46 | | 0.0 | 35.46 | 15194.4 | 40.281 | 23.40 | 0.009 |
| Jan | 31 | 14.2 | 120.98 | 106.8 | | 200.0 | 10.4 | 14.2 | 96.4 | 77.1 | 414.0 | 195.8 | 18.57 | 9.04 | 23.40 | | 558.79 | | 0.0 | 558.79 | 15753.2 | 40.579 | 23.40 | 0.009 |
| Feb | 28 | 17.9 | 55.14 | 37.2 | | 200.0 | 0.0 | 17.9 | 37.2 | 45.2 | 242.5 | 68.2 | 20.15 | 9.13 | 23.40 | | 258.05 | 40.715 | 1.1 | 256.99 | 16010.2 | 40.716 | 24.45 | 0.010 |
| Mar | 31 | 32.7 | 47.43 | 14.7 | | 200.0 | 0.0 | 32.7 | 14.7 | 20.8 | 111.6 | 27.0 | 20.82 | 9.34 | 23.40 | | 85.03 | 40.735 | 48.4 | 36.66 | 16046.8 | 40.735 | 71.77 | 0.027 |
| Apr | 30 | 50.9 | 46.78 | -4.2 | 4.2 | 195.4 | -4.6 | 51.3 | 0.0 | 4.2 | 22.3 | -7.6 | 20.10 | 9.27 | 23.40 | | -38.08 | 40.697 | 33.7 | -71.75 | 15975.1 | 40.697 | 57.07 | 0.022 |
| May | 31 | 77.0 | 16.25 | -60.8 | 64.9 | 145.7 | -49.7 | 66.0 | 0.0 | 0.7 | 3.8 | -111.5 | 22.25 | 10.76 | 23.40 | 7.77 | -171.82 | | 0.0 | -171.82 | 15803.2 | 40.605 | 23.40 | 0.009 |
| Jun | 30 | 97.1 | 16.44 | -80.7 | 145.6 | 98.7 | -47.0 | 63.5 | 0.0 | 0.1 | 0.5 | -148.0 | 33.89 | 11.67 | 23.40 | 15.54 | -232.02 | | 0.0 | -232.02 | 15571.2 | 40.482 | 23.40 | 0.009 |
| Jul | 31 | 113.1 | 2.16 | -111.0 | 256.6 | 57.7 | -40.9 | 43.1 | 0.0 | 0.0 | 0.0 | -203.5 | 47.17 | 16.36 | 23.40 | 23.31 | -313.77 | | 0.0 | -313.77 | 15257.5 | 40.314 | 23.40 | 0.009 |
| Aug | 31 | 102.6 | 18.60 | -84.0 | 340.7 | 38.5 | -19.3 | 37.9 | 0.0 | 0.0 | 0.0 | -154.1 | 43.03 | 14.27 | 23.40 | 23.31 | -258.12 | | 0.0 | -258.12 | 14999.3 | 40.177 | 23.40 | 0.009 |
| Sep | 30 | 73.0 | 30.06 | -42.9 | 383.6 | 31.3 | -7.2 | 37.3 | -0.0 | -0.0 | -0.0 | -78.7 | 23.83 | 9.41 | 23.40 | 7.77 | -143.09 | | 0.0 | -143.09 | 14856.2 | 40.100 | 23.40 | 0.009 |
| | | 657.9 | 574.0 | | | | | 443.1 | 148.3 | 148.0 | 794.8 | -153.8 | 307.4 | 125.6 | 280.8 | 77.7 | -150.5 | | 83.1 | | | | 363.9 | |

Shading indicates different formula or manually entered (Caused by negative values in column 5)




**NOTES:**

1. Mean potential evaporation (76/77 to 95/96) used in column 3
2. 1995-96 water demand was assumed. Fisheries flow was included
3. 1:50 dry year precipitation was used in column 4
4. An average (79/80 to 95/96) carry over soil stress was used in column 6

APPENDIX F

50dryc.wk3

Feb 08,1998

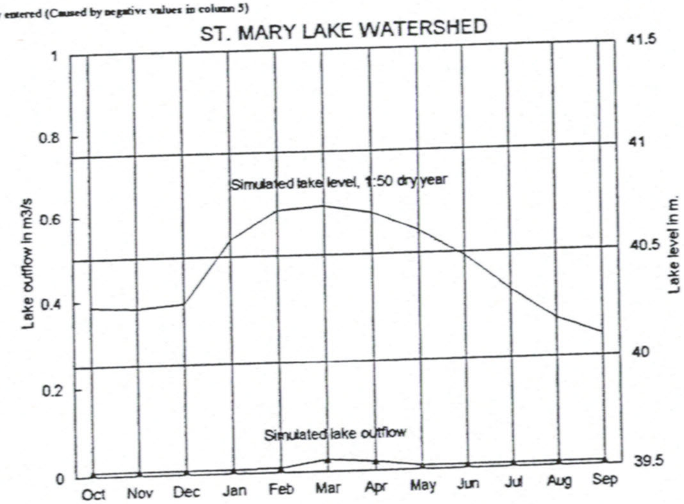
**St. MARY  E WATERSHED**
1:50 dry year precipitation

| 3.00 | = Spillway width, m. | 40.70 | = Spillw.  in metres |
|---|---|---|---|
| 124.05 | = Discharge coeff. | 15981 | = Total storage at spillway elev. |

1:50 dry yr. Simulation
Present Use

| 1 Month | 2 Days in Month | 3 Potential Evap. (PET) mm | 4 Precip. mm | 5 Precip. Minus PET mm | 6 Cumulativ Soil Stress mm | 7 Soil Moisture mm | 8 Change in soil Storage mm | 9 Actual Evap mm | 10 Surplus moisture mm | 11 Runoff Depth mm | 12 Land Runoff dam3 | 13 Net Precip into lake dam3 | 14 NSSWD Demand dam3 | 15 Other Water Users dam3 | 16 Fisheries dam3 | 17 Irrigation dam3 | 18 Net Inflow dam3 | 19 Trial lake elev. m | 20 Lake Spill dam3 | 21 Storage Change dam3 | 22 Total storage dam3 | 23 Lake elev. (Month end) m | 24 Lake Outflow dam3 | 25 Lake Outflow m3/s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 292.2 | 48.6 | | | 0.0 | | | | | | | | End Sept = | 40.225 | | | 15089.9 | | | |
| Oct | 31 | 43.6 | 121.45 | 77.8 | | 126.4 | 77.8 | 43.7 | 0.0 | 0.0 | 0.0 | 142.7 | 19.64 | 8.95 | 23.40 | | 90.70 | | 0.0 | 90.70 | 15180.6 | 40.273 | 23.40 | 0.009 |
| Nov | 30 | 22.5 | 38.60 | 16.1 | | 142.50 | 16.1 | 22.5 | 0.0 | 0.0 | 0.1 | 29.6 | 19.15 | 8.71 | 23.40 | | -21.65 | | 0.0 | -21.65 | 15158.9 | 40.262 | 23.40 | 0.009 |
| Dec | 31 | 13.0 | 60.11 | 47.1 | | 189.60 | 47.1 | 13.0 | -0.0 | -0.0 | -0.0 | 86.4 | 18.78 | 8.71 | 23.40 | | 35.46 | | 0.0 | 35.46 | 15194.4 | 40.281 | 23.40 | 0.009 |
| Jan | 31 | 14.2 | 120.98 | 106.8 | | 200.0 | 10.4 | 14.2 | 96.4 | 77.1 | 414.0 | 195.8 | 18.57 | 9.04 | 23.40 | | 558.79 | | 0.0 | 558.79 | 15753.2 | 40.579 | 23.40 | 0.009 |
| Feb | 28 | 17.9 | 55.14 | 37.2 | | 200.0 | 0.0 | 17.9 | 37.2 | 45.2 | 242.5 | 68.2 | 20.15 | 9.13 | 23.40 | | 258.05 | 40.715 | 1.1 | 256.99 | 16010.2 | 40.716 | 24.45 | 0.010 |
| Mar | 31 | 32.7 | 47.43 | 14.7 | | 200.0 | 0.0 | 32.7 | 14.7 | 20.8 | 111.6 | 27.0 | 20.82 | 9.34 | 23.40 | | 85.03 | 40.735 | 48.4 | 36.66 | 16046.8 | 40.735 | 71.77 | 0.027 |
| Apr | 30 | 50.9 | 46.78 | -4.2 | 4.2 | 195.4 | -4.6 | 51.3 | 0.0 | 4.2 | 22.3 | -7.6 | 20.10 | 9.27 | 23.40 | | -38.08 | 40.697 | 33.7 | -71.75 | 15975.1 | 40.697 | 57.07 | 0.022 |
| May | 31 | 77.0 | 16.25 | -60.8 | 64.9 | 145.7 | -49.7 | 66.0 | 0.0 | 0.7 | 3.8 | -111.5 | 22.25 | 10.76 | 23.40 | 7.77 | -171.82 | | 0.0 | -171.82 | 15803.2 | 40.605 | 23.40 | 0.009 |
| Jun | 30 | 97.1 | 16.44 | -80.7 | 145.6 | 98.7 | -47.0 | 63.5 | 0.0 | 0.1 | 0.5 | -148.0 | 33.89 | 11.67 | 23.40 | 15.54 | -232.02 | | 0.0 | -232.02 | 15571.2 | 40.482 | 23.40 | 0.009 |
| Jul | 31 | 113.1 | 2.16 | -111.0 | 256.6 | 57.7 | -40.9 | 43.1 | 0.0 | 0.0 | 0.0 | -203.5 | 47.17 | 16.36 | 23.40 | 23.31 | -313.77 | | 0.0 | -313.77 | 15257.5 | 40.314 | 23.40 | 0.009 |
| Aug | 31 | 102.6 | 18.60 | -84.0 | 340.7 | 38.5 | -19.3 | 37.9 | 0.0 | 0.0 | 0.0 | -154.1 | 43.03 | 14.27 | 23.40 | 23.31 | -258.12 | | 0.0 | -258.12 | 14999.3 | 40.177 | 23.40 | 0.009 |
| Sep | 30 | 73.0 | 30.06 | -42.9 | 383.6 | 31.3 | -7.2 | 37.3 | -0.0 | -0.0 | -0.0 | -78.7 | 23.83 | 9.41 | 23.40 | 7.77 | -143.09 | | 0.0 | -143.09 | 14856.2 | 40.100 | 23.40 | 0.009 |
| | | 657.9 | 574.0 | | | | | 443.1 | 148.3 | 148.0 | 794.8 | -153.8 | 307.4 | 125.6 | 280.8 | 77.7 | -150.5 | | 83.1 | | | | 363.9 | |

Shading indicates different formula or manually entered (Caused by negative values in column 5)




**NOTES:**

1. Mean potential evaporation (76/77 to 95/96) used in column 3
2. 1995-96 water demand was assumed. Fisheries flow was included
3. 1:50 dry year precipitation was used in column 4
4. An average (79/80 to 95/96) carry over soil stress was used in column 6

APPENDIX F

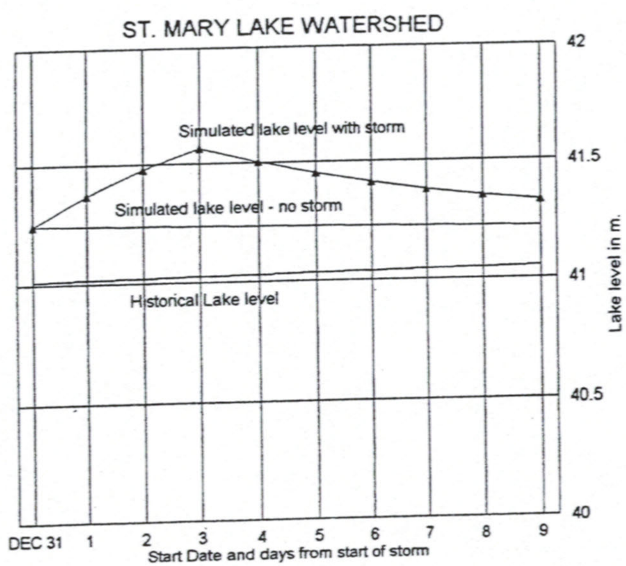
50dryc.wk3
Feb 08,1998

## ST. MARY LAKE WATERSHED
**1:50 year storm**

Start date = DEC 31 ,1990
Storm duration 3 Day
Return period = 1:50

3.00 = Spillway width in m.
124.05 = Discharge coeff.
41.00 = Spillway elev. in metres
16543.80 = Total storage at spillway elev.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after start of rain | Potential Evap. | Rain | Net Precip into lake | Land Runoff | NSSWD Demand | Other Water Users | Fisheries | Net Inflow | Trial lake elev. | Lake outflow | Storage Change | Total storage | Lake elev. with storm | Lake elev. (Historical) | Lake elev. no storm |
| | | mm | mm | dam3 | dam3 | dam3 | dam3 | dam3 | dam3 | m | dam3 | dam3 | dam3 | m | m | m |
| Start | DEC 31 | | | | | | | | | 41.241 | | | 16995.93 | 41.241 | 41.010 | 41.241 |
| | 1 | 0.45 | 42.67 | 77.4 | 226.7 | 0.5 | 0.26 | 0.75 | 302.60 | 41.368 | 63.6 | 239.05 | 17234.98 | 41.368 | 41.014 | 41.238 |
| | 2 | 0.45 | 42.67 | 77.4 | 226.7 | 0.5 | 0.26 | 0.75 | 302.60 | 41.475 | 102.5 | 200.15 | 17435.12 | 41.475 | 41.019 | 41.236 |
| | 3 | 0.45 | 42.67 | 77.4 | 226.7 | 0.5 | 0.26 | 0.75 | 302.60 | 41.562 | 139.3 | 163.29 | 17598.41 | 41.562 | 41.023 | 41.233 |
| | 4 | | | | | | | | 28.74 | 41.501 | 144.4 | -115.64 | 17482.77 | 41.501 | 41.028 | 41.230 |
| | 5 | | | | | | | | 28.74 | 41.451 | 122.3 | -93.60 | 17389.17 | 41.451 | 41.032 | 41.227 |
| | 6 | | | | | | | | 28.74 | 41.410 | 105.2 | -76.47 | 17312.70 | 41.410 | 41.036 | 41.225 |
| | 7 | | | | | | | | 28.74 | 41.376 | 91.8 | -63.01 | 17249.68 | 41.376 | 41.041 | 41.222 |
| | 8 | | | | | | | | 28.74 | 41.348 | 81.1 | -52.36 | 17197.32 | 41.348 | 41.045 | 41.219 |
| | 9 | | | | | | | | 28.74 | 41.325 | 72.7 | -43.94 | 17153.39 | 41.325 | 41.050 | 41.217 |
| | | | 128.0 | 232.3 | 680.0 | | | | | | | | | | | |




storm1c.wk3

Feb 08, 1998

APPENDIX G

# ST. MARY LAKE
# HYDROLOGY OF FLOODS

Prepared for:

**NORTH SALT SPRING WATERWORKS DISTRICT**
761 Upper Ganges Road, Salt Spring Island, B.C., V8K 1S1

By:


**Roy Hamilton, M.A.Sc., P. Eng.**
1138 Handsworth Road
North Vancouver, B.C. V7R 2A8


April, 1999

# ST. MARY LAKE
# HYDROLOGY OF FLOODS

## 1. PURPOSE

The purpose of this study is to determine the effect of precipitation extremes on the water levels of St. Mary Lake. This report supplements my 1998 report: "Hydrology of St. Mary Lake ".

## 2. TERMS OF REFERENCE

**A.** Meteorological data will be analyzed to determine the maximum precipitation likely to occur for return periods of 100 and 200 years. The Probable Maximum Precipitation will also be estimated.

**B.** Water budgets (similar to Appendix G of my February report) will be prepared for the 100 year and 200 year return periods and also for the Probable Maximum Precipitation. The estimated maximum lake levels will be tabulated for spillway widths of 3m, 4.5m, 6m, and 10m. A comparison will be made with the 50 year storm scenario presented in my February, 1998 report on St Mary Lake.

NOTES:

1. The spillway of the proposed dam will be assumed to be at elevation 40.7 m.

1. Existing data available from the district and from government agencies will be used.

2. Information from my February,1998 report "Hydrology of St. Mary Lake" will be utilized.

## 3. RESULTS

### 3.1 Maximum precipitation

The estimated maximum three day precipitation amounts for the St. Mary Lake area are as follows ( see Table A):

131 mm. for a 1:50 yr. return period
143 mm. for a 1:100 yr return period
154 mm. for a 1:200 yr. return period
406 mm. for the Probable Maximum Precipitation

The three day duration was used because it was found to be the most critical. See Section 6.3 of my February 1998 report, "Hydrology of St. Mary Lake".

The three day precipitation for the 1:50 yr. return period of 131mm. obtained in this analysis is only slightly greater than the value of 128 mm. used in my 1998 report.

### 3.2 Maximum water levels

The estimated maximum water levels in St. Mary Lake resulting from 3 day extreme storms were obtained by water budget calculations. Maximum water levels for various spillway widths and return periods are given in Table B.

## 4. METEOROLOGICAL DATA AND ANALYSIS

### 4.1 Frequency analysis

Frequency analyses were done for two meteorological stations using annual maximum three day precipitation data. Fifty-seven years of Victoria International Airport data and 89 years of Victoria Gonzales Heights data were used. I applied the Gumbel Extreme Value Distribution, Type 1 to both sets of data. The results are shown in Table A.

Figures 1 and 2 show the result of my analyses. The data points for the three day maximum annual precipitation are shown as x's. The solid line was fitted using the Gumbel Distribution. Although the line fits the data quite well it should be noted that there are only a few data points between the 10 year return period and the 100 year return period, and these are the points that govern the position of the upper end of the line which is used to estimate the 50, 100, and 200 year return periods.

Estimates for the 50 return period, 100 year return period and the P.M.P. (Probable Maximum Precipitation) were also obtained from analyses made by the Atmospheric Environment Branch of Environment Canada (A.E.B.) using 58 years of Victoria Airport data and 89 years of Gonzales Heights data. These values are also shown in Table A.

Three day precipitation data for the years 1941 to 1987 was available from both stations. This concurrent data was correlated to provide an estimate of the relationship between the two stations. The analysis gave the following ratios of the maximum 3 day precipitation at Victoria Airport to the maximum 3 day precipitation at Gonzales Heights:

0.946 for the 50 year return period
0.930 for the 100 year return period
0.916 for the 200 year return period

I applied these factors to the 89 year Gonzales Heights Gumbel values in Table A to obtain an estimate for the St Mary Lake area. The values obtained in this way are a little higher than the Victoria Airport values in Table A, but I elected to use them as they are based on more years of record.

### 4.2 Probable maximum precipitation

The "Probable Maximum Precipitation" represents the upper limit of possible precipitation obtained by a theoretical maximization of all relevant meteorological factors. It is considered as a possible but highly unlikely event. The three day P.M.P. was estimated by the Atmospheric Environment Branch using statistical equations (involving the mean and standard deviation of the annual extreme events). These estimates of the P.M.P. are considered to be only very approximate.

Table A shows the values for both Victoria Airport and Gonzales Heights. I have chosen the Victoria Airport value of 406 mm for this analysis because the airport is closer to the St Mary Lake area and should be more representative.

## 5. WATER BUDGET CALCULATIONS

Water budgets were prepared for the 50 yr., 100yr., 200yr., and P.M.P. events for each of the spillway widths of 3 m., 4.5 m., 6 m., and 10 m. The results are shown in Table B.

The storm events were assumed to take place in winter when the lake level would be at an average peak level. This peak level was obtained by averaging the actual historical end of month lake levels for the peak month for the recent 7 year period, 1990 to 1996. The average turned out to be very close to the lake level at the end of December 1990; therefore, this date was used as the starting point for all cases. The water level that would have occurred on Dec. 31, 1990 if a dam had already been in place was estimated for each alternative spillway width and used as the starting water level in the budget calculation.

Table C is a sample water budget for the case of a 4.5 metre spillway width and a 200 year return period. The various water demands over the three day period are allowed for but their effect on the budget is very minor. The graph shows the simulated lake level if the new dam had been in place: for both cases of no storm and the 3 day storm event. The historical lake level for the first few days of January 1991 is also shown for comparison.

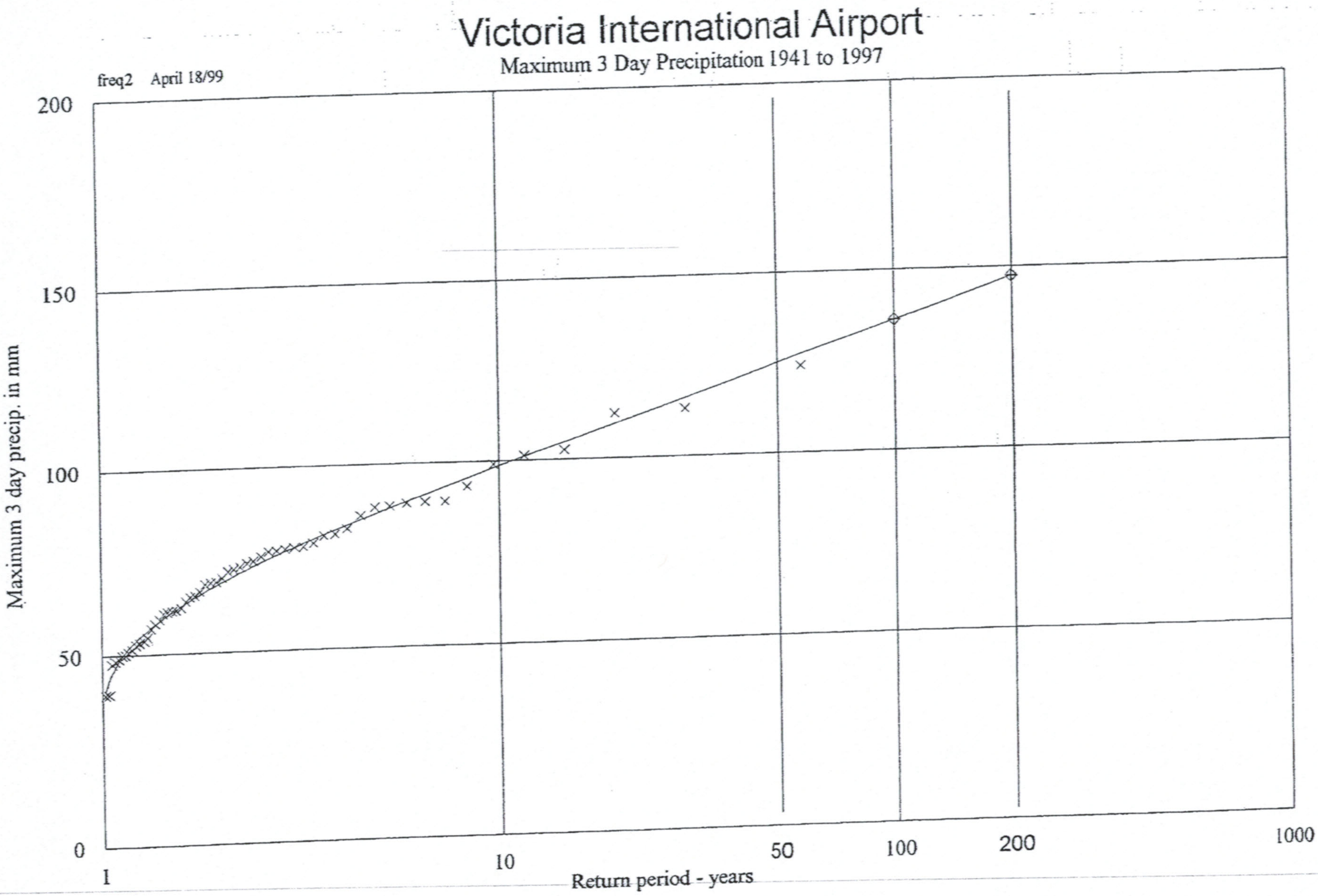
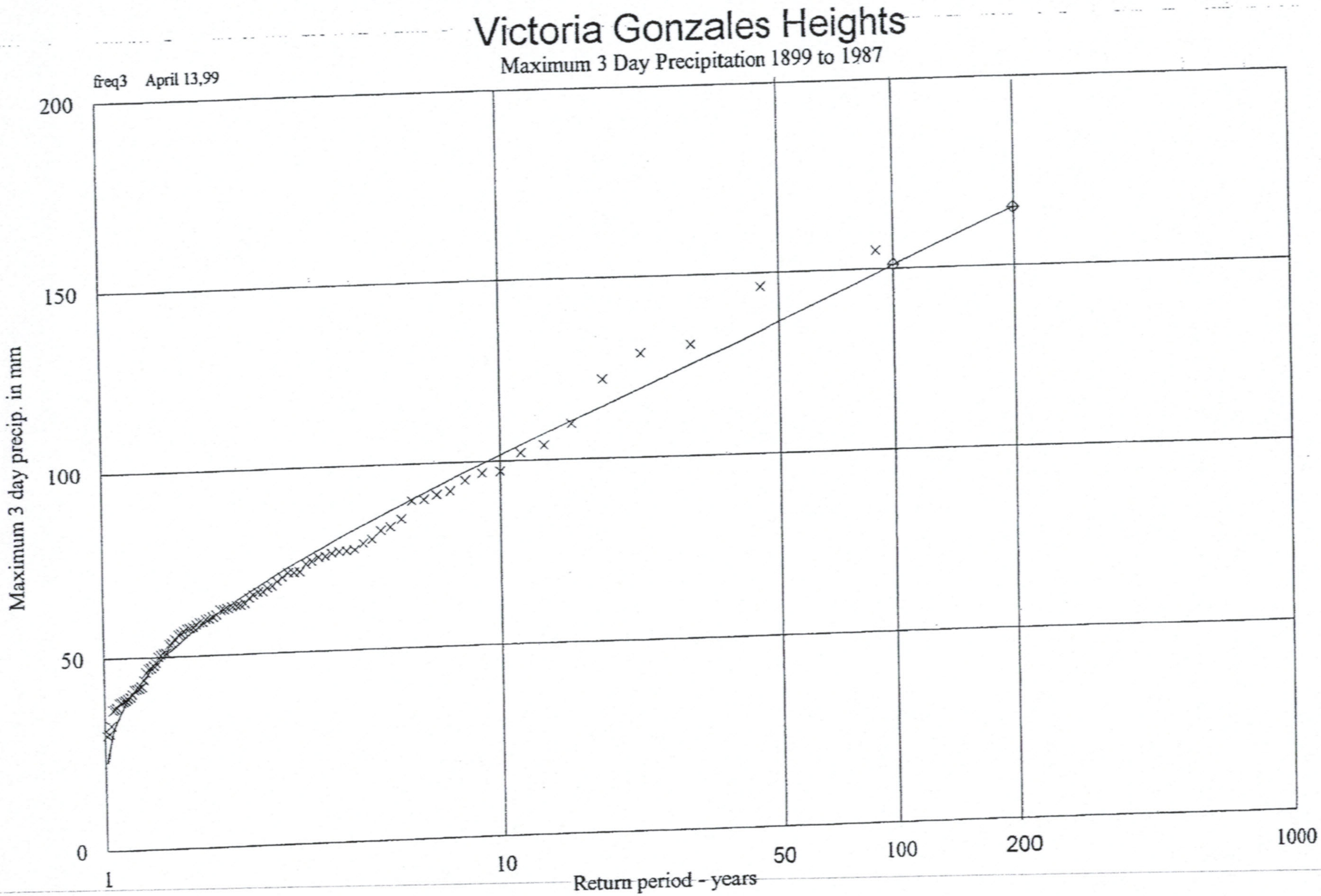

Victoria International Airport
Maximum 3 Day Precipitation 1941 to 1997
freq2 April 18/99
Maximum 3 day precip. in mm
200
150
100
50
0
1
10
50
100
200
1000
Return period - years

FIGURE 1



Victoria Gonzales Heights
Maximum 3 Day Precipitation 1899 to 1987
freq3 April 13,99
200
150
100
50
0
Maximum 3 day precip. in mm
1
10
50
100
200
1000
Return period - years

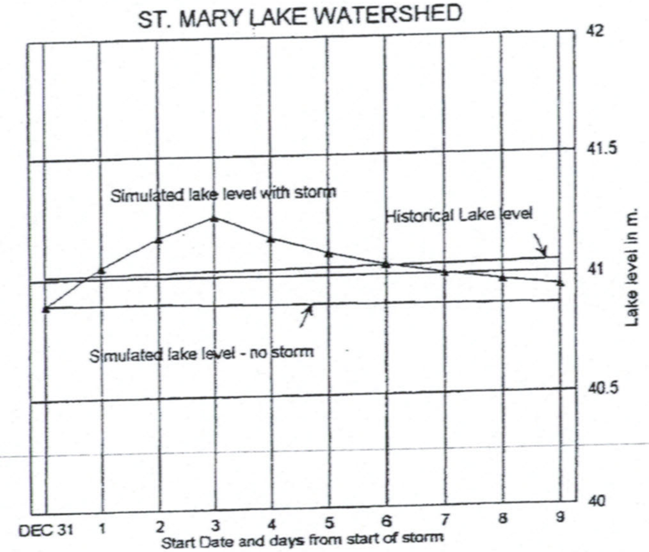

FIGURE 2

## ST. MARY LAKE WATERSHED
### 1:200 year storm

Start date = DEC 31 ,1990
Storm duration 3 Day

| | |
|---|---|
| 4.50 | = Spillway width in m. |
| 124.05 | = Discharge coeff. |
| 40.70 | = Spillway elev. in metres |
| 15980.98 | = Total storage at spillway elev. |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after start of precip. | Potential Evap. mm | Precip mm | Net Precip into lake dam3 | Land Runoff dam3 | NSSWD Demand dam3 | Other Water Users dam3 | Fisheries dam3 | Net Inflow dam3 | Trial lake elev. m | Lake outflow dam3 | Storage Change dam3 | Total storage dam3 | Lake elev. with storm m | Lake elev. (Historical) m | Lake elev. no storm m |
| Start | DEC 31 | | | | | | | | | 40.894 | | | 16344.94 | 40.894 | 41.010 | 40.894 |
| | 1 | 0.45 | 51.33 | 93.3 | 273.2 | 0.5 | 0.26 | 0.75 | 365.00 | 41.046 | 80.7 | 284.34 | 16629.28 | 41.046 | 41.014 | 40.891 |
| | 2 | 0.45 | 51.33 | 93.3 | 273.2 | 0.5 | 0.26 | 0.75 | 365.00 | 41.163 | 144.7 | 220.26 | 16849.54 | 41.163 | 41.019 | 40.889 |
| | 3 | 0.45 | 51.33 | 93.3 | 273.2 | 0.5 | 0.26 | 0.75 | 365.00 | 41.250 | 201.8 | 163.22 | 17012.76 | 41.250 | 41.023 | 40.886 |
| | 4 | | | | | | | | 28.74 | 41.158 | 200.4 | -171.62 | 16841.14 | 41.158 | 41.028 | 40.883 |
| | 5 | | | | | | | | 28.74 | 41.091 | 154.8 | -126.01 | 16715.13 | 41.091 | 41.032 | 40.880 |
| | 6 | | | | | | | | 28.74 | 41.041 | 123.8 | -95.08 | 16620.05 | 41.041 | 41.036 | 40.878 |
| | 7 | | | | | | | | 28.74 | 41.002 | 101.9 | -73.16 | 16546.89 | 41.002 | 41.041 | 40.875 |
| | 8 | | | | | | | | 28.74 | 40.971 | 85.7 | -56.96 | 16489.93 | 40.971 | 41.045 | 40.872 |
| | 9 | | | | | | | | 28.74 | 40.947 | 73.6 | -44.90 | 16445.03 | 40.947 | 41.050 | 40.870 |
| | Totals | | 154.0 | 280.0 | 819.6 | | | | | | | | | | | |




s200c.wk3
April 19, 1999

**TABLE C**