Analysis of Trends in Evaporation – Phase 1

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Executive Summary

Trend analyses of evaporation data were conducted for three time periods dating from 1971 to 2000, 1961 to 2000 and 1951 to 2000. Significant trends were identified using the Mann-Kendall statistical test for trend and bootstrapping resampling. Different time periods provided unique results, but the June, July, October and annual evaporation produced significant decreasing trends in the 30, 40 and 50-year period. The longer record length for the 50-year period identified an increasing trend in April. The only other significant increasing trend occurred for the 30-year period in September. The September results progressed into a significant decreasing trend as the record length increased.

Mapping the location of significant monthly trends indicated that increasing trends were typically situated in the more northern regions and decreasing trends in the more southern regions. Temporal patterns were apparent at multiple stations for the three record lengths used. The 40-year period showed the highest percentage of decreasing trends, but quite a few of these became an insignificant trend in the 50-year period. In several cases, stations that possessed no trend in the 40-year period became significant increasing trends in the 50-year period; most of these were in April.

Trend slopes were generally negative with a seasonal tendency of decreasing median values from April to July and increasing values from July to September. In the 40-year period, the months of May, June, July, August and October have 75th percentile of trend slopes that are negative. In the 50-year period the values of the 75th percentiles are increased to equal to, or greater than, their values in the 30-year period.

Comparisons made between gross evaporation trends and pan evaporation trends revealed many similar results, but most of these indicated no trend for either. Four cases show matching significant trends, all of which are decreasing. Two cases show opposing significant trends with increasing pan evaporation trends and decreasing gross evaporation trends. Despite the opposing trends, plots of pan and gross evaporation show similar timing of maximum and minimum values.

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1.0 Introduction

1.1 Estimation of Evaporation

Evaporation is the process by which water leaves the earth's surface in its gaseous form and enters the atmosphere. Evaporation is an important component of the hydrological cycle and affects the balance of water on the earth's surface. Higher evaporation rates result in more arid environments, while lower rates create more humid conditions. Concerns have been raised regarding the impact global warming may have on evaporation. The identification of possible trends, due to recent warming, will indicate possible future conditions of the environment. In order to examine evaporation trends on the Canadian Prairies, gross evaporation was estimated by means of the Meyer formula and pan evaporation data were obtained from standard Class A evaporation pans. According to Martin (2002), the Meyer Formula has been employed since the 1960s to estimate gross evaporation on the Canadian Prairies. Modifications of relationships used by the formula were made in the 1980s to improve the accuracy of estimations specifically for conditions on the Canadian Prairies. Variables required for estimating monthly gross evaporation are monthly values of dew point temperature (or relative humidity), wind speed, and air temperature. In addition, station parameters of site elevation (above sea level), anemometer height and spatial designation (i.e., north or south) are also required. Assumptions made include arbitrarily setting gross monthly evaporation to zero if the mean monthly temperature of the surface water is less than 0°C.

1.2 Climate Change and Potential Impact on the Hydrological Cycle

Increased concentrations of greenhouse gases released into the atmosphere are impacting the environment. It has been reported by Douville et al. (2001) that the mean average global temperature has increased 0.6°C over the twentieth century, and is predicted by Loaiciga et al. (1995) to increase by 1 to 5°C by the middle of the twenty-first century when using 1990 as the basis for comparison. In the Canadian Prairies specifically, Bootsma et al. (1995a, 1995b) identified recent warming trends in Brandon, Manitoba and Indian Head, Saskatchewan.

Trends for the timing and magnitude of hydrological events taking place in the Canadian Prairies have also been discovered. Burn (1994) and Westmacott and Burn (1997) presented evidence of earlier spring run-off, decreasing mean annual streamflow and decreasing extreme annual streamflow. In addition, Bootsma et al. (1995a, 1995b) reported the increased duration of the growing season due to later first frost days and earlier last frost days.

Globally, Loaiciga et al. (1995), Trenberth (1998) and Douville et al. (2001) predict an intensified hydrological cycle in response to increasing temperatures. An expected result of the intensification is an increase in evaporation rates, leading to more arid environments. Studies of evaporation trends from many regions have been conducted and the conclusions vary. Increasing pan evaporation trends have been documented in Bet Dagan, Israel by Cohen et al. (2002), and in Phoenix, Arizona and northeast Brazil by da Silva (2003). However, decreasing trends in pan evaporation were reported by Roderick and Farquhar (2004) in Australia, Peterson et al. (1995) in the United States, the former Soviet Union, Europe and Siberia, and by Chattopadhyay and Hulme (1996) in India. Reports for decreased potential evaporation are limited but have been produced by Cohen et al. (2002), while increasing trends have been reported by Shahgedanova (1997) in Oxford, England and Douville et al. (2001) in Sudan-Suhel and Northern Hemisphere mid-latitudes for summer months. Increasing potential evaporation trends have also been associated with increasing atmospheric moisture over the United States, Carribean, and Hawaii (Trenberth, 1998). Additionally, it is interesting to note that decreases in potential evapotranspiration have been discovered by Chattopadhyay and Hulme (1996) in India, and for Italy and several locations in Canada by Moonen et al. (2002).

The control mechanisms causing these trends are not clearly understood and several hypotheses exist. Although the increases in temperatures are generally agreed upon, there are many factors that can have an increasing or decreasing effect on evaporation. Palle and Butler (2001) have reported reduced sunshine and increased cloudiness in Ireland. It is believed by Roderick and Farquhar (2002) and Loaiciga et al. (1995) that increased cloudiness is causing less solar irradiance resulting in a decreasing evaporation trend. Speculations from Trenberth (1998), based on climate models, conclude that only the magnitude of increasing evaporation trends would decline due to increased cloudiness. Evidence of decreasing trends for pan evaporation is more plentiful than that of potential evaporation. As a result, questions pertaining to the relationship between pan evaporation and gross evaporation have arisen. Brutsaert and Parlange (1998) present a theory of an inverse relationship between the two. Due to increasing actual evaporation, Roderick and Farquhar (2002) examine the possibility of a cooler, more humid climate over the evaporation pan, reducing the evaporation measured. In the study by Cohen et al. (2002) an explanation was provided to support decreasing potential evaporation while observing increasing pan evaporation trends.

The purpose of this study is to identify and quantify any significant evaporation trends in the Canadian Prairies. Gross evaporation trends are examined for three time periods; 1951 to 2000, 1961 to 2000 and 1971 to 2000. For several stations, a comparison is made between trends in estimated gross evaporation and trends in pan evaporation observations. Martin (2002) acknowledges that the identification of evaporation trends will provide insight into the future water balance on the prairies and allow for appropriate water resources management.

2.0 Methodology

The methodology involved the selection of stations for trend analysis, the application of a trend test at individual stations, the determination of the global, or field, significance of the trend results at the set of stations and spatial and temporal analysis of the trend results. Each of these components of the methodology is explained in further detail below.

2.1 Station Selection

A total of 55 meteorological sites located throughout the Canadian Prairies were available for this study. The record lengths and quality of data collected vary for the different stations. Based on the required 30, 40 and 50-year analysis periods examined, locations were selected based on the availability of data for the desired time frame. Sites that had a record length that was slightly shorter than the requirement were still considered provided that there were no more than four years of missing data. Sites in this category include Nipawin and Slave Lake for the 30 year period, Jasper and Wynyard for the 40 year period, and Cold Lake, Coronation, Fort McMurray, Moose Jaw, Yorkton, and Portage La Prairie for the 50 year period. Despite this allowance, some locations were still eliminated based on insufficient data. From the 55 stations available 48, 36, and 30 locations were utilized for the 30, 40 and 50-year analysis periods, respectively.

Stations with acceptable record lengths were further explored to classify the integrity of the data. These classifications were based on the number of estimations made to compensate for missing input information, the distance from which the estimations were made, and the type of data estimated. Also taken into consideration was the replacement of stations, thereby altering the location and possibly leading to the identification of a trend that does not exist. All sites with multiple station locations were subjected to a t-test to statistically analyze if a change in mean took place at the time of change in location. In the event that the t-test displayed a significant change, locations within a close proximity were also examined. If adjacent sites possessed the same discrepancy, the site with multiple station locations was still considered reliable. After performing these verifications, it was found that only Buffalo Narrows had potentially compromised data as a result of numerous station locations. These steps to establish the reliability of the data ensured that identified trends were valid trends.

2.2 Trend Test

The statistical trend test selected was the Mann-Kendall non-parametric test for trend (Mann, 1945; Kendall, 1975). This trend test has been used by other researchers in similar applications (Hirsch et al., 1982; Gan and Kwong, 1992) and has been found to be an effective tool for identifying trends in hydrological and other related variables. The test statistic for the Mann-Kendall test is given as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \qquad (1)$$

where the x_j are the sequential data values, n is the length of the data set, and sgn(θ) is the sign function defined as

$$\operatorname{sgn}(\theta) = \begin{cases} 1 & \text{if } \theta > 0 \\ 0 & \text{if } \theta = 0 \\ -1 & \text{if } \theta < 0 \end{cases} \qquad (2)$$

where θ is the argument of the sign function.

The theoretical mean and variance of the test statistic, under the null hypothesis of no trend in the series, are given as

$$E[S] = 0 \qquad (3)$$

and

$$\operatorname{Var}[S] = \frac{n(n-1)(2n+5) - \sum t(t-1)(2t+5)}{18} \qquad (4)$$

where t is the extent of any tie (i.e., the number of data points involved in a tie) and the summation is over all ties. For sample sizes larger than ten, the statistic is very nearly Normally distributed if a continuity correction is applied giving

$$S' = S - \operatorname{sgn}(S) \qquad (5)$$

where S' is the corrected test statistic value. A Z value associated with the trend statistic can be calculated, assuming the corrected test statistic follows the Normal distribution, as follows

$$Z = \frac{S'}{\sqrt{Var[S]}} \tag{6}$$

where Z is a standard normal variate. The magnitude of the Z value obtained can then be used to determine the significance of any trend in the data set. This significance value is referred to as the local significance level.

It is also possible to obtain a non-parametric estimate for the magnitude of the slope following Hirsch et al. (1982)

$$\beta = \text{Median}\left\{\frac{x_j - x_k}{j-k}\right\} \qquad \text{for all } \; k < j \tag{7}$$

where β is a robust estimate of the slope.

2.3 Field Significance

Global, or field, significance allows the determination of the percentage of tests that are expected to show a trend, at a given local (nominal) significance level, purely by chance. Douglas et al. (2000) adopted an approach for determining the field significance that involves calculating a regional value for the Mann-Kendall statistic.

A bootstrap, or resampling, approach was used herein to determine the critical value for the percentage of sites expected to show a trend by chance. Based on this critical value, it is possible to determine whether the observed number of trends exceeds what is expected to occur by chance. Any temporal structure (i.e., a trend or pattern) that exists in the original data set will not be reproduced in the resampled data sets because of the nature of the resampling process, which selects the years to be included at random. However, the cross-correlations in the original data sets are preserved through including all data values for a given year in the resampled data set. This allows the impact of cross-correlation to be determined in establishing the critical value for the percentage of stations exhibiting a trend. A more detailed description of the regional bootstrap resampling technique can be found in Burn and Hag Elnur (2002).

2.4 Spatial and Temporal Analysis

Spatial patterns in the trends results can be examined by plotting the trend results using a geographic information system (GIS). This facilitates the identification of geographic regions that have an unusually large or small number of trends. Temporal patterns in the evaporation values can be examined using techniques from exploratory data analysis. One of the intents with exploratory data analysis is to ascertain the overall pattern, or tendency, of a data set, which is often difficult to visualize as a result of the natural variability in the data set. A smoothing technique, referred to as LOWESS (Cleveland, 1979), is used to examine the behaviour of evaporation over time. The resulting time series plots are used to determine the overall tendency of the evaporation series at a given location.

3.0 Results

3.1 Stations and Time Periods Examined

The 30-year period makes use of 48 meteorological stations. The names and locations of these sites are provided in Table 1.

Table 1: Sites selected for the 30-year analysis period

Location	Province	Latitude	Longitude	Available Years of Record
Brandon	MB	49.92	99.95	30
Broadview	SK	50.37	102.57	30
Buffalo Narrows	SK	55.19	108.42	30
Calgary	AB	51.10	114.02	30
Churchill	MB	58.73	94.05	30
Cold Lake	AB	54.42	110.27	30
Coronation	AB	52.07	111.45	30
Dauphin	MB	51.10	100.05	30
Edmonton Intl	AB	53.32	113.57	30
Edmonton Municipal	AB	53.57	113.52	30
Edson	AB	53.57	116.47	30
Estevan	SK	49.22	102.97	30
Flin Flon	MB	54.67	101.67	30
Fort McMurray	AB	56.65	111.22	30
Fort Nelson	BC	58.83	122.60	30
Fort St. John	BC	56.23	120.73	30
Gillam	MB	56.35	94.70	30
Gimli	MB	50.62	97.02	30
Grande Prairie	AB	55.17	118.88	30
High Level	AB	58.62	117.15	30
Island Lake	MB	53.85	94.65	30
Jasper	AB	52.87	118.07	30
Kindersley	SK	51.52	109.17	30
La Ronge	SK	55.15	105.27	30
Lethbridge	AB	49.62	112.80	30
Lynn Lake	MB	56.85	101.07	30
Meadow Lake	SK	54.12	108.52	30
Medicine Hat	AB	50.02	110.72	30
Moose Jaw	SK	50.32	105.55	30
Nipawin	SK	53.32	104.00	27
North Battleford	SK	52.77	108.25	30
Norway House	MB	53.95	97.85	30
Peace River	AB	56.22	117.45	30
Pincher Creek	AB	49.50	114.00	30
Portage La Prairie	MB	49.90	98.27	30

Table 1 (continued): Sites selected for the 30-year analysis period

Location	Province	Latitude	Longitude	Available Years of Record
Prince Albert	SK	53.22	105.67	30
Red Deer	AB	52.17	113.88	30
Regina	SK	50.42	104.67	30
Rocky Mtn House	AB	52.43	114.92	30
Saskatoon	SK	52.17	106.72	30
Slave Lake	AB	55.30	114.77	29
Swift Current	SK	50.30	107.67	30
The Pas	MB	53.97	101.10	30
Thompson	MB	55.80	97.87	30
Whitecourt	AB	54.13	115.78	30
Winnipeg	MB	49.92	97.22	30
Wynyard	SK	51.77	104.20	30
Yorkton	SK	51.27	102.47	30

The stations in Table 1 provide a good representation of the various regions and environments in the Canadian Prairies. The 30-year period examined is from 1971 to 2000. Records were discontinued prior to 2000 for Cree Lake, Dafoe, Pilot Mound, Vermillion, and Wagner. Data for Key Lake and Lloydminster existed until 2000, but did not date back to 1971. As a result, these stations were excluded from this study.

The second time interval examined was 40 years in length from 1961 to 2000. This time frame utilizes the 36 meteorological stations listed in Table 2. In addition to the sites omitted from the 30-year period, further stations were eliminated as the required record length increased. Buffalo Narrows, Flin Flon, Gillam, High Level, Island Lake, La Ronge, Lynn Lake, Meadow Lake, Norway House, Pilot Mound, Slave Lake and Thompson all have insufficient data for the period back to 1961. These 12 sites are concentrated mostly in the northern regions, with seven located in northern Manitoba. As a result, the spatial representation of the 40-year period is more limited to southern areas when compared to the distribution of sites for the 30-year period.

Among the 55 stations from which data were collected, over half were sufficient in length to allow a 50-year study period. These locations are presented in Table 3. The 50-year period studied dates from 1951 to 2000. Only six stations were unsuccessful in making the transition from the 40-year period to the 50-year period. These sites include Edmonton Intl, Edson, Jasper, Kindersley, Pincher Creek and Wynyard. As a result of so few stations being eliminated, the spatial representation of the 50-year period is comparable to that of the 40-year period.

Table 2: Sites selected for the 40-year analysis period

Location	Province	Latitude	Longitude	Available Years of Record
Brandon	MB	49.92	99.95	40
Broadview	SK	50.37	102.57	40
Calgary	AB	51.10	114.02	40
Churchill	MB	58.73	94.05	40
Cold Lake	AB	54.42	110.27	40
Coronation	AB	52.07	111.45	40
Dauphin	MB	51.10	100.05	40
Edmonton Intl	AB	53.32	113.57	40
Edmonton Municipal	AB	53.57	113.52	40
Edson	AB	53.57	116.47	40
Estevan	SK	49.22	102.97	40
Fort McMurray	AB	56.65	111.22	40
Fort Nelson	BC	58.83	122.60	40
Fort St. John	BC	56.23	120.73	40
Gimli	MB	50.62	97.02	40
Grande Prairie	AB	55.17	118.88	40
Jasper	AB	52.87	118.07	39
Kindersley	SK	51.52	109.17	40
Lethbridge	AB	49.62	112.80	40
Medicine Hat	AB	50.02	110.72	40
Moose Jaw	SK	50.32	105.55	40
North Battleford	SK	52.77	108.25	40
Peace River	AB	56.22	117.45	40
Pincher Creek	AB	49.50	114.00	40
Portage La Prairie	MB	49.90	98.27	40
Prince Albert	SK	53.22	105.67	40
Red Deer	AB	52.17	113.88	40
Regina	SK	50.42	104.67	40
Rocky Mtn House	AB	52.43	114.92	40
Saskatoon	SK	52.17	106.72	40
Swift Current	SK	50.30	107.67	40
The Pas	MB	53.97	101.10	40
Whitecourt	AB	54.13	115.78	40
Winnipeg	MB	49.92	97.22	40
Wynyard	SK	51.77	104.20	36
Yorkton	SK	51.27	102.47	40

Table 3: Sites selected for the 50-year analysis period

Location	Province	Latitude	Longitude	Available Years of Record
Brandon	MB	49.92	99.95	50
Broadview	SK	50.37	102.57	50
Calgary	AB	51.10	114.02	50
Churchill	MB	58.73	94.05	50
Cold Lake	AB	54.42	110.27	46
Coronation	AB	52.07	111.45	48
Dauphin	MB	51.10	100.05	50
Edmonton Municipal	AB	53.57	113.52	50
Estevan	SK	49.22	102.97	50
Fort McMurray	AB	56.65	111.22	48
Fort Nelson	BC	58.83	122.60	50
Fort St. John	BC	56.23	120.73	50
Gimli	MB	50.62	97.02	50
Grande Prairie	AB	55.17	118.88	50
Lethbridge	AB	49.62	112.80	50
Medicine Hat	AB	50.02	110.72	50
Moose Jaw	SK	50.32	105.55	48
North Battleford	SK	52.77	108.25	50
Peace River	AB	56.22	117.45	50
Portage La Prairie	MB	49.90	98.27	48
Prince Albert	SK	53.22	105.67	50
Red Deer	AB	52.17	113.88	50
Regina	SK	50.42	104.67	50
Rocky Mtn House	AB	52.43	114.92	50
Saskatoon	SK	52.17	106.72	50
Swift Current	SK	50.30	107.67	50
The Pas	MB	53.97	101.10	50
Whitecourt	AB	54.13	115.78	50
Winnipeg	MB	49.92	97.22	50
Yorkton	SK	51.27	102.47	48

The location of stations selected for each time period studied can be viewed in Figure 1. Stations marked by squares are used only for the 30-year period, stations with circles are used in the 30 and 40-year analyses, and those with diamonds are used in the 30, 40 and 50-year study. Figure 1 illustrates the northern stations used only in the 30-year period, most of which are in Manitoba and Saskatchewan. Stations used for the 40-year period but not the 50-year period are concentrated toward the west, four out of the six sites are situated in Alberta. The spatial distribution of stations shown in Figure 1 was the best distribution possible based on the availability of data.

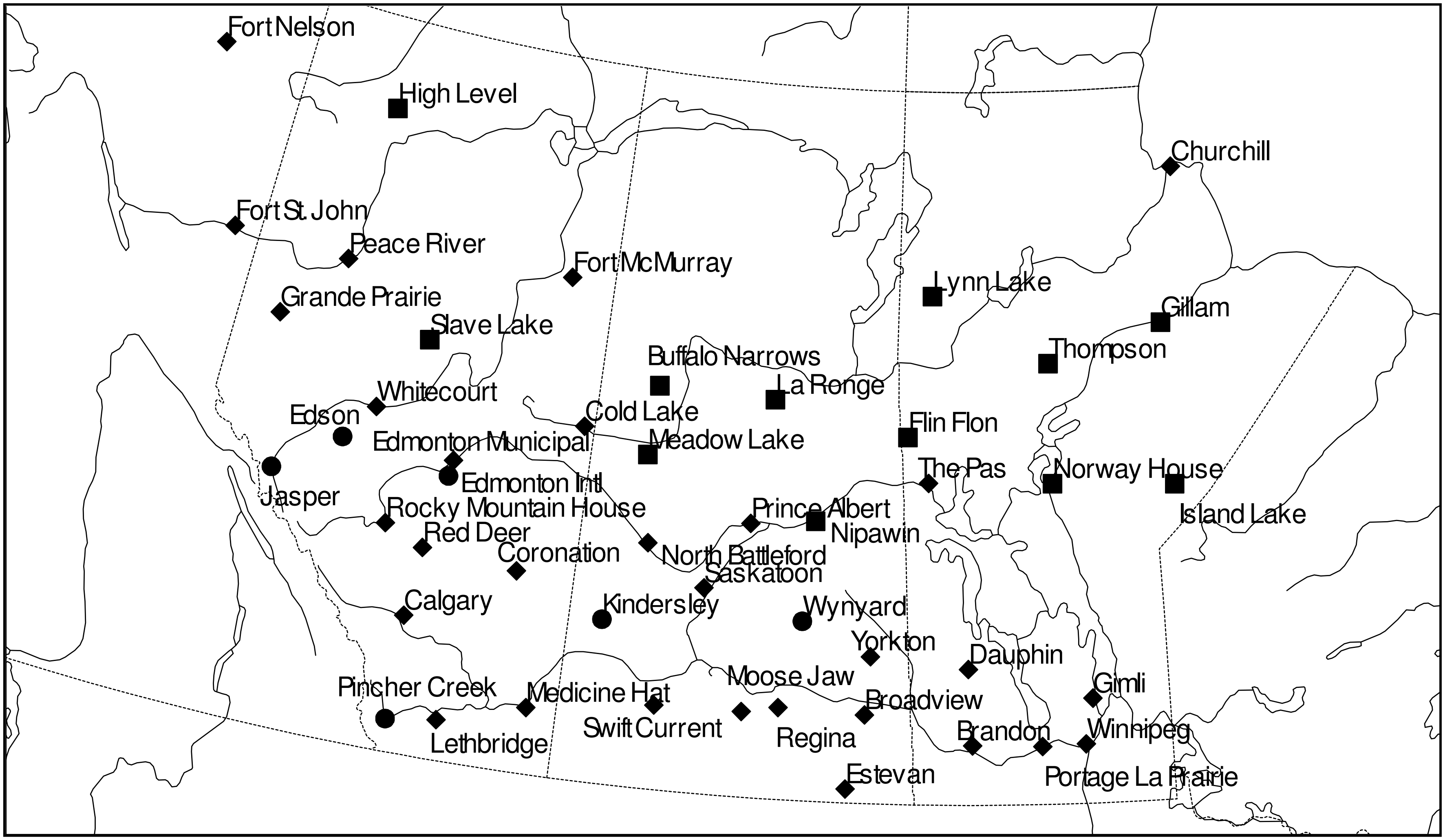

Figure 1: Location of stations used to investigate evaporation trends in the Canadian Prairies. ■ denotes stations used only for the 30-year period, ● denotes stations used in the 30 and 40-year analyses, and ◆ denotes stations used in the 30, 40 and 50-year study.

3.2 Analyzing Trend Results

The Mann-Kendall statistical test was applied to the stations in Table 1 to establish evaporation trends in the 30-year period. With a significance level of 10%, increasing, decreasing, or no trends were categorized based on monthly and annual time intervals. The percent occurrence is summarized in Table 4.

Table 4: Percentage of stations with trends (10% significance level) from 1971 to 2000

Trend	April	May	June	July	August	September	October	Annual
Increasing	13.6%	6.3%	8.3%	2.1%	4.2%	20.8%	2.1%	10.4%
Decreasing	2.3%	10.4%	35.4%	45.8%	25.0%	12.5%	43.8%	41.7%
No Trend	84.1%	83.3%	56.3%	52.1%	70.8%	66.7%	54.2%	47.9%

After the Mann-Kendall results in Table 4 were obtained, simulations were run using the bootstrap resampling procedure to determine if the percentage of trends is significant, or could occur by chance. Field significant trends (at the 10% level) are highlighted in Table 4. It was found from this analysis that the months of June through October, as well as the annual gross evaporation, possessed a significant number of significant trends. It is interesting to note that significant trends are mostly decreasing except for the month of September.

The 40-year period examined produced the results categorized in Table 5 when analyzed using the Mann-Kendall test.

Table 5: Percentage of stations with trends (10% significance level) from 1961 to 2000

Trend	April	May	June	July	August	September	October	Annual
Increasing	25.7%	2.8%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%
Decreasing	0.0%	16.7%	47.2%	66.7%	47.2%	13.9%	52.8%	61.1%
None	74.3%	80.6%	52.8%	33.3%	52.8%	80.6%	47.2%	38.9%

The results displayed in Table 5 were subjected to analysis by the bootstrap resampling procedure, similar to the steps taken for the 30-year period. Table 5 highlights the field significant trends that were discovered. This investigation revealed that a significant number of significant trends take place in June, July, August, October and on an annual basis. Significant trends are indicating a mostly decreasing nature in evaporation with time. In comparison to the results for the 30-year period listed in Table 4, all decreasing trends are becoming stronger; the required percentage from the bootstrap resampling simulation for field significant trends has decreased, while the occurrence of stations possessing a significant trend has increased. The increasing trend observed in the month of September for the 30-year period is no longer significant in the 40-year period. The loss of significance is due to a reduction in the percentage of increasing trends to the extent that September possesses mostly decreasing trends in the 40-year period.

Table 6 presents trends in the 30-year period for stations used in the 40-year analysis. Trend results found to be significant by means of the bootstrap resampling have been highlighted.

Table 6: Percentage of trends in 30-year period at stations used for 40-year analysis

Trend	April	May	June	July	August	September	October	Annual
Increasing	8.6%	2.8%	0.0%	0.0%	0.0%	13.9%	2.8%	2.8%
Decreasing	2.9%	13.9%	44.4%	55.6%	30.6%	8.3%	58.3%	52.8%
None	88.6%	83.3%	55.6%	44.4%	69.4%	77.8%	38.9%	44.4%

It can be seen from Table 6 that the percentage of trends is comparable to the all inclusive 30-year period (Table 4). Cases showing mainly decreasing or mainly increasing trends display the same tendency in Table 6. The incidence of 30-year decreasing trends has increased in the analysis of 40-year stations for the months of May, June, July, August, October, and on an annual basis. This is likely a result of the smaller data set, with fewer northern stations, which was used for the 40-year analysis. Significant trends match between both 30-year analyses for all cases except September. The elimination of 12 stations for the analysis of the 40-year sites decreased the percentage of increasing trends from 20.8% to 13.9%, no longer qualifying as field significant. Despite this reduction to 13.9%, the 30-year September trends at 40-year stations are still mostly increasing. In contrast, when examining the 40-year trends for September (Table 5) they are mostly decreasing. The above observations indicate that the change from mostly increasing in the 30-year period to mostly decreasing in the 40-year period is a result of introducing a longer record length, rather than the removal of several stations from the analysis.

The percentage of sites for the 50-year period displaying increasing, decreasing, or no trend for each month and on an annual basis are illustrated in Table 7.

Table 7: Percentage of stations with trends (10% significance level) from 1951 to 2000

Trend	April	May	June	July	August	September	October	Annual
Increasing	62.1%	6.7%	10.0%	0.0%	0.0%	10.0%	3.3%	6.7%
Decreasing	0.0%	10.0%	20.0%	56.7%	16.7%	20.0%	40.0%	33.3%
None	37.9%	83.3%	70.0%	43.3%	83.3%	70.0%	56.7%	60.0%

Field significant trends that are evident after the bootstrap resampling analysis are highlighted in Table 7 for April, June, July, September, October, and on an annual basis. June, July, October and annual gross evaporation trends continue to be mostly decreasing. Although the percentages decreasing are slightly lower than that of the 40-year period, they are still field significant. September has progressed from a field significant increasing trend in the 30-year period to a field significant decreasing trend when examining the 50-year period. The percentage of sites with an increasing trend in April consistently rises from the 30-year period to become statistically significant in the 50-year period.

The stations used for the 50-year period were examined to determine the trends present for both the 30 and 40-year time period. Trends for the 30-year period at the 50-year stations can be viewed in Table 8, with field significant trends highlighted.

Table 8: 30-year trends at stations used for the 50-year analysis

Trend	April	May	June	July	August	September	October	Annual
Increasing	6.90%	0.00%	0.00%	0.00%	0.00%	10.00%	3.33%	0.00%
Decreasing	0.00%	13.33%	43.33%	60.00%	30.00%	10.00%	63.33%	56.67%
None	93.10%	86.67%	56.67%	40.00%	70.00%	80.00%	33.33%	43.33%

When comparing Table 8 to the all inclusive 30-year trends (Table 4) it can be seen that the percentage of decreasing trends has increased for May, June, July, August, October, and on an annual basis. This behaviour is similar to that observed when comparing 30-year trends that included all possible stations to those only at sites used in the 40-year analysis and is again likely due to differences in the stations included in the data sets. Another similarity is that all significant trends match except for the month of September. When comparing 30-year trends for 50-year stations to the all inclusive 30-year study the percent of increasing trends in September is reduced to 10% from 20.8%. This causes September to no longer possess a field significant increasing trend. It is shown in Table 7 that the 50-year trend for the month of September is field significant; however, it indicates a decreasing tendency, as mentioned previously. This transition is a result of increasing the record length examined.

The lengthened record length causes the month of April to acquire a significant increasing trend. The 30-year trends for stations used in the 50-year analysis show 6.9% of the stations with an increasing trend for April, while the 50-year results show 62.1% of the stations are increasing. In contrast to the behaviour of April trends, the month of August loses its significant decreasing trend due to the record length increasing. The 50-year trends show 16.7% of the stations have a decreasing trend, while the same stations show a significant 30% decreasing trends for the 30-year period. In general, most months show a higher percentage of decreasing trends in the 30-year period than in the 50-year period.

Trends occurring for the 40-year period at stations used for the 50-year analysis are summarized in Table 9.

Table 9: 40-year trends at stations used for the 50-year analysis

Trend	April	May	June	July	August	September	October	Annual
Increasing	27.59%	3.33%	0.00%	0.00%	0.00%	7.69%	0.00%	0.00%
Decreasing	0.00%	13.33%	50.00%	70.00%	50.00%	15.38%	56.67%	63.33%
None	72.41%	83.33%	50.00%	30.00%	50.00%	92.31%	43.33%	36.67%

Months with field significant trends highlighted in Table 9 match those for the all inclusive 40-year period (Table 5). In most cases the percentage of decreasing trends is slightly higher for stations used in the 50-year analysis but there are no major differences. The resemblance between the 40-year results that includes all possible stations and that which includes stations used in the 50-year analysis is to be expected, as there is only a difference of six stations between the two data sets.

The relationship between the 40-year trends at 50-year stations (Table 9) and 50-year trends (Table 7) is similar to that between 30-year trends at 50-year stations and 50-year trends. The relationship between the 40-year trends for 50-year stations and 50-year trends illustrates the transition between the gaps that occur when comparing 30-year trends at 50-year stations (Table 8) and 50-year trends (Table 7). The percentage of decreasing trends for September has increased in the 40-year period, but has not yet reached a level of field significance. The incidence of increasing trends at the 50-year stations in April has risen from 6.9% for the 30-year trends to 27.59% for the 40-year trends. Similar to the comparison of 30-year trends at 50-year stations to 50-year trends, 40-year trends at 50-year stations have a higher percentage of decreasing trends than 50-year trends. This is especially true for the month of August.

The significant decreasing trend for the 30-year period is still present in the 40-year period, however, as mentioned previously, the percent occurrence drops to 16.7% in the 50-year analysis for the same stations, resulting in the trends no longer being considered field significant.

3.3 Temporal Patterns in Trends

Examining the results in Table 4, Table 5 and Table 7 in more depth shows that various sites show different trend characteristics for the different time periods analyzed. For example, one particular site may show a decreasing trend in the 30-year period, but no trend in the 40-year period or vice versa. Sites with such discrepancies are summarized for several comparisons which include the 30 to 40-year period and the 40 to 50-year period. In addition to this, discontinuities between the 40 and 50-year period are further examined by observing the behaviour of these sites for the 30-year time frame.

Disagreements in the trend results between the 30 and 40-year period can be classified into four types as summarized in Table 10.

Table 10: Types of discrepancies between trend results for the 30 and 40-year periods

Type	30 Year Trend	40 Year Trend	Number of Occurrences
Type 1	none	increasing	9
Type 2	none	decreasing	38
Type 3	increasing	none	8
Type 4	decreasing	none	24

A total of 287 comparisons produced the 79 discrepancies noted in Table 10; these can be viewed in Appendix A. The most common inconsistency was 38 trends changing in the manner of Type 2. Frequently, the change was explained from decreasing trends only, or mostly, apparent in the earlier section of the 40-year record. An example of such behaviour is seen at Cold Lake, Alberta for the month of June. The raw data is plotted in Figure 2, as well as the LOWESS smoothed results to observe trends through the natural variation of the data.

The decreasing nature in Figure 2 is shown mostly in the earlier part of the record before a slightly increasing trend in the 1990s. In a few cases of Type 2 behaviour, the decreasing trend existed for the 30-year period, but was subtle, and required a longer record length to identify the trend as being significant.

In comparison, 24 trends changed in agreement with Type 4 behaviour from a decreasing trend in the 30-year period to no trend in the 40-year period. This transition is accounted for by the tendency of various records to show decreasing trends in recent years, but an increasing trend in the earlier portion of the record. This is illustrated in Figure 3. Figure 3 shows the trend for annual evaporation in Brandon, Manitoba. The increasing trend in the earlier years of the record ends in the early 1970s and a decreasing trend is observed in the latter half of the record.

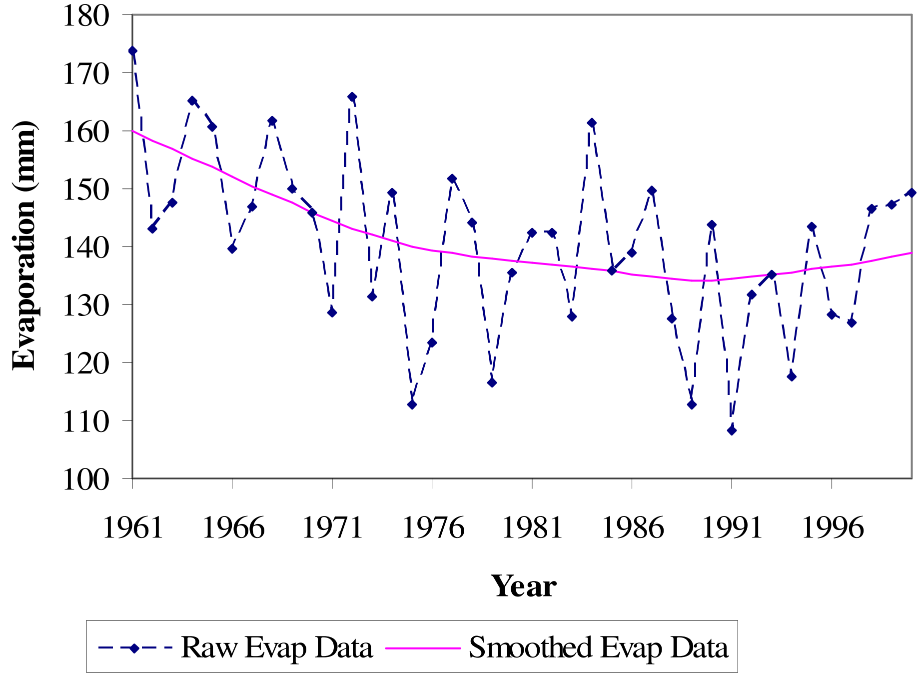

Figure 2: Typical Type 2 behaviour at Cold Lake, AB in June

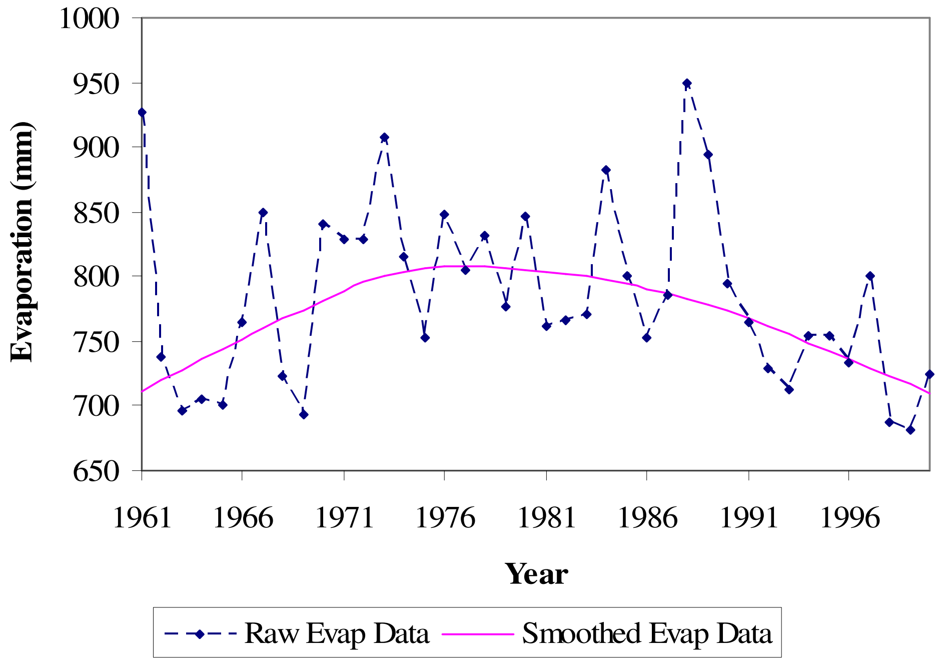

Figure 3: Typical Type 4 behaviour at Brandon, MB on an annual basis

Approximately the same number of trends changed from an increasing trend (in the 30-year period) to no trend (for the 40-year period) and from no trend to an increasing trend. Changes in accordance with Type 1 did so because an increasing trend was mostly, or only, present in the earlier years or toward the middle of the record, while recent years were inclined to display a decreasing trend. Although this is similar to the typical behaviour of Type 4, the increasing trends for Type 1 are usually more dramatic, or the decreasing trends more subtle. An example of Type 1 is illustrated in Figure 4. Brandon, Manitoba exhibited Type 1 behaviour for the month of April. The dramatic increasing trend is clearly displayed, with a peak in the early 1980s before a decreasing trend begins.

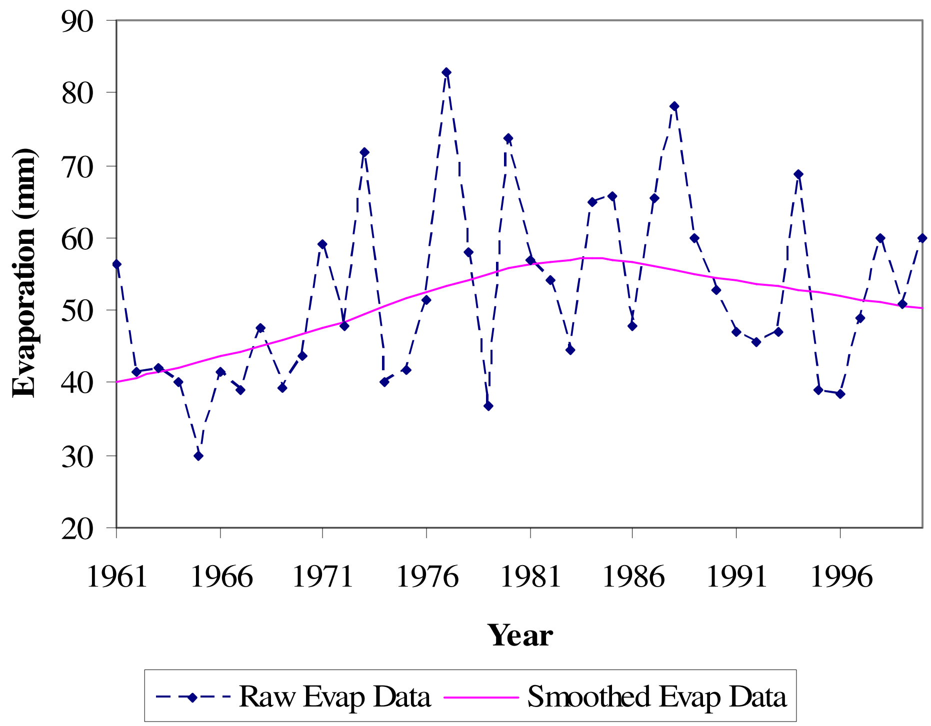

Figure 4: Typical Type 1 behaviour at Brandon, MB in April

Behaviour such as Type 3 can be attributed to the nature of some stations to mostly, or only, display increasing trends in the middle or recent part of the record. In most of these cases a decreasing trend existed in earlier years. Type 3 behaviour can be observed in Figure 5. The month of April at Broadview, Saskatchewan produced the trends shown in Figure 5. A distinct increasing trend can be seen in the middle of the record, while earlier and more recent years possess little to no trend.

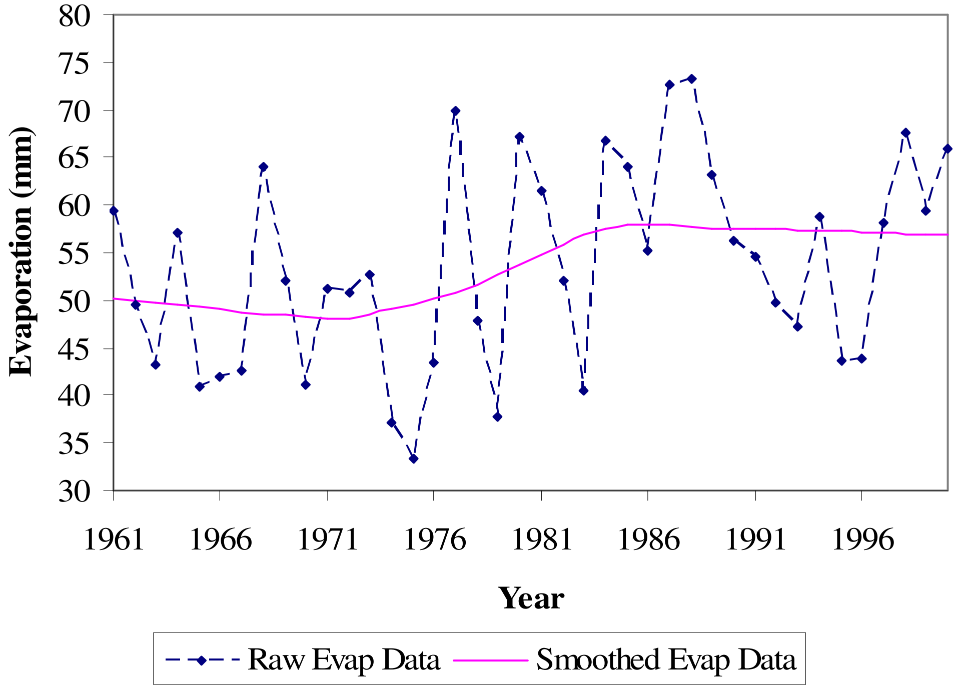

Figure 5: Typical Type 3 behaviour at Broadview, SK in April

Two-hundred and thirty-nine comparisons were made between the 40 and 50-year period. Types of discrepancies found can be classified in the same manner as those between the 30 and 40-year time frame. Table 11 lists the progression of trends between the different periods.

Table 11: Types of discrepancies between trends results for the 40 and 50-year periods

Type	40 Year Trend	50 Year Trend	Number of Occurrences
Type 1	none	increasing	19
Type 2	none	decreasing	5
Type 3	increasing	none	1
Type 4	decreasing	none	41

The specific cases exhibiting each type of behaviour in Table 11 can be found in Appendix A, which also includes the cases where there was no discrepancy. There is a tendency for annual and monthly evaporation trends to behave in the manner of Type 4, as 41 out of the 66 cases demonstrate this pattern. The dominance of this behaviour is because of the typical increasing trend that occurs in the earlier segment of the 50-year record. In some cases the increasing trend is dramatic and short in duration; in others it is subtle and fairly lengthy, but a longer record length was needed to establish its presence. The behaviour of Type 4 is illustrated in Figure 6.

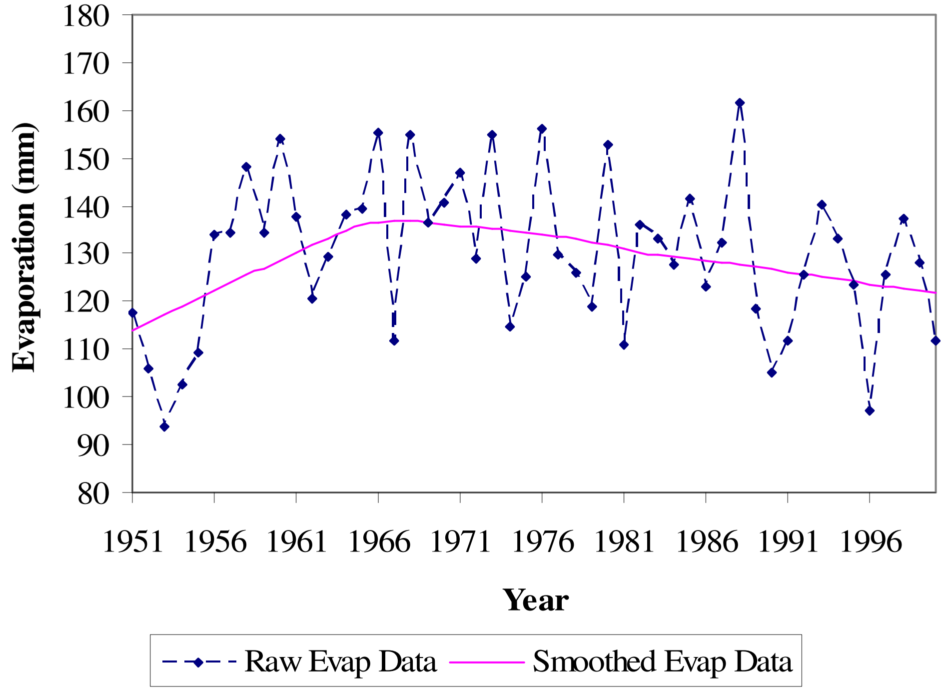

Figure 6: Typical Type 4 behaviour at Red Deer, AB in May

Figure 6 depicts the trends for May in Red Deer, Alberta. A decreasing trend is consistent from the early 1960s until 2000, but prior to that a strong increasing trend is evident. The increasing trend in the earlier years brings question to the decreasing trend in the last 40 years of the record. As a result, the station is deemed to have no trend for the 50-year analysis period.

A change in the manner of Type 1 was also common, occurring in 19 cases. Out of the 19 instances, it was found that 11 of them occur in April. An example of Type 1 behaviour is seen in Figure 7 at Edmonton Municipal, Alberta for April. Figure 7 shows a strong increasing trend in the earlier years of the record that is similar to that shown in Type 4. Differences between Type 1 and 4 arise in recent years of the record. Type 1 does not indicate trends after 1961 that are significant enough to be detected using a shorter record length. This is an example of a longer record length being required such that the Mann-Kendall test has sufficient power to identify the trend that is present in the data set.

Very few examples materialized for trend changes that reflect the behaviour of Type 2 or 3. It is possible that the low frequency of these events is because so few cases show a decreasing trend that mostly or only exists in the earlier parts of the 50-year records. Any trends that arise in the 1950s and early 1960s, that are inconsistent with behaviour in later years, are normally increasing.

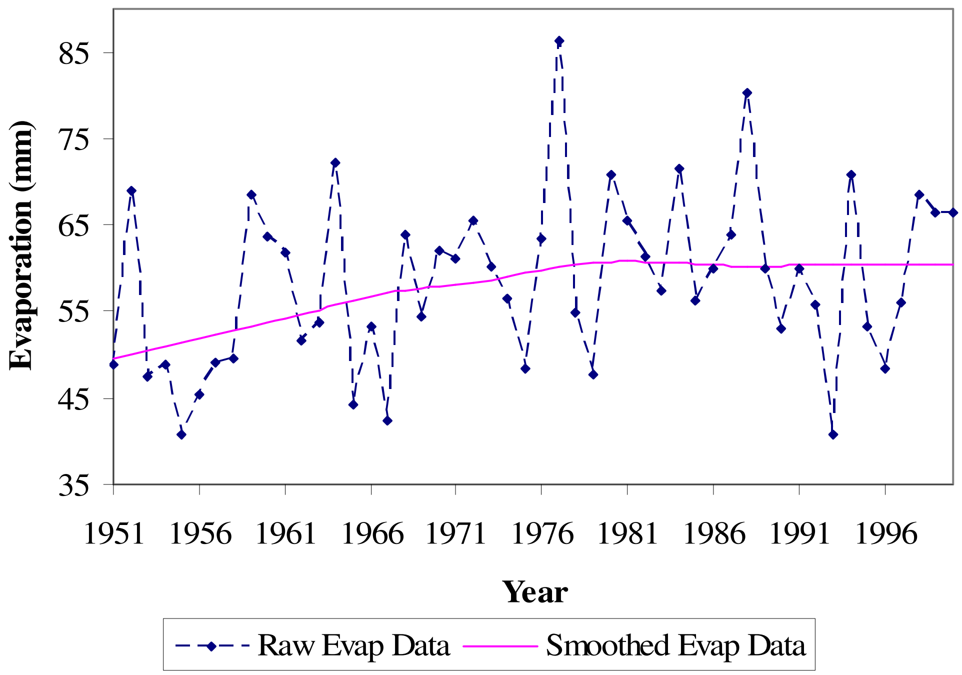

Figure 7: Typical behaviour for Type 1 at Edmonton Municipal, AB in April

The discrepancies between the 40 and 50-year periods were further examined by investigating the trends that appeared from 1971 to 2000. All comparisons can be viewed in Appendix A. The prevailing change in accordance with Type 4 in Table 11 is broken down into two categories: those that possess a decreasing trend in the 30-year period and those that do not possess a trend in the 30-year period. Those that possess a decreasing pattern in the 30-year period are more frequent, occurring 23 times. In most cases, the change in trend from decreasing in the 30 and 40-year period to none in the 50-year period is a result of increasing trends that exist in earlier portions of the records. This can be observed in Figure 8.

Figure 8 shows the trends for Swift Current, Saskatchewan for annual evaporation. This behaviour is similar to that shown in Red Deer, Alberta in Figure 6. An increasing trend is apparent in the earlier years of the record, but after the mid 1960s a decreasing trend is observed.

The second category, those that do not possess a trend in the 30 year period, accounts for 18 of the 41 cases. An example of this can be seen in Figure 9. The pattern in Figure 9 is a result of decreasing trends that are more apparent or only exist in the middle or recent years of the record. In most cases the trend is inconsistent, changing slopes multiple times. Increasing trends are common in earlier years and can be viewed in Figure 9.

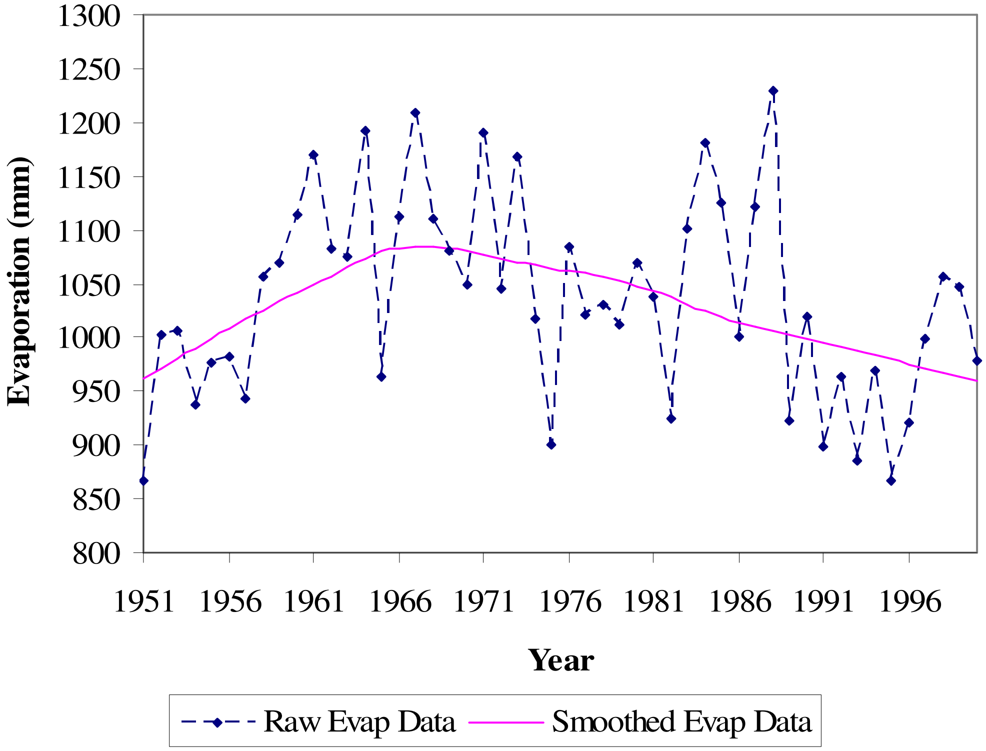

Figure 8: Type 4 behaviour with a decreasing 30-year trend at Swift Current, SK

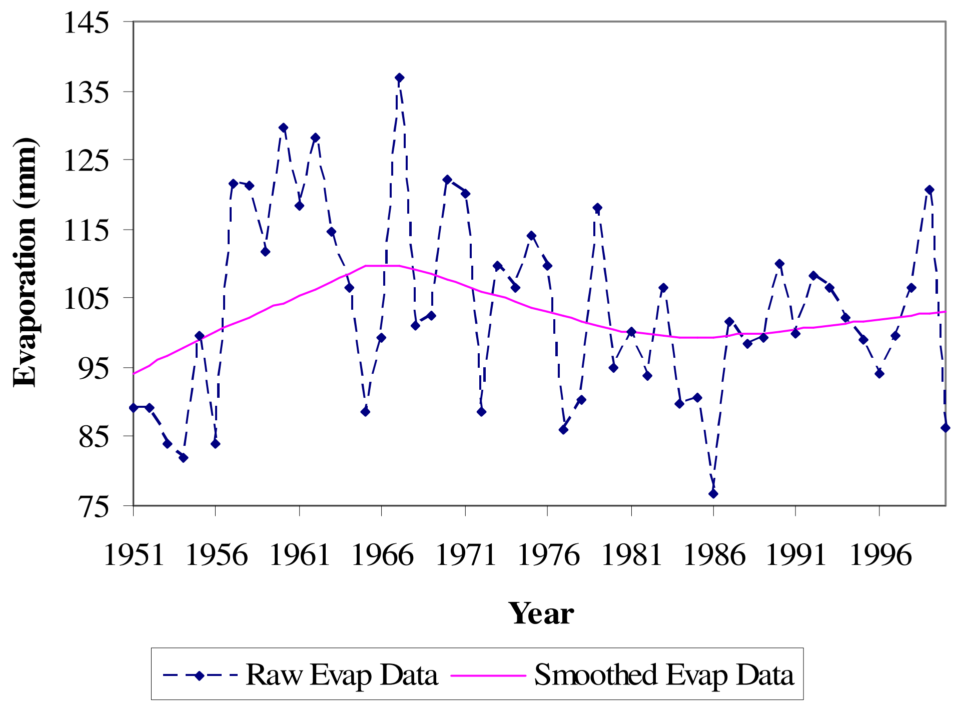

Figure 9: Type 4 behaviour with no 30-year trend at Red Deer, AB in September

When examining the trends in the 30-year period for Type 1 shown in Figure 7, it was found that in every case the 30-year period did not possess a significant trend. Common increasing trends in the earlier years that are observed for other types of behaviour are also present in this case. In some examples the increasing trends are found more toward the middle of the record rather than in earlier years.

3.4 Spatial Analysis

Trends in evaporation data throughout the prairies have been mapped for the three time periods for each month and on an annual basis. These spatial distributions can be found in Appendix B. The spatial distribution of trends varies for different months and time periods. In all the graphs below and in Appendix B, increasing trends are indicated using a triangle pointing upward, decreasing trends by a triangle pointing downward and stations with no trends are illustrated using a circle. All results are for the 10% significance level. Typically, when significant increasing trends exist, they occur at the more northerly stations; examples of this can be seen in September and June in the 30 and 50-year period (see Appendix B). Decreasing trends generally occur at the more southerly stations. This is evident in the summer months of June, July, and August, for the 30 and 40-year periods. These maps also reinforce the progression of trends throughout the three time periods for individual months. April, for example, develops significant increasing trends as the record length gets longer. The 50-year trends in April are mapped in Figure 10.

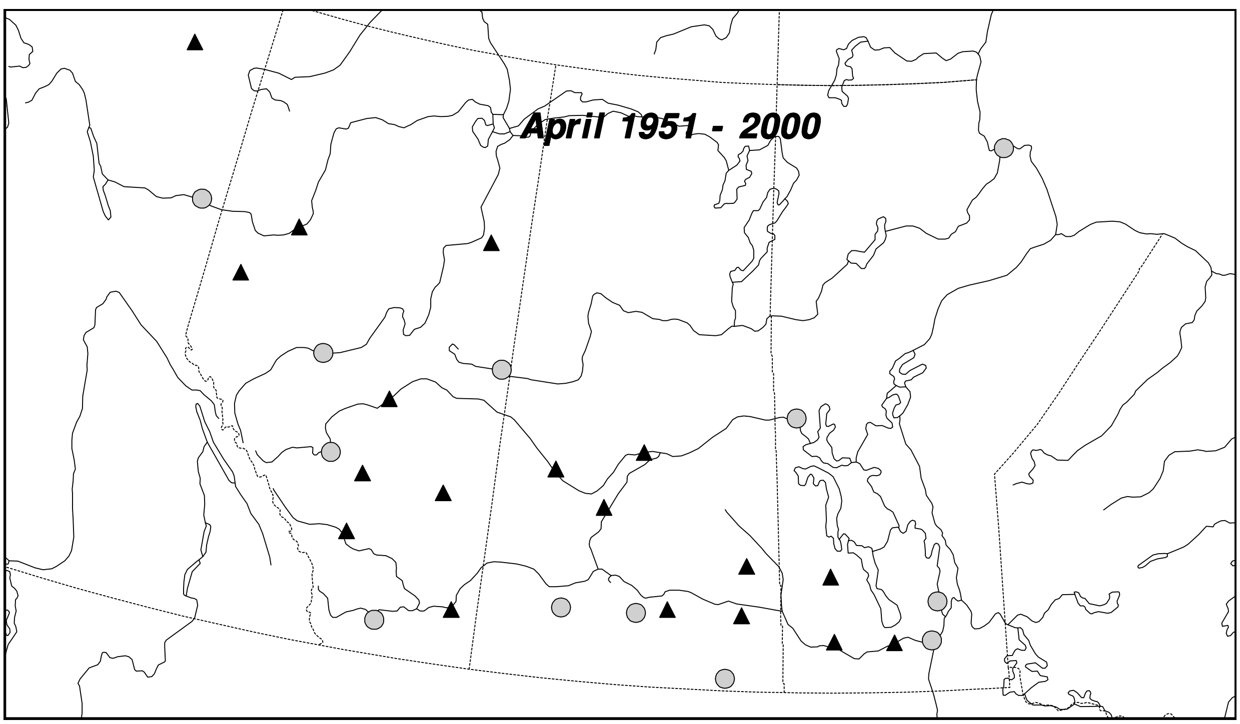

Figure 10: Spatial distribution of April evaporation trends in the 50-year period. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

The strong increasing trend in April for the 50-year time frame is presented in Figure 10; these significant trends are not as numerous in the shorter time periods. The distribution of trends is fairly uniform and does not appear to favour a particular region. It can be seen in

Appendix B that April for the 30-year period shows increasing trends only in the more northern stations, while the 40-year period shows a higher frequency in the south-easterly stations. The comparison of all three time periods shows that these patterns only appear temporarily.

Trends in July are significantly decreasing in the 30, 40 and 50-year period. The 50-year trends are depicted in Figure 11. The 50-year decreasing trends in Figure 11 display a distinct spatial pattern. Southern stations in Saskatchewan and Manitoba all show decreasing trends, but this pattern is not apparent in Alberta. Alberta possesses a high frequency of no trends, tripling that of Saskatchewan and Manitoba combined. Refer to Appendix B to observe the distribution of decreasing trends in July for the 30 and 40-year time periods. When reviewing the 30-year trends for July, the high occurrence of decreasing trends in the more southern stations is still noticeable. The addition of stations examined in Alberta has carried the trend toward the west, although Saskatchewan and Manitoba still possess the strongest indication of the decreasing trend in the southern portion of the study area. The decreasing trends in the 40-year period show similar patterns to the 30-year distribution. Manitoba and Saskatchewan still display the southern tendency of decreasing trends, although Alberta's decreasing trends are slightly more dispersed than the 30-year trends.

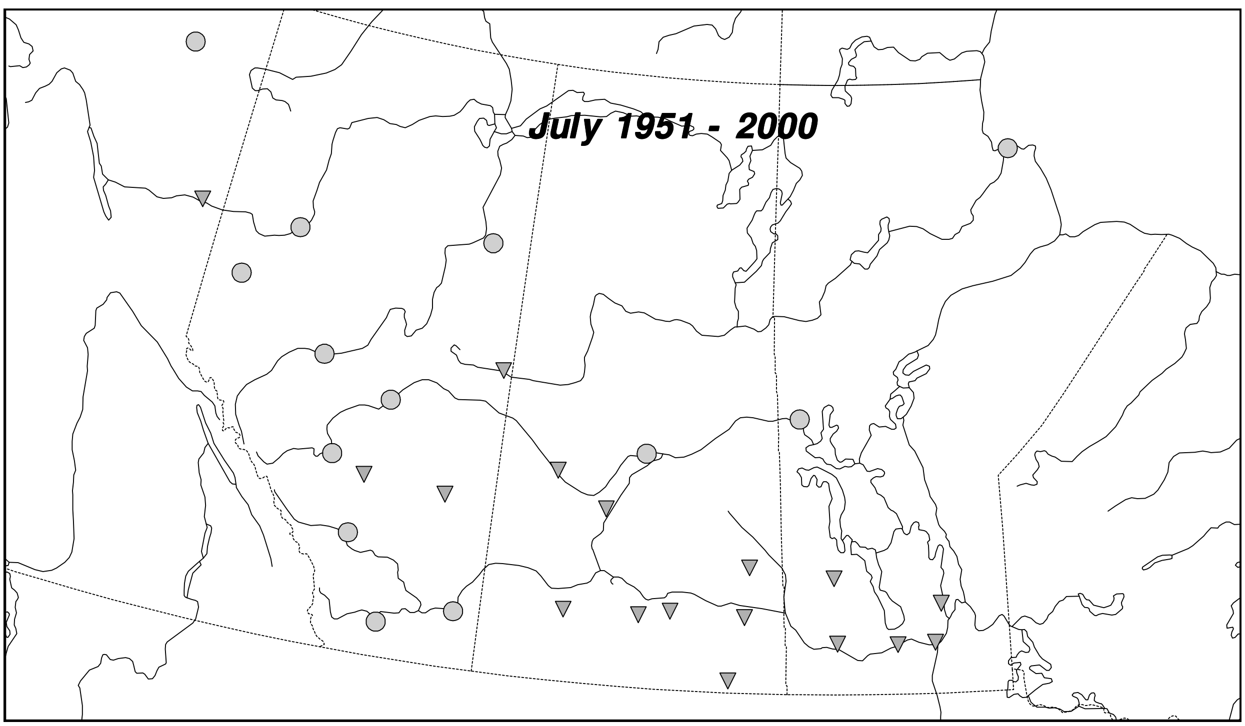

Figure 11: Spatial distribution of July evaporation trends in the 50-year period. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

Annual evaporation trends throughout the Canadian Prairies are displayed in Figure 12. These trends are based on the 30-year analysis dating from 1971-2000.

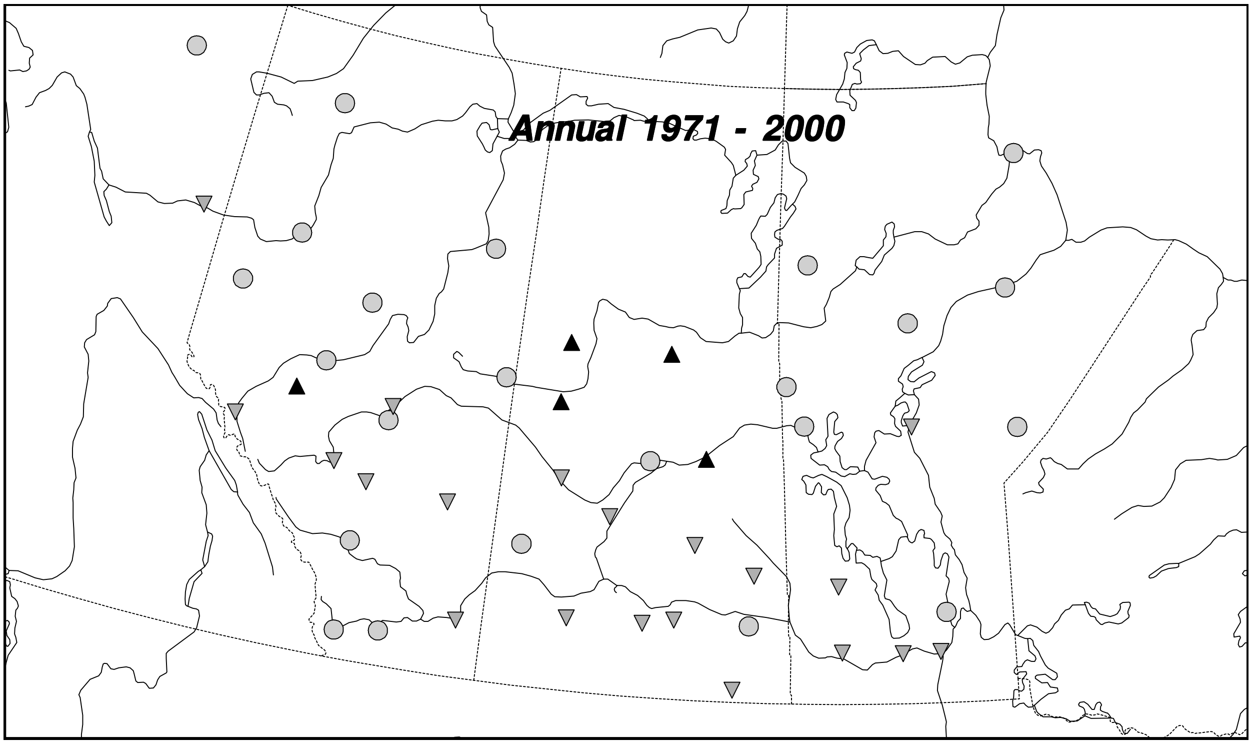

Figure 12: Spatial distribution of annual evaporation trends in the 30-year period. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

It can be observed from Figure 12 that, similar to the July spatial distribution, the decreasing trends appear most dominant in the southern stations. The majority of the increasing trends are the most northern stations in Saskatchewan; however, when considering all of the Canadian Prairies, it is more common for northern stations to display no trend. In the distribution of 40-year annual trends, presented in Appendix B, increasing trends are no longer present, possibly due to the elimination of four of the five stations displaying the trend. The dominant decreasing trend in southern regions is still evident despite the transition from the 30-year period to the 40-year period. The 50-year period, illustrated in Appendix B, shows increasing trends beginning to resurface in northern Alberta due to the longer record lengths. Nonetheless, the number of significant increasing trends in the 50-year period for annual evaporation is relatively small, thereby diminishing the existence of any spatial tendencies.

3.5 Analysis of Trend Slopes

Trend slopes for each month, and on an annual basis, were estimated using the procedure outlined earlier (see Equation (7)). The results for the 30-year period for the months of April through October are displayed using box and whisker plots in Figure 13, which shows the distribution, across the sites, of the slope magnitude for each time period.

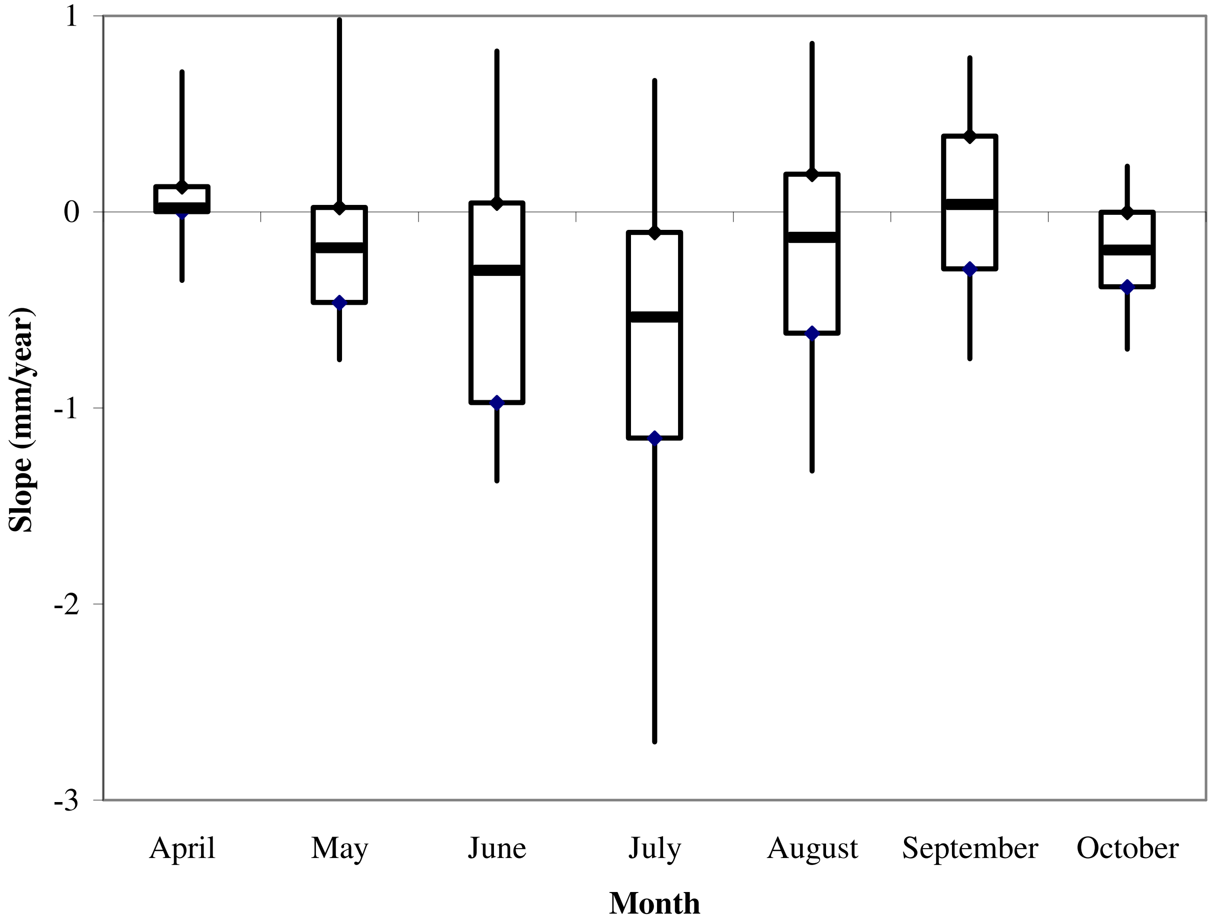

Figure 13: Box and whisker plots for trend slopes in the 30-year period

Figure 13 depicts the minimum values at the bottom of the lower whiskers and the maximums at the top of the higher whiskers. The 25th percentile appears as a diamond on the lower horizontal line of each box, the median at the horizontal line inside the box and the 75th percentile as a diamond on the upper horizontal line of the box. The range of slope values is the smallest for April and October. The 25th percentile in April is in very close proximity to the median, while the range between the minimum and maximum value in October is comparatively small. The largest range of slope values occurs in July, due to the considerable distance between its minimum slope and the lower quartile. The median trend slope values consistently decrease from April to July and then increase until September; April and September possess the highest values. The maximum slope values do not surpass 1.0 (mm/year), however the minimum slope value drops to -2.7 (mm/year) indicating that decreasing slopes are more dramatic (and common) than increasing slopes. The strong decreasing tendency of July is evident as the 75th percentile lies below zero.

The box and whisker plots produced when analyzing slopes for the 40-year analysis period are depicted in Figure 14.

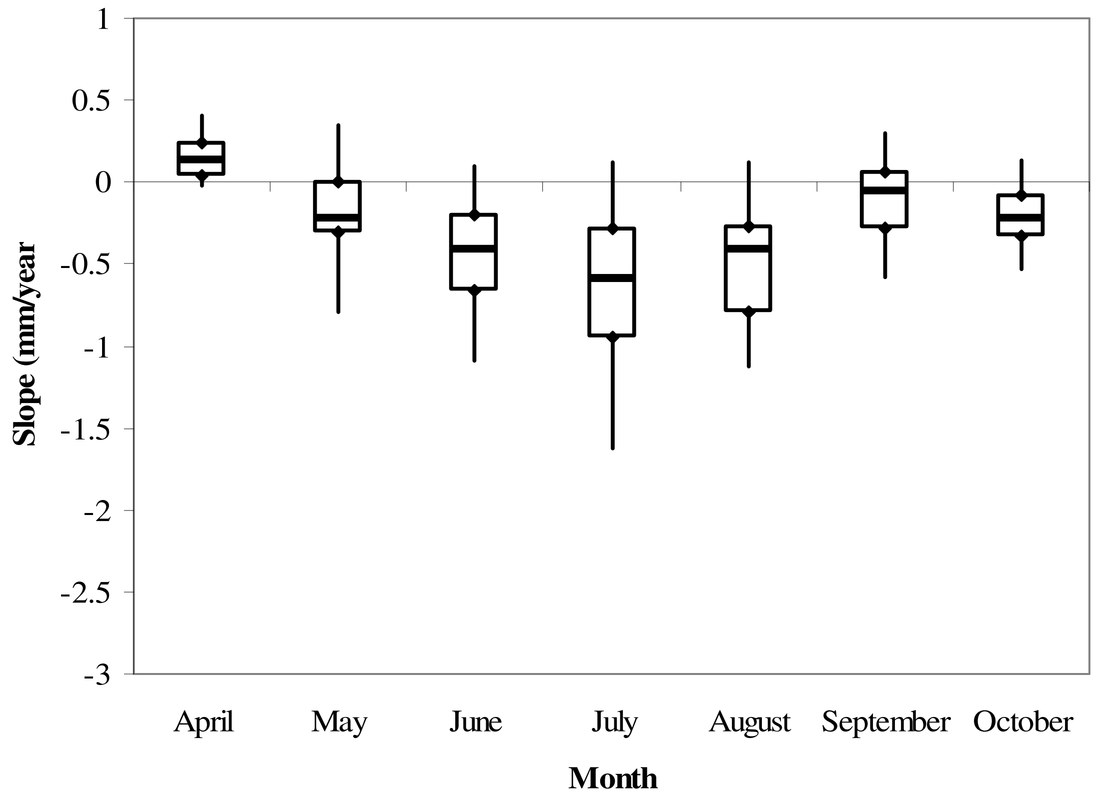

Figure 14: Box and whisker plots for trend slopes in the 40-year period

The behaviour of the median is similar to the 30-year slopes with a decrease until July and then an increase until September. April shows a more even distribution between the 25th percentile, median and 75th percentile, but the range from the minimum value to 25th percentile is much smaller than for the 30 year period. Also, the majority of the April slopes are above zero, illustrating an increasing nature. From May through October the 75th percentiles are below zero, except for September, which has a value of 0.058 (mm/year). This suggests that even if the probabilities were not low enough to identify a trend at the 10% significance level, there is a decreasing nature at many of the sites studied in the months of May, June, July, August, and October.

The slopes for the 50-year analysis period were also examined using box and whisker plots to illustrate the behaviour of the slopes (see Figure 15). The 50-year period further confirms the seasonal decrease in median slope values until July followed by an increase until September. Differences in the pattern for the 50-year period can be noted in the fact that the median in May is comparable to the value in September. The 75th percentile values are all increased from the 40-year period to close to, or sometimes greater than, the corresponding values in the 30-year analysis. It can also be noted that the minimum, 25th percentile and maximum also follow this pattern. These results may be the product of the strong increasing nature that is typically displayed in the earlier portion of the 50-year records.

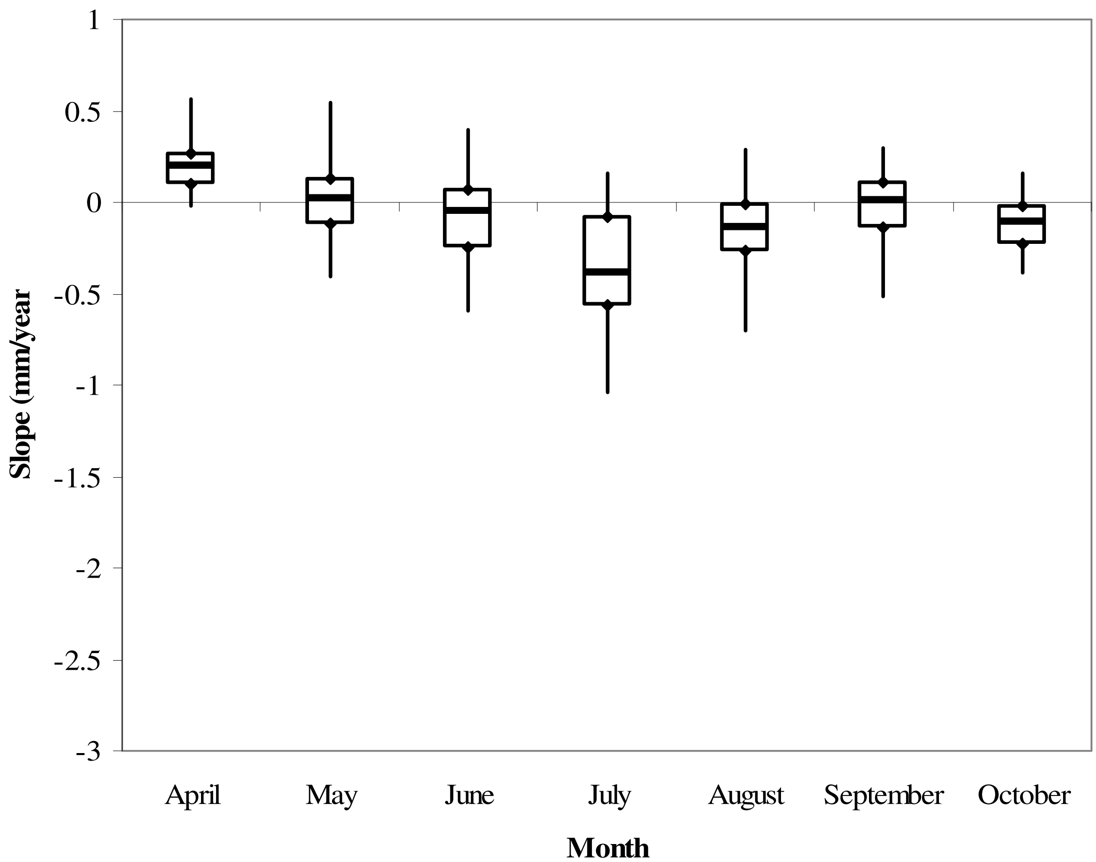

Figure 15: Box and whisker plots for trend slopes in the 50-year period

Annual slope values possess a much larger range than individual months. These values are depicted in Figure 16. It can be seen from Figure 16 that the largest range occurs in the 30-year period from -7.19 to 3.38 (mm/year). The median values do not follow a pattern associated with the adjustment in record lengths, possessing the highest median at 50-years but the lowest at 40-years. However, it is evident from this graph that the minimum and 25th percentiles of annual slopes are increasing as the record length gets longer. This may be an indication that decreasing trends are mostly present in recent years.

3.6 Comparison of Pan and Gross Evaporation

Comparisons were made between trends for pan evaporation and trends for gross evaporation for 13 sites. Sites were chosen based on data availability and with a goal of providing a comparison with gross evaporation sites for multiple situations, including sites that displayed increasing, decreasing and no trends in gross evaporation. Time periods for the pan evaporation data vary and do not match the previously designated time frames. Table 12 outlines the most commonly used time period for each station.

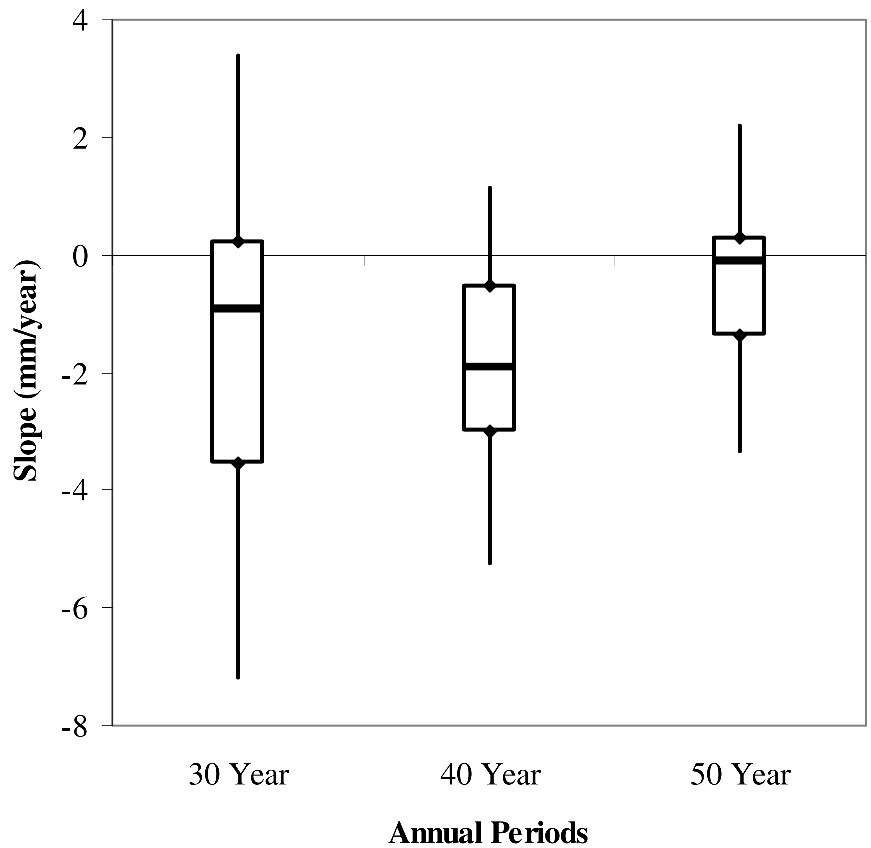

Figure 16: Box and whisker plots for annual trend slopes

Table 12: Time periods and months used for comparing pan and gross evaporation

Pan Evaporation Station	Gross Evaporation Station	Months Compared	Time Period
Altawan	Medicine Hat	May to September	1966-1996
Calgary Intl A	Calgary	June to September	1964-1994
Churchill A	Churchill	July to August	1964-2000
Estevan A	Estevan	May to September	1962-2000
Indian Bay	Winnipeg	June to September	1962-2000
Morden CDA	Portage La Prairie	May to September	1963-1998
Nipawin A	Nipawin	May to September	1974-2000
Norway House Forestry	Norway House	June to September	1971-1999
Regina A	Regina	May to September	1963-1995
Swift Current CDA	Swift Current	May to September	1960-2000
Weyburn	Regina	May to September	1962-2000
Winnipeg Intl A	Winnipeg	May to September	1962-1994
Wynyard	Wynyard	May to September	1967-2000

Each station in Table 12 has a potentially unique time period and the time period will sometimes differ from month to month for a given location. These inconsistencies arise from the lack of available data for pan evaporation. Gross evaporation data were, for every case, analyzed to match the available time periods for pan evaporation.

Daily estimates were provided for pan evaporation, so monthly evaporation values were calculated as the sum of the daily values. In the event of missing values, an average was determined from the existing daily evaporation within the specified month. These averages were then substituted for the missing values. In the event that more than nine daily measurements were missing, the monthly evaporation estimates were considered unreliable and were not used. Figure 17 shows the location of the pan and gross evaporation stations listed in Table 12. In Figure 17, the square symbol represents locations for which the pan and gross evaporation sites are coincident and the other pairs of symbols denote the locations of a pair of stations. As can be seen from the figure, only four station pairs are not coincident. For these four station pairs, the maximum separation between a pan evaporation site and the corresponding gross evaporation site is 150 km. Although the maximum separation distance between station pairs is 150 km, the results for Indian Bay and Winnipeg should be analyzed with caution due to the potential effects of different climatic conditions at the two sites. It should also be noted that Winnipeg and Regina are used both as a gross evaporation site to match with a pan evaporation site and as a pan/gross evaporation pair.

Appendix C contains the results comparing pan evaporation stations with the associated gross evaporation site. A summary of the behaviour when evaluating the two types of evaporation is provided in Table 13.

Table 13: Behaviour of trends between pan evaporation and gross evaporation

Type	Description	Number of Occurrences
Type 1	significant trend for only one	17
Type 2	close to matching results	7
Type 3	matching results	30
Type 4	opposing results	2
Type 5	close to opposing results	3

It can be observed from Table 13 that 59 comparisons were made. The poor availability of pan evaporation data limited the extent of this investigation in terms of the number of stations and months examined. The months analyzed for each of the 13 sites were dependent on proper documentation of evaporation. Months excluded vary for specific stations, but in all cases April, October and Annual evaporation were omitted.

Thirty cases show similar behaviour between pan and gross evaporation. The majority of these are examples of no significant trends for either. Five results show matching decreasing trends, four of which occur in July. One example takes place in July at Regina, Saskatchewan. The behaviour of the raw data and the LOWESS trend lines for pan and gross evaporation in Regina are illustrated in Figure 18.

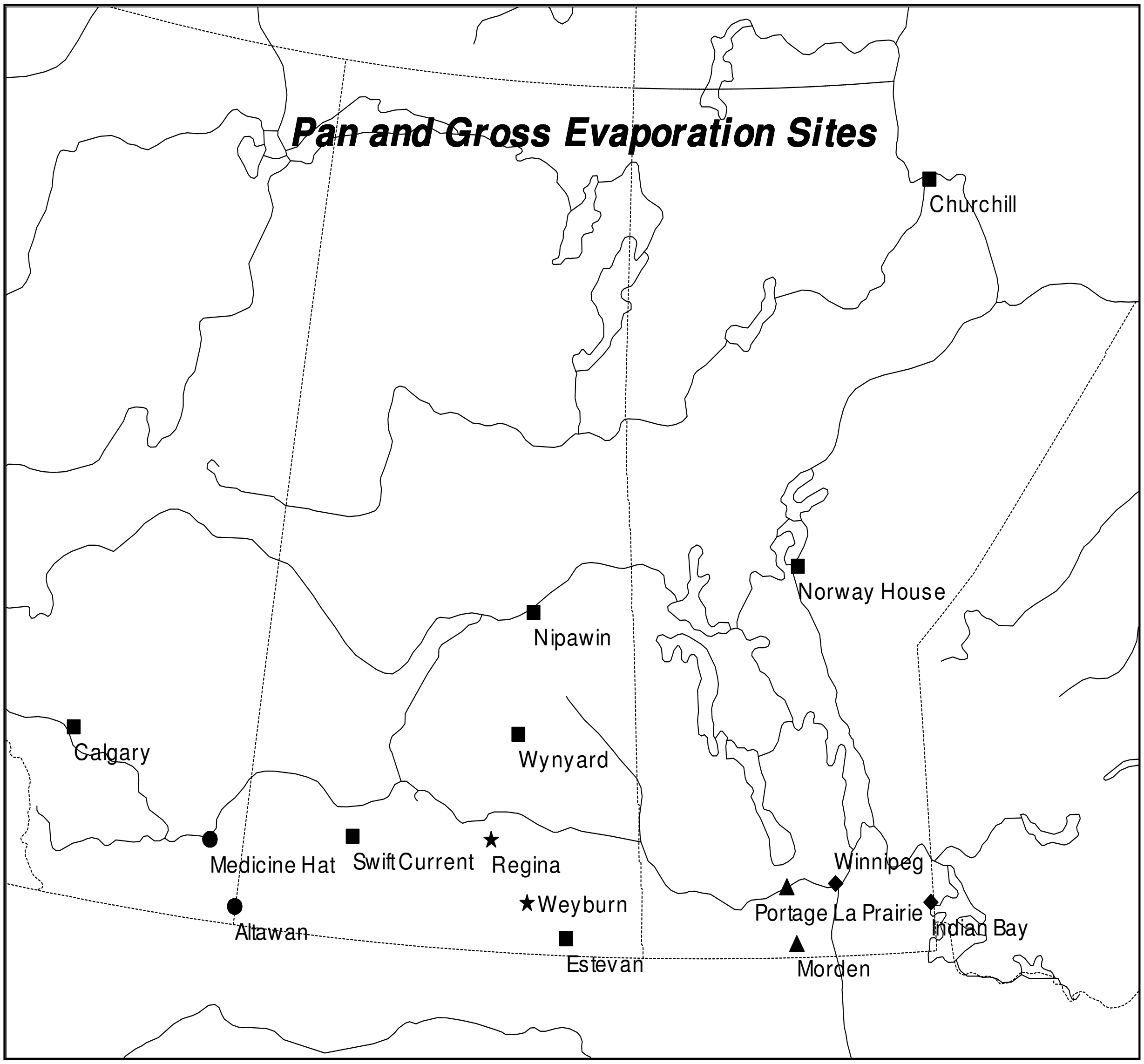

Figure 17: Location of the sites used for the comparison of pan and gross evaporation. ■ represents locations for which the pan and gross evaporation sites are coincident. ●, ★, ▲, and ◆ denote the locations of a pair of stations

Figure 18 depicts similar behaviour between pan evaporation and that of gross evaporation. Natural variations between the two respond in the same manner, creating identical timing for peaks and minimum values. In more recent years, it appears that the decreasing trend in pan evaporation is slightly steeper than the slope displayed by gross evaporation. The correlation between pan and gross evaporation at Regina can be seen in Figure 19.

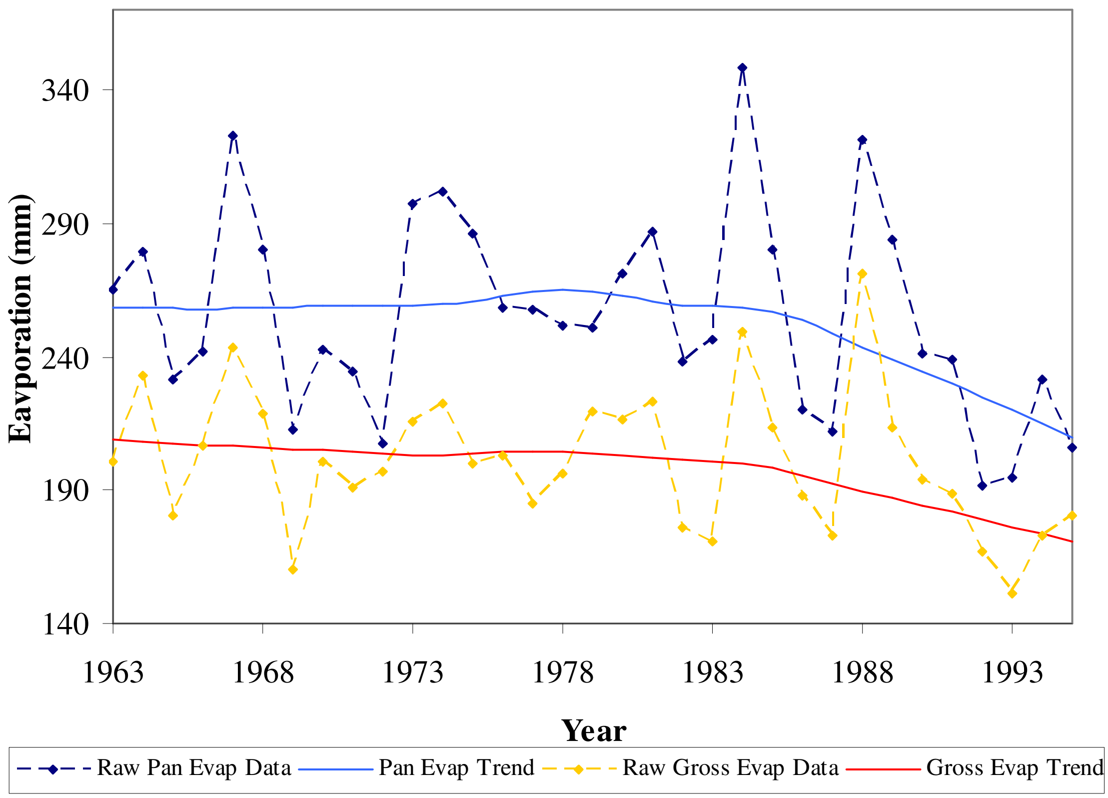

Figure 18: Raw data and LOWESS trend lines at Regina in July

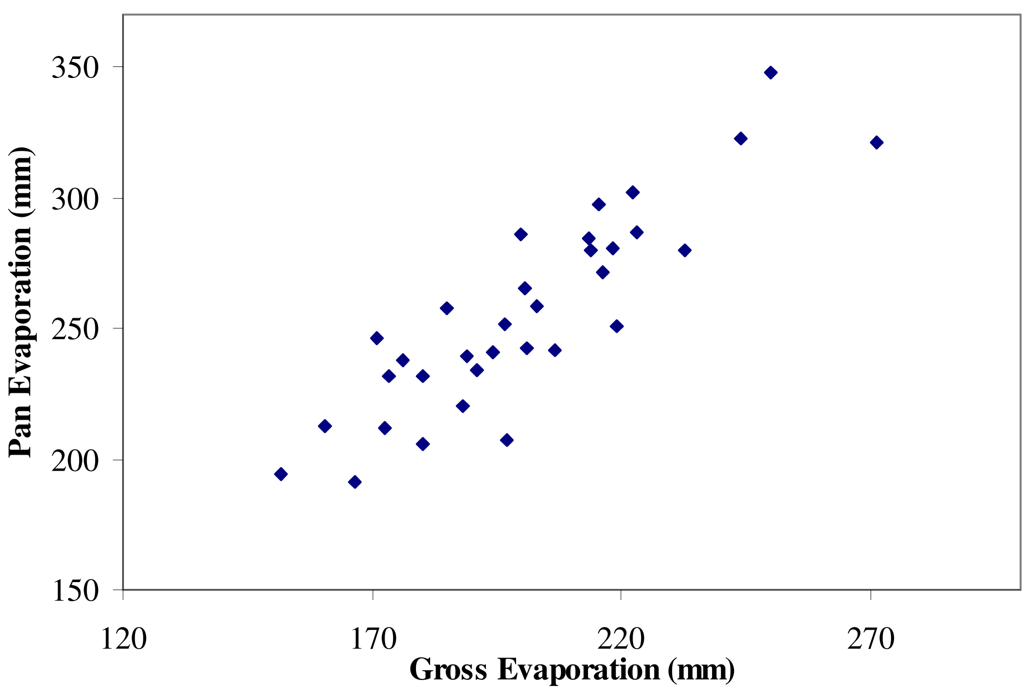

Figure 19: Scatter plot of pan and gross evaporation at Regina in July (r = 0.88)

Figure 19 shows the close relationship between the pan and gross evaporation at Regina in July. As gross evaporation increases, the increase in pan evaporation is fairly proportional such that the correlation between the two series is 0.879. Gross evaporation values are smaller than pan evaporation, as can be expected from their relationship. It can be seen in Table 13 that seven cases result in close to matching trends between pan and gross evaporation. Pan evaporation for Estevan, Indian Bay, and three instances at Wynyard in the months of August, July, May, July and August, respectively were within a close range of the decreasing trend observed at the associated gross evaporation station. The remaining two cases, Nipawin and Calgary in September and June, respectively, possessed one significant increasing trend and one close to increasing trend. Plots depicting these results can be found in Appendix D.

It was found that the results opposed each other in two cases, both showing an increasing trend in pan evaporation and a decreasing trend in gross evaporation. The first divergence occurred when comparing pan evaporation at Morden to gross evaporation at Portage La Prairie, both of which are situated in Manitoba. In Figure 20 both the raw data and the LOWESS smoothed lines are displayed.

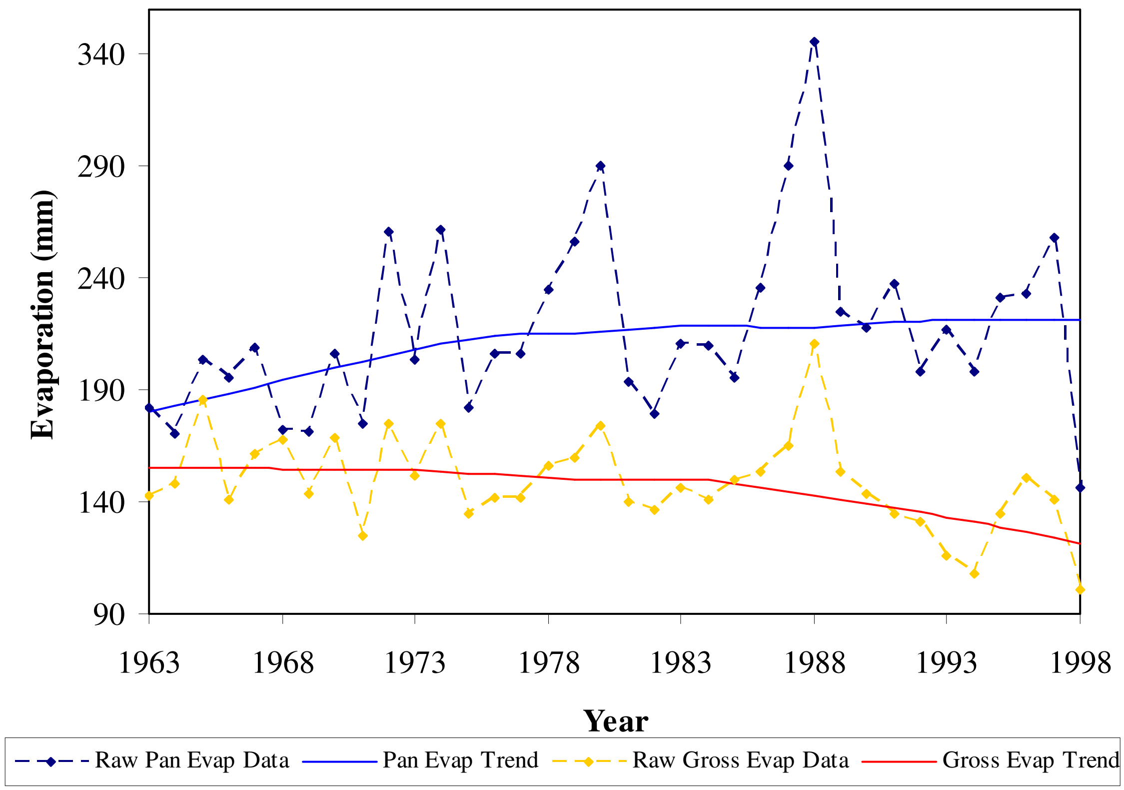

Figure 20: Raw data and LOWESS trend lines for Morden and Portage La Prairie in June

Figure 20 shows the pan evaporation and gross evaporation in the month of June at the specified locations. Although pan and gross evaporation have opposing overall trends, a direct correlation can be made between the two sets of raw data. Local maximums and minimums for both types of evaporation have similar behaviour. The relationships between them are represented using a scatter plot in Figure 21.

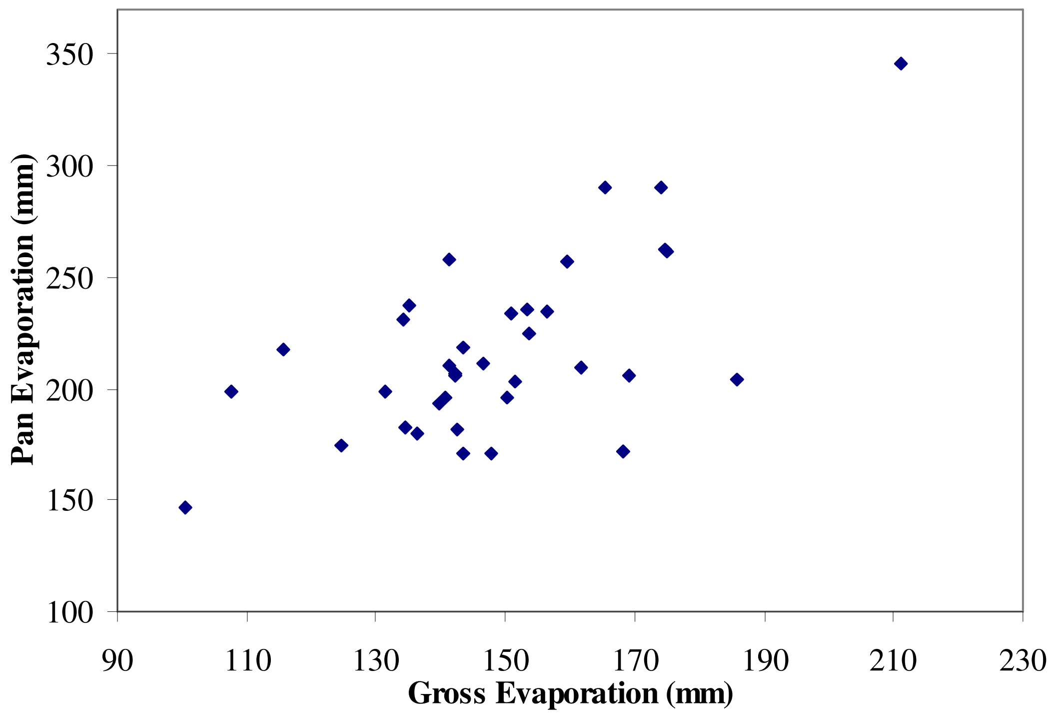

Figure 21: Scatter plot of pan evaporation at Morden and gross evaporation at Portage La Prairie in June (r = 0.64)

Figure 21 displays some association between the pan and gross evaporation, but the range in pan evaporation for a given gross evaporation value is much larger than that seen in Figure 19. The correlation between the pan and gross evaporation is reduced in this case to 0.641. The drop in correlation is probably caused by the diverging overall trends that occur between the two.

The second case with opposing trends between pan evaporation and gross evaporation also occurs in Manitoba. Figure 22 plots the raw data and LOWESS smoothed trend lines for Churchill. Figure 22 displays opposing trend slopes for pan evaporation and gross evaporation in August. As pan evaporation increases, gross evaporation decreases until the late 1980s where the trend lines begin to converge toward a simultaneous increasing trend. Similar to the results when comparing pan evaporation in Morden to gross evaporation in Portage La Prairie, a relationship can be made between substantial increases or decreases occurring in pan and gross evaporation. One important difference in this graph is that pan evaporation is not larger than gross evaporation for the majority of the record. This is contrary to the expected behaviour. The scatter plot to further examine their relationship is illustrated in Figure 23.

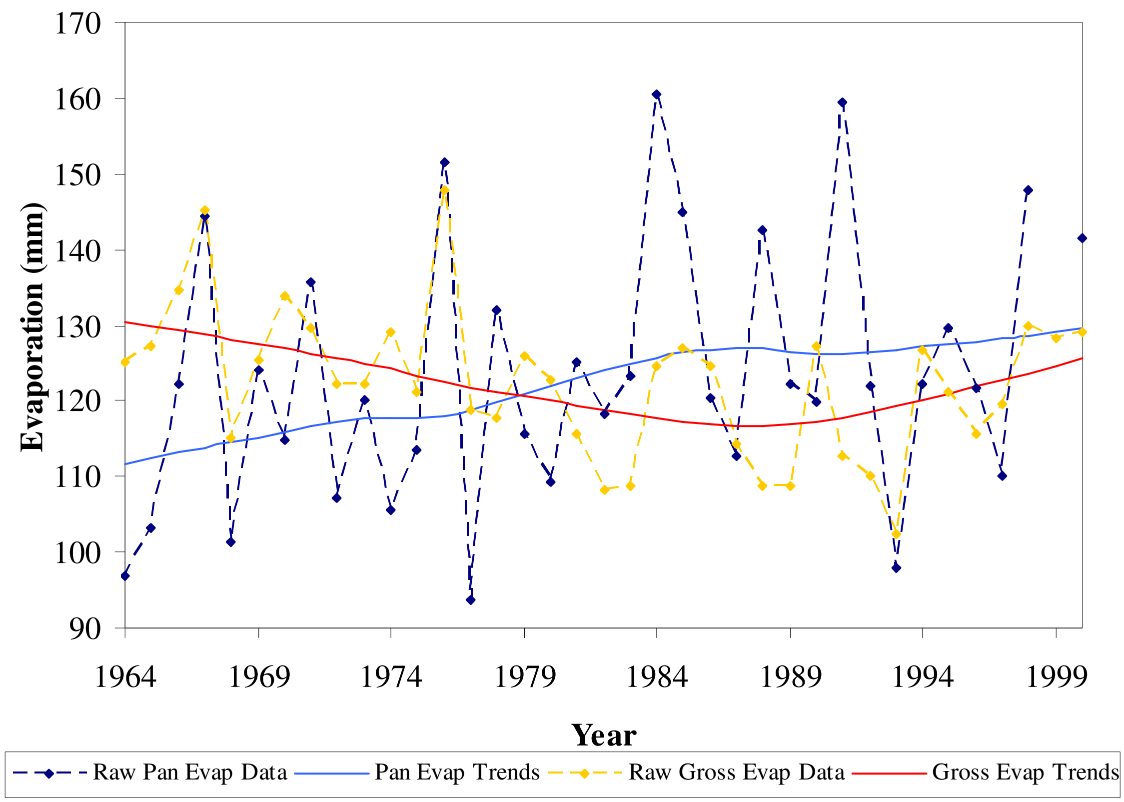

Figure 22: Raw data and LOWESS trend lines at Churchill in August

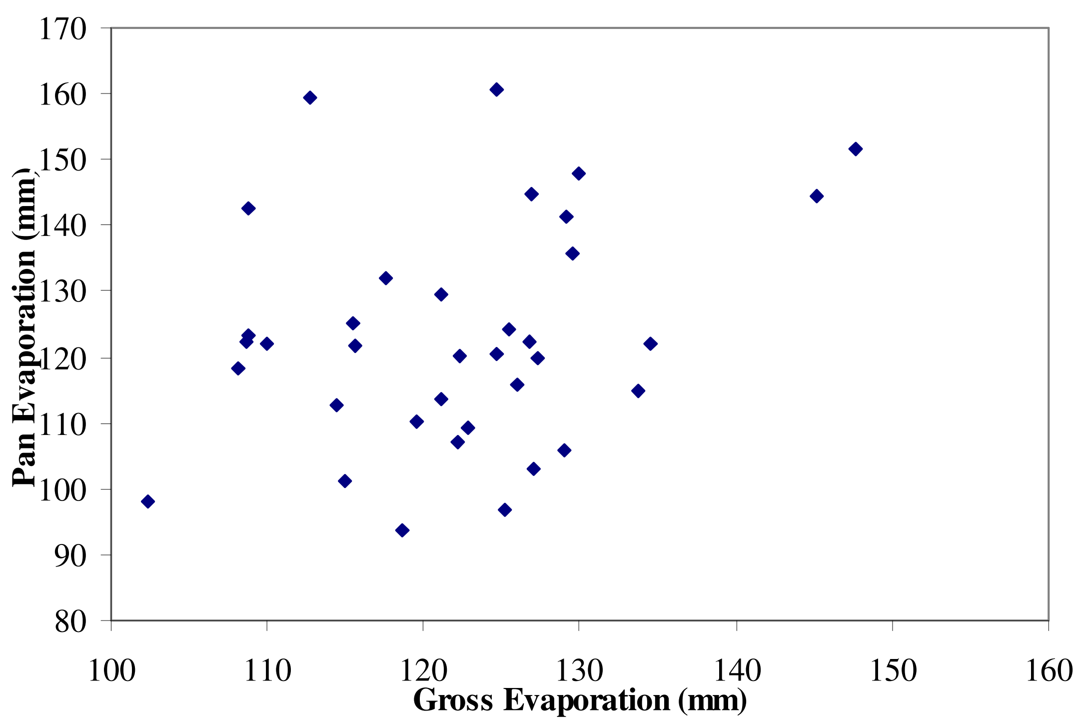

Figure 23: Scatter plot of pan and gross evaporation at Churchill in August (r = 0.28)

When comparing Figure 23 to the previous scatter plots, the positioning of points is more dispersed, creating difficulty in establishing a relationship between pan and gross evaporation. It is understandable after observing the results in Figure 23 that the correlation between pan and gross evaporation in this case is only 0.282. Additional results obtained through the evaluation of pan and gross evaporation were within a close range to displaying opposing trends. Comparing pan evaporation for Weyburn (in June), Churchill (in July) and Norway House Forestry (in September) to gross evaporation for Regina, Churchill and Norway House, respectively showed a wide spread in probabilities. Each case had close to increasing trends for pan evaporation, accompanied by close to decreasing trends for gross evaporation.

4.0 Conclusions and Recommendations

Examining evaporation trends on a monthly and annual basis revealed significant decreasing trends in June, July, October and annual evaporation for the 30, 40 and 50-year time periods. September exhibited a significantly increasing trend in the 30-year period but progressed into a significantly decreasing trend in the 50-year period. The longer record length of 50-years revealed a significant increasing trend in April. The transition of trends between time periods was investigated and the different record lengths were generally found to explain any discrepancies rather than the exclusion of stations when using a longer time period.

Some stations were found to exhibit temporal trends between the time periods. A common decreasing trend in the earlier years of 40-year records caused a high occurrence of cases with no trend in the 30-year period and a decreasing trend in the 40-year period. Comparisons made between the 40 and 50-year period illustrated many cases of decreasing trends changing to no trend with the longer record. Additionally, examples of increasing trends in the 50-year period were found when no trend was present in the 40-year period.

The significant trends were mapped to identify spatial tendencies. In general, increasing trends were typically situated in the more northern regions and decreasing trends in the more southern regions. Spatial tendencies in the 40 and 50-year period became more biased than the 30-year period because many stations in the north-eastern area did not have sufficient record lengths to be included in the longer analysis periods.

Trend slopes were generally negative with a seasonal tendency of decreasing median values from April to July and increasing values from July to September in all three time periods. The months of May, June, July, August and October all have 75^{th} percentile trend slope values below zero in the 40-year period. In the 50-year period the 75^{th} percentiles are equal to or greater than the values in the 30-year period. Increasing tendencies are seen in the 30 and 50-year period for September and April as the median trend slopes are above zero. May also shows a median above zero for the 50-year period, but it lies below zero for the 30-year period.

In general, the majority of the stations are indicating a decreasing nature in evaporation trends. July shows the highest percentage of stations with significant decreasing trends, followed by October. An increasing nature became evident in April as the record length examined lengthened, but the annual evaporation trends remained significantly decreasing for all time periods studied. The spatial distributions show a tendency of increasing trends to occur at more northern stations while decreasing trends are more inclined toward southern stations.

Comparisons were made between gross evaporation trends and pan evaporation trends for 13 stations. In most cases pan and gross evaporation had matching trends, but the majority of these cases involved no trend for either series. Four cases show matching significant trends, all of which are decreasing. Two cases show opposing significant trends, yet graphs still showed similar timing of maximum and minimum values of evaporation. In several cases pan evaporation was less than gross evaporation for part, or all, of the record. In the future, when more reliable pan evaporation data become available, studies should be conducted to further investigate the relationship between pan and gross evaporation.

Further research is recommended to explore the origins of the trends identified in gross evaporation. This can best be done by examining trends in variables that represent inputs to the formula used to calculate gross evaporation and from this determining the contribution of the different variables to the overall trend in evaporation. This investigation should also shed light on the observed differences in evaporation trends for different months, at different locations and during different time periods. An outcome of a study of this nature will be a better capability of projecting future evaporation trends for different climate change scenarios.

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Appendix A

Comparisons for Temporal Trends

Table A1: Comparison between 30 and 40-year period trends

Location	Month	30 Year Trend	40 Year Trend	Type
Brandon	April	none	increasing	1
	May	decreasing	none	2
	June	decreasing	none	2
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	None	2
	Annual	decreasing	none	2
Broadview	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	increasing	none	4
	Oct	increasing	none	4
	Annual	none	none	
Calgary	April	none	none	
	May	none	none	
	June	decreasing	none	2
	July	decreasing	none	2
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Churchill	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Cold Lake	April	none	none	
	May	none	none	
	June	none	decreasing	3
	July	none	decreasing	3
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	none	decreasing	3
Coronation	April	none	none	
	May	decreasing	none	2
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	none	decreasing	3
	Sept	none	none	
	Oct	decreasing	decreasing	

Coronation	Annual	decreasing	decreasing	
Dauphin	April	none	increasing	1
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	none	2
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	decreasing	
Edmonton Intl	April	none	none	
	May	none	none	
	June	none	none	
	July	none	decreasing	3
	Aug	none	none	
	Sept	increasing	none	4
	Oct	none	none	
	Annual	none	decreasing	3
Edmonton Municipal	April	none	none	
	May	none	none	
	June	none	decreasing	3
	July	none	decreasing	3
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Edson	April	increasing	none	4
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	increasing	none	4
	Oct	none	none	
	Annual	increasing	none	4
Estevan	April	none	none	
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	decreasing	none	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Fort McMurray	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	none	increasing	1
	Oct	none	none	
	Annual	none	none	

Fort Nelson	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	decreasing	3
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	none	none	
Fort St. John	April	none	none	
	May	none	decreasing	3
	June	none	decreasing	3
	July	none	decreasing	3
	Aug	none	decreasing	3
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Gimli	April	none	none	
	May	none	decreasing	3
	June	none	decreasing	3
	July	decreasing	decreasing	
	Aug	none	decreasing	3
	Sept	none	decreasing	3
	Oct	none	decreasing	3
	Annual	none	decreasing	3
Grande Prairie	April	increasing	increasing	
	May	none	none	
	June	none	decreasing	3
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	none	none	
Jasper	April	decreasing	none	2
	May	decreasing	decreasing	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	decreasing	3
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Kindersley	April	none	increasing	1
	May	increasing	none	4
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	

Lethbridge	April	none	none	
	May	none	none	
	June	decreasing	none	2
	July	none	decreasing	3
	Aug	none	none	
	Sept	none	none	
	Oct	none	decreasing	3
	Annual	none	none	
Medicine Hat	April	none	none	
	May	none	none	
	June	decreasing	none	2
	July	none	none	
	Aug	none	decreasing	3
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Moose Jaw	April	none	none	
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	none	decreasing	3
	Sept	none	decreasing	3
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
North Battleford	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	none	
	Oct	decreasing	none	2
	Annual	decreasing	decreasing	
Peace River	April	increasing	increasing	
	May	none	increasing	1
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	increasing	increasing	
	Oct	none	none	
	Annual	none	none	
Pincher Creek	April	none	none	
	May	none	none	
	June	decreasing	none	2
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	decreasing	3
	Annual	none	none	

Portage La Prairie	April	none	none	
	May	decreasing	none	2
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	decreasing	none	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Prince Albert	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	none	2
	Annual	none	none	
Red Deer	April	none	none	
	May	none	decreasing	3
	June	none	decreasing	3
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	decreasing	3
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Regina	April	none	none	
	May	none	none	
	June	decreasing	none	2
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Rocky Mtn House	April	none	none	
	May	decreasing	none	2
	June	decreasing	none	2
	July	decreasing	none	2
	Aug	decreasing	decreasing	
	Sept	decreasing	none	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Saskatoon	April	none	none	
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	none	
	Oct	decreasing	none	2
	Annual	decreasing	decreasing	

Swift Current	April	none	none	
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	none	decreasing	3
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
The Pas	April	none	none	
	May	none	decreasing	3
	June	none	decreasing	3
	July	none	decreasing	3
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	decreasing	3
Whitecourt	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	increasing	none	4
	Oct	none	none	
	Annual	none	none	
Winnipeg	April	none	increasing	1
	May	none	none	
	June	none	decreasing	3
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	decreasing	
Wynyard	April	none	none	
	May	none	decreasing	3
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	none	
	Oct	decreasing	none	2
	Annual	decreasing	decreasing	
Yorkton	April	none	none	
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	decreasing	3
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	

Table A2: Comparison between 40 and 50-year period trends

Location	Month	40 Year Trend	50 Year Trend	Type
Brandon	April	increasing	increasing	
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Broadview	April	increasing	increasing	
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Calgary	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Churchill	April	none	none	
	May	none	none	
	June	none	increasing	1
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	none	none	
Cold Lake	April	none	none	
	May	none	decreasing	2
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	decreasing	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Coronation	April	none	increasing	1
	May	none	none	
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	none	4

Coronation	Annual	decreasing	none	4
Dauphin	April	increasing	increasing	
	May	none	none	
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	none	4
Edmonton Municipal	April	none	increasing	1
	May	none	none	
	June	decreasing	none	4
	July	decreasing	none	4
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	none	4
	Annual	decreasing	none	4
Estevan	April	none	none	
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	none	4
Fort McMurray	April	none	increasing	1
	May	none	increasing	1
	June	none	increasing	1
	July	none	none	
	Aug	none	none	
	Sept	increasing	increasing	
	Oct	none	none	
	Annual	none	increasing	1
Fort Nelson	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	none	none	
Fort St. John	April	none	none	
	May	decreasing	decreasing	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	decreasing	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	

Gimli	April	none	none	
	May	decreasing	decreasing	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	decreasing	decreasing	
	Oct	decreasing	none	4
	Annual	decreasing	decreasing	
Grande Prairie	April	increasing	increasing	
	May	none	none	
	June	decreasing	none	4
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	none	none	
Lethbridge	April	none	none	
	May	none	none	
	June	none	none	
	July	decreasing	none	4
	Aug	none	none	
	Sept	none	none	
	Oct	decreasing	none	4
	Annual	none	none	
Medicine Hat	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	none	4
Moose Jaw	April	none	none	
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	decreasing	decreasing	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
North Battleford	April	increasing	increasing	
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	decreasing	

Peace River	April	increasing	increasing	
	May	increasing	increasing	
	June	none	increasing	1
	July	none	none	
	Aug	none	none	
	Sept	increasing	increasing	
	Oct	none	increasing	1
	Annual	none	increasing	1
Portage La Prairie	April	none	increasing	1
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	
Prince Albert	April	increasing	increasing	
	May	none	none	
	June	none	none	
	July	decreasing	none	4
	Aug	none	none	
	Sept	none	increasing	1
	Oct	none	none	
	Annual	none	none	
Red Deer	April	none	increasing	1
	May	decreasing	none	4
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	decreasing	none	4
	Oct	decreasing	none	4
	Annual	decreasing	decreasing	
Regina	April	none	increasing	1
	May	none	none	
	June	none	none	
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	none	4
	Annual	decreasing	none	4
Rocky Mtn House	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	decreasing	none	4
	Sept	none	decreasing	2
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	

Saskatoon	April	none	increasing	1
	May	none	none	
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	none	4
Swift Current	April	none	none	
	May	none	none	
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	decreasing	none	4
	Sept	none	none	
	Oct	decreasing	decreasing	
	Annual	decreasing	none	4
The Pas	April	none	none	
	May	decreasing	none	4
	June	decreasing	none	4
	July	decreasing	none	4
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	none	4
Whitecourt	April	none	none	
	May	none	none	
	June	none	none	
	July	none	none	
	Aug	none	none	
	Sept	none	none	
	Oct	none	decreasing	2
	Annual	none	none	
Winnipeg	April	increasing	none	3
	May	none	none	
	June	decreasing	none	4
	July	decreasing	decreasing	
	Aug	none	none	
	Sept	none	none	
	Oct	none	none	
	Annual	decreasing	decreasing	
Yorkton	April	none	increasing	1
	May	none	none	
	June	decreasing	decreasing	
	July	decreasing	decreasing	
	Aug	decreasing	decreasing	
	Sept	decreasing	decreasing	
	Oct	decreasing	decreasing	
	Annual	decreasing	decreasing	

Table A3: Comparison of 30, 40 and 50-year period trends

Location	Month	30 Year Trend	40 year Trend	50 Year Trend
Brandon	April	none	increasing	increasing
	May	decreasing	none	none
	June	decreasing	none	none
	July	decreasing	decreasing	decreasing
	August	none	none	none
	September	none	none	none
	October	decreasing	none	none
	Annual	decreasing	none	none
Broadview	April	none	increasing	increasing
	May	none	none	none
	June	none	none	none
	July	decreasing	decreasing	decreasing
	August	none	none	none
	September	increasing	none	none
	October	increasing	none	none
	Annual	none	none	none
Calgary	April	none	none	increasing
	May	none	none	none
	June	decreasing	none	none
	July	decreasing	none	none
	August	none	none	none
	September	none	none	none
	October	none	none	none
	Annual	none	none	none
Churchill	April	none	none	none
	May	none	none	none
	June	none	none	increasing
	July	none	none	none
	August	none	none	none
	September	none	none	none
	October	none	none	none
	Annual	none	none	none
Cold Lake	April	none	none	none
	May	none	none	decreasing
	June	none	decreasing	decreasing
	July	none	decreasing	decreasing
	August	none	none	none
	September	none	none	decreasing
	October	decreasing	decreasing	decreasing
	Annual	none	decreasing	decreasing
Coronation	April	none	none	increasing
	May	decreasing	none	none
	June	decreasing	decreasing	none
	July	decreasing	decreasing	decreasing
	August	none	decreasing	none
	September	none	none	none
	October	decreasing	decreasing	none

Coronation	Annual	decreasing	decreasing	none
Dauphin	April	none	increasing	increasing
	May	none	none	none
	June	decreasing	decreasing	none
	July	decreasing	decreasing	decreasing
	August	decreasing	none	none
	September	none	none	none
	October	none	none	none
	Annual	decreasing	decreasing	none
Edmonton Municipal	April	none	none	increasing
	May	none	none	none
	June	none	decreasing	none
	July	none	decreasing	none
	August	none	none	none
	September	none	none	none
	October	decreasing	decreasing	none
	Annual	decreasing	decreasing	none
Estevan	April	none	none	none
	May	none	none	none
	June	none	none	none
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	none
	September	decreasing	none	none
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	none
Fort McMurray	April	none	none	increasing
	May	none	none	increasing
	June	none	none	increasing
	July	none	none	none
	August	none	none	none
	September	none	increasing	increasing
	October	none	none	none
	Annual	none	none	increasing
Fort Nelson	April	none	none	increasing
	May	none	none	none
	June	none	none	none
	July	none	none	none
	August	none	decreasing	none
	September	none	none	none
	October	decreasing	decreasing	decreasing
	Annual	none	none	none
Fort St. John	April	none	none	none
	May	none	decreasing	decreasing
	June	none	decreasing	decreasing
	July	none	decreasing	decreasing
	August	none	decreasing	decreasing
	September	none	none	decreasing
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	decreasing

Gimli	April	none	none	none
	May	none	decreasing	decreasing
	June	none	decreasing	decreasing
	July	decreasing	decreasing	decreasing
	August	none	decreasing	decreasing
	September	none	decreasing	decreasing
	October	none	decreasing	none
	Annual	none	decreasing	decreasing
Grande Prairie	April	increasing	increasing	increasing
	May	none	none	none
	June	none	decreasing	none
	July	none	none	none
	August	none	none	none
	September	none	none	none
	October	decreasing	decreasing	decreasing
	Annual	none	none	none
Lethbridge	April	none	none	none
	May	none	none	none
	June	decreasing	none	none
	July	none	decreasing	none
	August	none	none	none
	September	none	none	none
	October	none	decreasing	none
	Annual	none	none	none
Medicine Hat	April	none	none	increasing
	May	none	none	none
	June	decreasing	none	none
	July	none	none	none
	August	none	decreasing	none
	September	none	none	none
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	none
Moose Jaw	April	none	none	none
	May	none	none	none
	June	decreasing	decreasing	decreasing
	July	decreasing	decreasing	decreasing
	August	none	decreasing	decreasing
	September	none	decreasing	decreasing
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	decreasing
North Battleford	April	none	increasing	increasing
	May	none	none	none
	June	none	none	none
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	none
	September	none	none	none
	October	decreasing	none	none
	Annual	decreasing	decreasing	decreasing

Peace River	April	increasing	increasing	increasing
	May	none	increasing	increasing
	June	none	none	increasing
	July	none	none	none
	August	none	none	none
	September	increasing	increasing	increasing
	October	none	none	increasing
	Annual	none	none	increasing
Portage La Prairie	April	none	none	increasing
	May	decreasing	none	none
	June	decreasing	decreasing	decreasing
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	decreasing
	September	decreasing	none	none
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	decreasing
Prince Albert	April	none	increasing	increasing
	May	none	none	none
	June	none	none	none
	July	decreasing	decreasing	none
	August	none	none	none
	September	none	none	increasing
	October	decreasing	none	none
	Annual	none	none	none
Red Deer	April	none	none	increasing
	May	none	decreasing	none
	June	none	decreasing	none
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	none
	September	none	decreasing	none
	October	decreasing	decreasing	none
	Annual	decreasing	decreasing	decreasing
Regina	April	none	none	increasing
	May	none	none	none
	June	decreasing	none	none
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	none
	September	none	none	none
	October	decreasing	decreasing	none
	Annual	decreasing	decreasing	none
Rocky Mtn House	April	none	none	none
	May	decreasing	none	none
	June	decreasing	none	none
	July	decreasing	none	none
	August	decreasing	decreasing	none
	September	decreasing	none	decreasing
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	decreasing

Saskatoon	April	none	none	increasing
	May	none	none	none
	June	decreasing	decreasing	none
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	none
	September	none	none	none
	October	decreasing	none	none
	Annual	decreasing	decreasing	none
Swift Current	April	none	none	none
	May	none	none	none
	June	decreasing	decreasing	none
	July	decreasing	decreasing	decreasing
	August	none	decreasing	none
	September	none	none	none
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	none
The Pas	April	none	none	none
	May	none	decreasing	none
	June	none	decreasing	none
	July	none	decreasing	none
	August	none	none	none
	September	none	none	none
	October	none	none	none
	Annual	none	decreasing	none
Whitecourt	April	none	none	none
	May	none	none	none
	June	none	none	none
	July	none	none	none
	August	none	none	none
	September	increasing	none	none
	October	none	none	decreasing
	Annual	none	none	none
Winnipeg	April	none	increasing	none
	May	none	none	none
	June	none	decreasing	none
	July	decreasing	decreasing	decreasing
	August	none	none	none
	September	none	none	none
	October	none	none	none
	Annual	decreasing	decreasing	decreasing
Yorkton	April	none	none	increasing
	May	none	none	none
	June	decreasing	decreasing	decreasing
	July	decreasing	decreasing	decreasing
	August	decreasing	decreasing	decreasing
	September	none	decreasing	decreasing
	October	decreasing	decreasing	decreasing
	Annual	decreasing	decreasing	decreasing

Appendix B

Maps of Spatial Distribution of Trends

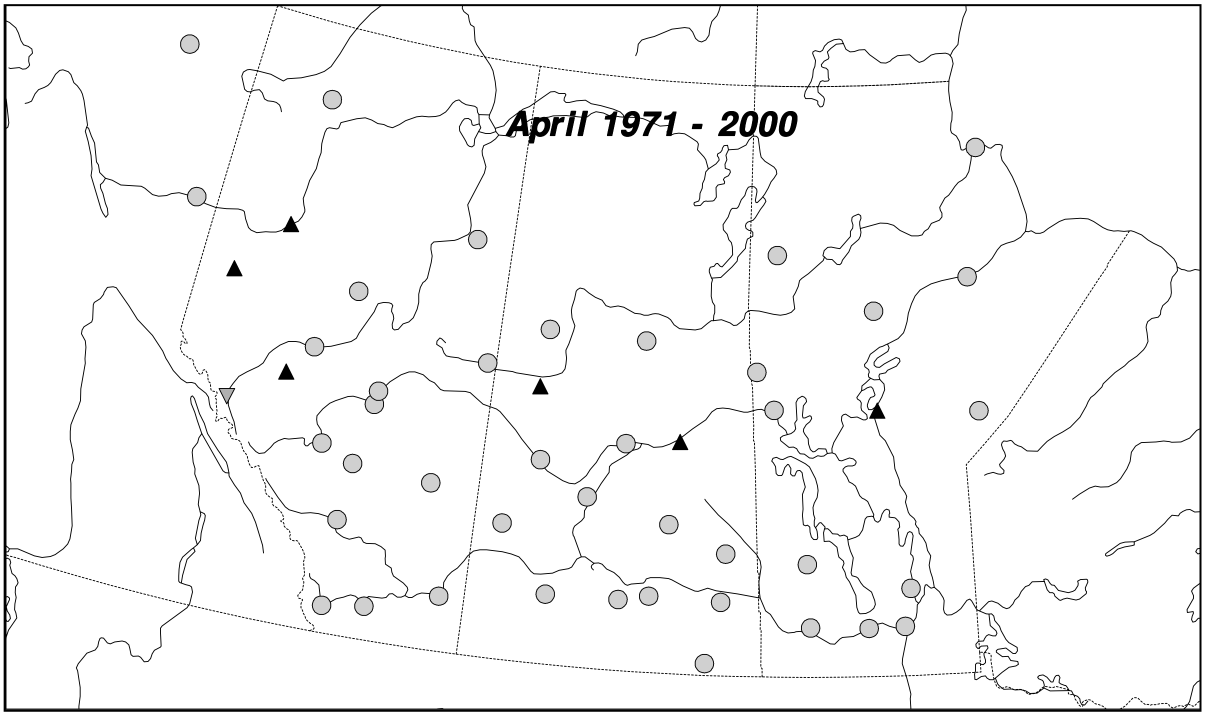

Figure B1: Evaporation trends in April from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

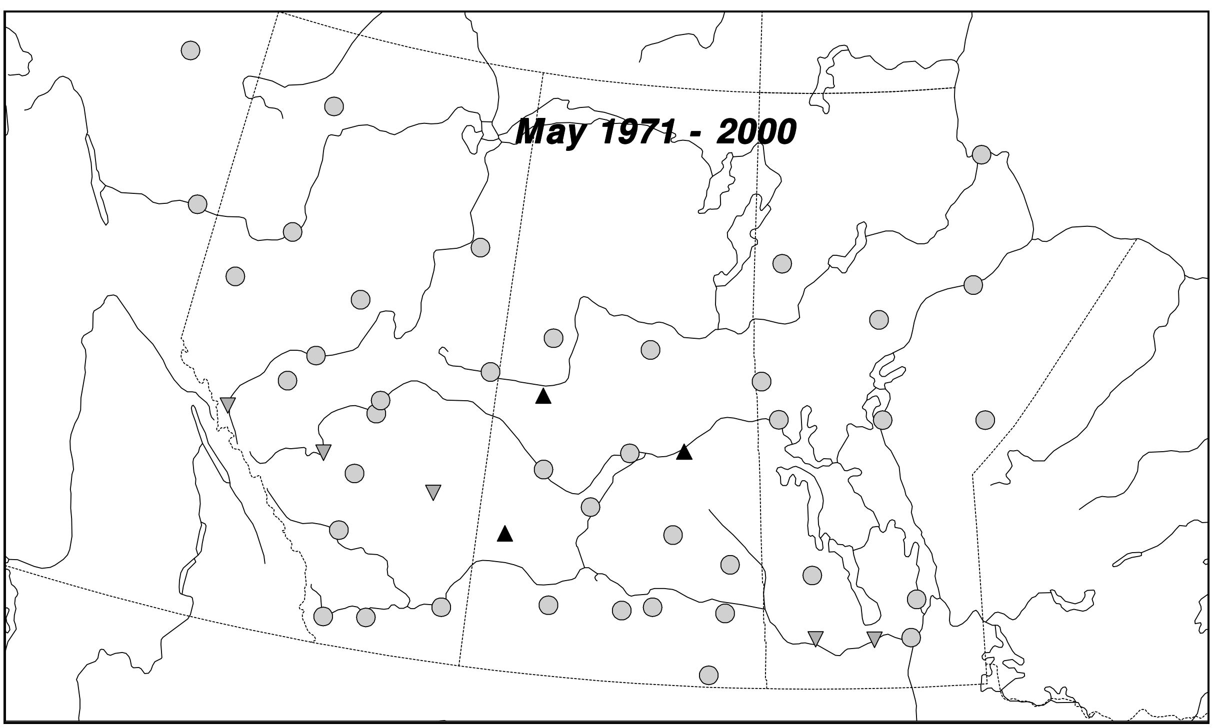

Figure B2: Evaporation trends in May from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

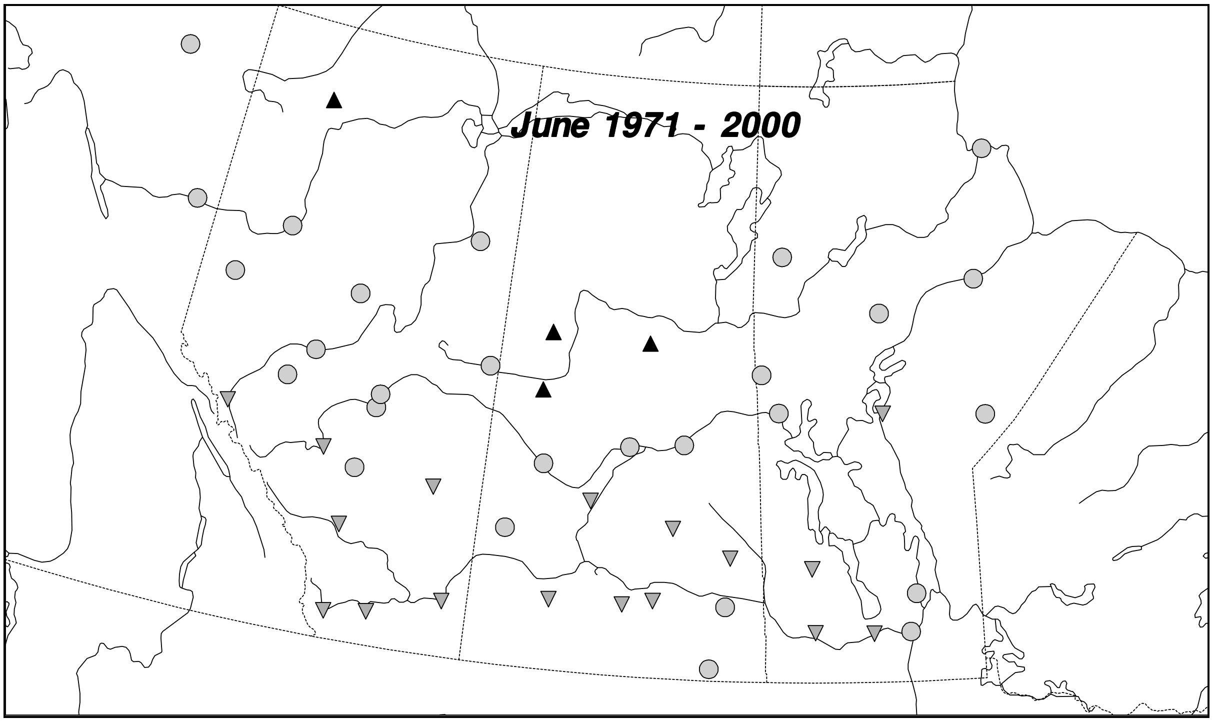

Figure B3: Evaporation trends in June from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

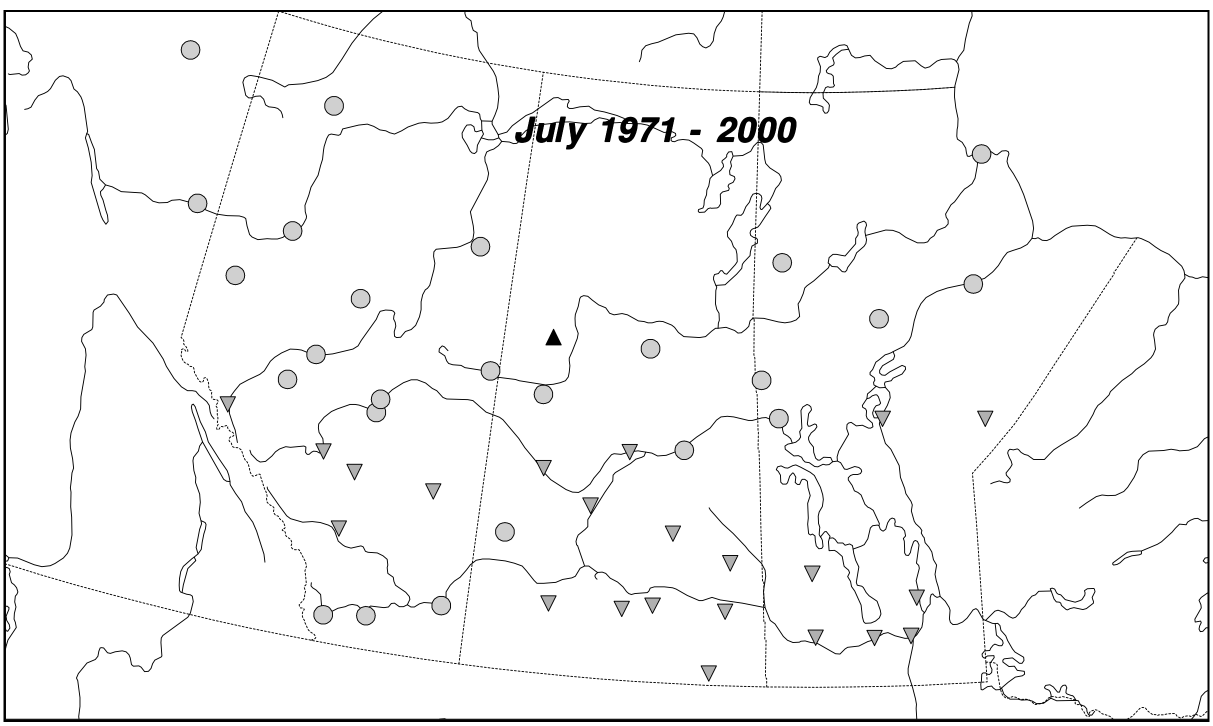

Figure B4: Evaporation trends in July from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

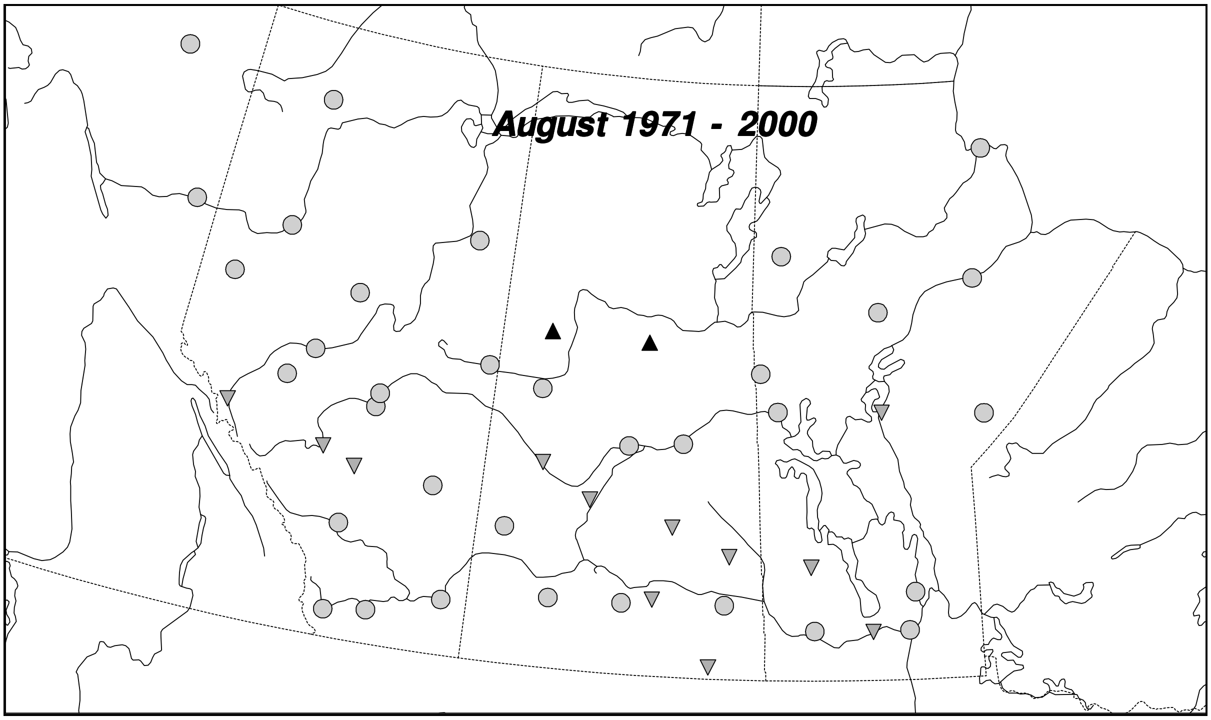

Figure B5: Evaporation trends in August from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

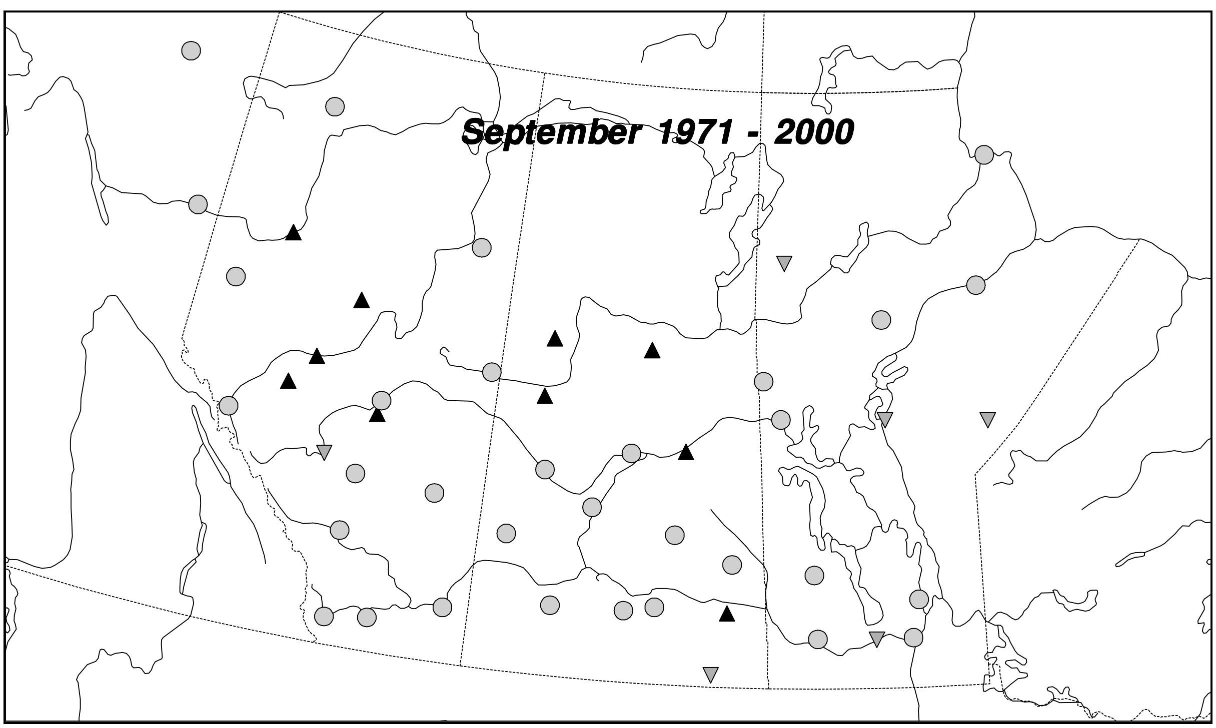

Figure B6: Evaporation trends in September from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

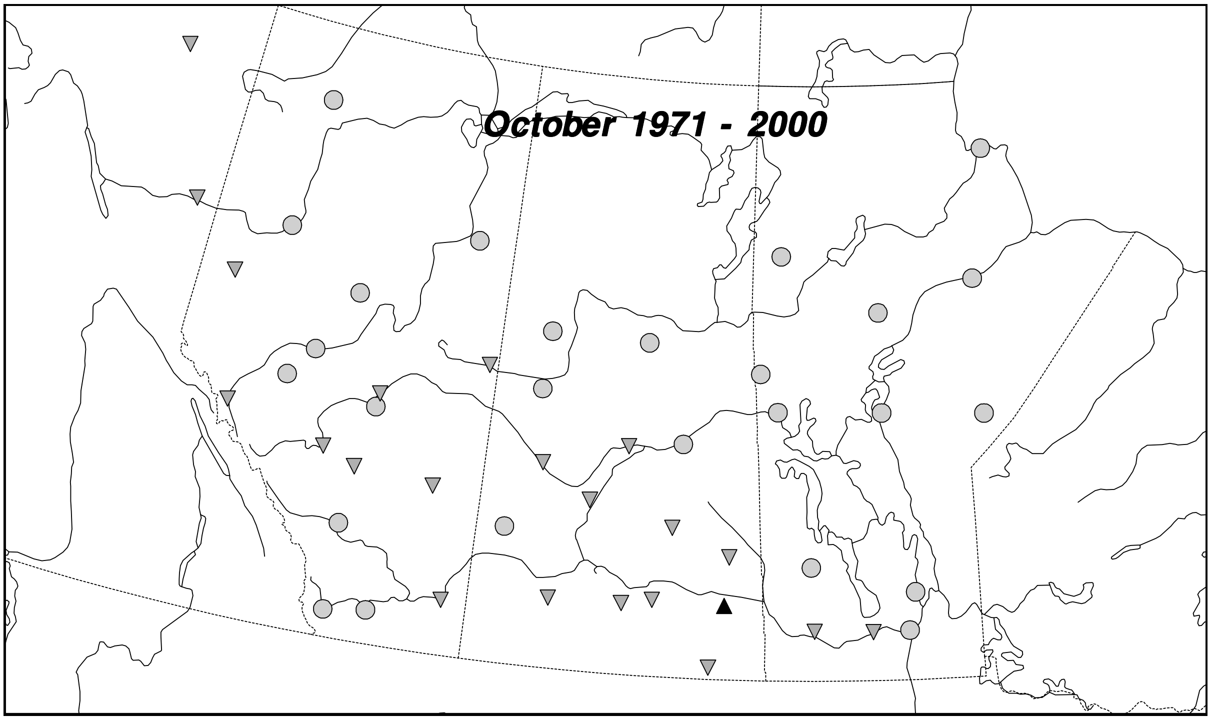

Figure B7: Evaporation trends in October from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

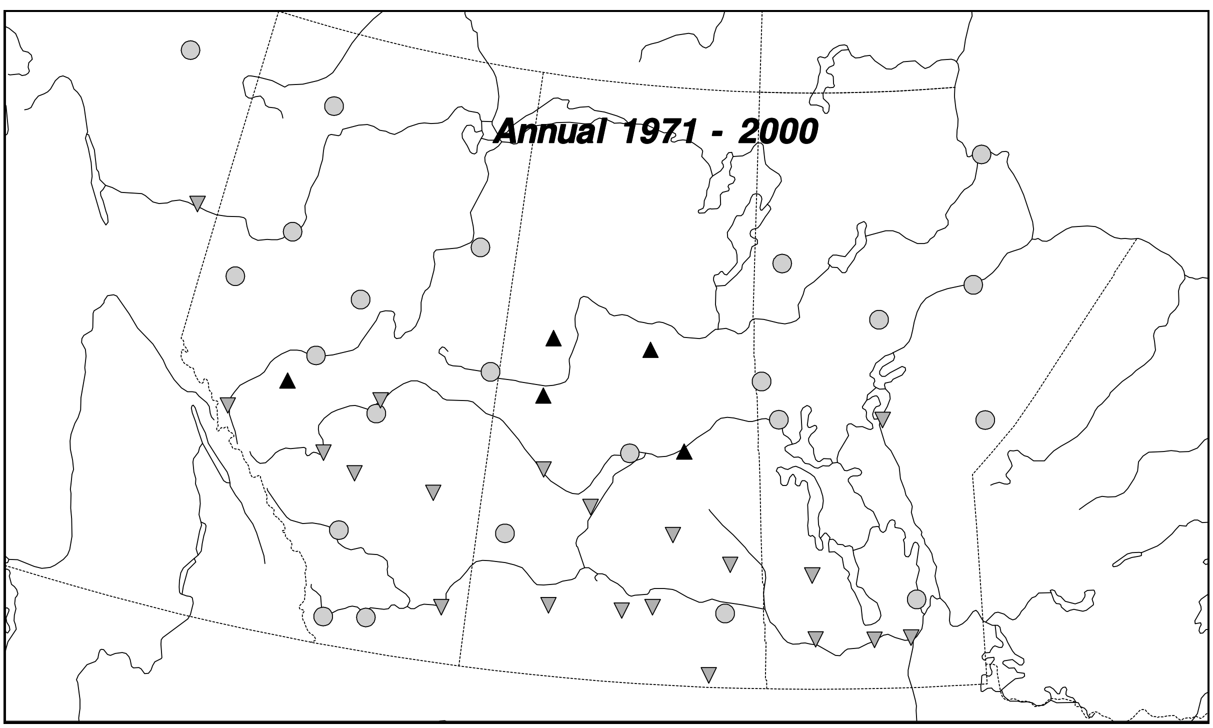

Figure B8: Annual evaporation trends from 1971-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

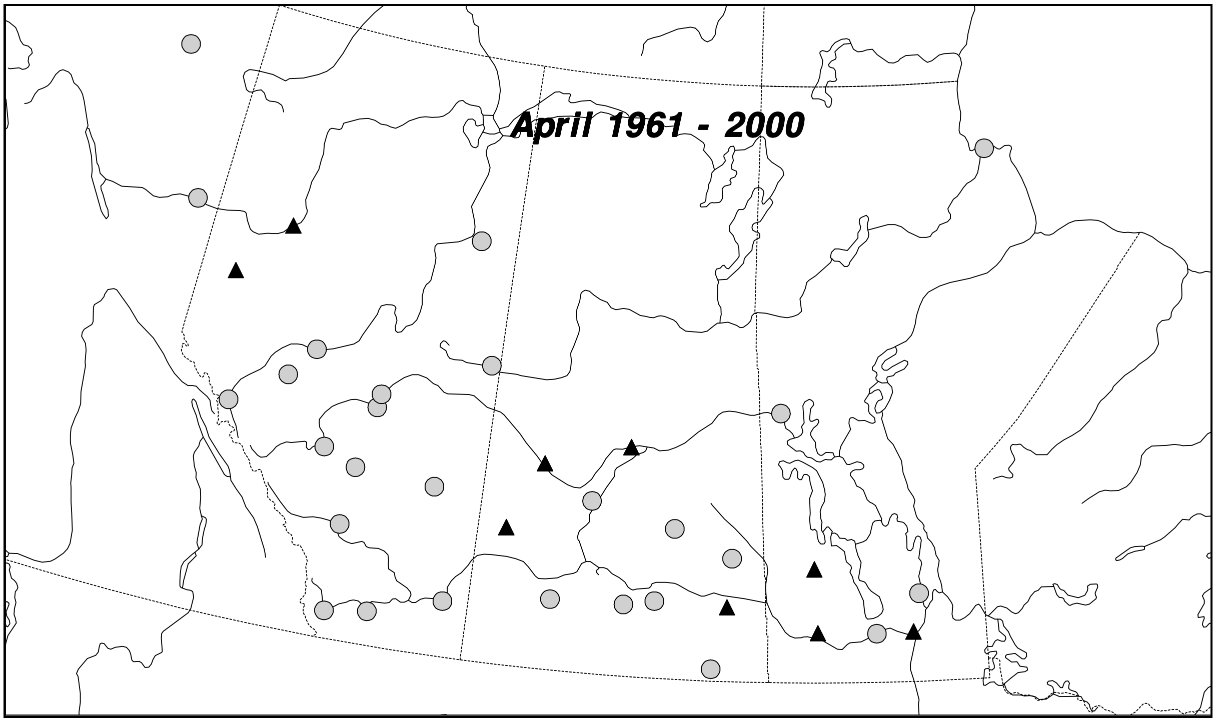

Figure B9: Evaporation trends in April from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

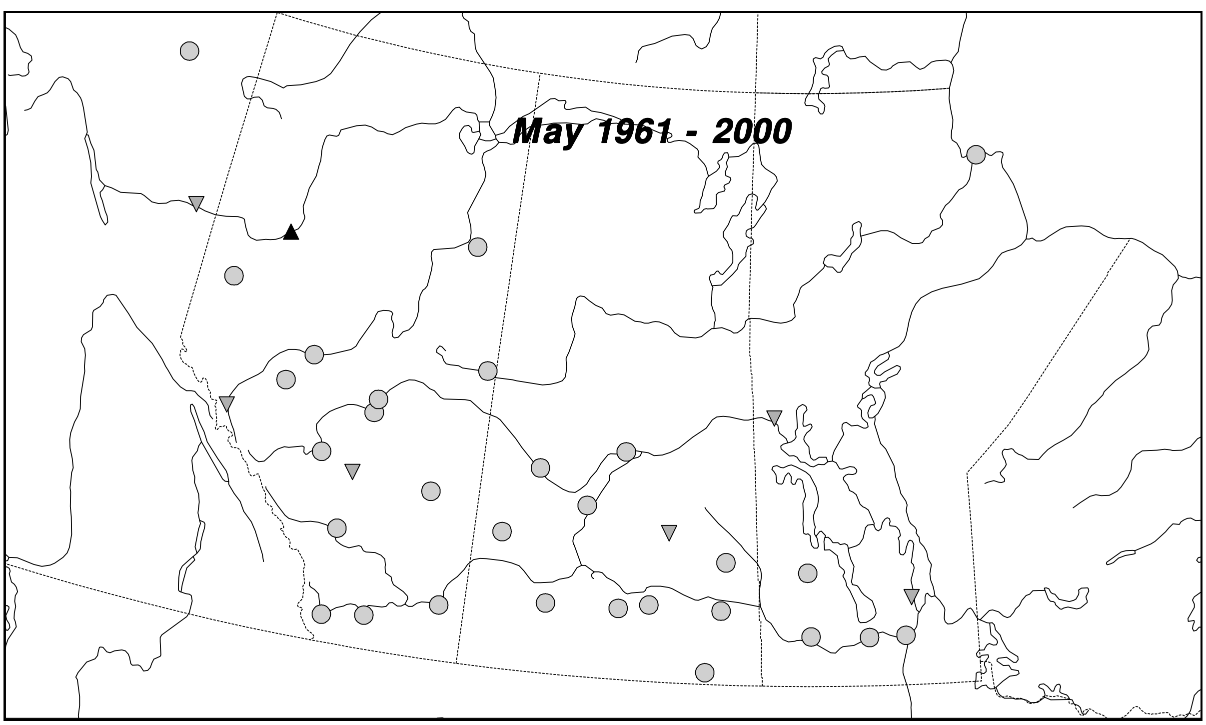

Figure B10: Evaporation trends in May from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

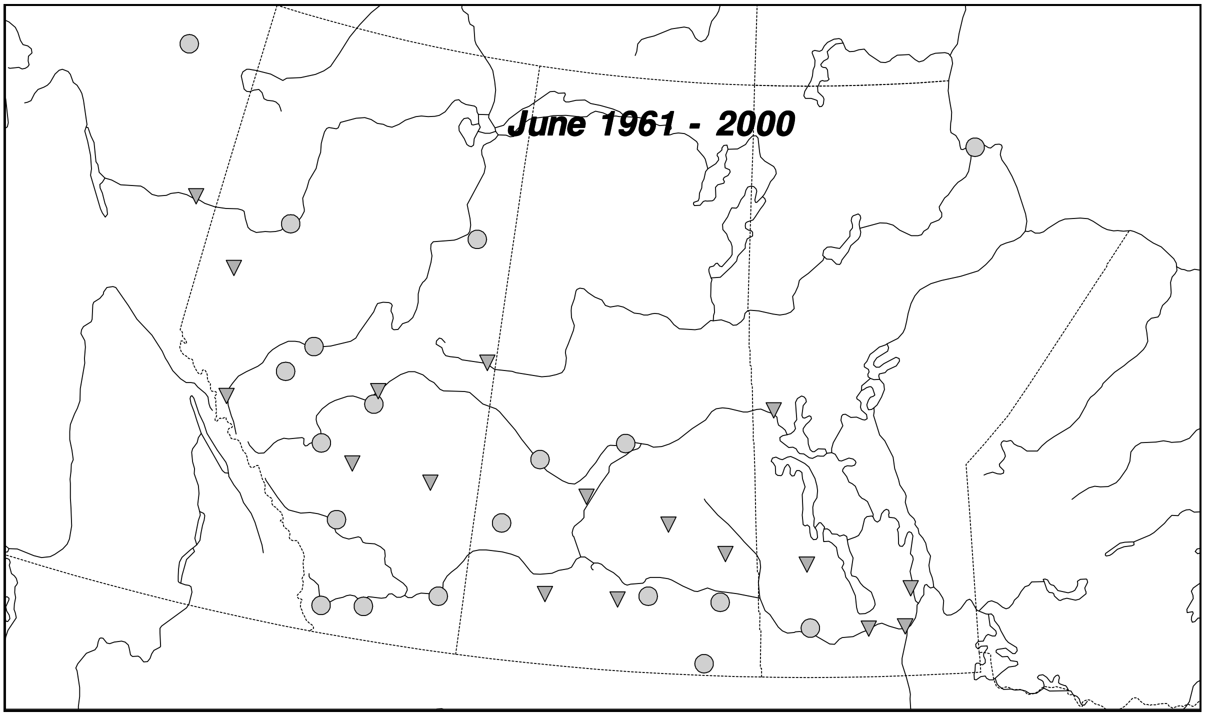

Figure B11: Evaporation trends in June from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

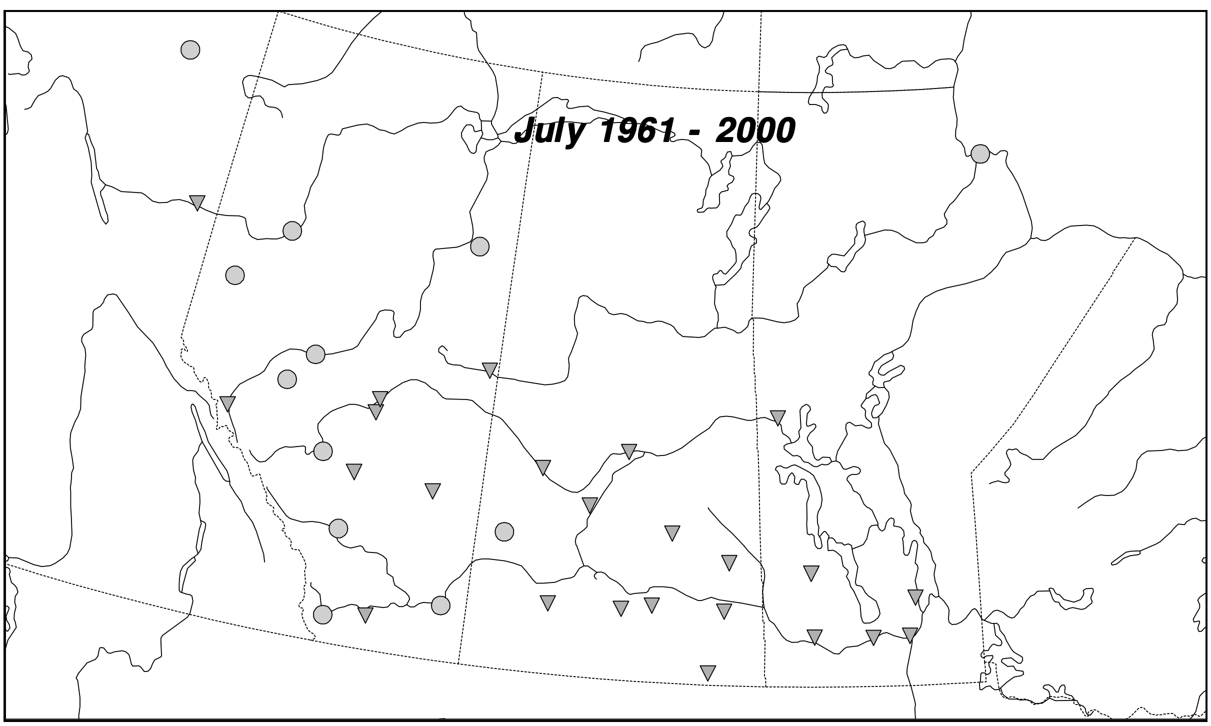

Figure B12: Evaporation trends in July from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

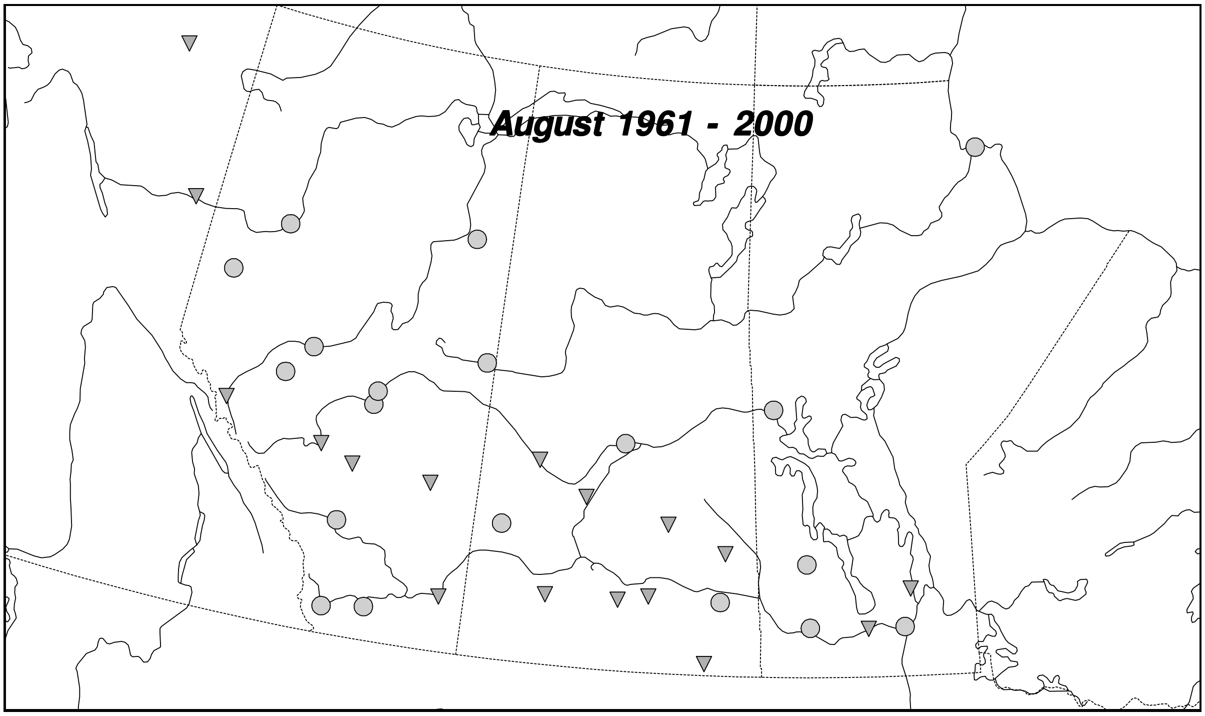

Figure B13: Evaporation trends in August from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

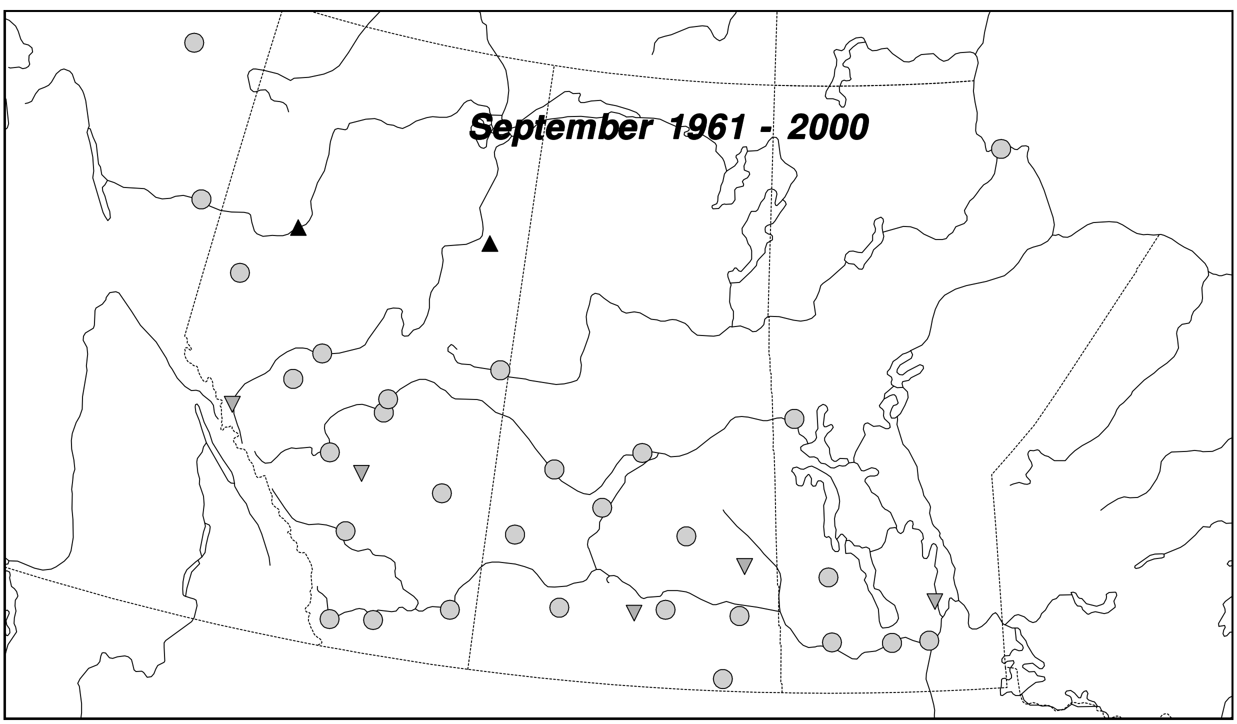

Figure B14: Evaporation trends in September from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

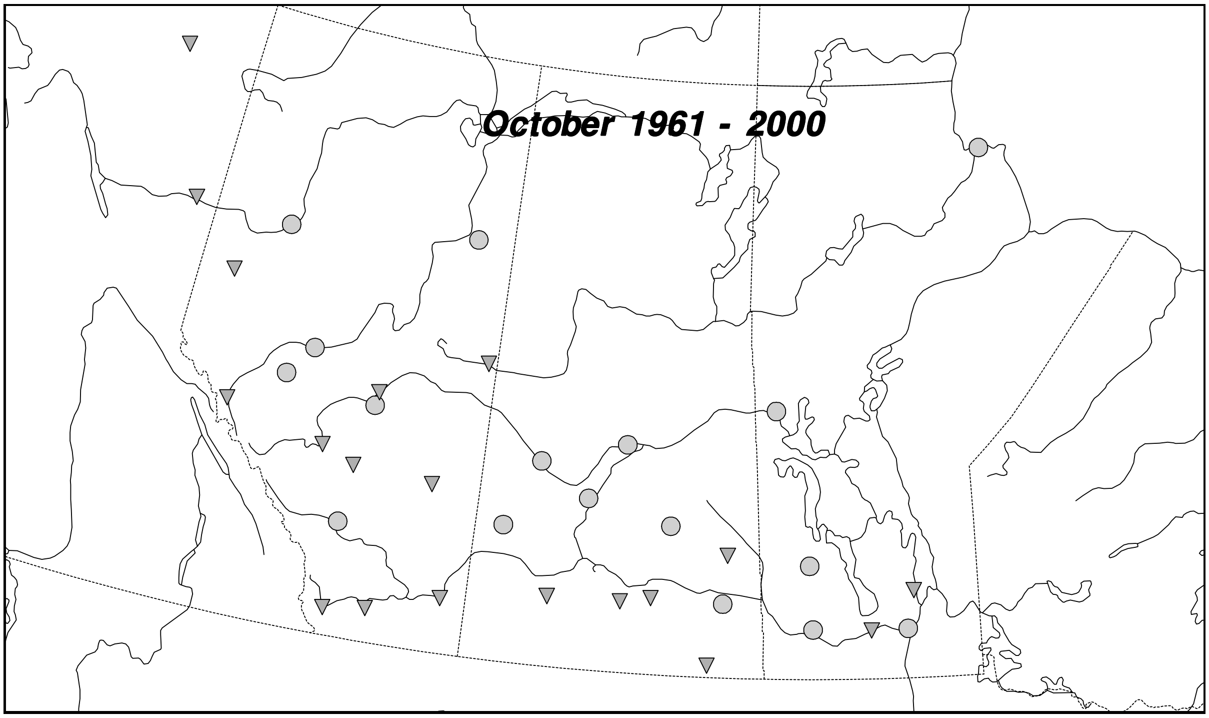

Figure B15: Evaporation trends in October from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

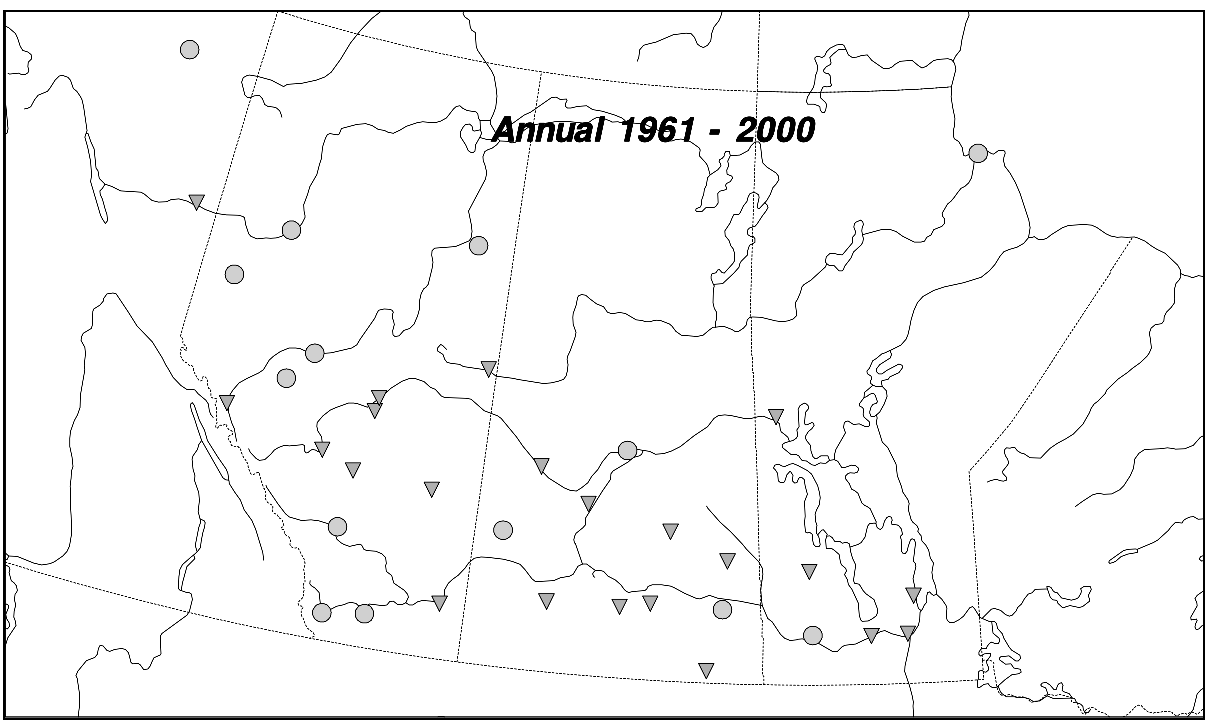

Figure B16: Annual evaporation trends from 1961-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

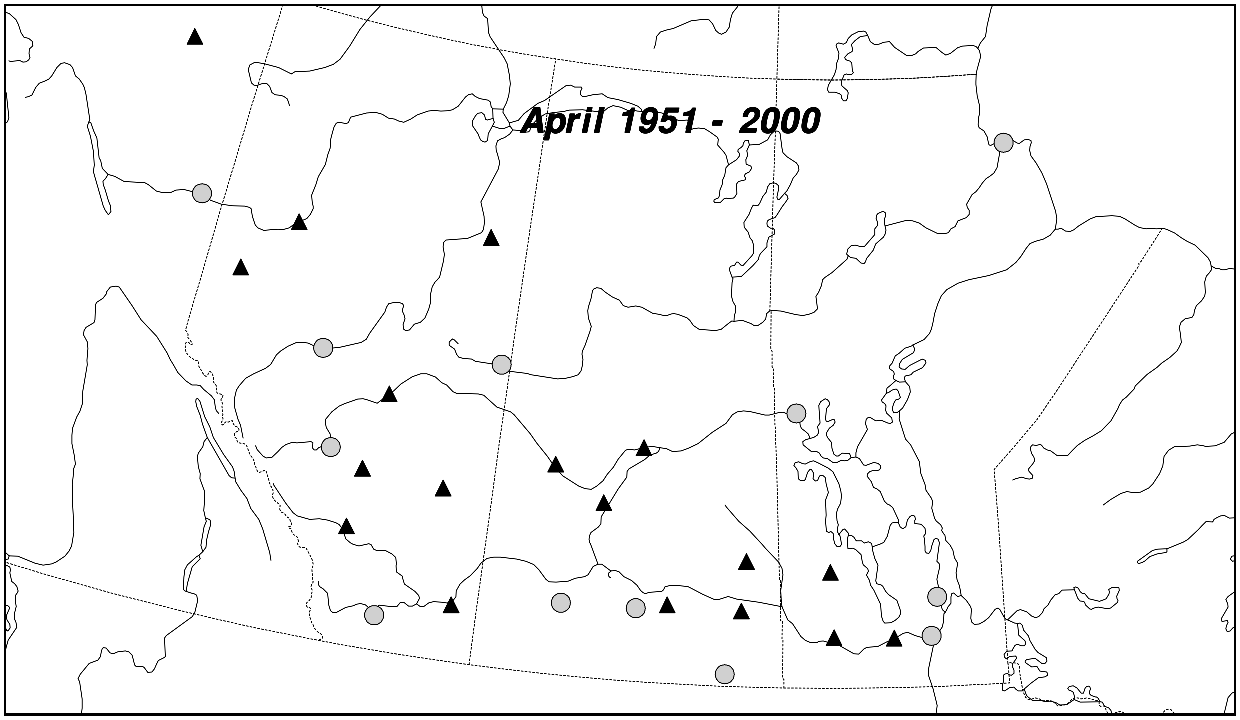

Figure B17: Evaporation trends in April from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

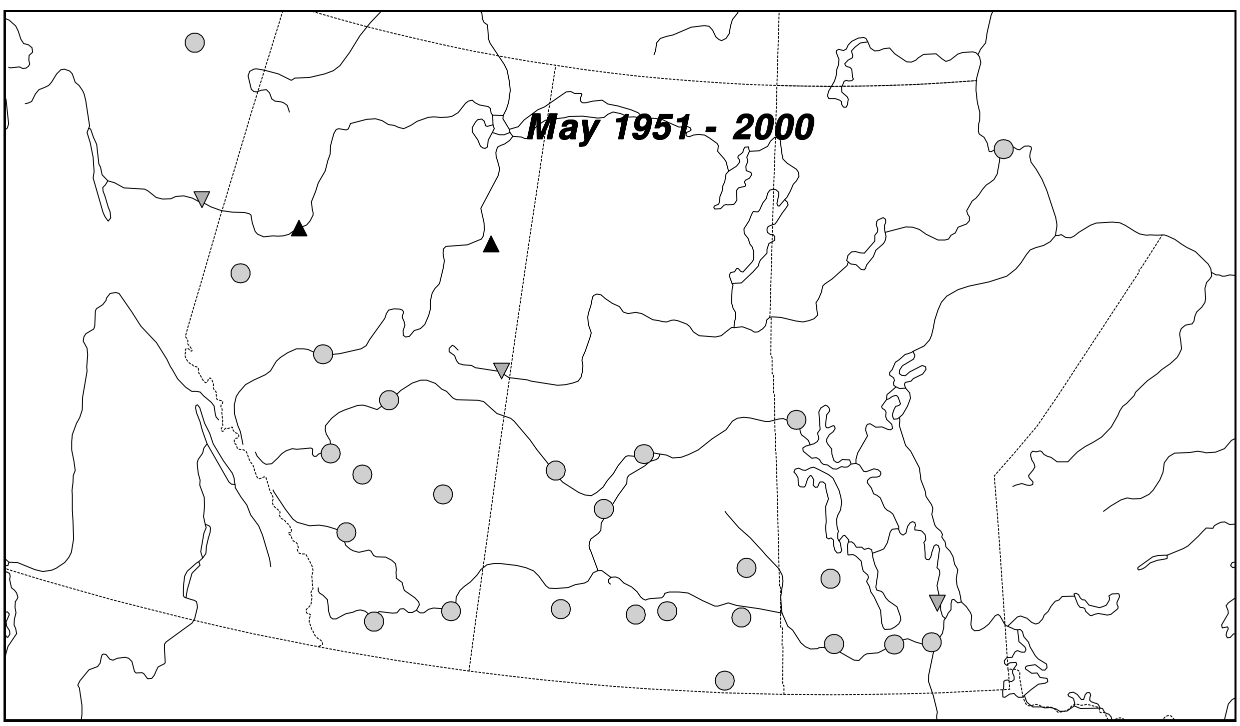

Figure B18: Evaporation trends in May from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

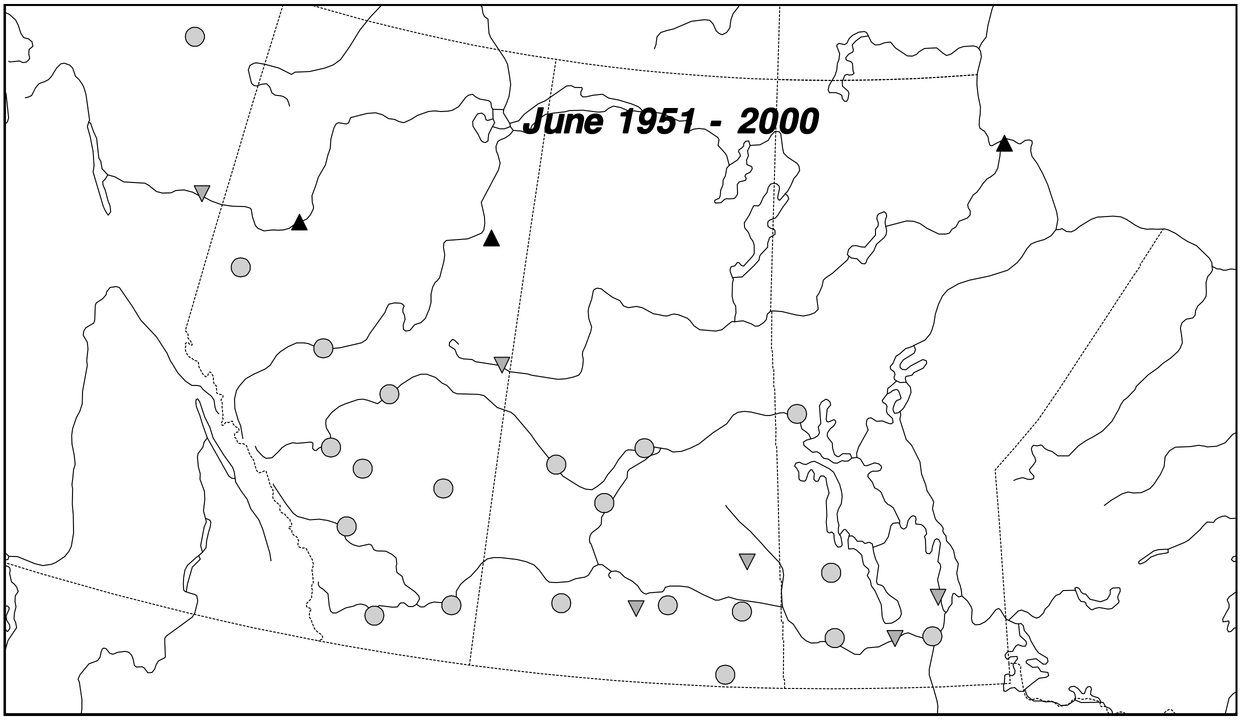

Figure B19: Evaporation trends in June from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

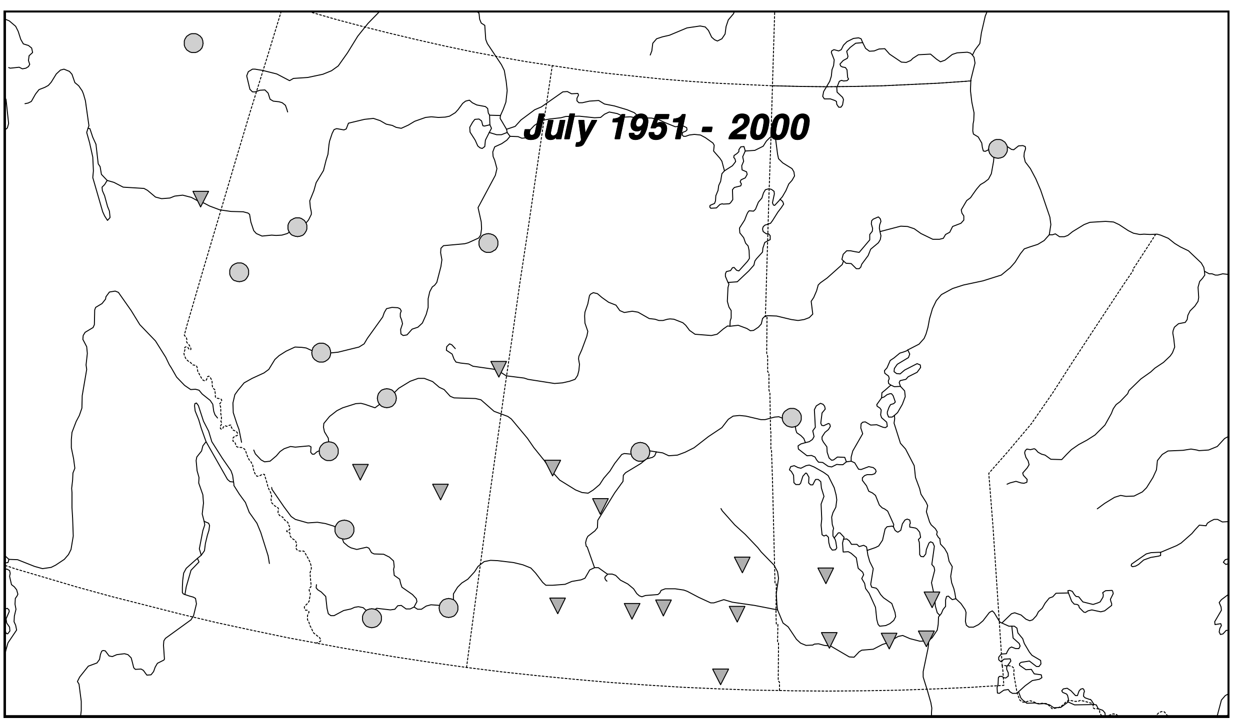

Figure B20: Evaporation trends in July from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

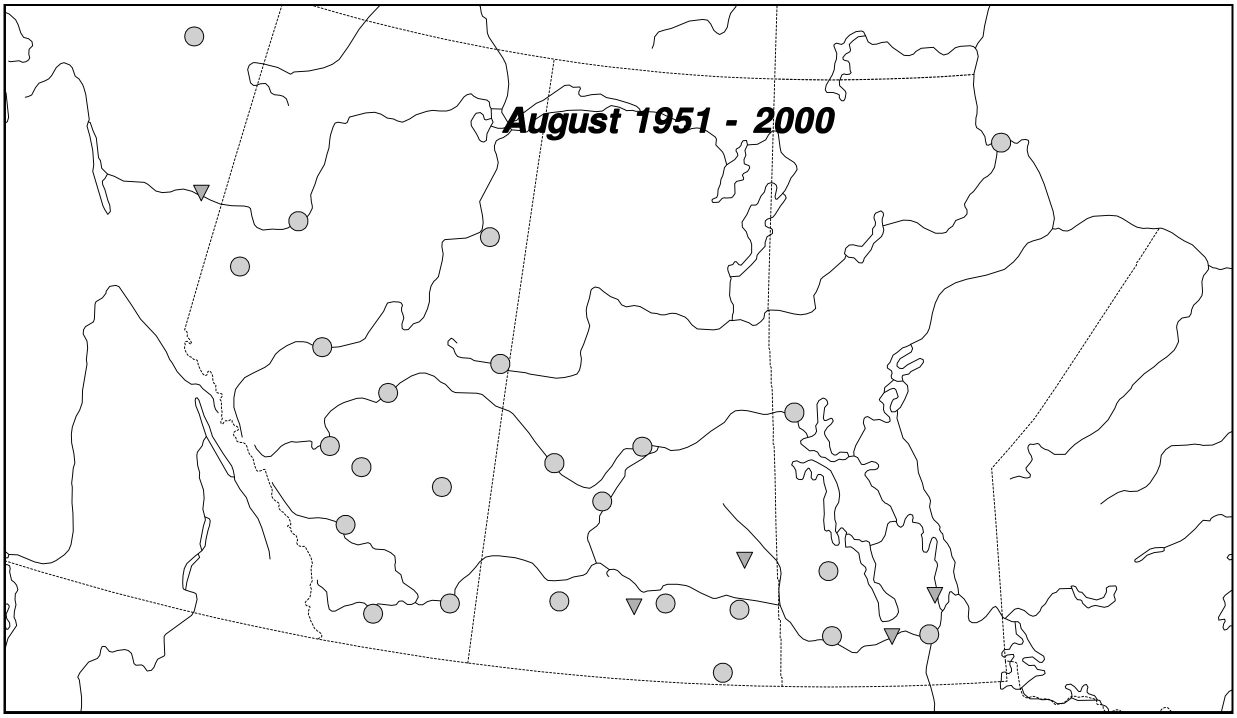

Figure B21: Evaporation trends in August from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

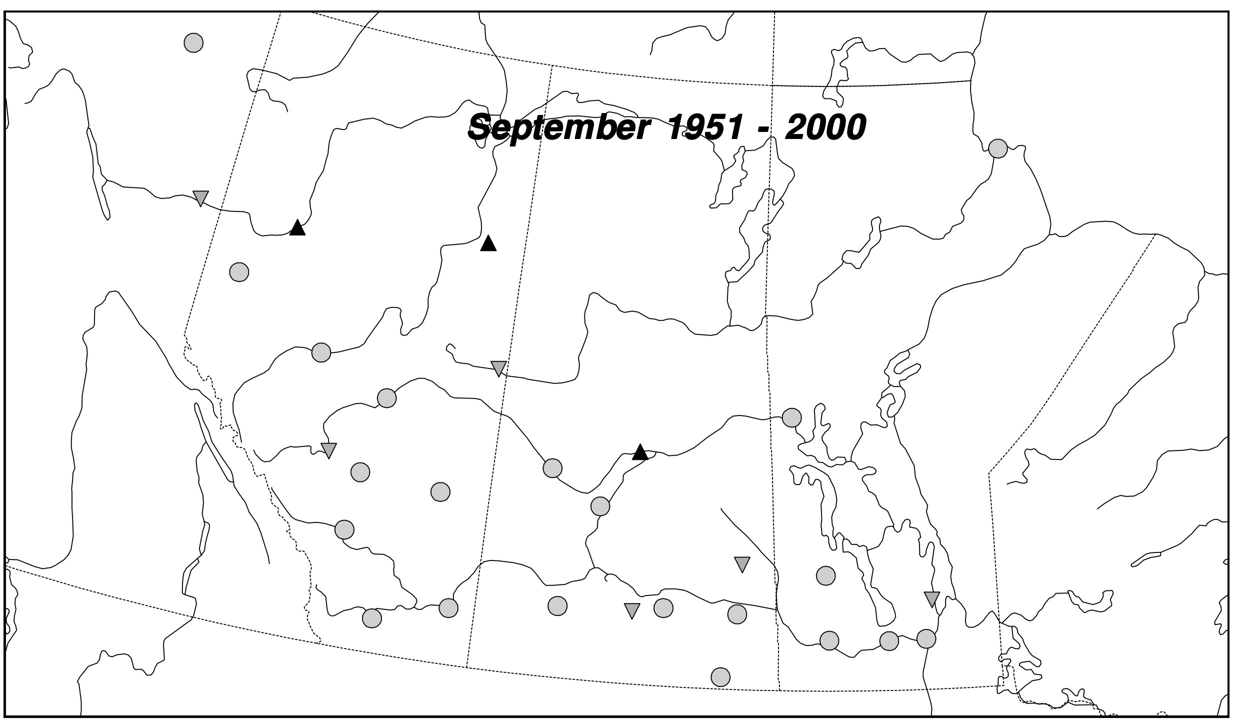

Figure B22: Evaporation trends in September from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

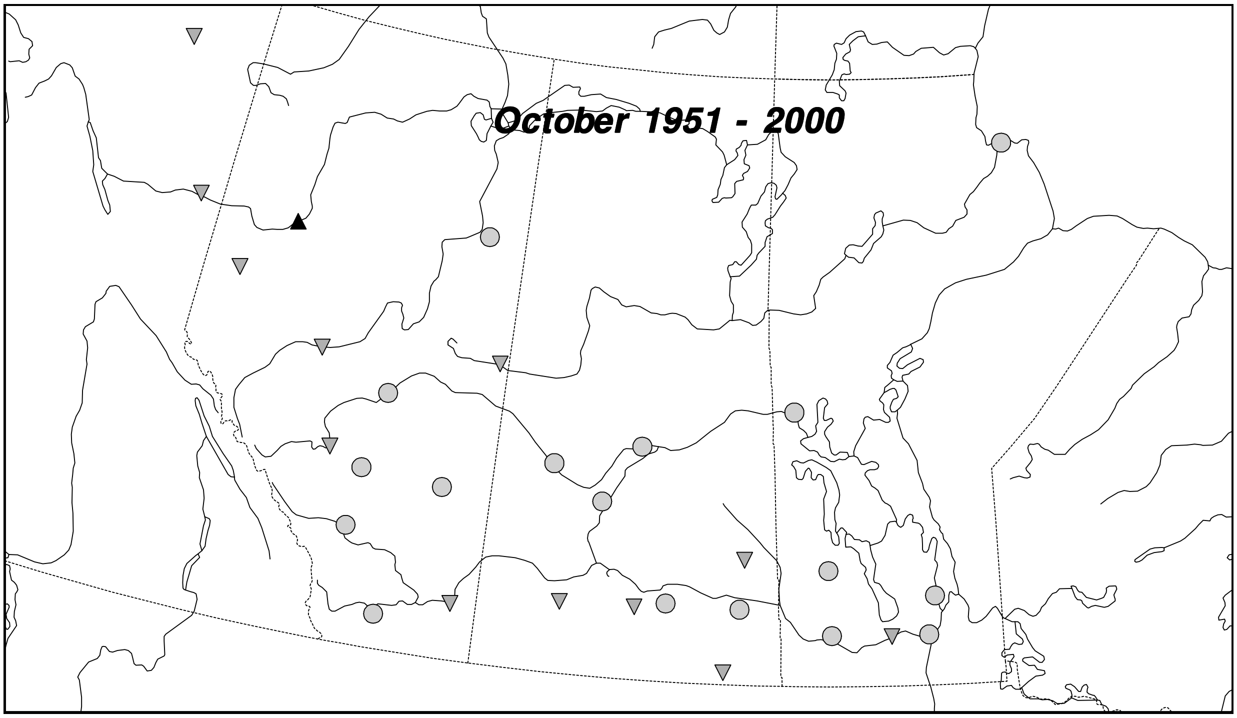

Figure B23: Evaporation trends in October from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

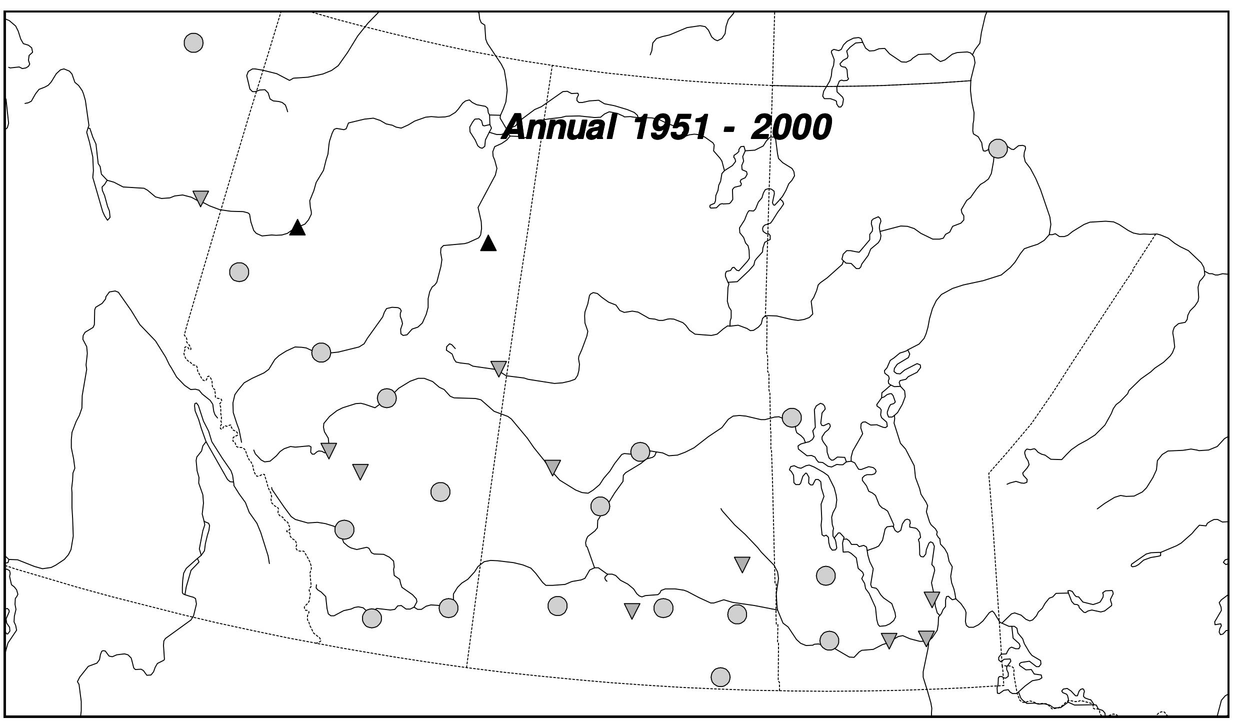

Figure B24: Annual evaporation trends from 1951-2000. ▲ denotes upward trend, ▽ denotes downward trend and ○ denotes no trend at the 10% significance level.

Appendix C

Comparison of Results for Pan and Gross Evaporation Analyses

Table C1: Comparison of pan and gross evaporation

Pan Evaporation Station	Gross Evaporation Station	Province	Month	Period of Record	Probability Pan	Probability Gross	Slope(mm/year) Pan	Slope(mm/year) Gross	Type	Corr.
Altawan	Medicine Hat	AB	May	1966-1996	0.355	0.070	-1.3156	-0.6148	3	0.40
Altawan	Medicine Hat	AB	June	1966-1996	0.301	0.466	-0.9683	-0.0400	3	0.52
Altawan	Medicine Hat	AB	July	1966-1996	0.012	0.111	-3.2563	-0.9640	1	0.70
Altawan	Medicine Hat	AB	Aug	1966-1996	0.280	0.030	-1.1042	-1.0750	1	0.54
Altawan	Medicine Hat	AB	Sept	1966-1996	0.490	0.004	-0.1535	-0.9952	1	0.50
Calgary Intl A	Calgary	AB	June	1965-1994	0.987	0.946	1.2066	0.4923	2	0.72
Calgary Intl A	Calgary	AB	July	1964-1994	0.633	0.259	0.3850	-0.2500	3	0.85
Calgary Intl A	Calgary	AB	Aug	1964-1994	0.500	0.265	-0.0059	-0.4000	3	0.83
Calgary Intl A	Calgary	AB	Sept	1964-1994	0.831	0.793	0.4170	0.2875	3	0.77
Churchill A	Churchill	MB	July	1964-2000	0.916	0.063	0.5065	-0.3548	5	0.59
Churchill A	Churchill	MB	Aug	1964-2000	0.965	0.043	0.5500	-0.3081	4	0.28
Estevan A	Estevan	SK	May	1962-2000	0.410	0.628	-0.1500	0.1050	3	0.89
Estevan A	Estevan	SK	June	1962-2000	0.157	0.362	-0.5815	-0.1449	3	0.90
Estevan A	Estevan	SK	July	1962-2000	0.000	0.001	-2.7891	-1.6396	3	0.90
Estevan A	Estevan	SK	Aug	1962-2000	0.089	0.038	-0.7710	-0.6682	2	0.86
Estevan A	Estevan	SK	Sept	1962-2000	0.080	0.102	-0.6640	-0.3633	3	0.87
Indian Bay	Winnipeg	MB	June	1962-2000	0.352	0.067	-0.1798	-0.3900	3	0.45
Indian Bay	Winnipeg	MB	July	1962-2000	0.055	0.001	-0.4875	-0.6950	2	0.65
Indian Bay	Winnipeg	MB	Aug	1962-2000	0.766	0.158	0.1646	-0.2846	3	0.52
Indian Bay	Winnipeg	MB	Sept	1962-2000	0.432	0.050	-0.0519	-0.3371	1	0.51
Morden CDA	Portage La Prairie	MB	May	1963-1998	0.989	0.121	1.7340	-0.2535	1	0.66
Morden CDA	Portage La Prairie	MB	June	1963-1998	0.992	0.010	1.1745	-0.6760	4	0.64
Morden CDA	Portage La Prairie	MB	July	1963-1998	0.811	0.002	0.3540	-1.0937	1	0.64
Morden CDA	Portage La Prairie	MB	Aug	1963-1998	0.946	0.113	1.0262	-0.4401	3	0.57
Morden CDA	Portage La Prairie	MB	Sept	1963-1998	0.729	0.160	0.3333	-0.2310	3	0.53

Light Highlighting -decreasing trend   Dark Highlighting-increasing trend   Not highlighted-no trend

Pan Evaporation Station	Gross Evaporation Station	Province	Month	Period of Record	Probability		Slope(mm/year)		Type	Corr.
					Pan	Gross	Pan	Gross		
Nipawin A	Nipawin	SK	May	1974-2000	0.214	0.958	-1.0417	0.9800	1	0.72
Nipawin A	Nipawin	SK	June	1974-2000	0.026	0.820	-1.5357	0.3571	1	0.73
Nipawin A	Nipawin	SK	July	1974-2000	0.017	0.180	-1.7600	-0.5250	1	0.77
Nipawin A	Nipawin	SK	Aug	1974-2000	0.706	0.874	0.4400	0.5556	3	0.85
Nipawin A	Nipawin	SK	Sept	1974-2000	0.930	0.989	1.0125	0.7857	2	0.82
Norway House Forestry	Norway House	MB	June	1972-2000	0.874	0.021	0.3810	-0.4660	1	0.36
Norway House Forestry	Norway House	MB	July	1971-2000	0.853	0.000	0.2795	-1.0714	1	0.32
Norway House Forestry	Norway House	MB	Aug	1971-1999	0.294	0.010	-0.2143	-0.6306	1	0.38
Norway House Forestry	Norway House	MB	Sept	1971-1999	0.891	0.004	0.4250	-0.3862	5	0.03
Regina A	Regina	SK	May	1963-1995	0.343	0.432	-0.4333	-0.1770	3	0.87
Regina A	Regina	SK	June	1963-1995	0.918	0.639	0.8276	0.1745	3	0.86
Regina A	Regina	SK	July	1963-1995	0.046	0.030	-1.2581	-0.8856	3	0.88
Regina A	Regina	SK	Aug	1963-1994	0.139	0.058	-0.7956	-0.9085	3	0.83
Regina A	Regina	SK	Sept	1962-1994	0.580	0.243	0.1870	-0.2512	3	0.81
Swift Current CDA	Swift Current	SK	May	1961-2000	0.570	0.144	0.1589	-0.3682	3	0.84
Swift Current CDA	Swift Current	SK	June	1960-1999	0.570	0.021	0.1016	-0.6750	1	0.91
Swift Current CDA	Swift Current	SK	July	1960-1999	0.043	0.000	-1.6227	-1.3712	3	0.92
Swift Current CDA	Swift Current	SK	Aug	1960-2000	0.377	0.040	-0.2856	-0.7225	1	0.87
Swift Current CDA	Swift Current	SK	Sept	1960-2000	0.451	0.148	-0.1719	-0.3585	3	0.86
Weyburn	Regina	SK	May	1962-2000	0.939	0.340	0.8259	-0.2762	3	0.79
Weyburn	Regina	SK	June	1962-2000	0.911	0.083	0.7420	-0.4951	5	0.77

Light Highlighting -decreasing trend Dark Highlighting-increasing trend Not highlighted-no trend

Pan Evaporation Station	Gross Evaporation Station	Province	Month	Period of Record	Probability		Slope (mm/year)		Type	Corr.
					Pan	Gross	Pan	Gross		
Weyburn	Regina	SK	July	1962-2000	0.198	0.000	-0.4996	-1.2783	1	0.77
Weyburn	Regina	SK	Aug	1962-2000	0.637	0.011	0.2118	-0.9600	1	0.77
Weyburn	Regina	SK	Sept	1962-2000	0.628	0.104	0.2333	-0.3350	3	0.72
Winnipeg Intl A	Winnipeg	MB	May	1963-1994	0.914	0.885	0.8520	0.3208	3	0.73
Winnipeg Intl A	Winnipeg	MB	June	1962-1996	0.126	0.197	-0.6633	-0.2200	3	0.67
Winnipeg Intl A	Winnipeg	MB	July	1962-1996	0.007	0.012	-1.2554	-0.6087	3	0.83
Winnipeg Intl A	Winnipeg	MB	Aug	1962-1994	0.469	0.248	-0.0627	-0.2923	3	0.78
Winnipeg Intl A	Winnipeg	MB	Sept	1962-1994	0.180	0.206	-0.4000	-0.1914	3	0.71
Wynyard	Wynyard	SK	May	1967-2000	0.077	0.043	-0.9020	-0.7400	2	0.91
Wynyard	Wynyard	SK	June	1967-2000	0.040	0.001	-0.8200	-1.2600	3	0.88
Wynyard	Wynyard	SK	July	1967-1999	0.062	0.000	-0.8580	-2.0662	2	0.84
Wynyard	Wynyard	SK	Aug	1967-1999	0.079	0.001	-0.9118	-1.4788	2	0.86
Wynyard	Wynyard	SK	Sept	1967-2000	0.743	0.039	0.2700	-0.4045	1	0.83

Light Highlighting -decreasing trend   Dark Highlighting-increasing trend   Not highlighted-no trend

Appendix D

Graphs Comparing Pan and Gross Evaporation

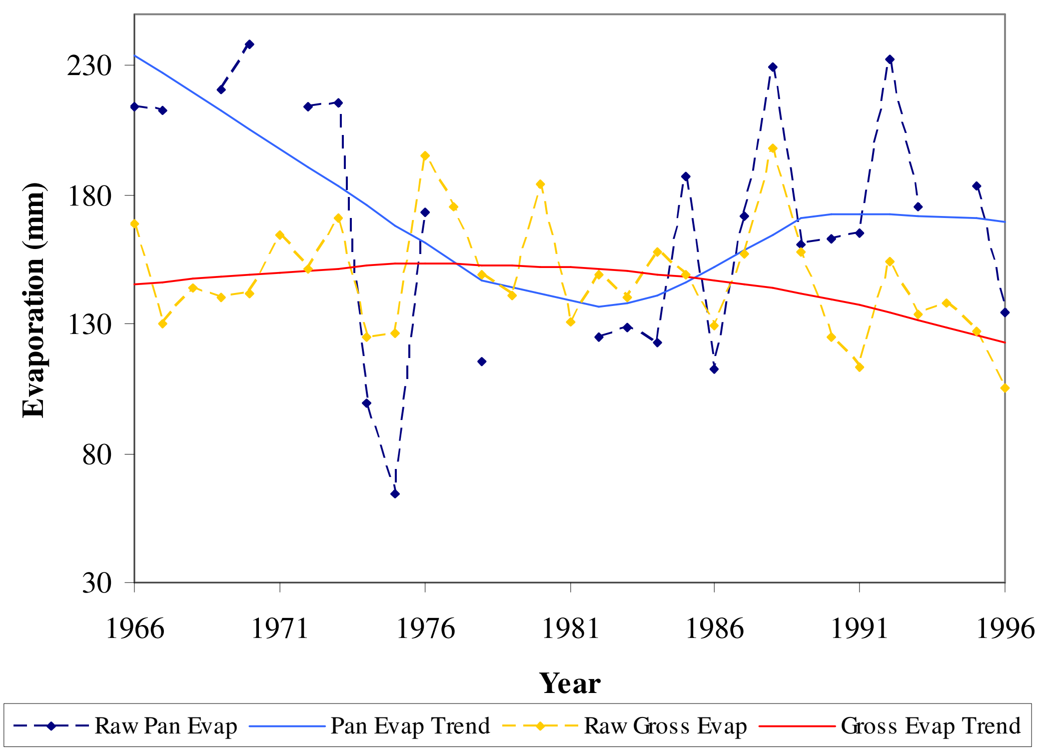

Figure D1: Comparison of Altawan pan evaporation and Medicine Hat gross evaporation in May - Type 3

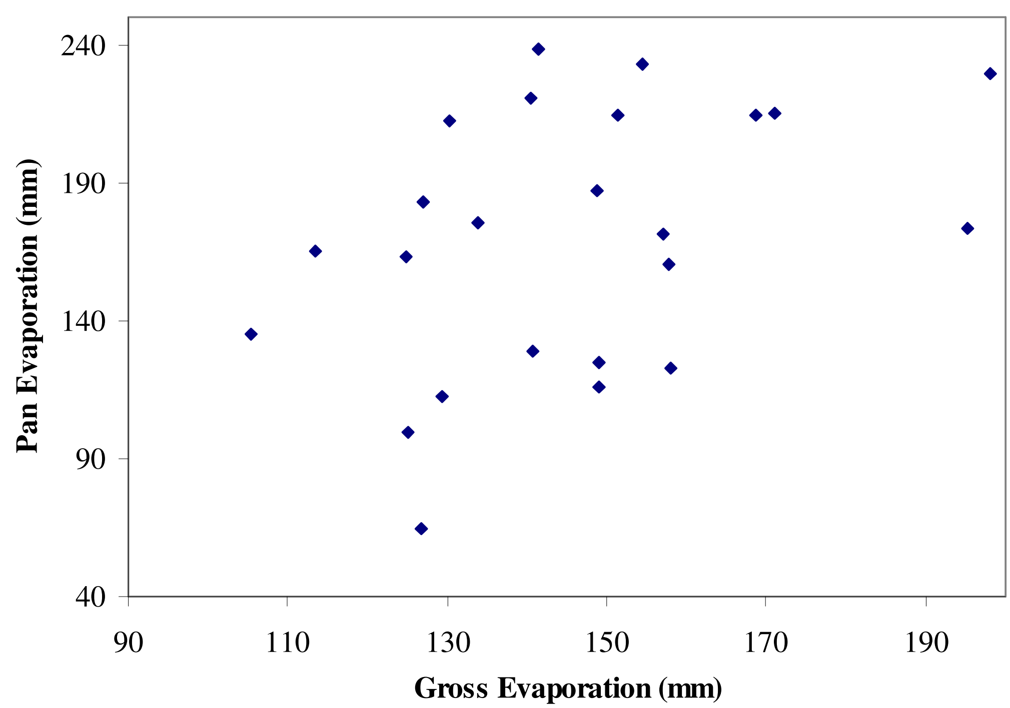

Figure D2: Scatter graph of pan evaporation at Altawan vs. gross evaporation at Medicine Hat in May (r = 0.4)

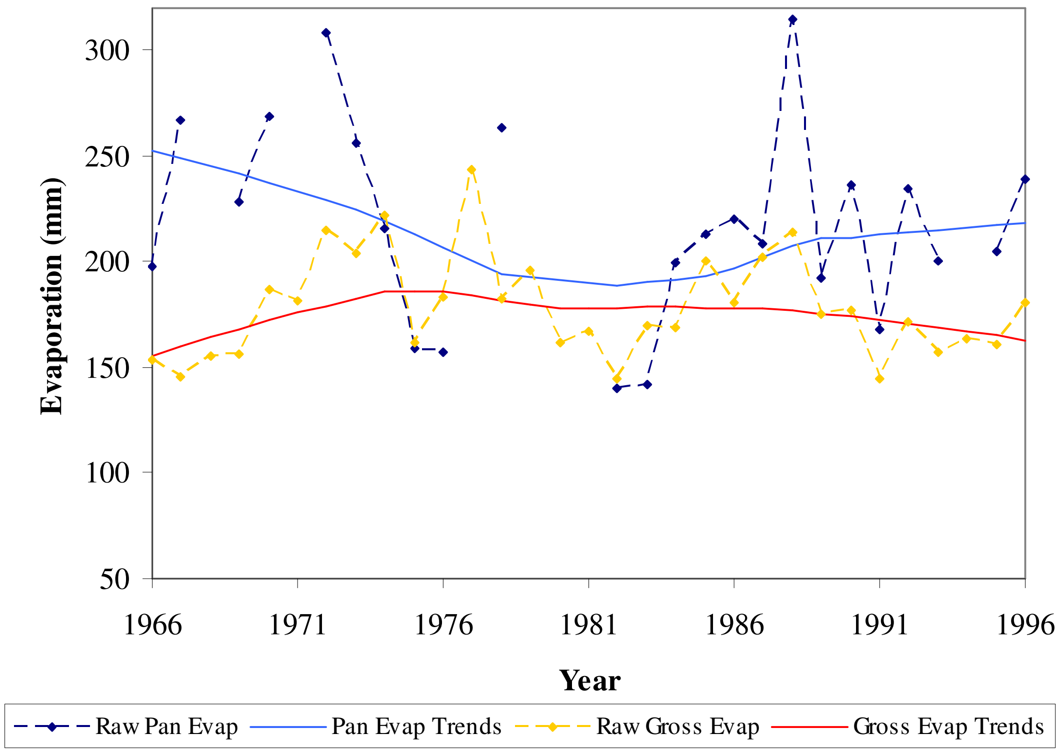

Figure D3: Comparison of Altawan pan evaporation and Medicine Hat gross evaporation in June - Type 3

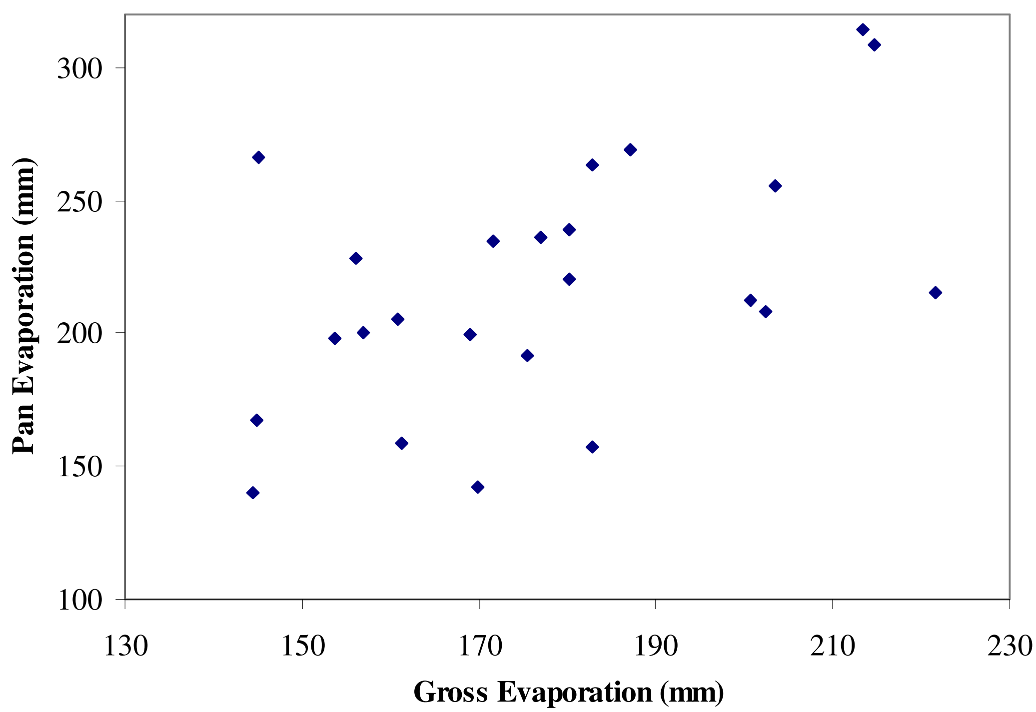

Figure D4: Scatter graph of pan evaporation at Altawan vs. gross evaporation at Medicine Hat in June (r = 0.52)

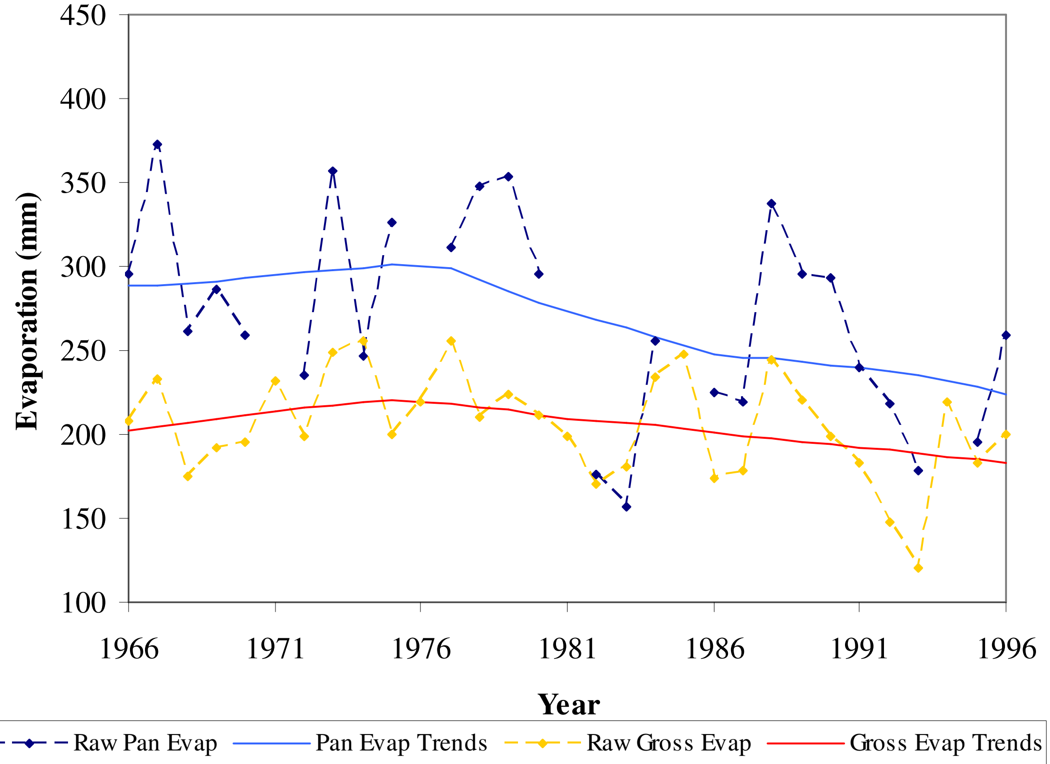

Figure D5: Comparison of Altawan pan evaporation and Medicine Hat gross evaporation in July - Type 1

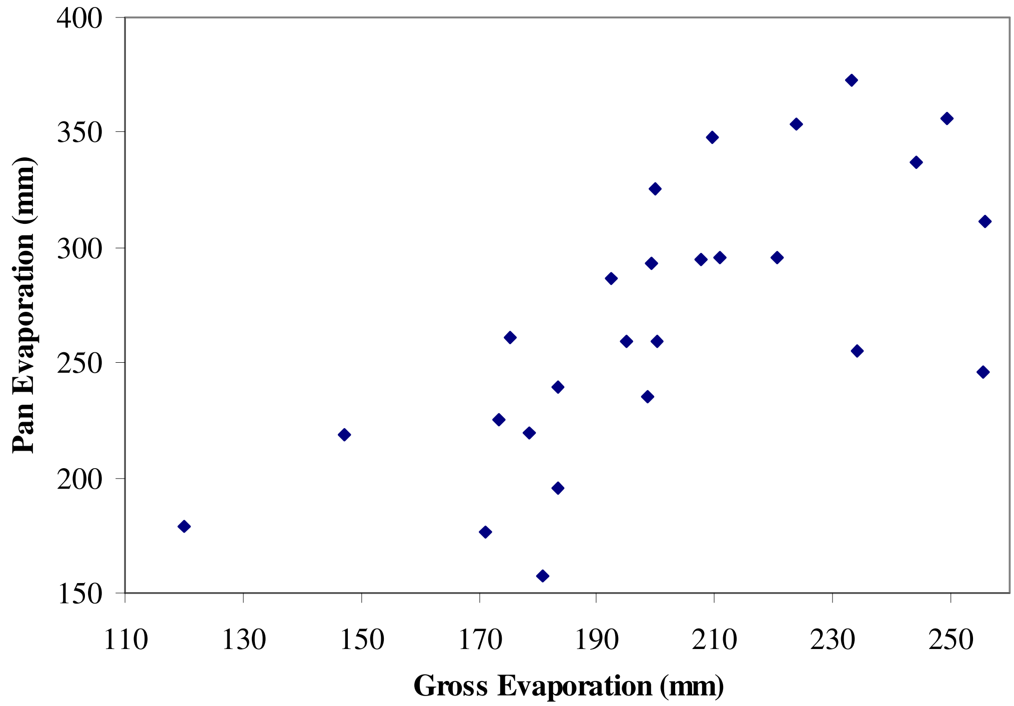

Figure D6: Scatter graph of pan evaporation at Altawan vs. gross evaporation at Medicine Hat in July (r = 0.70)

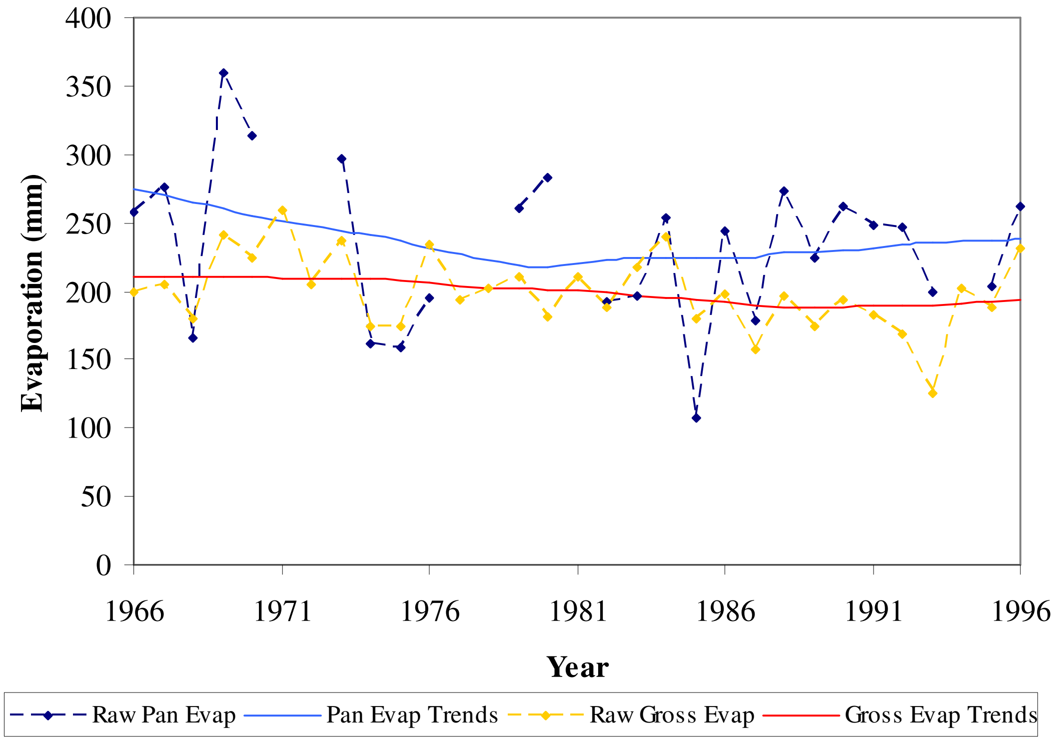

Figure D7: Comparison of Altawan pan evaporation and Medicine Hat gross evaporation in August – Type 1

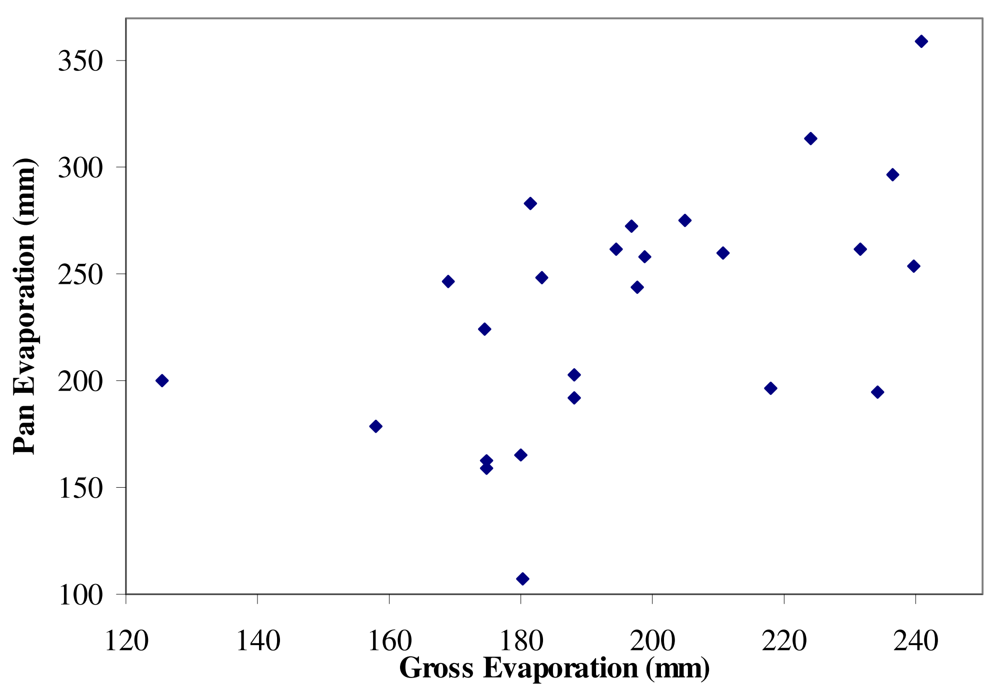

Figure D8: Scatter graph of pan evaporation at Altawan vs. gross evaporation at Medicine Hat in August (r = 0.54)

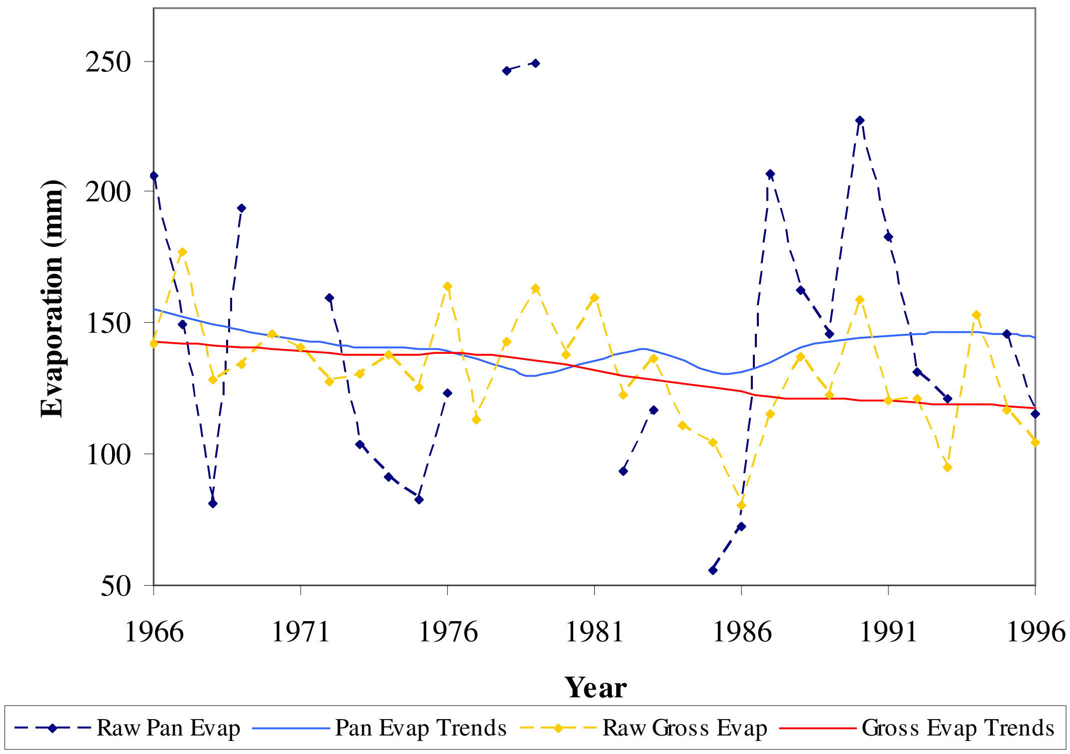

Figure D9: Comparison of Altawan pan evaporation and Medicine Hat gross evaporation in September – Type 1

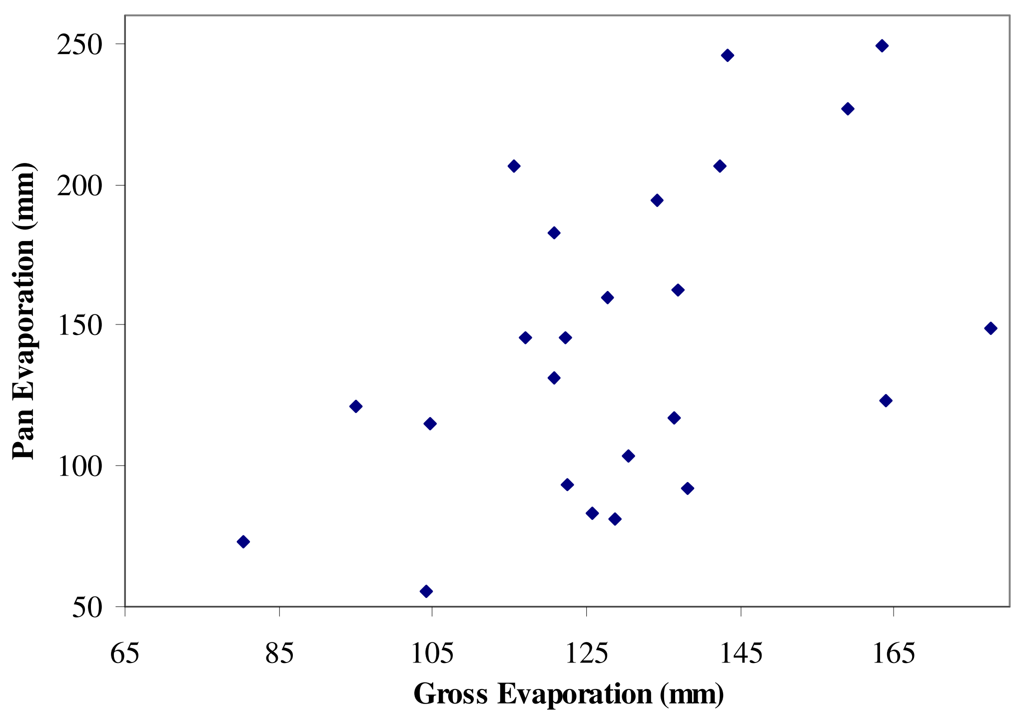

Figure D10: Scatter graph of pan evaporation at Altawan vs. gross evaporation at Medicine Hat in September (r = 0.50)

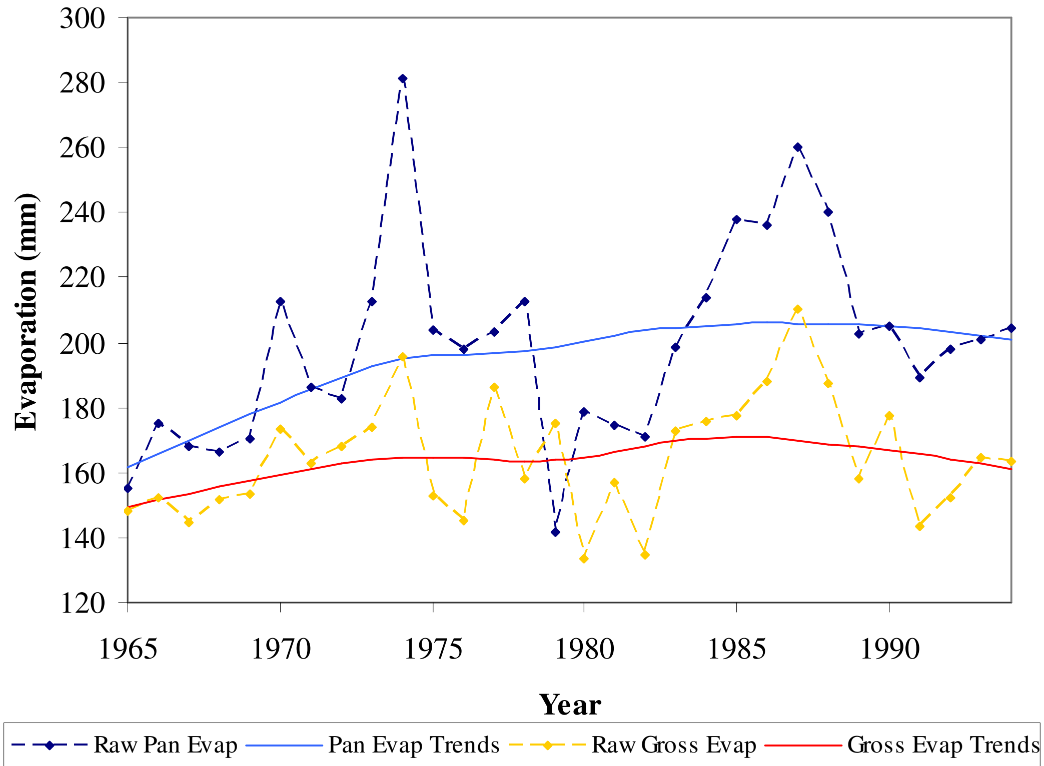

Figure D11: Comparison of Calgary pan evaporation and gross evaporation in June – Type 2

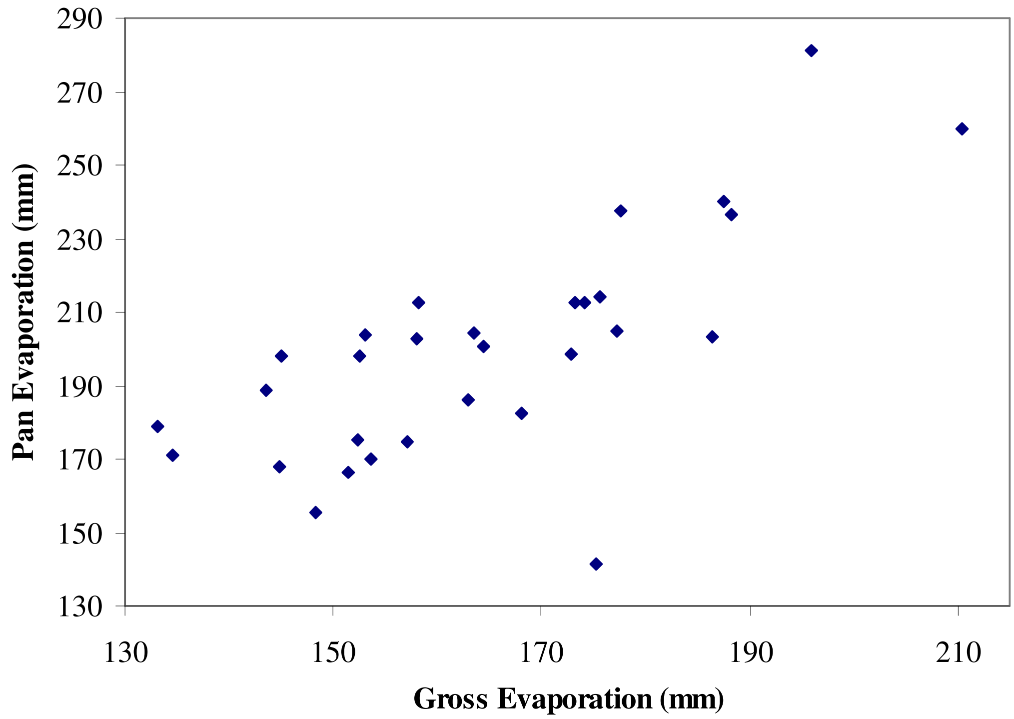

Figure D12: Scatter graph of pan evaporation vs. gross evaporation at Calgary in June (r = 0.72)

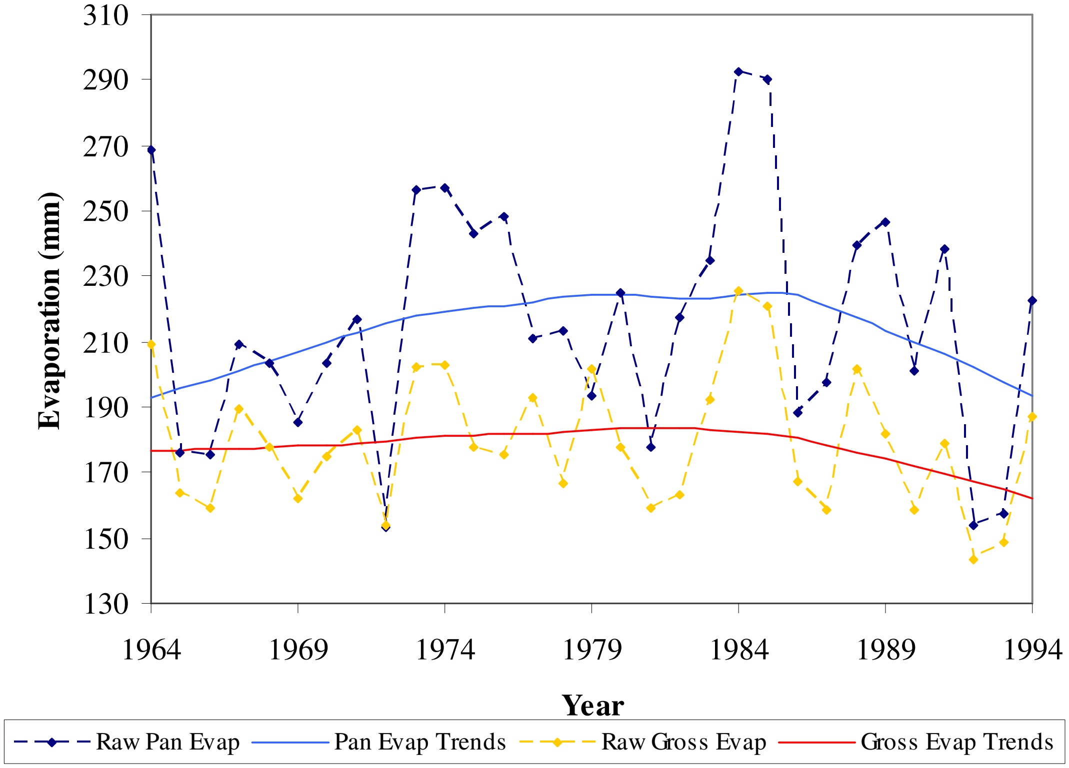

Figure D13: Comparison of Calgary pan evaporation and gross evaporation in July – Type 3

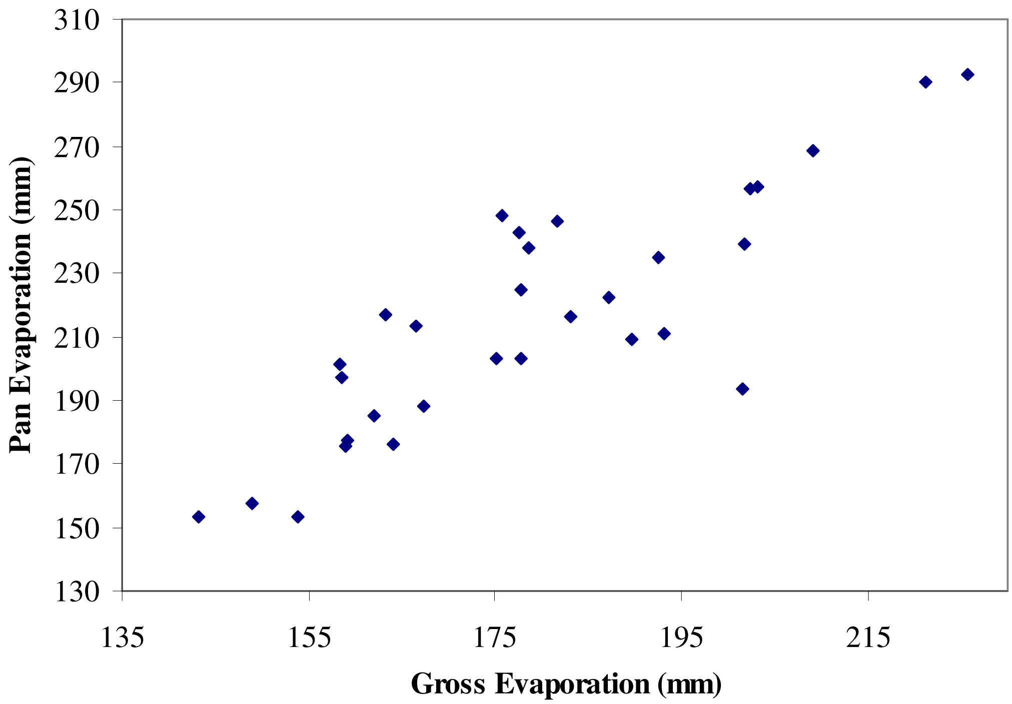

Figure D14: Scatter graph of pan evaporation vs. gross evaporation at Calgary in July (r = 0.85)

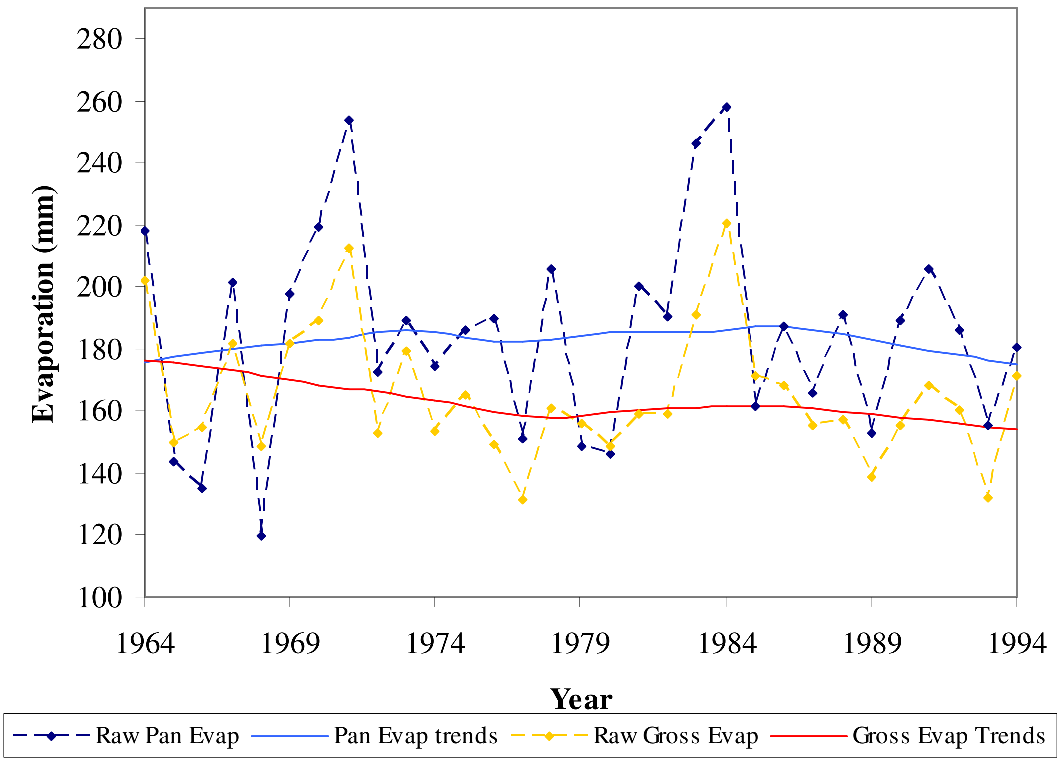

Figure D15: Comparison of Calgary pan evaporation and gross evaporation in August – Type 3

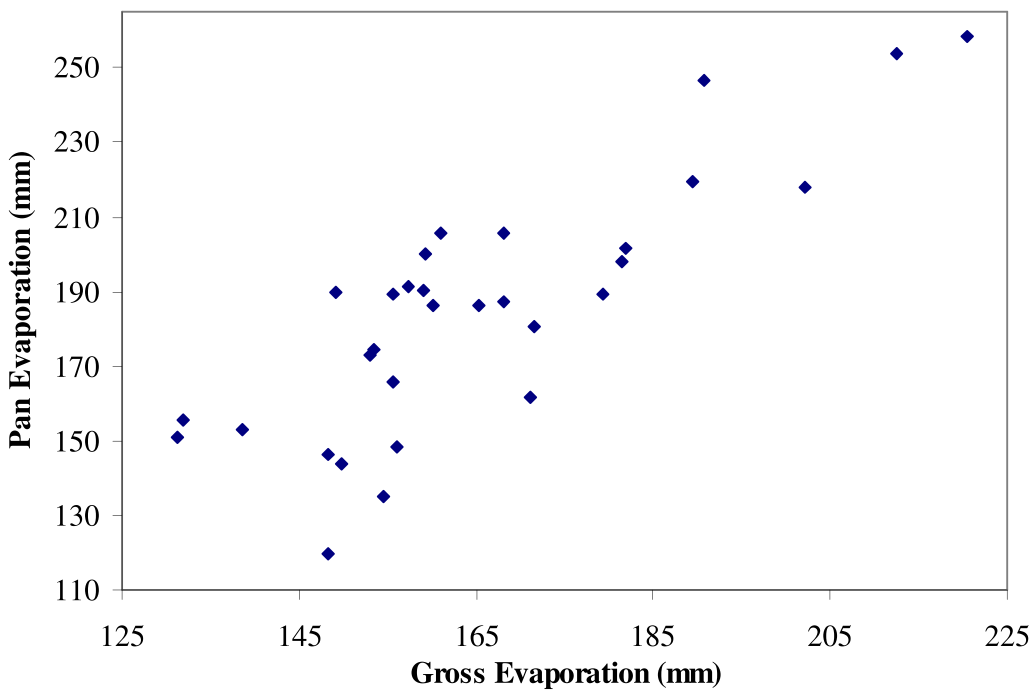

Figure D16: Scatter graph of pan evaporation vs. gross evaporation at Calgary in August (r = 0.83)

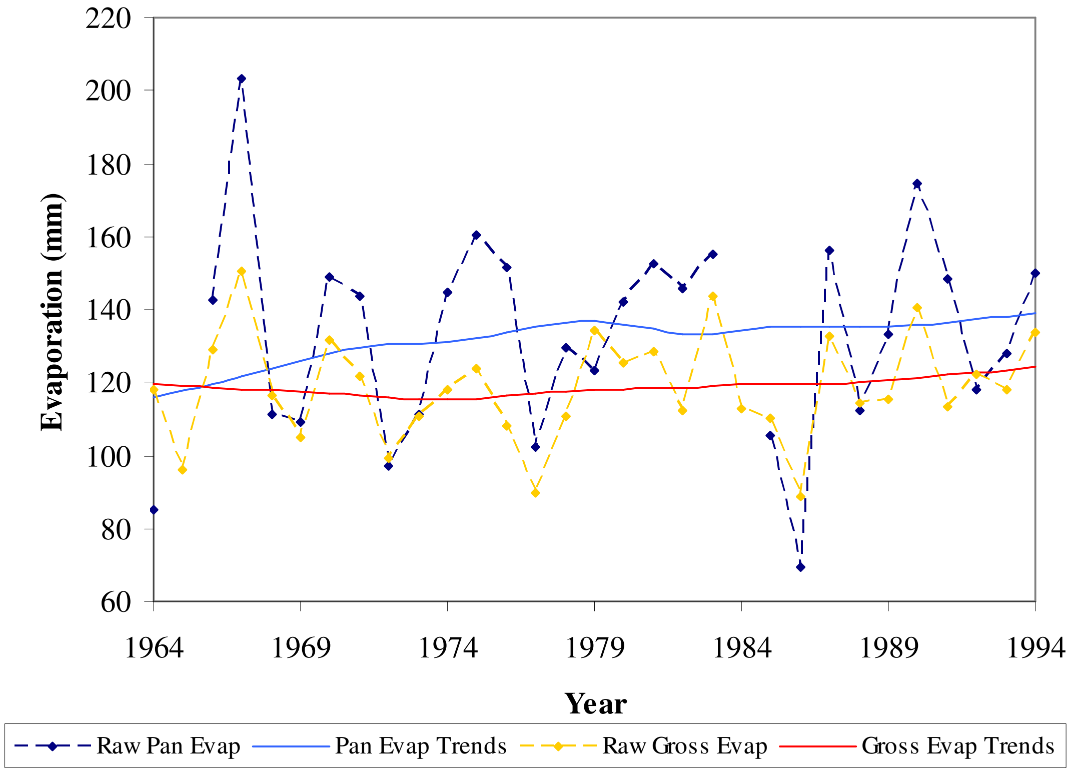

Figure D17: Comparison of Calgary pan evaporation and gross evaporation in September – Type 3

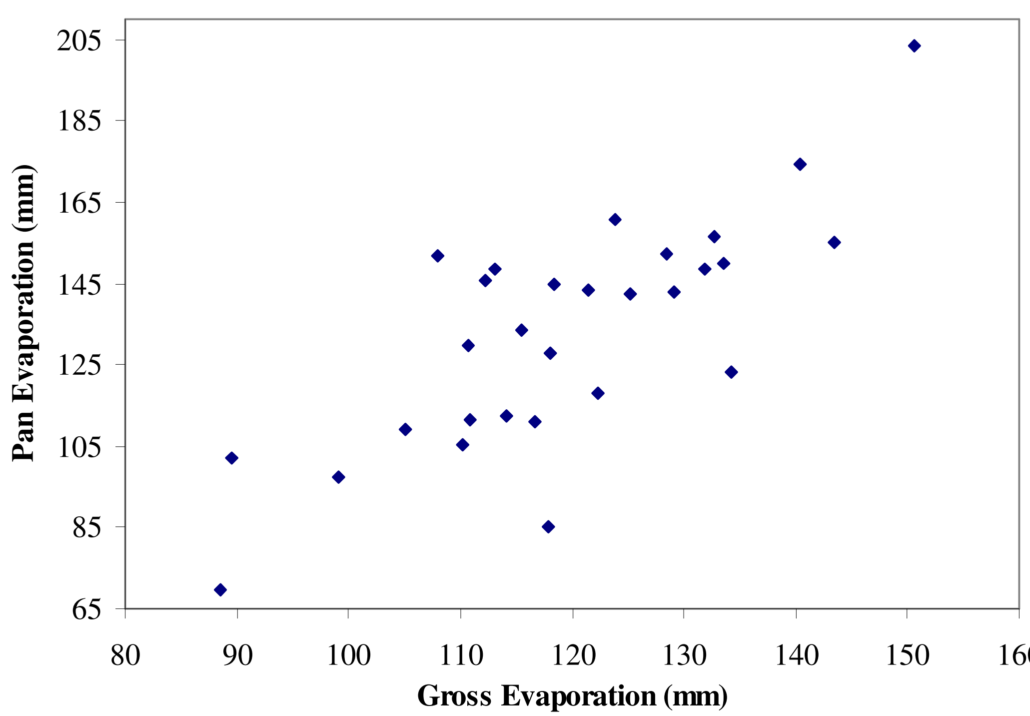

Figure D18: Scatter graph of pan evaporation vs. gross evaporation at Calgary in September (r = 0.77)

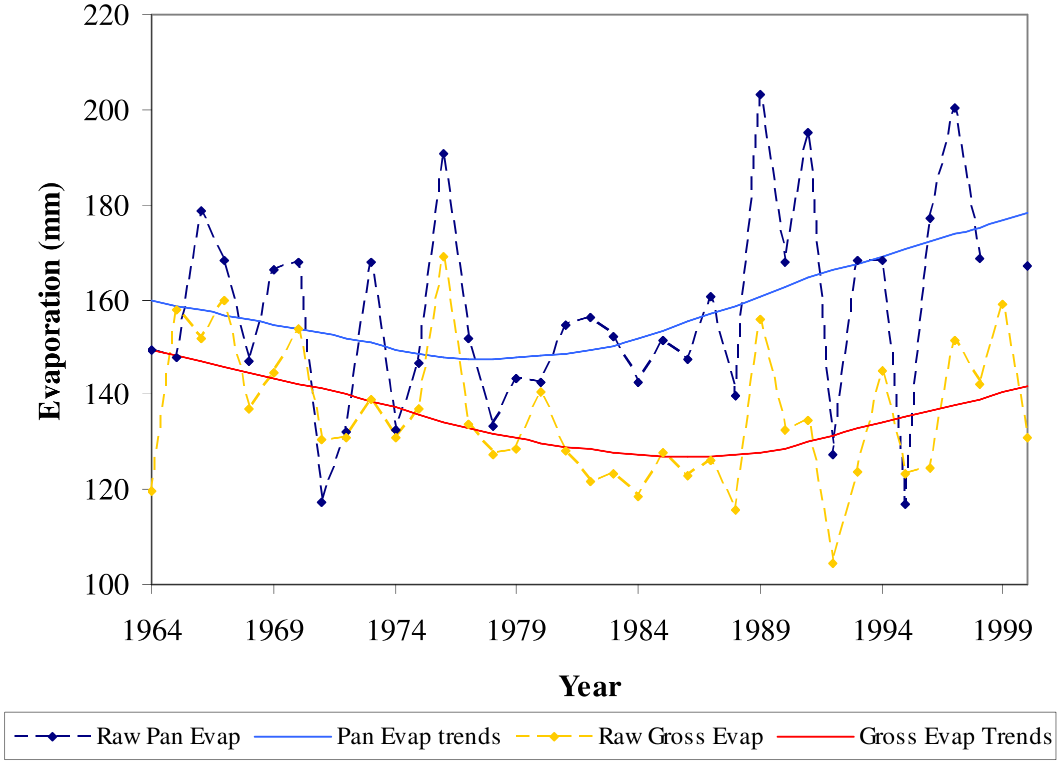

Figure D19: Comparison of Churchill pan evaporation and gross evaporation in July – Type 5

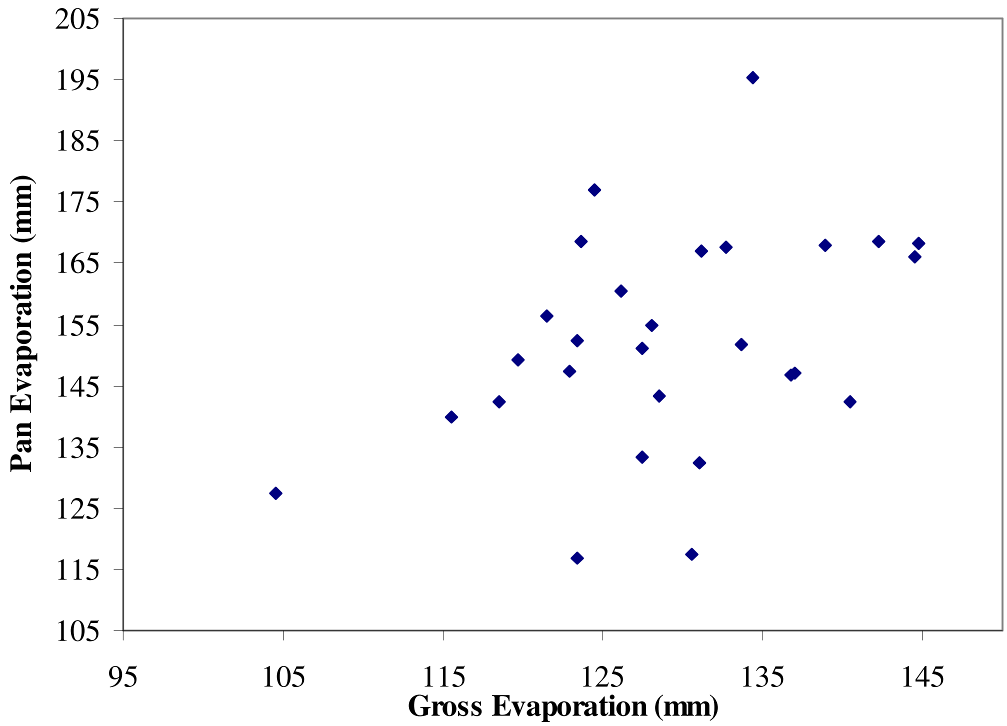

Figure D20: Scatter graph of pan evaporation vs. gross evaporation at Churchill in July (r = 0.59)

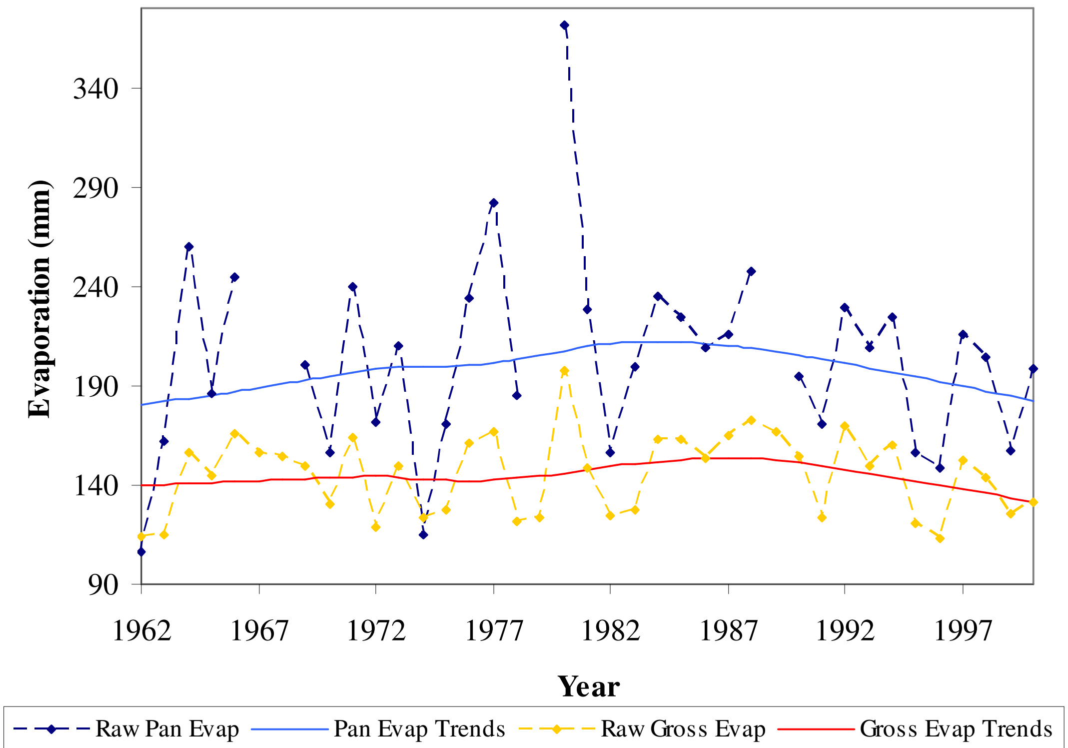

Figure D21: Comparison of Estevan pan evaporation and gross evaporation in May – Type 3

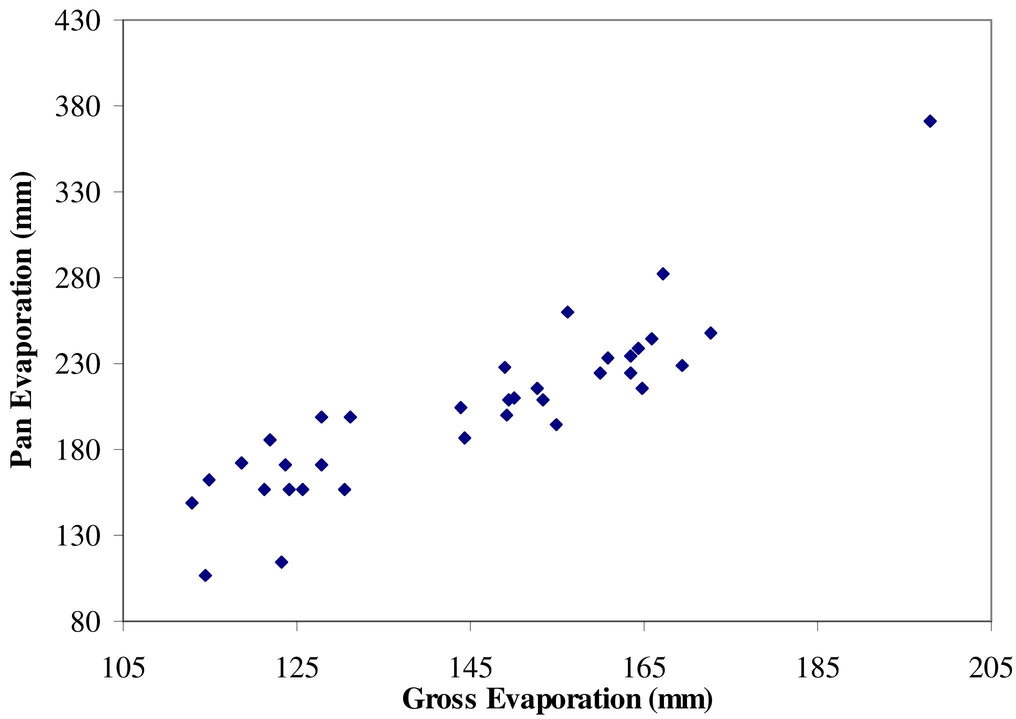

Figure D22: Scatter graph of pan evaporation vs. gross evaporation at Estevan in May (r = 0.89)

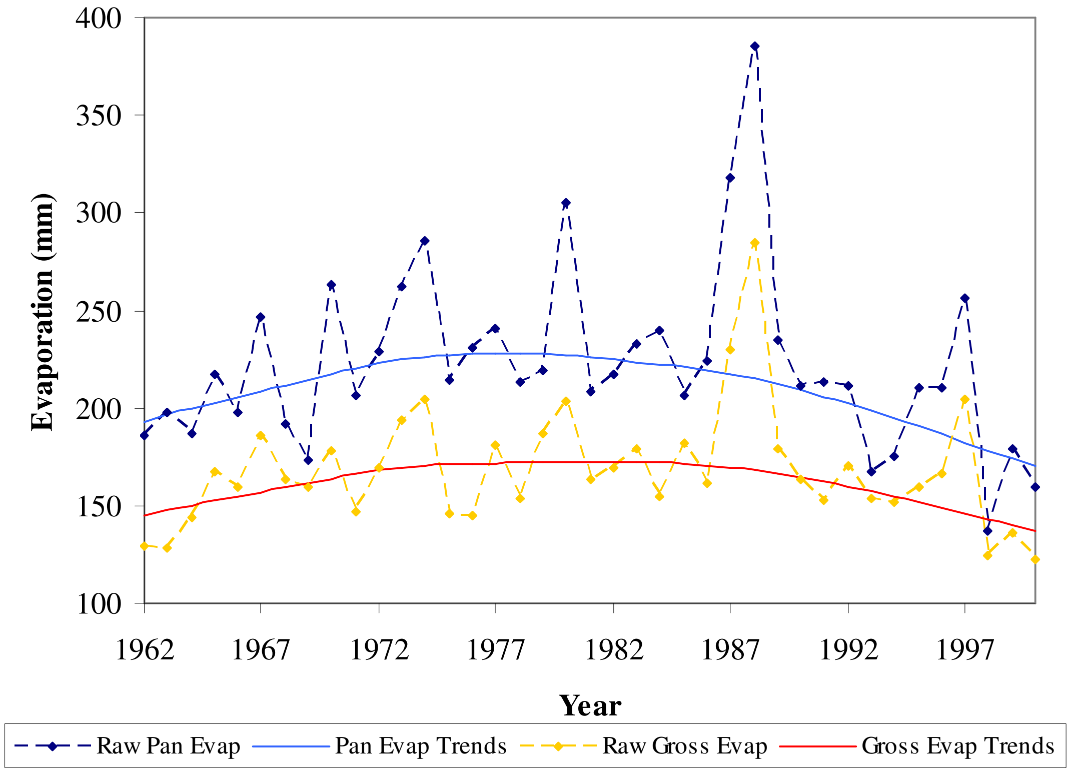

Figure D23: Comparison of Estevan pan evaporation and gross evaporation in June – Type 3

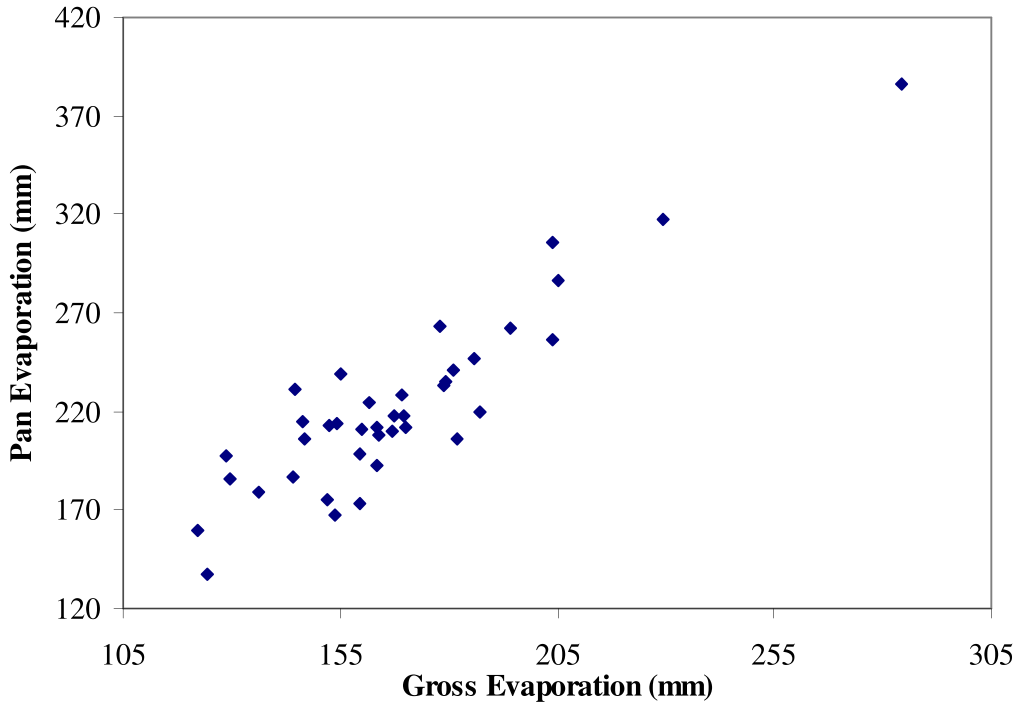

Figure D24: Scatter graph of pan evaporation vs. gross evaporation at Estevan in June (r = 0.90)

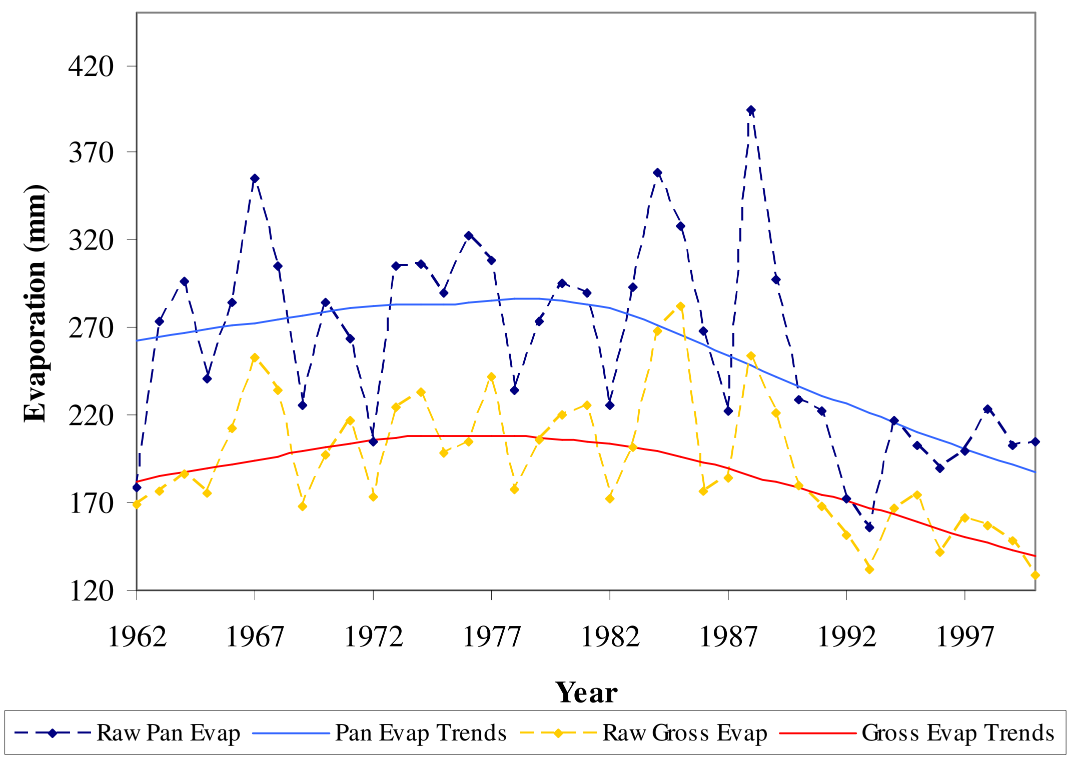

Figure D25: Comparison of Estevan pan evaporation and gross evaporation in July – Type 3

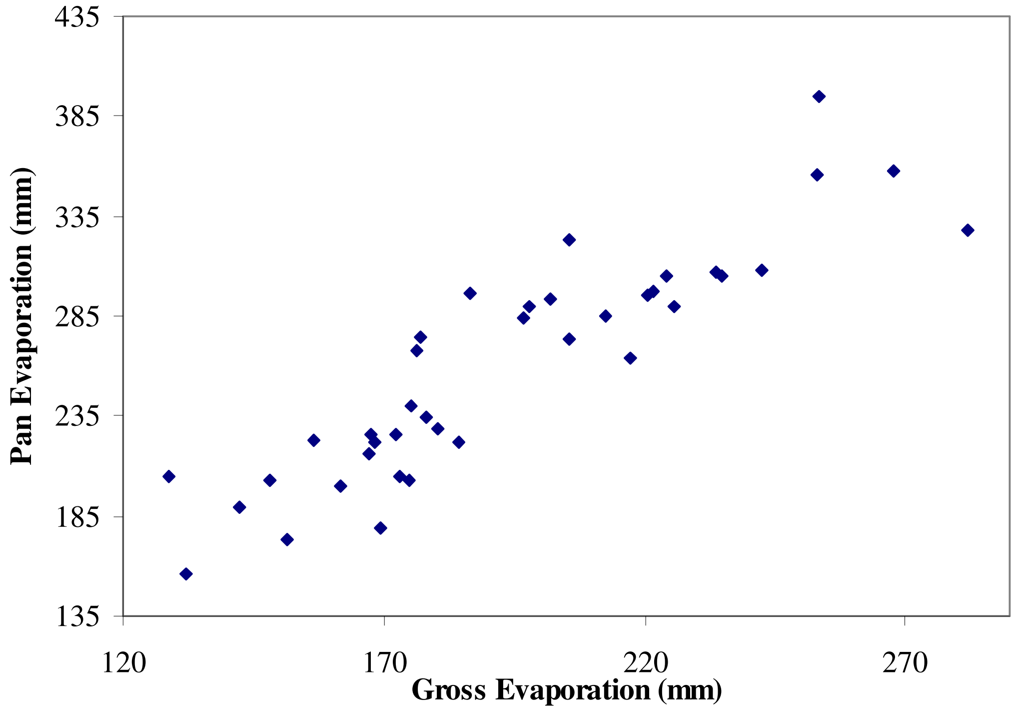

Figure D26: Scatter graph of pan evaporation vs. gross evaporation at Estevan in July (r = 0.90)

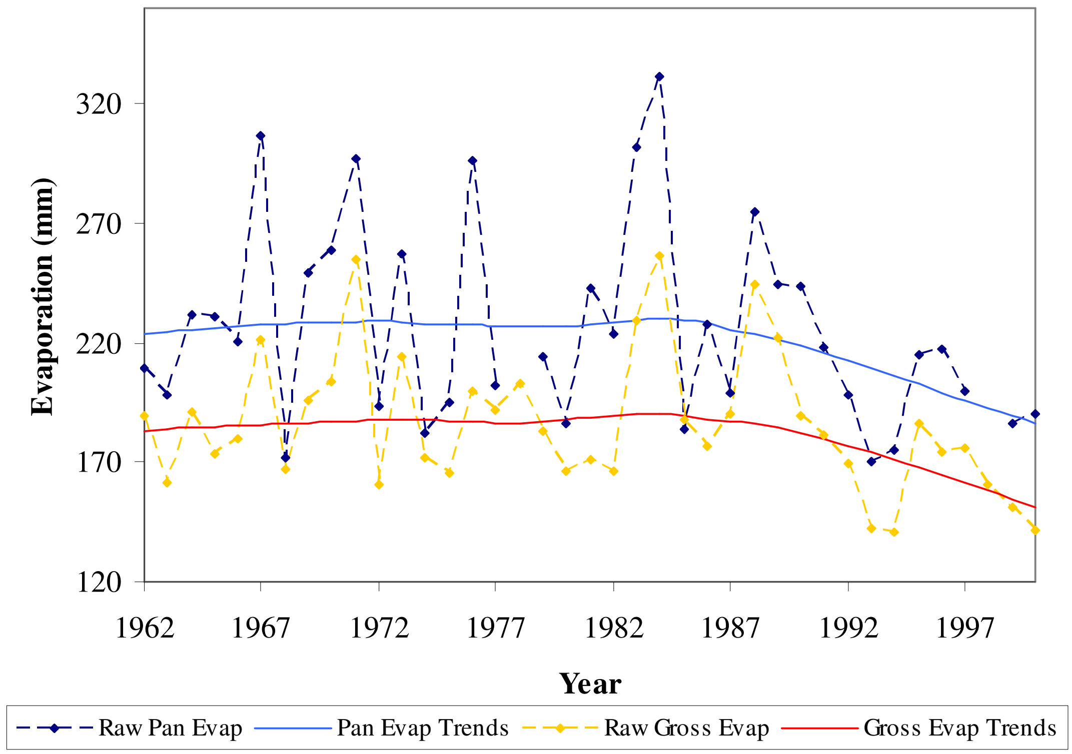

Figure D27: Comparison of Estevan pan evaporation and gross evaporation in August – Type 2

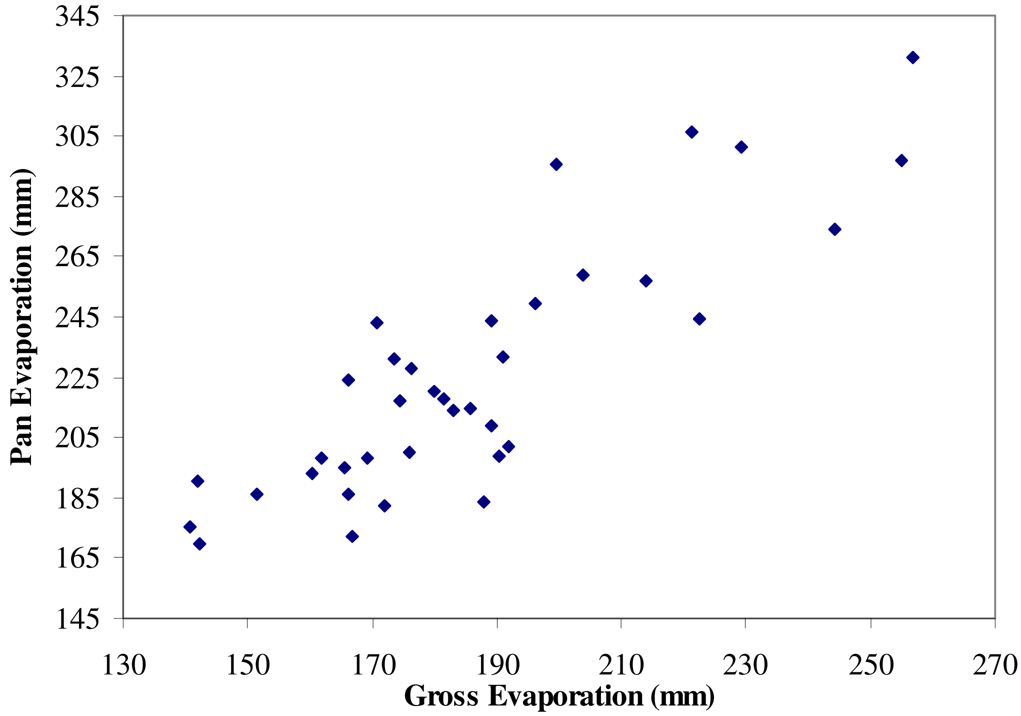

Figure D28: Scatter graph of pan evaporation vs. gross evaporation at Estevan in August (r = 0.86)

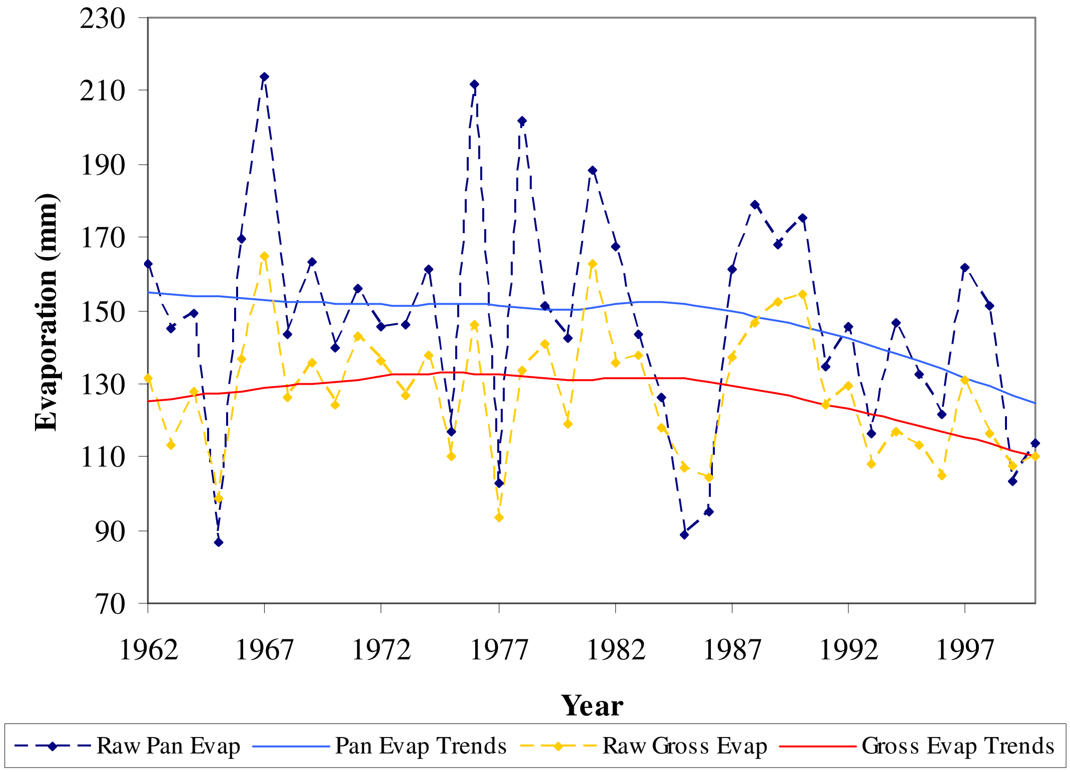

Figure D29: Comparison of Estevan pan evaporation and gross evaporation in September – Type 3

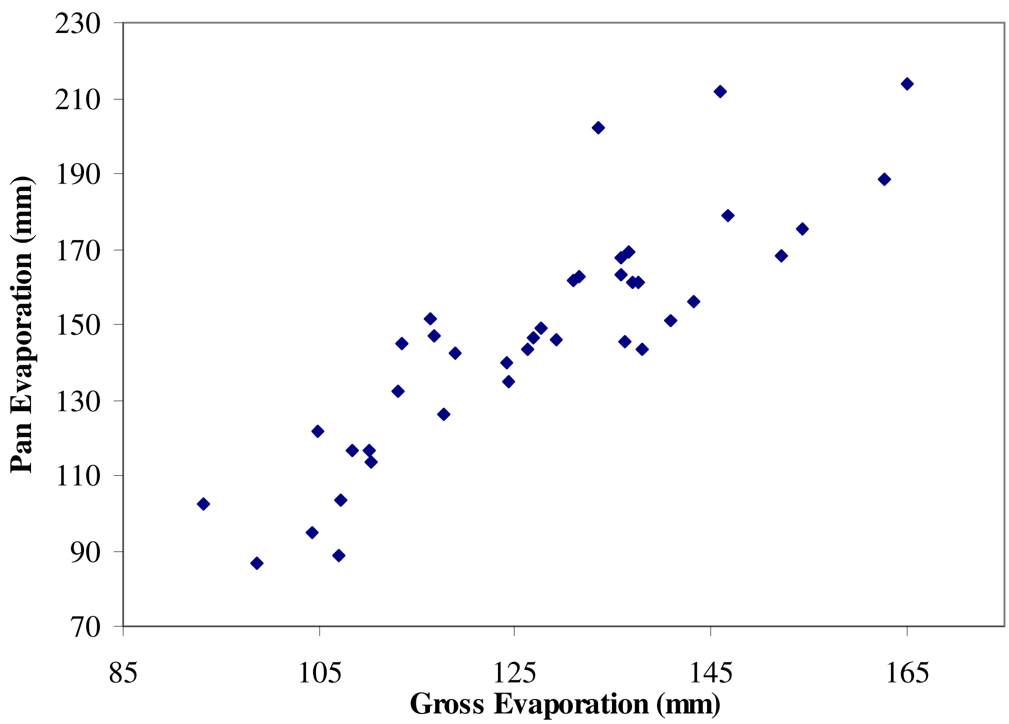

Figure D30: Scatter graph of pan evaporation vs. gross evaporation at Estevan in September (r = 0.87)

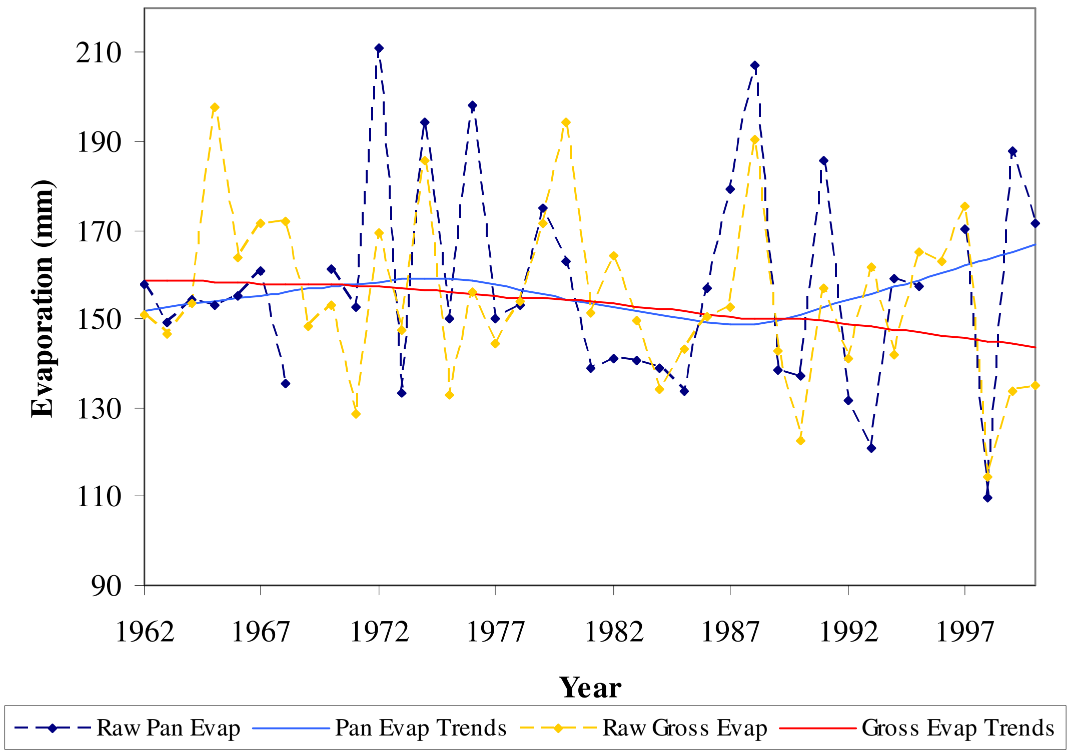

Figure D31: Comparison of Indian Bay pan evaporation and Winnipeg gross evaporation in June – Type 3

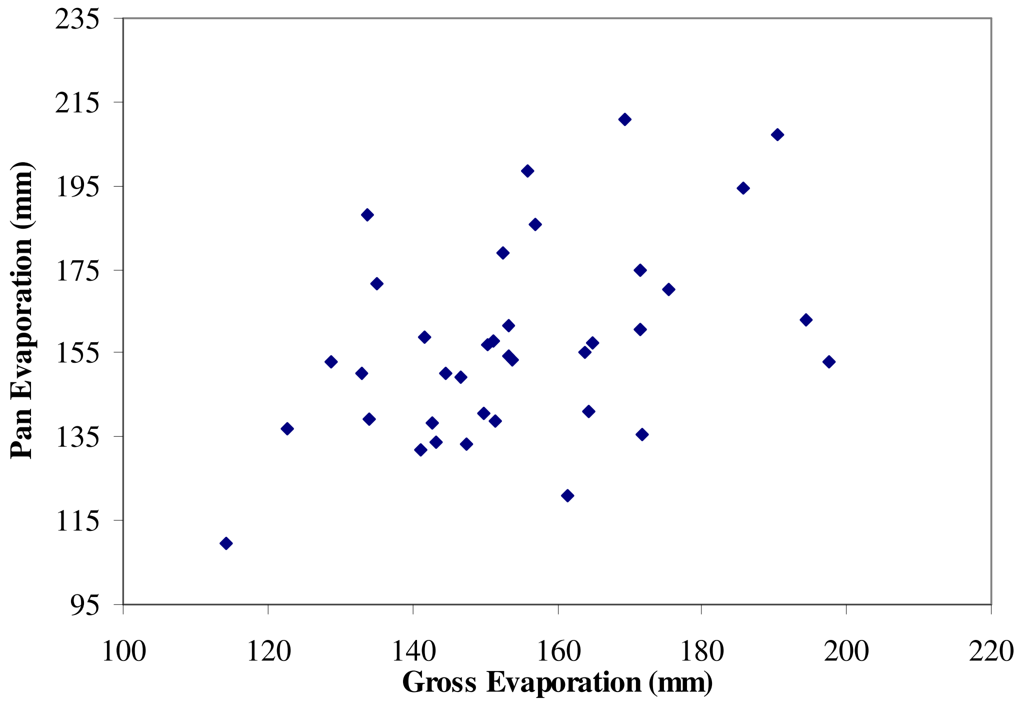

Figure D32: Scatter graph of pan evaporation at Indian Bay vs. gross evaporation at Winnipeg in June (r = 0.45)

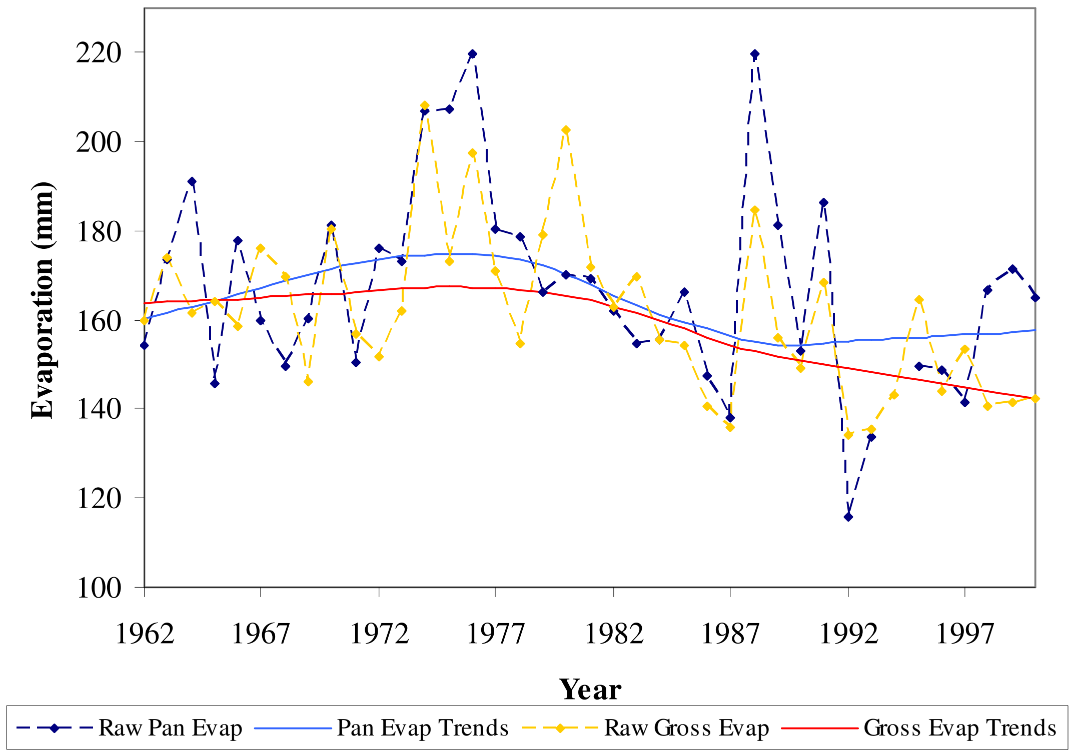

Figure D33: Comparison of Indian Bay pan evaporation and Winnipeg gross evaporation in July – Type 2

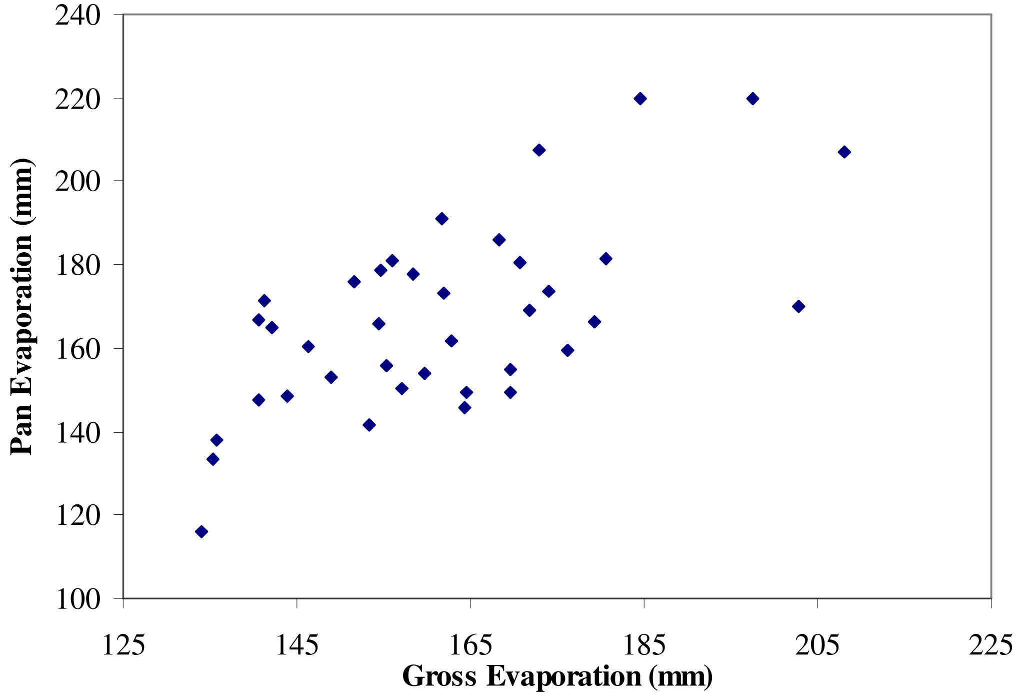

Figure D34: Scatter graph of pan evaporation at Indian Bay vs. gross evaporation at Winnipeg in July (r = 0.65)

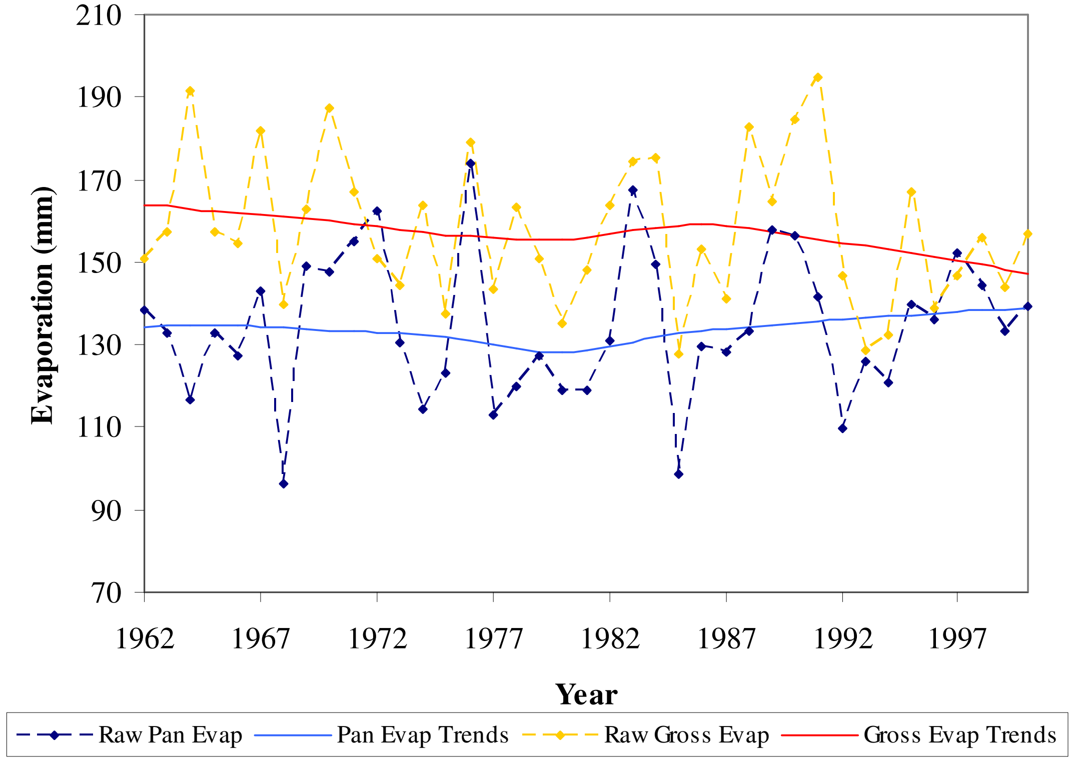

Figure D35: Comparison of Indian Bay pan evaporation and Winnipeg gross evaporation in August – Type 3

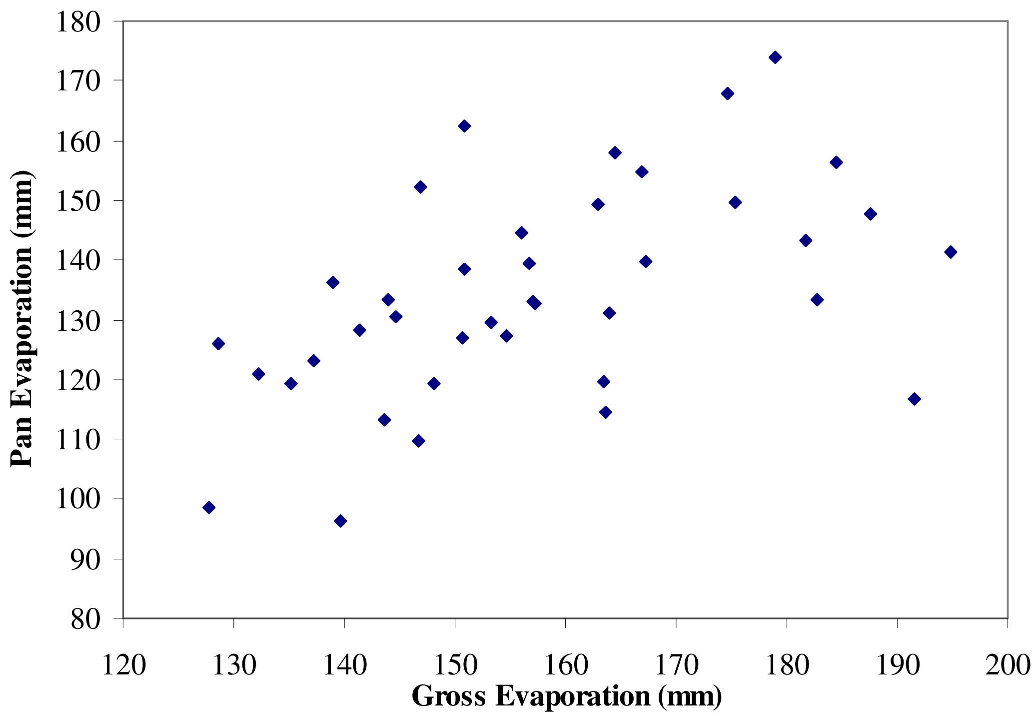

Figure D36: Scatter graph of pan evaporation at Indian Bay vs. gross evaporation at Winnipeg in August (r = 0.52)

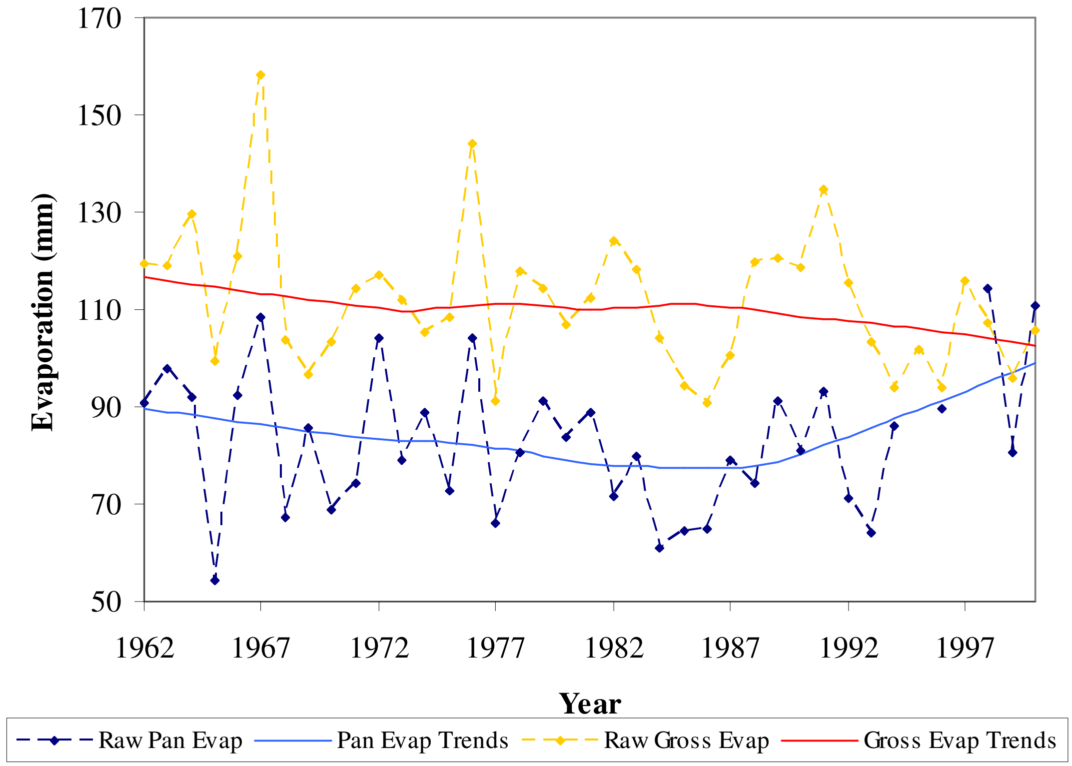

Figure D37: Comparison of Indian Bay pan evaporation and Winnipeg gross evaporation in September – Type 1

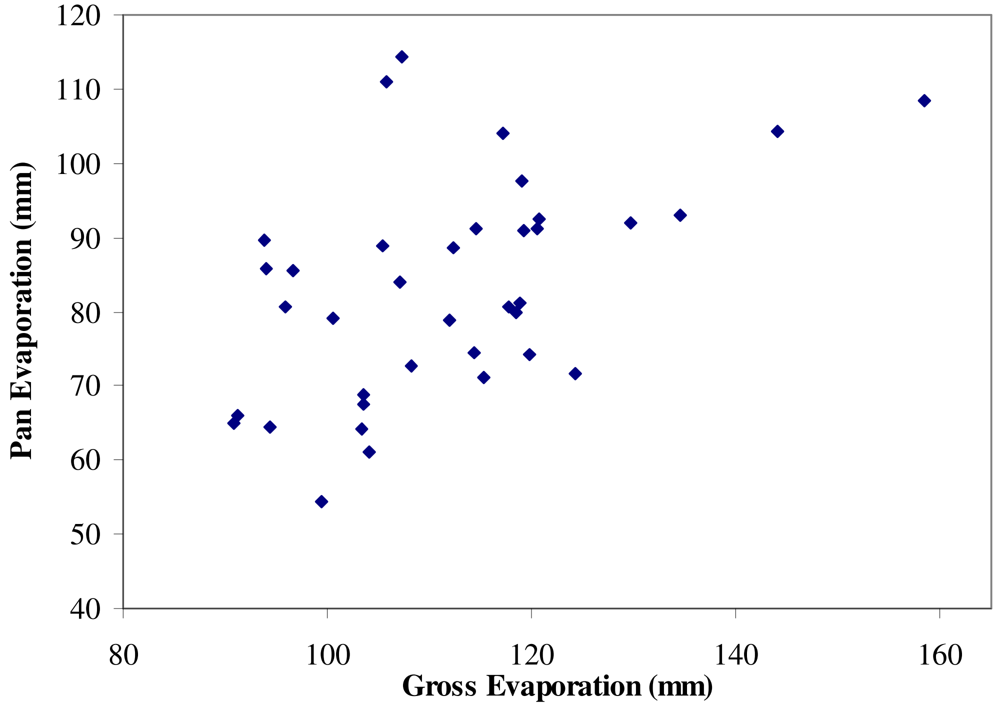

Figure D38: Scatter graph of pan evaporation at Indian Bay vs. gross evaporation at Winnipeg in September (r = 0.51)

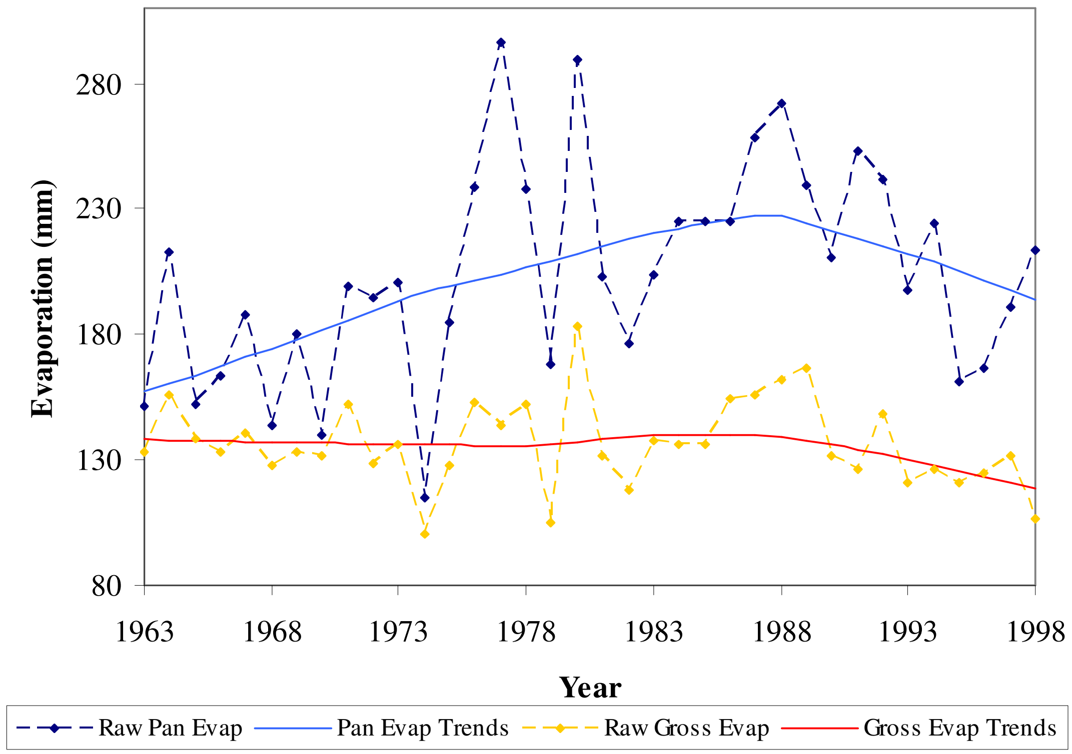

Figure D39: Comparison of Morden pan evaporation and Portage La Prairie gross evaporation in May – Type 1

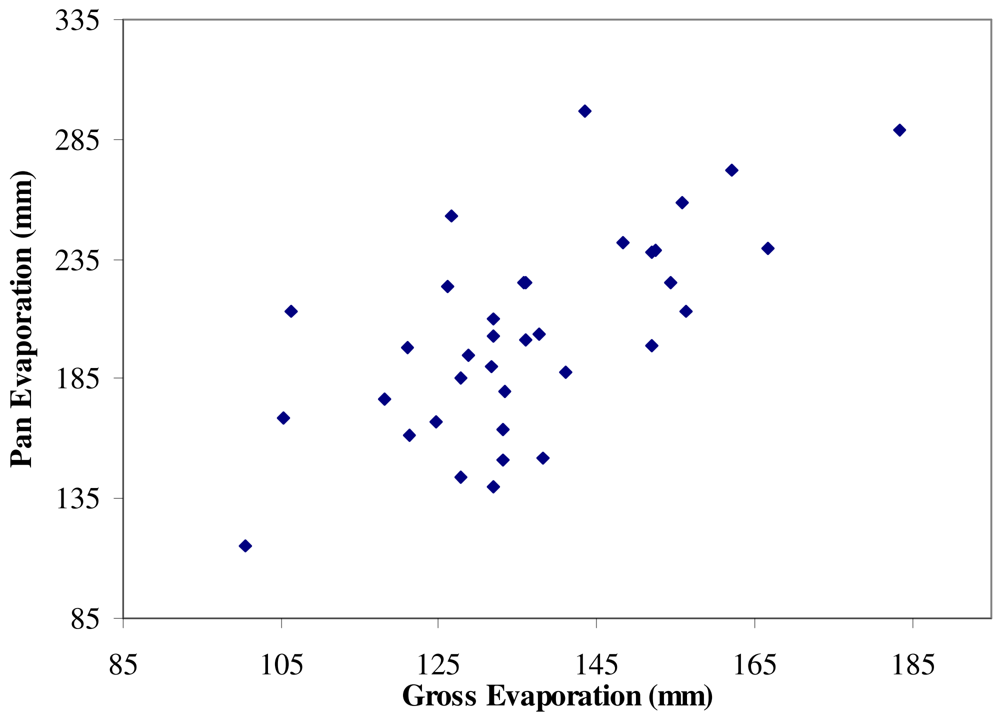

Figure D40: Scatter graph of pan evaporation at Morden vs. gross evaporation at Portage La Prairie in May (r = 0.66)

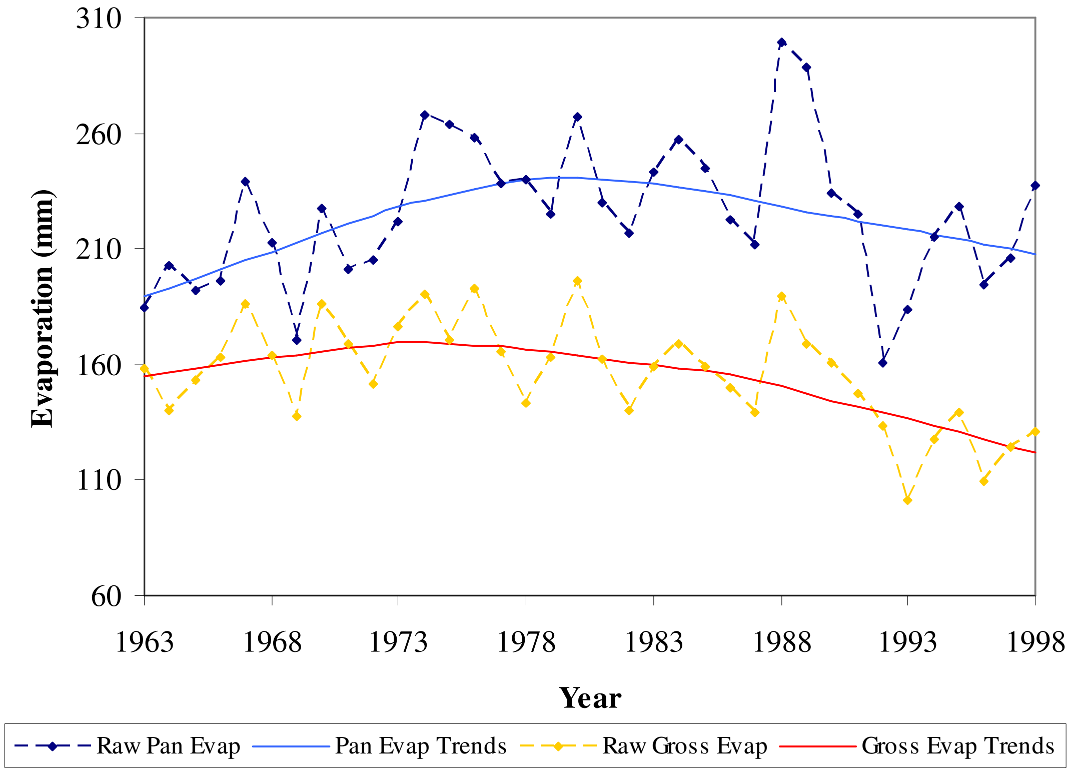

Figure D41: Comparison of Morden pan evaporation and Portage La Prairie gross evaporation in July – Type 1

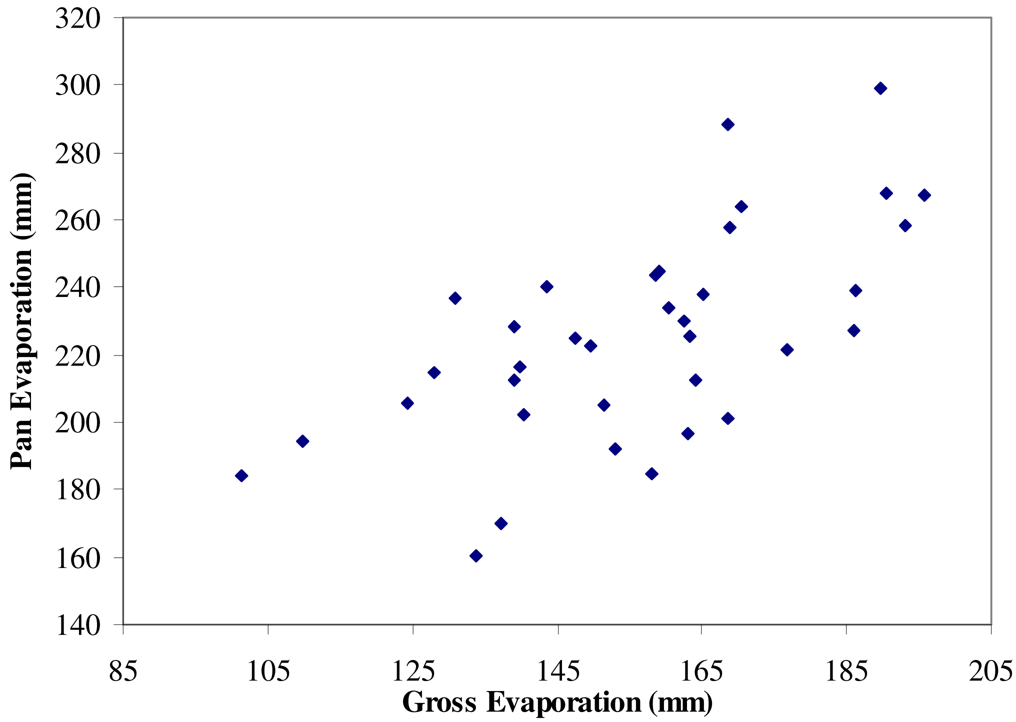

Figure D42: Scatter graph of pan evaporation at Morden vs. gross evaporation at Portage La Prairie in July (r = 0.64)

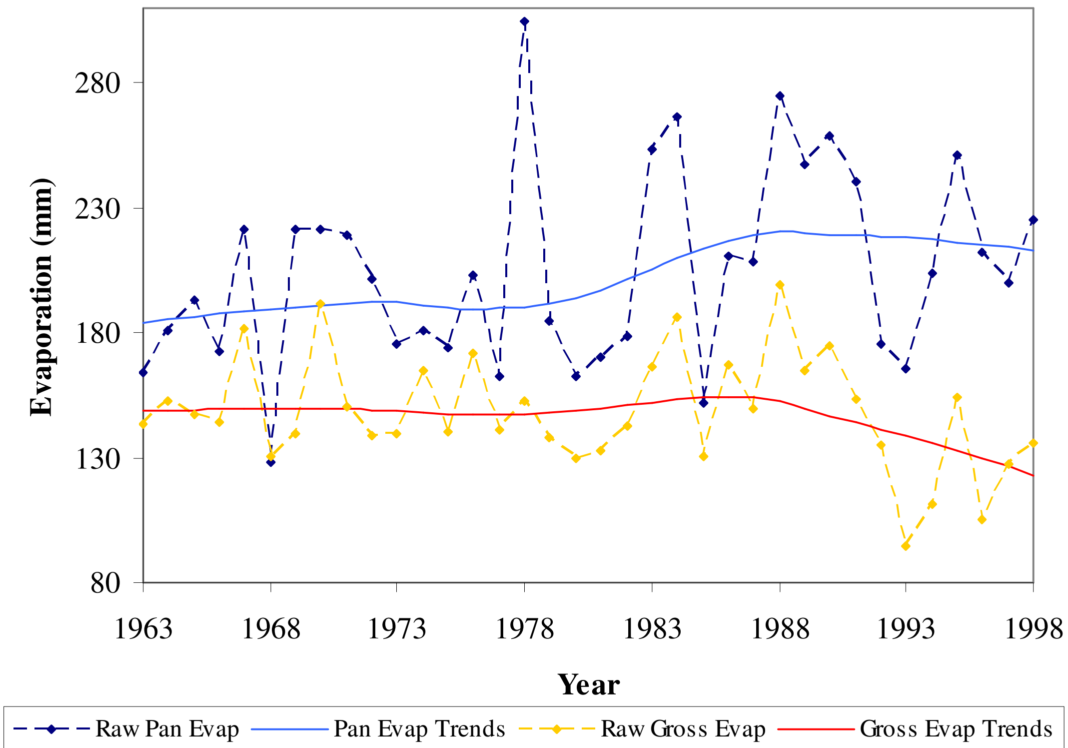

Figure D43: Comparison of Morden pan evaporation and Portage La Prairie gross evaporation in August – Type 3

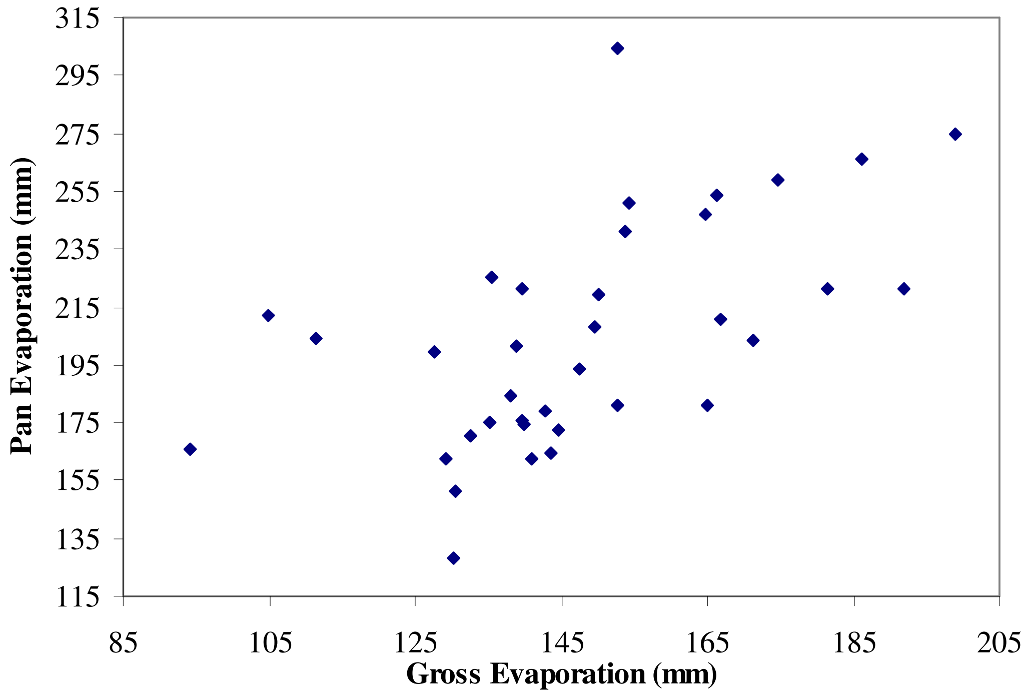

Figure D44: Scatter graph of pan evaporation at Morden vs. gross evaporation at Portage La Prairie in August (r = 0.57)

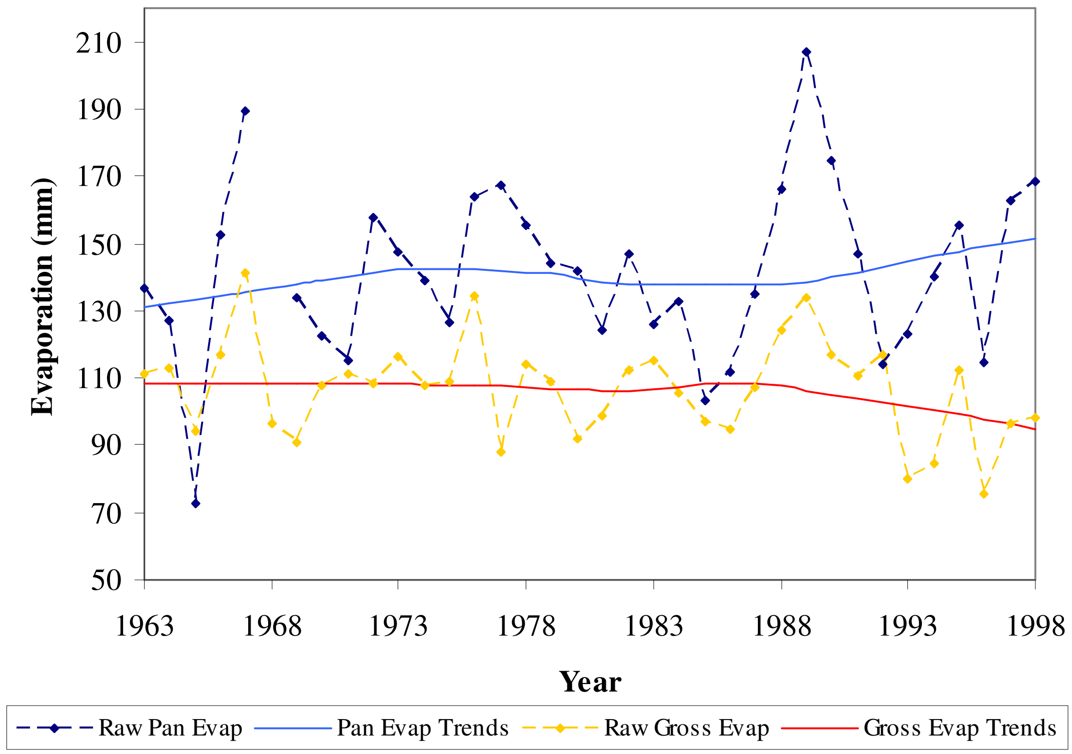

Figure D45: Comparison of Morden pan evaporation and Portage La Prairie gross evaporation in September – Type 3

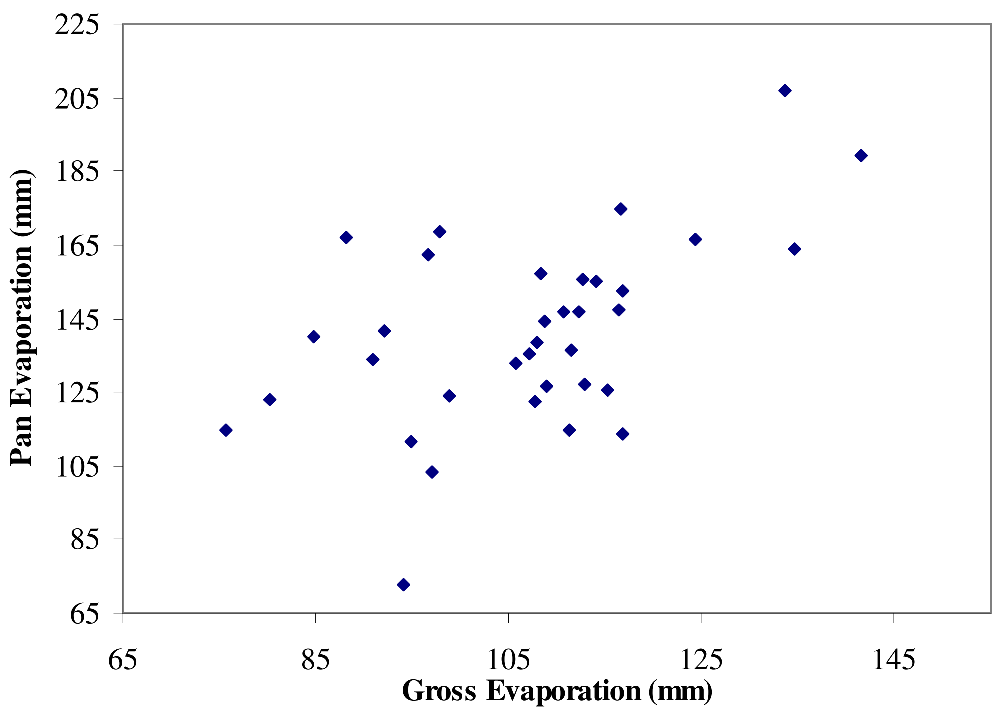

Figure D46: Scatter graph of pan evaporation at Morden vs. gross evaporation at Portage La Prairie in September (r = 0.53)

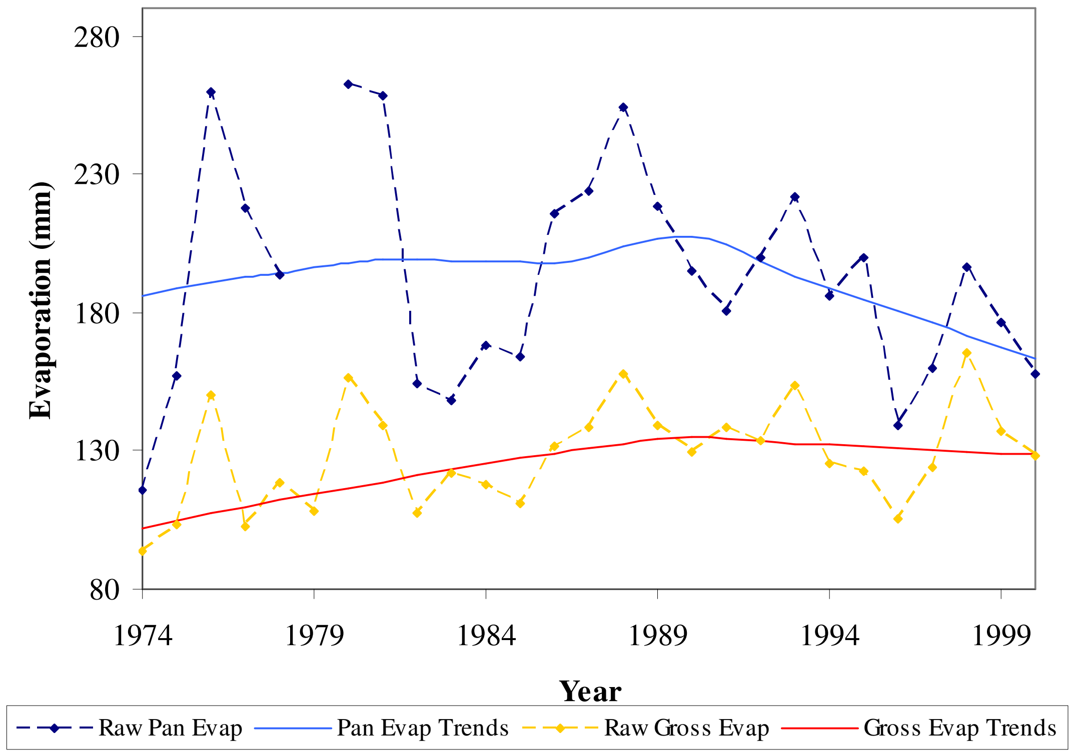

Figure D47: Comparison of Nipawin pan evaporation and gross evaporation in May – Type 1

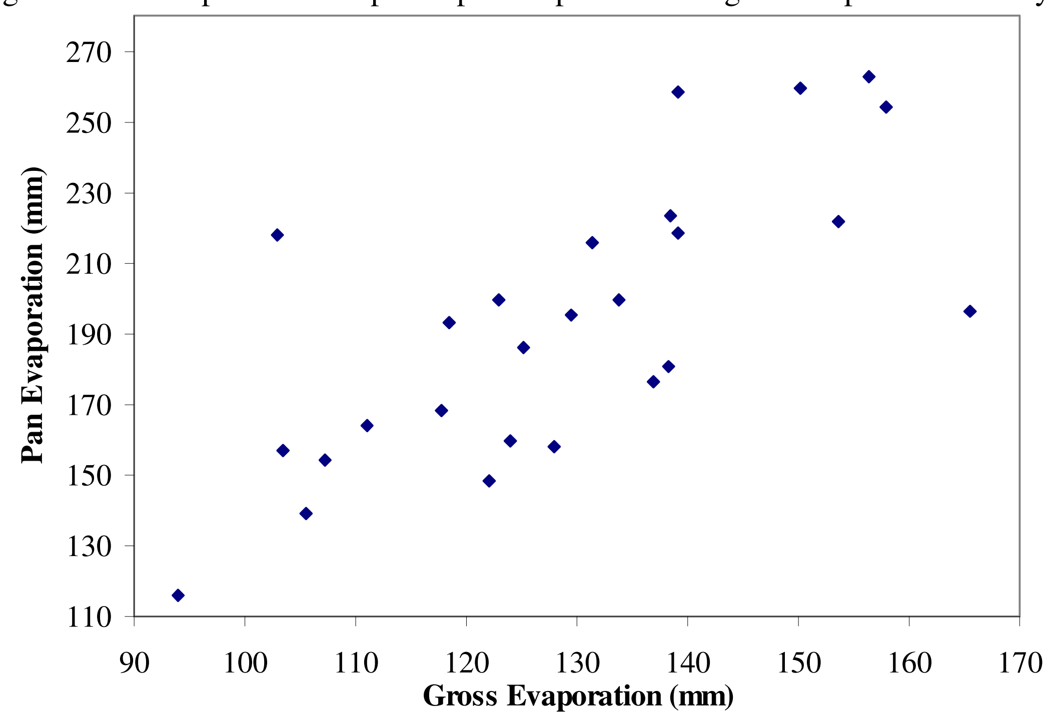

Figure D48: Scatter graph of pan evaporation vs. gross evaporation at Nipawin in May (r = 0.72)

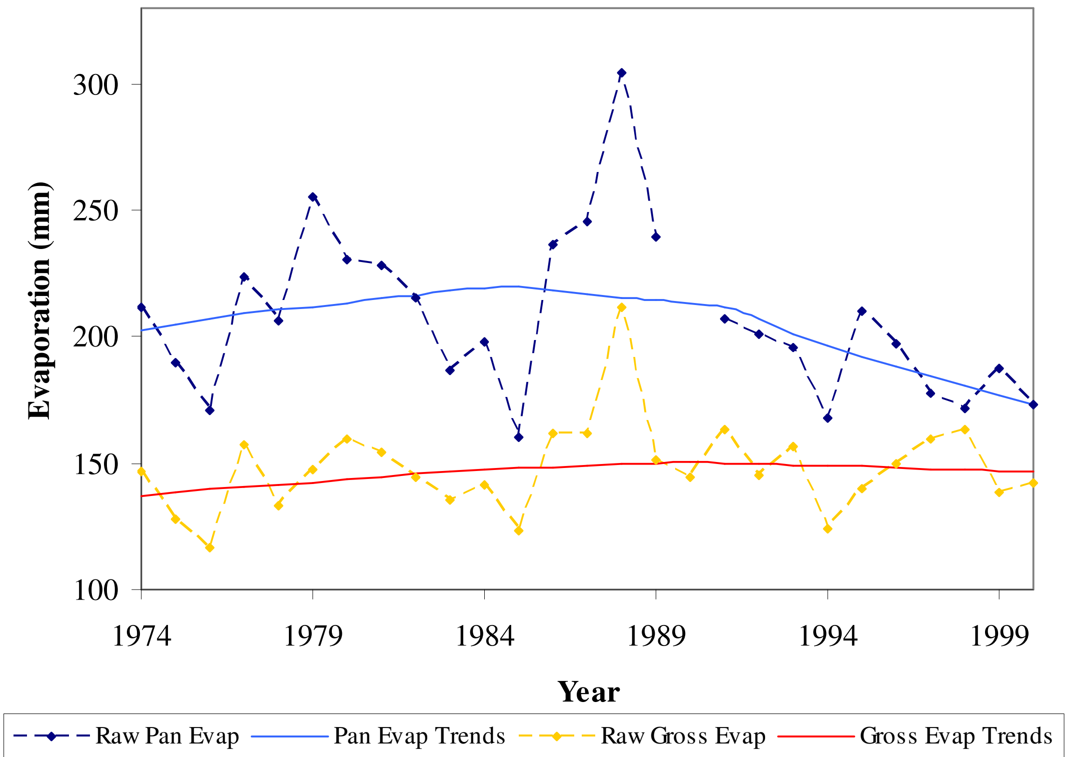

Figure D49: Comparison of Nipawin pan evaporation and gross evaporation in June – Type 1

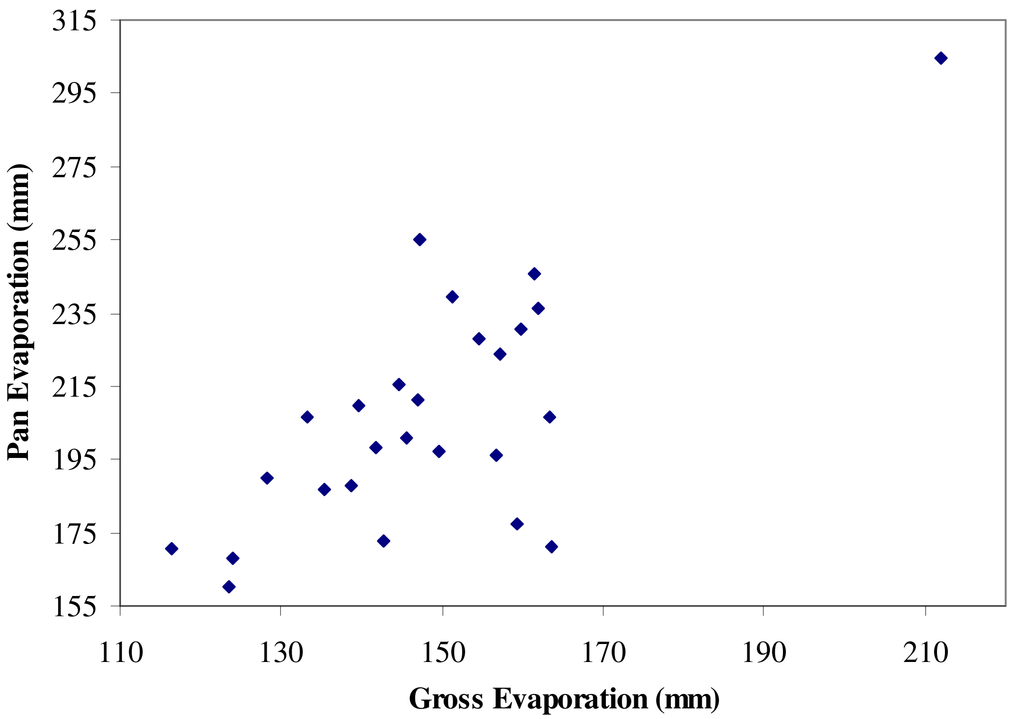

Figure D50: Scatter graph of pan evaporation vs. gross evaporation at Nipawin in June (r = 0.73)

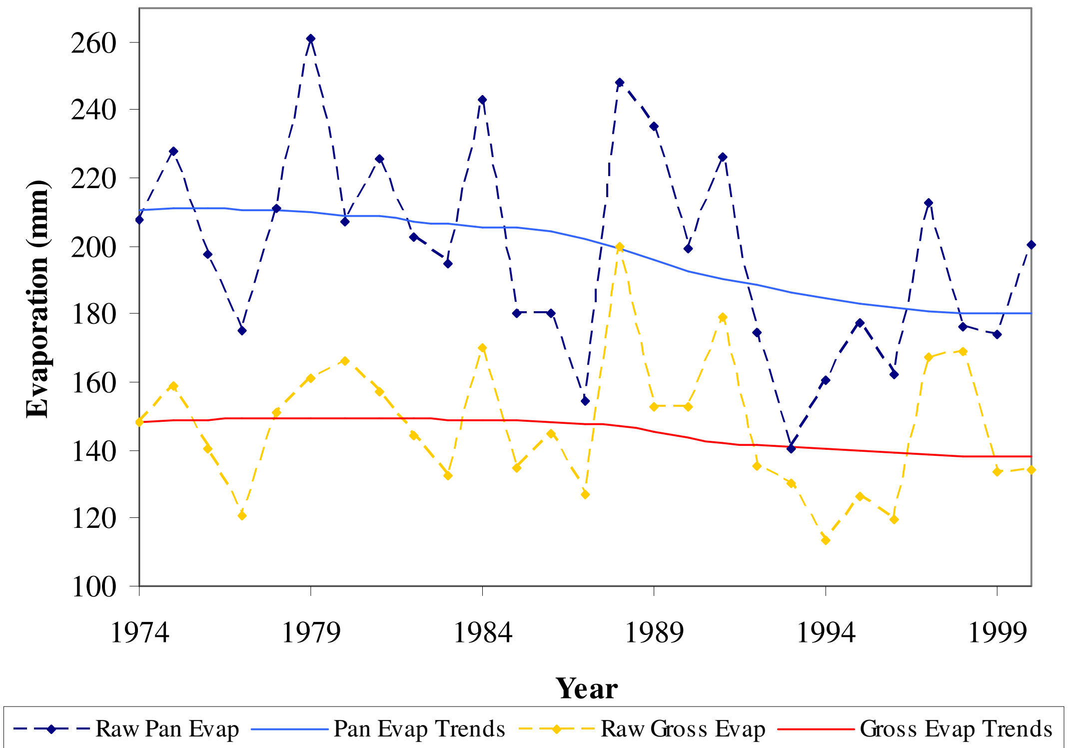

Figure D51: Comparison of Nipawin pan evaporation and gross evaporation in July – Type 1

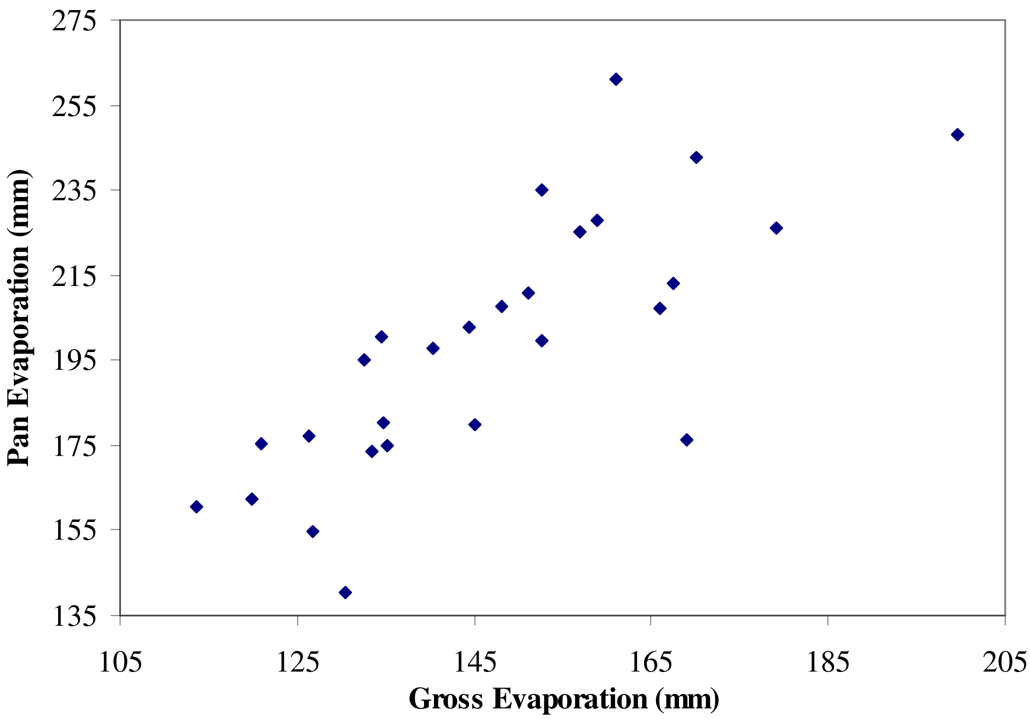

Figure D52: Scatter graph of pan evaporation vs. gross evaporation at Nipawin in July (r = 0.77)

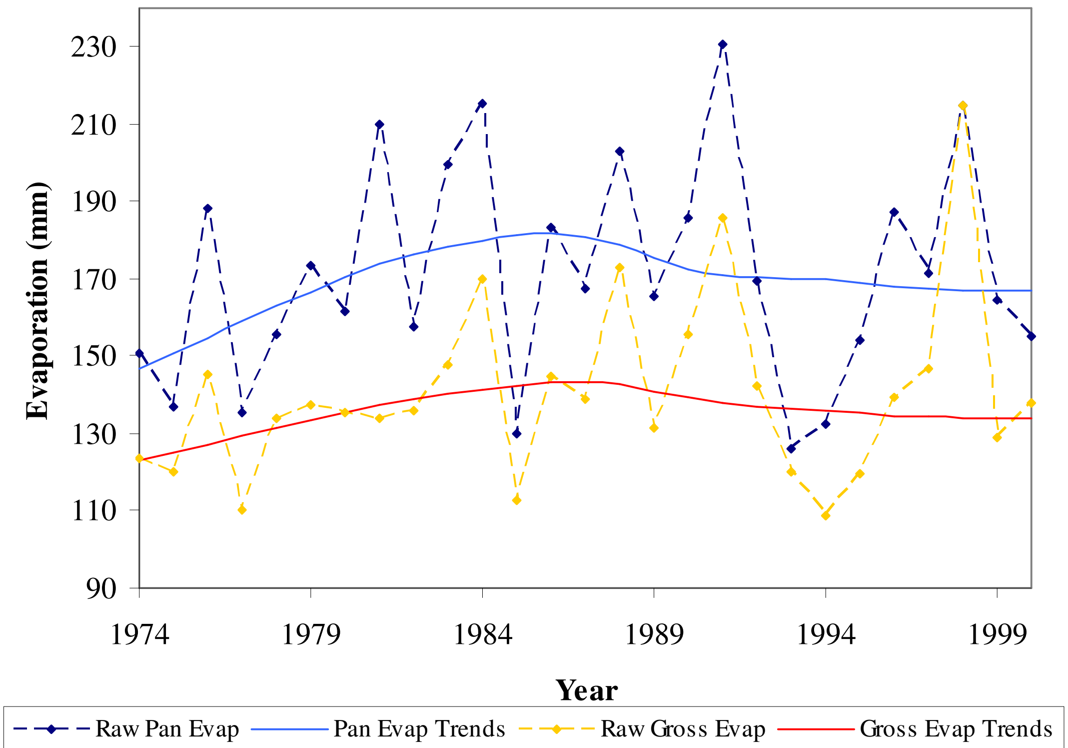

Figure D53: Comparison of Nipawin pan evaporation and gross evaporation in August – Type 3

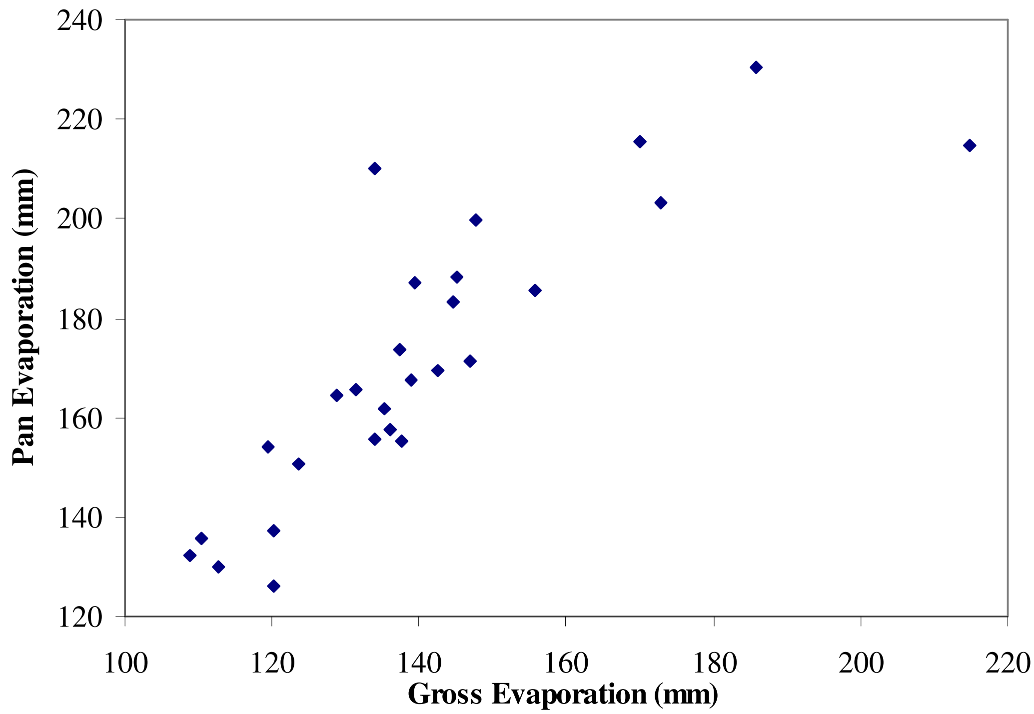

Figure D54: Scatter graph of pan evaporation vs. gross evaporation at Nipawin in August (r = 0.85)

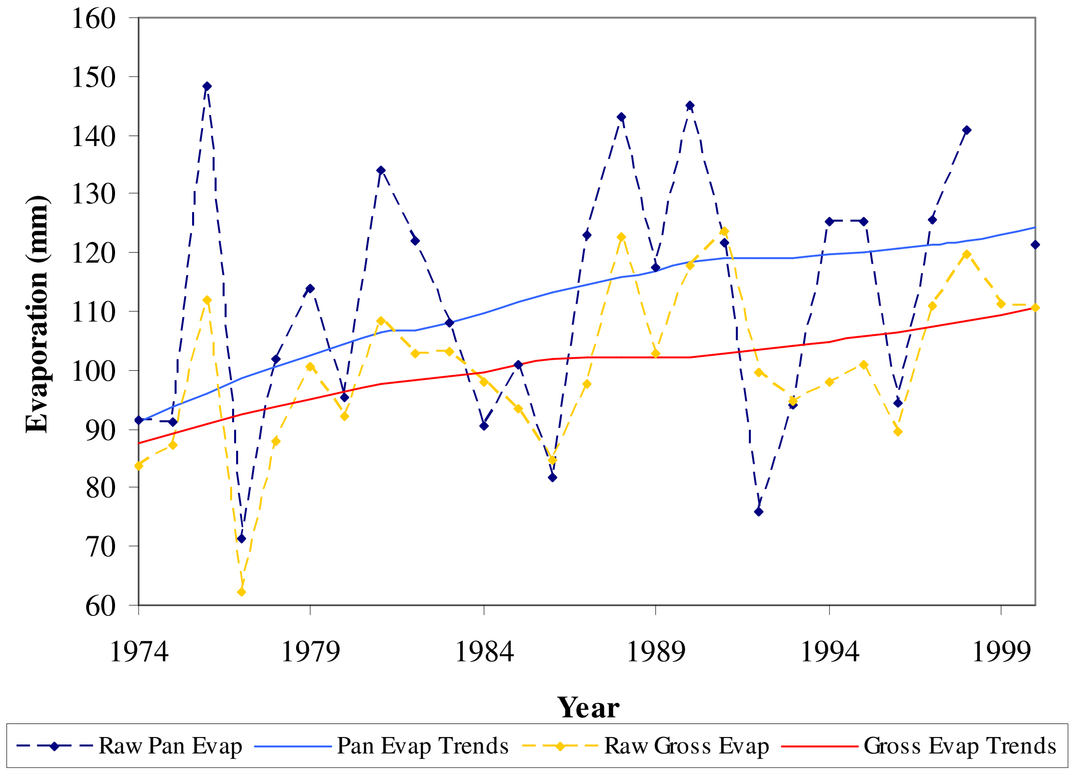

Figure D55: Comparison of Nipawin pan evaporation and gross evaporation in September – Type 2

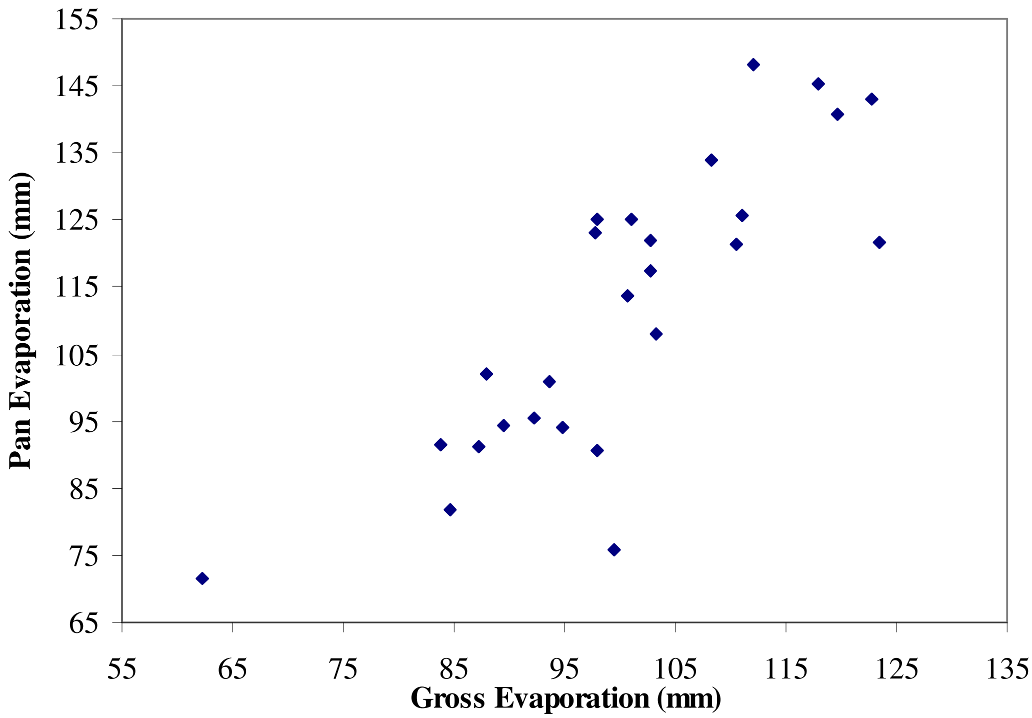

Figure D56: Scatter graph of pan evaporation vs. gross evaporation at Nipawin in September (r = 0.82)

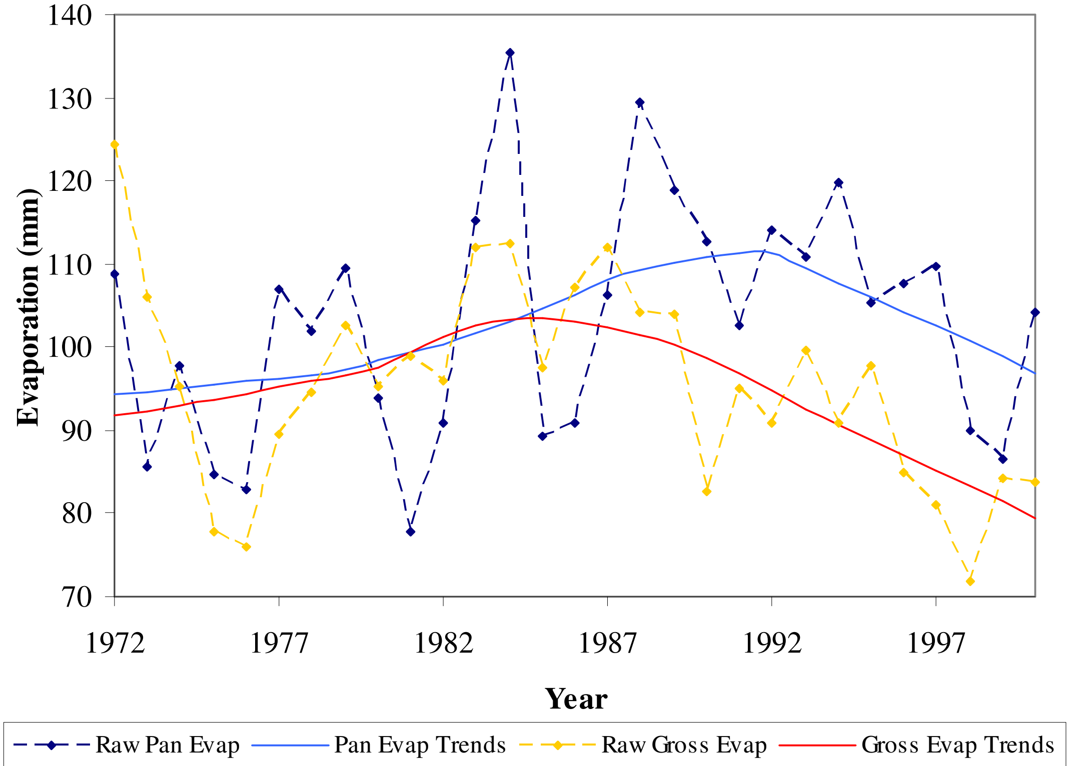

Figure D57: Comparison of Norway Forestry pan evaporation and Norway House gross evaporation in June – Type 1

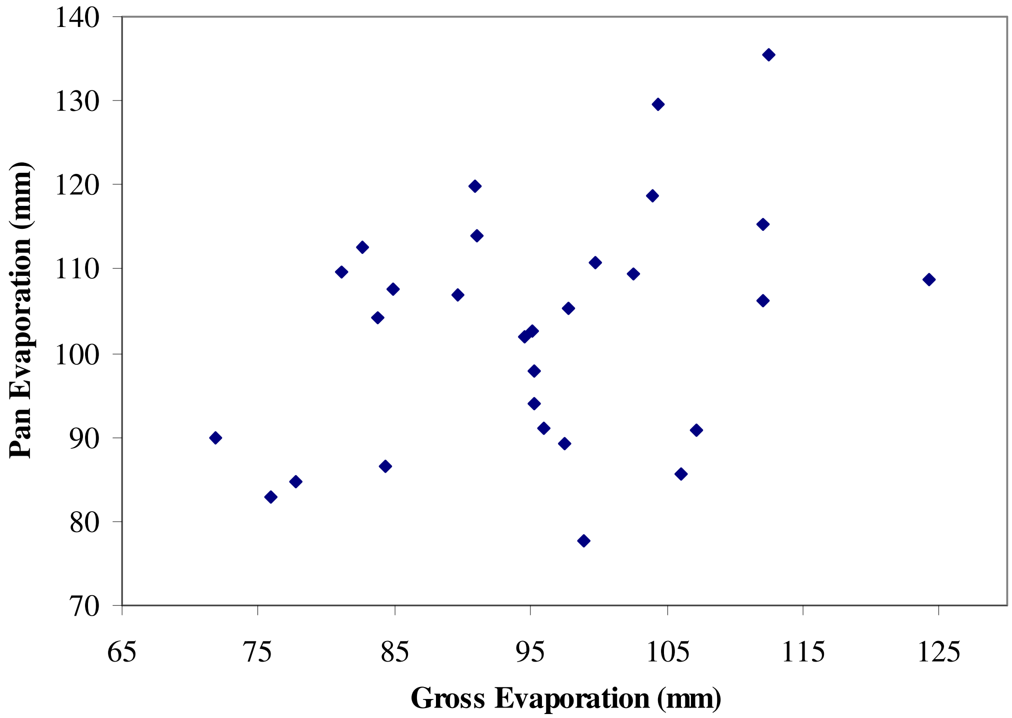

Figure D58: Scatter graph of pan evaporation at Norway Forestry vs. gross evaporation at Norway House in June (r = 0.36)

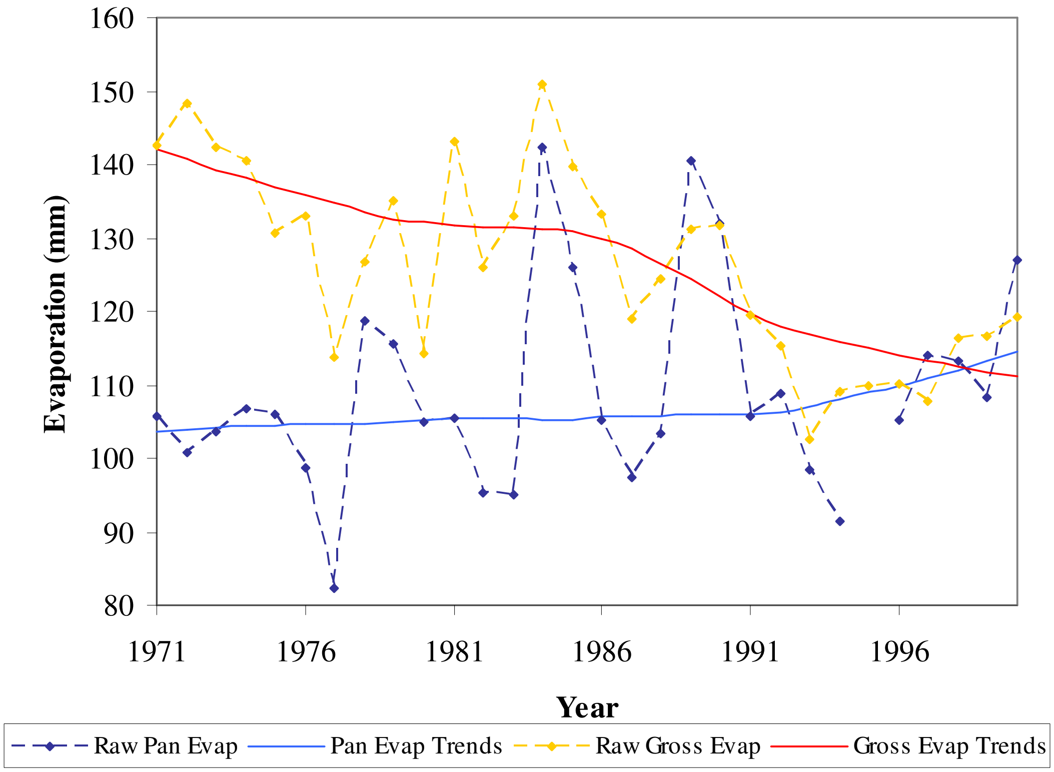

Figure D59: Comparison of Norway Forestry pan evaporation and Norway House gross evaporation in July – Type 1

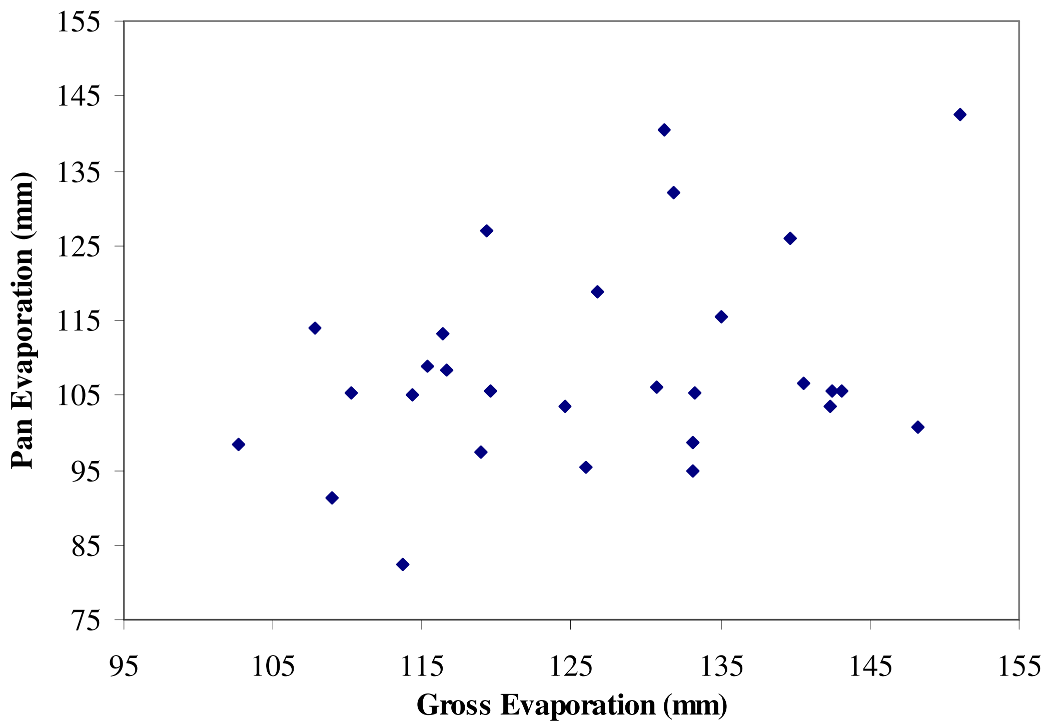

Figure D60: Scatter graph of pan evaporation at Norway Forestry vs. gross evaporation at Norway House in July (r = 0.32)

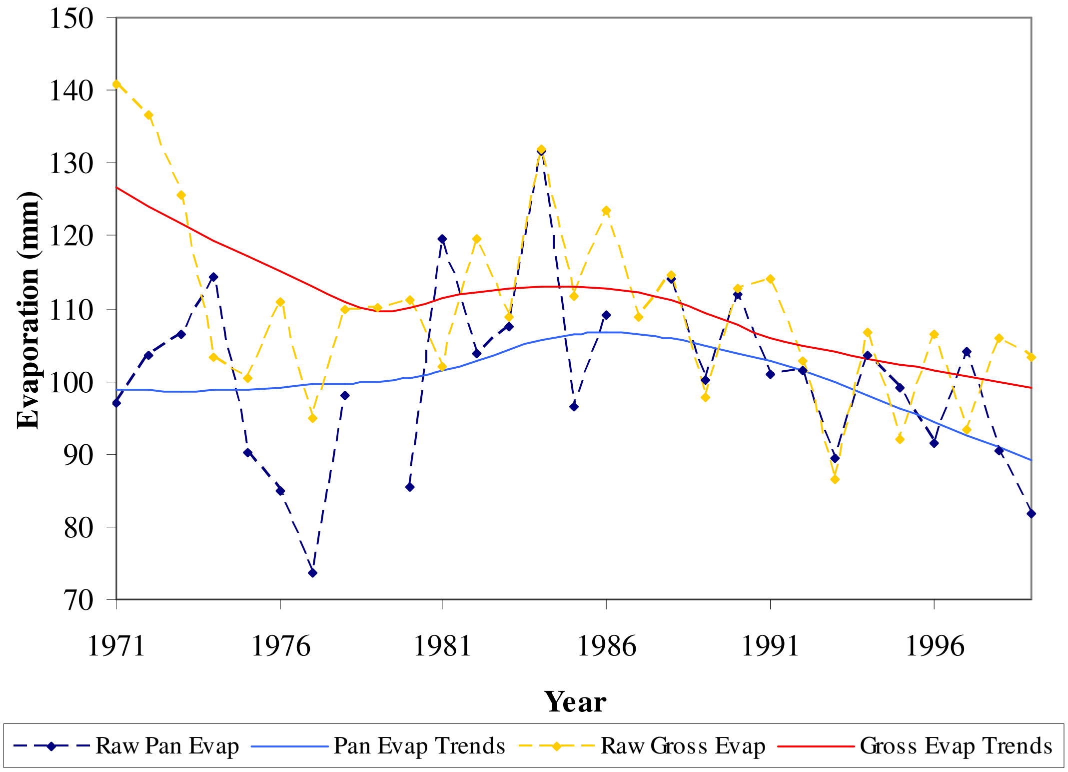

Figure D61: Comparison of Norway Forestry pan evaporation and Norway House gross evaporation in August – Type 1

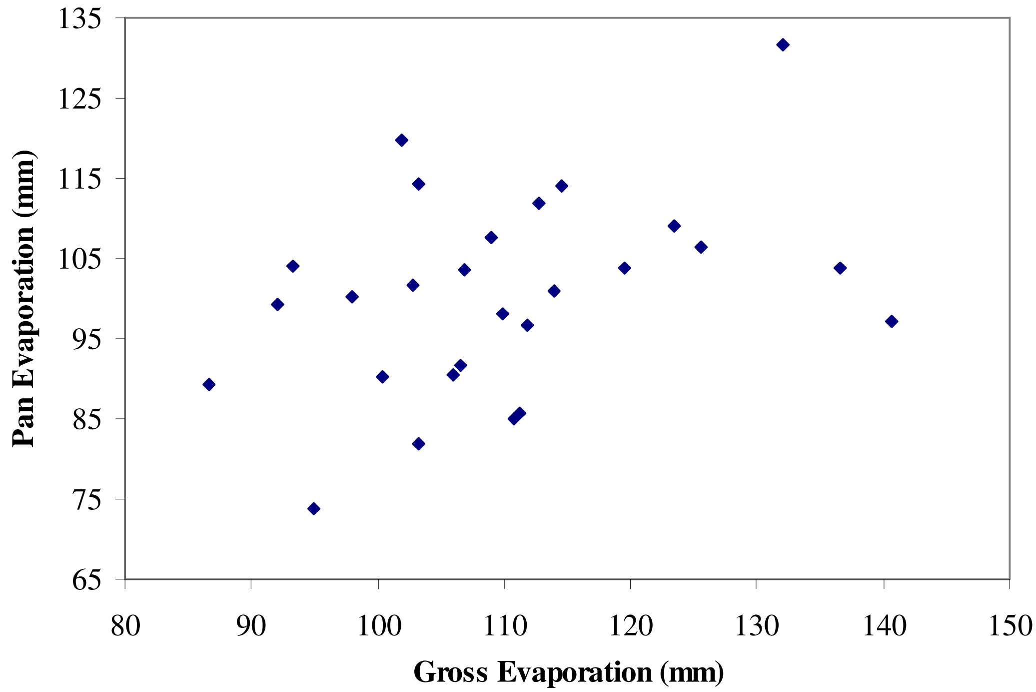

Figure D62: Scatter graph of pan evaporation at Norway Forestry vs. gross evaporation at Norway House in August (r = 0.38)

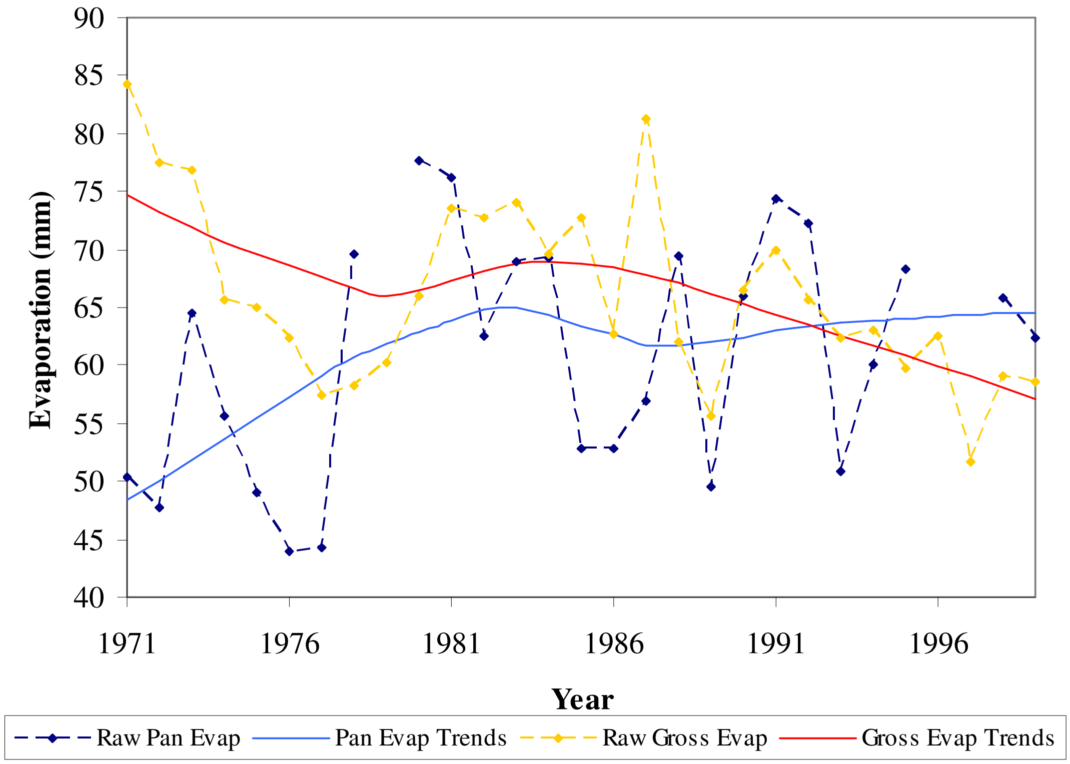

Figure D63: Comparison of Norway Forestry pan evaporation and Norway House gross evaporation in September – Type 5

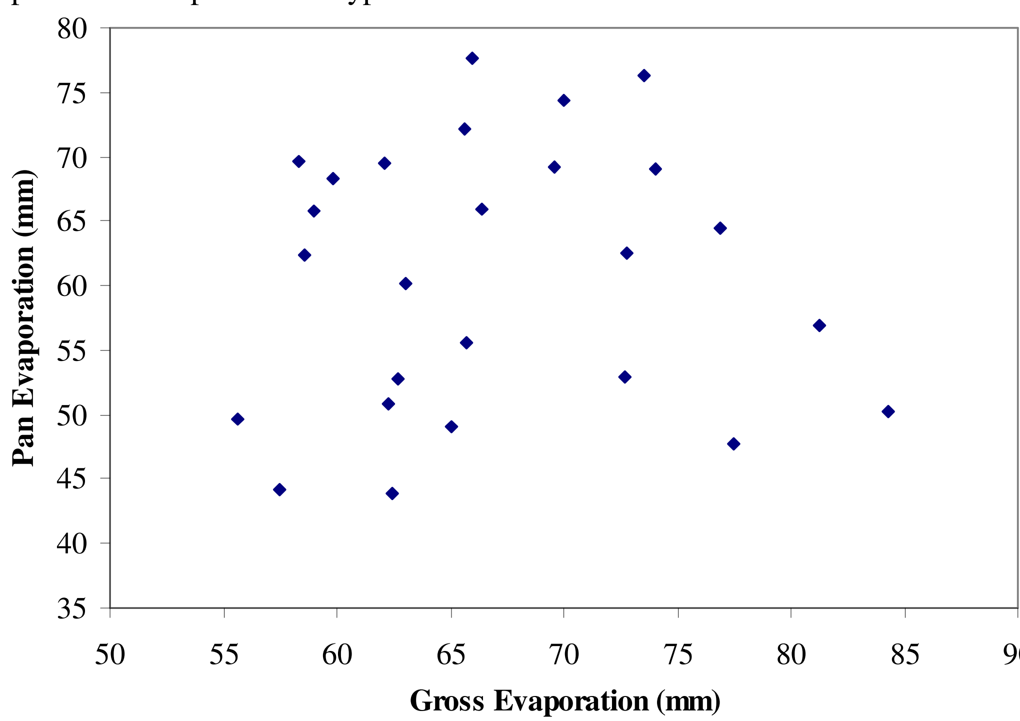

Figure D64: Scatter graph of pan evaporation at Norway Forestry vs. gross evaporation at Norway House in September (r = 0.03)

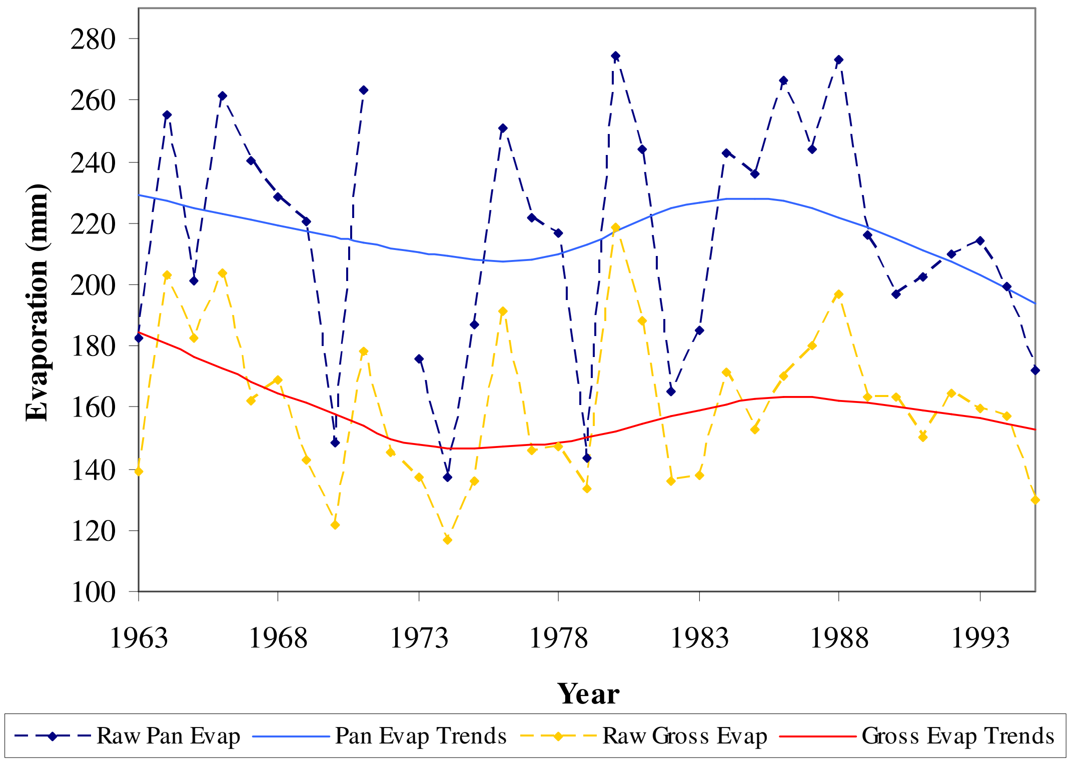

Figure D65: Comparison of Regina pan evaporation and gross evaporation in May – Type 3

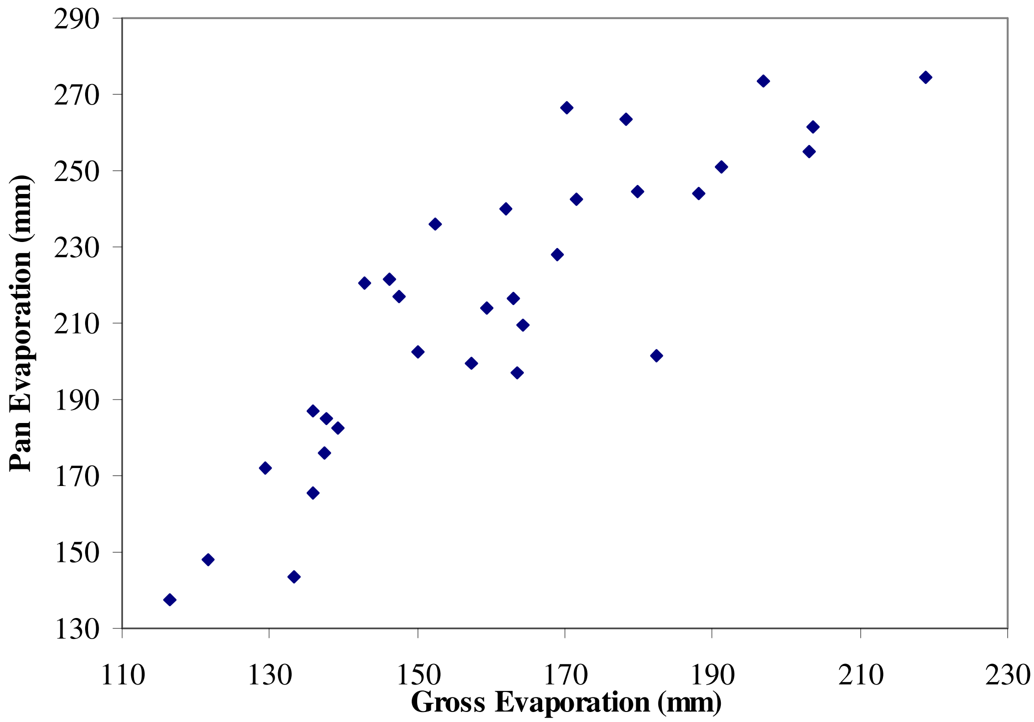

Figure D66: Scatter graph of pan evaporation vs. gross evaporation at Regina in May (r = 0.87)

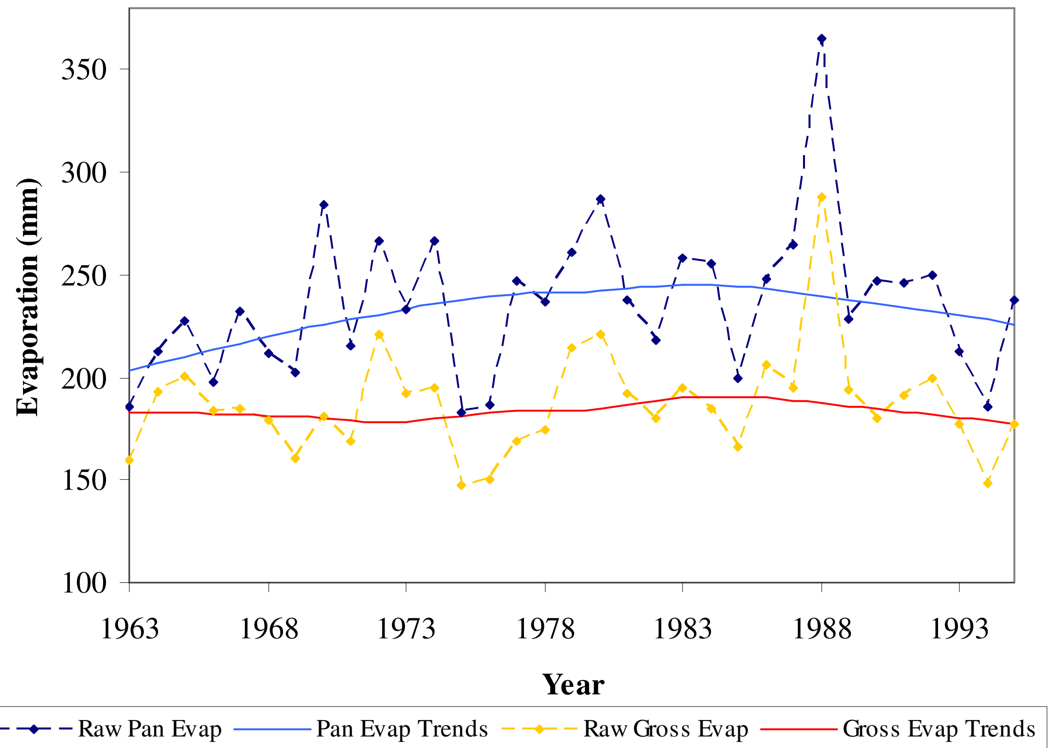

Figure D67: Comparison of Regina pan evaporation and gross evaporation in June – Type 3

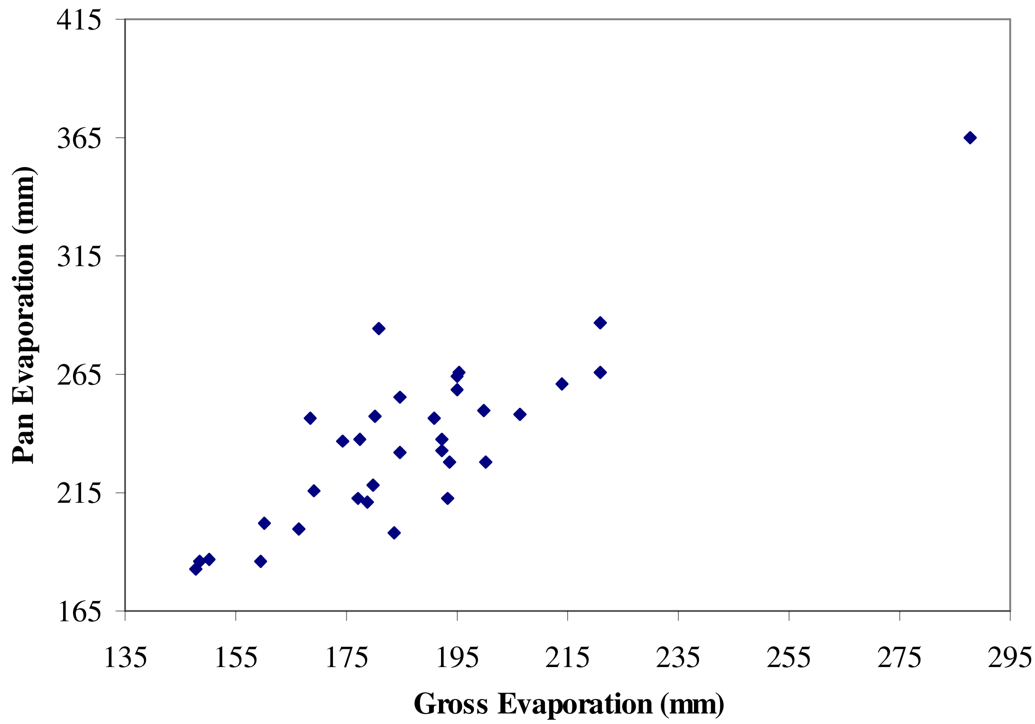

Figure D68: Scatter graph of pan evaporation vs. gross evaporation at Regina in June (r = 0.86)

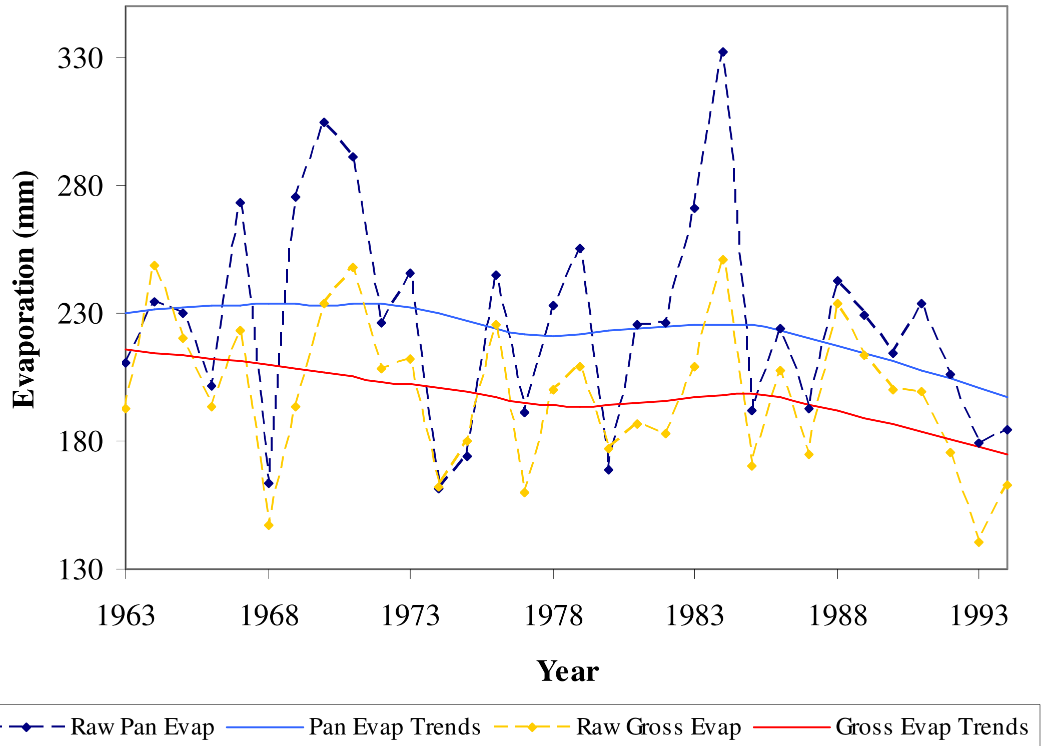

Figure D69: Comparison of Regina pan evaporation and gross evaporation in August – Type 3

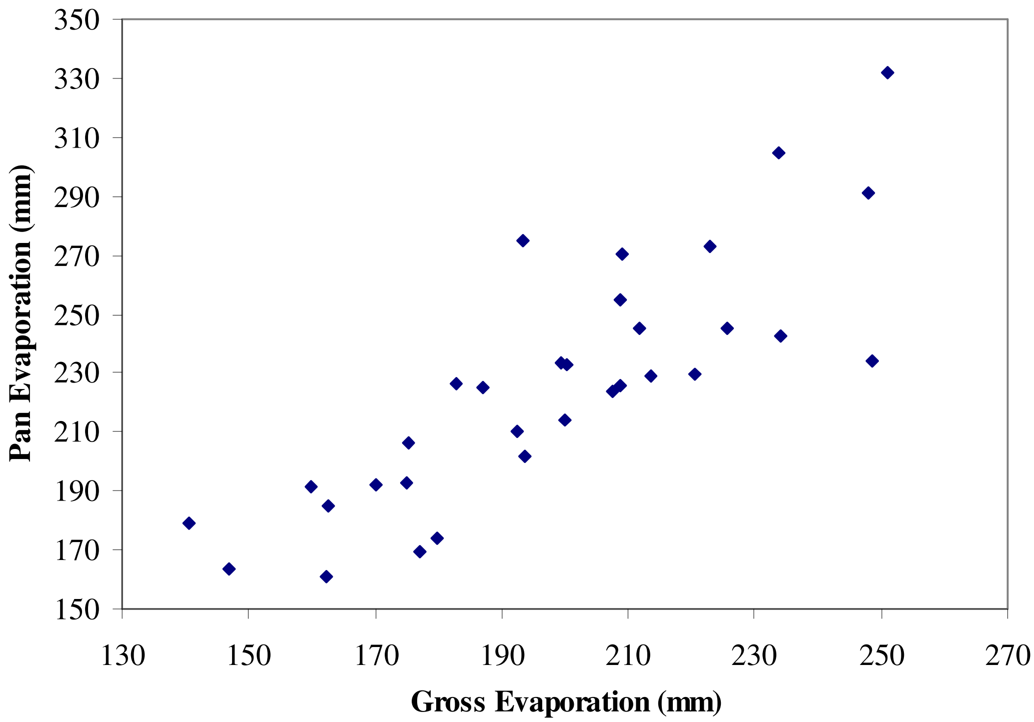

Figure D70: Scatter graph of pan evaporation vs. gross evaporation at Regina in August (r = 0.83)

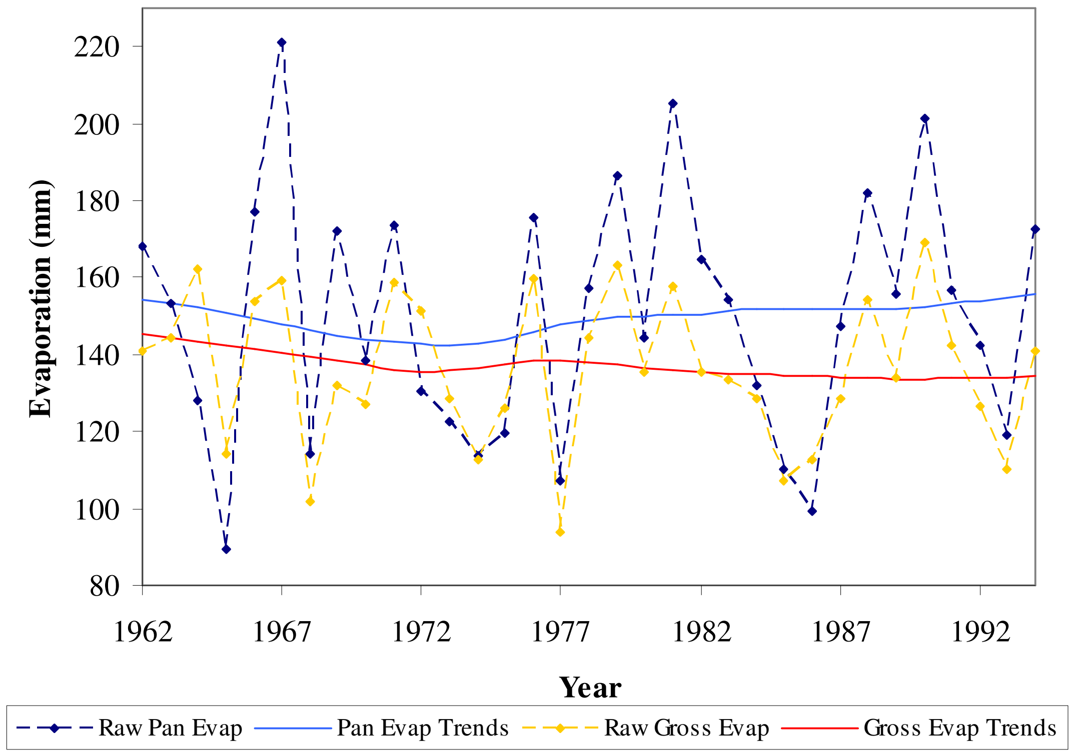

Figure D71: Comparison of Regina pan evaporation and gross evaporation in September – Type 3

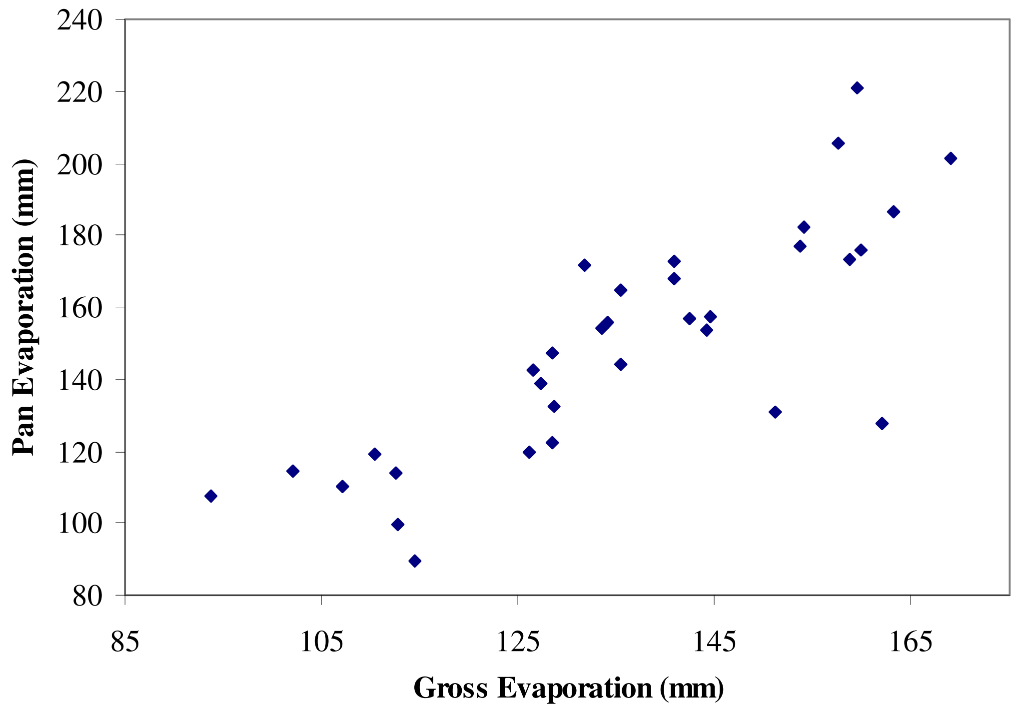

Figure D72: Scatter graph of pan evaporation vs. gross evaporation at Regina in September (r = 0.81)

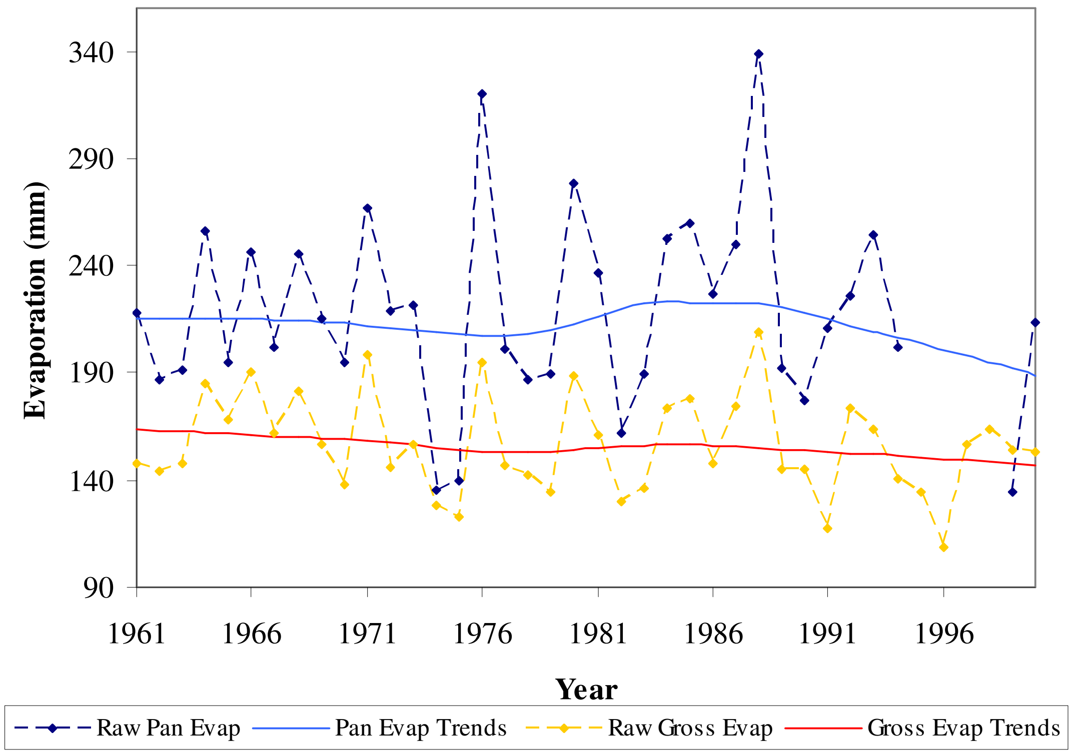

Figure D73: Comparison of Swift Current pan evaporation and gross evaporation in May – Type 3

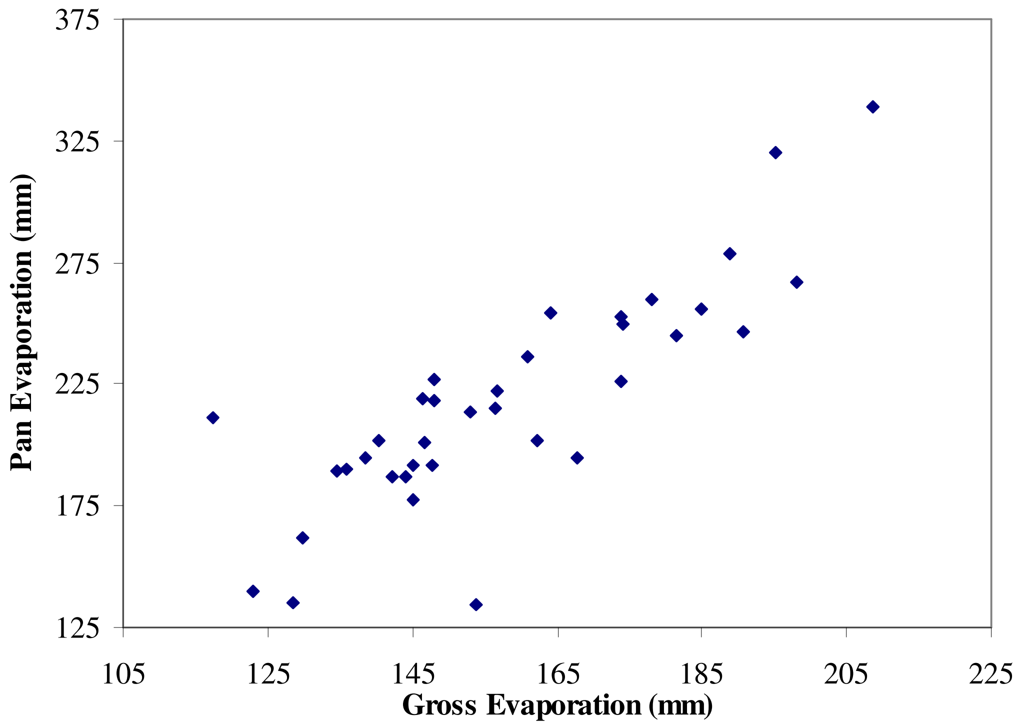

Figure D74: Scatter graph of pan evaporation vs. gross evaporation at Swift Current in May (r = 0.84)

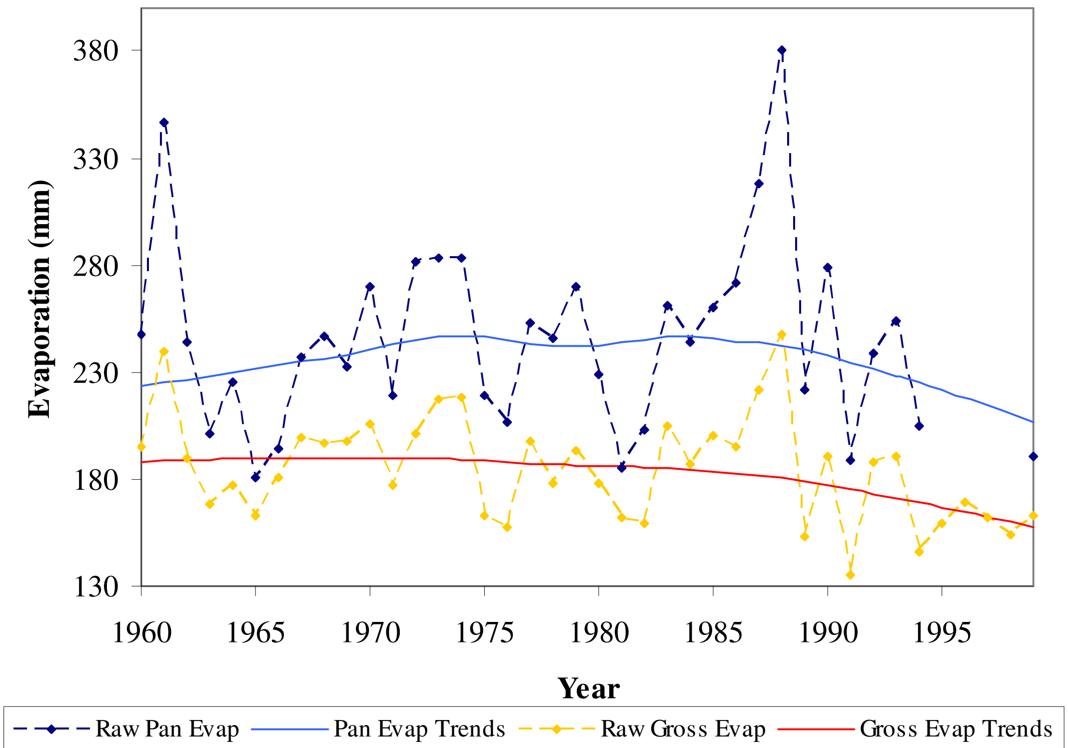

Figure D75: Comparison of Swift Current pan evaporation and gross evaporation in June – Type 1

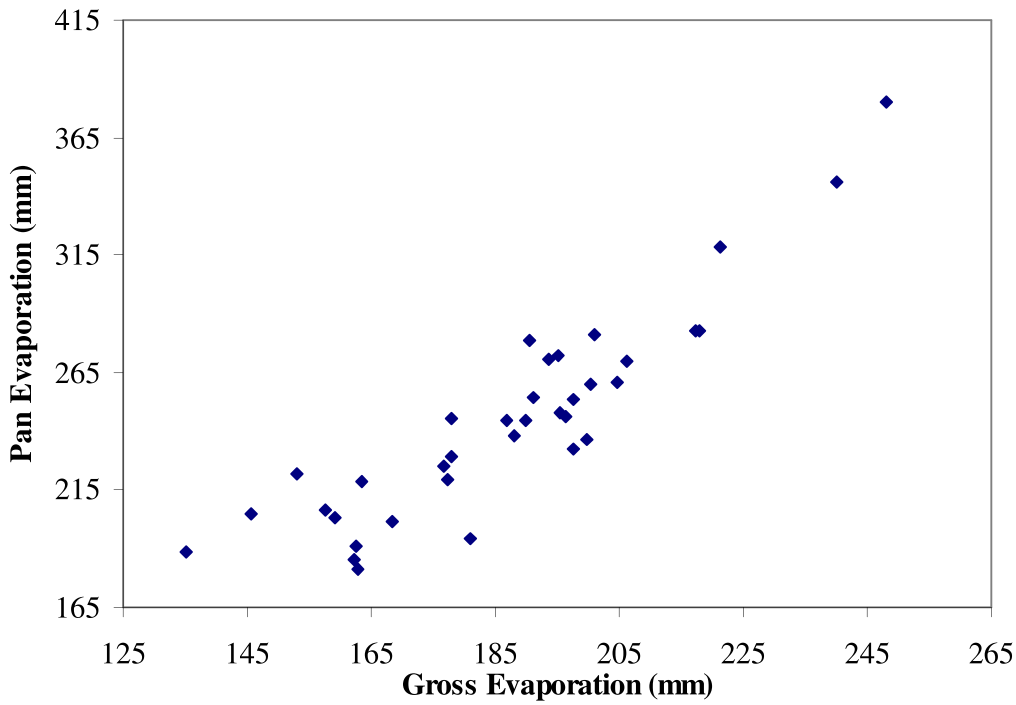

Figure D76: Scatter graph of pan evaporation vs. gross evaporation at Swift Current in June (r = 0.91)

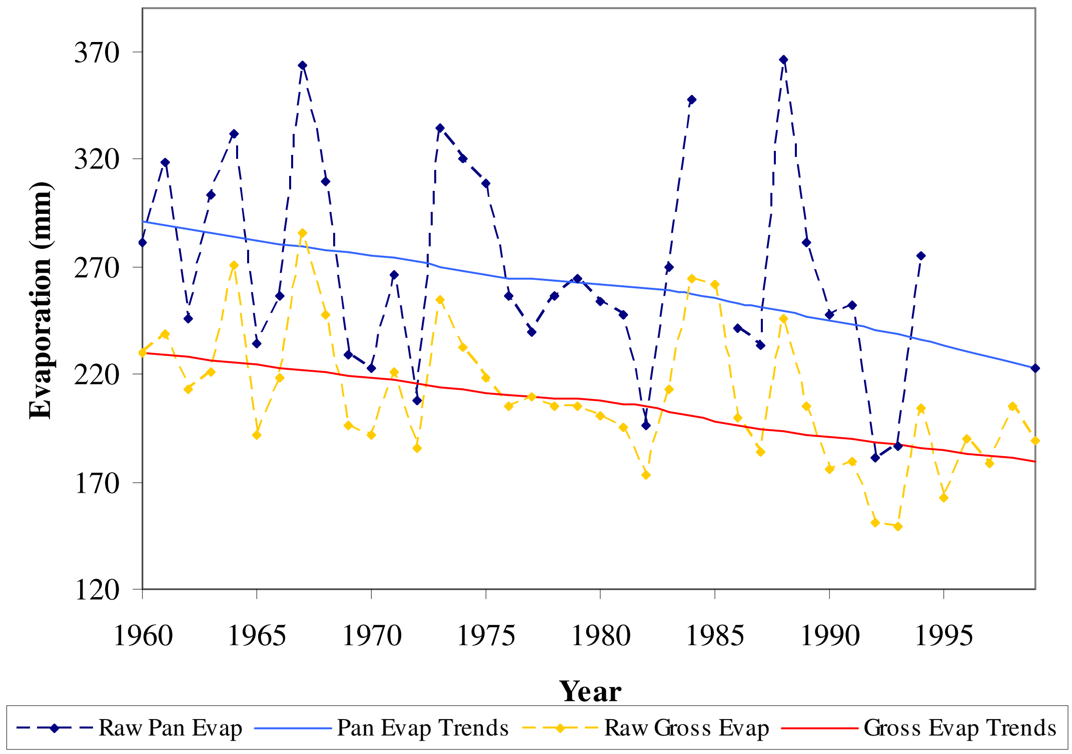

Figure D77: Comparison of Swift Current pan evaporation and gross evaporation in July – Type 3

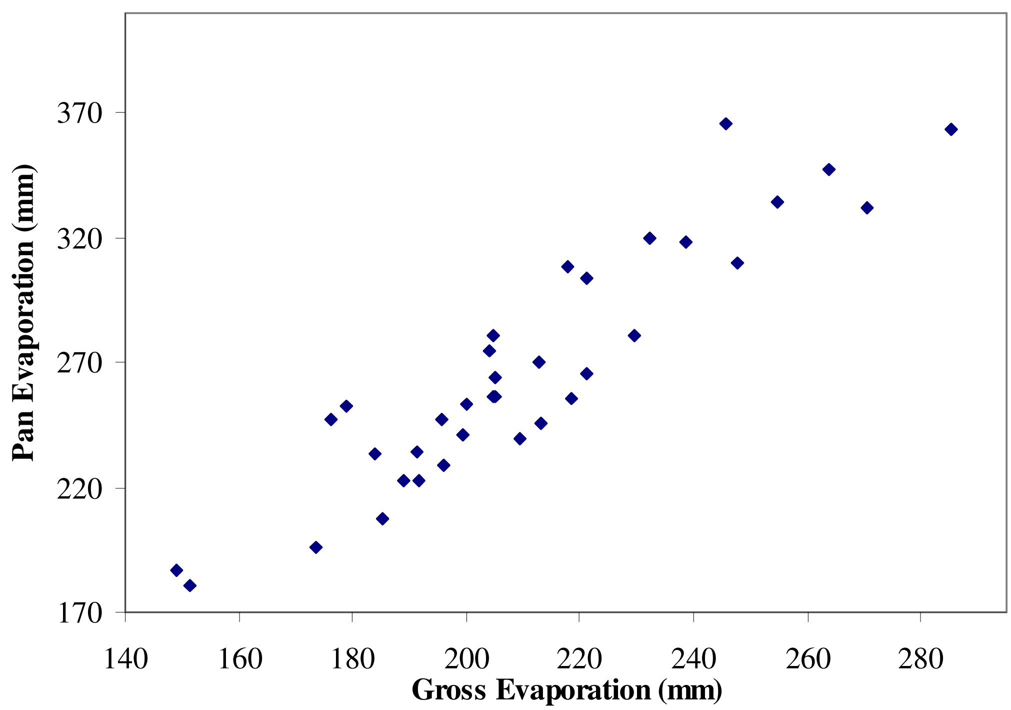

Figure D78: Scatter graph of pan evaporation vs. gross evaporation at Swift Current in July (r = 0.92)

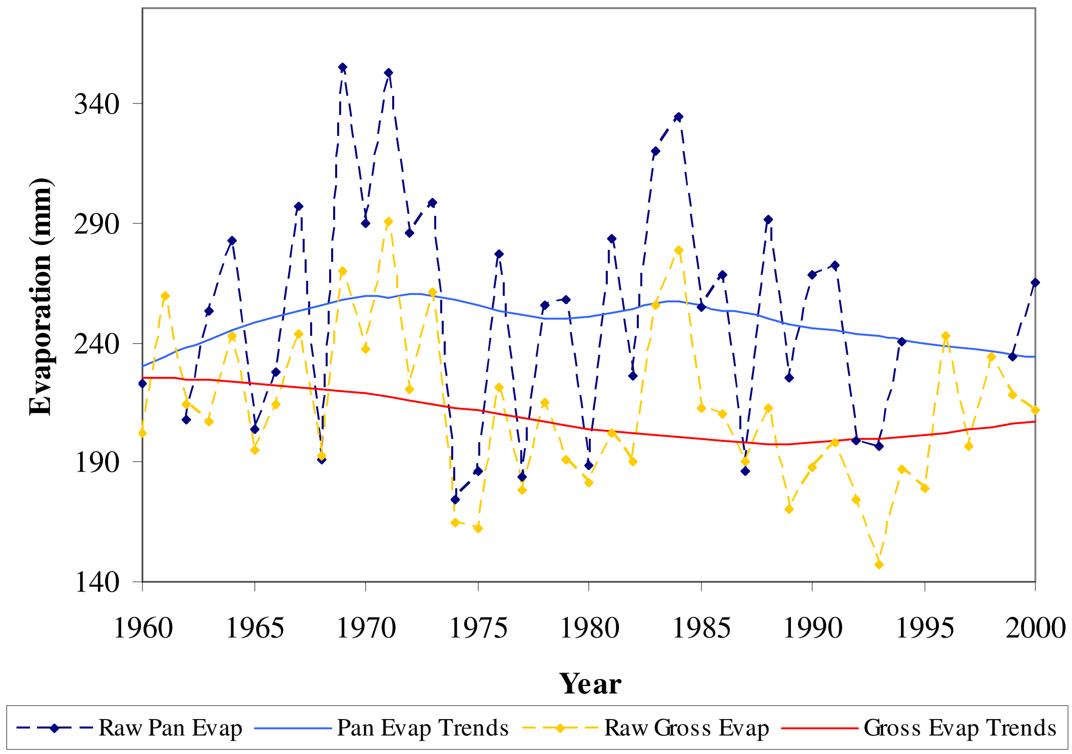

Figure D79: Comparison of Swift Current pan evaporation and gross evaporation in August – Type 1

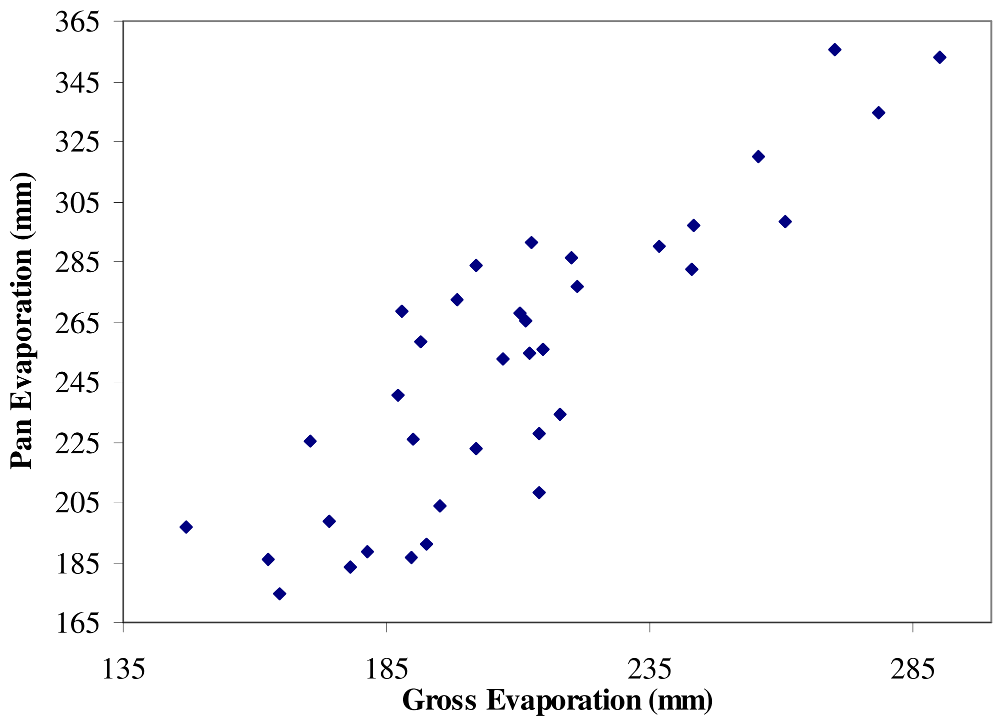

Figure D80: Scatter graph of pan evaporation vs. gross evaporation at Swift Current in August (r = 0.87)

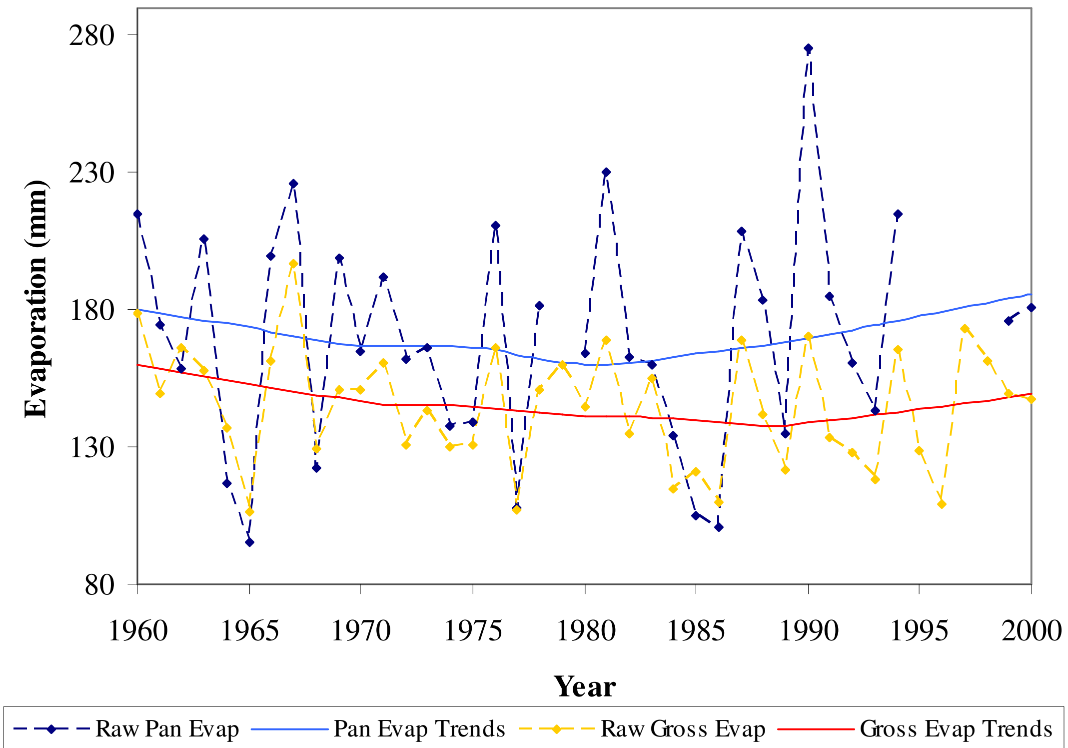

Figure D81: Comparison of Swift Current pan evaporation and gross evaporation in September – Type 3

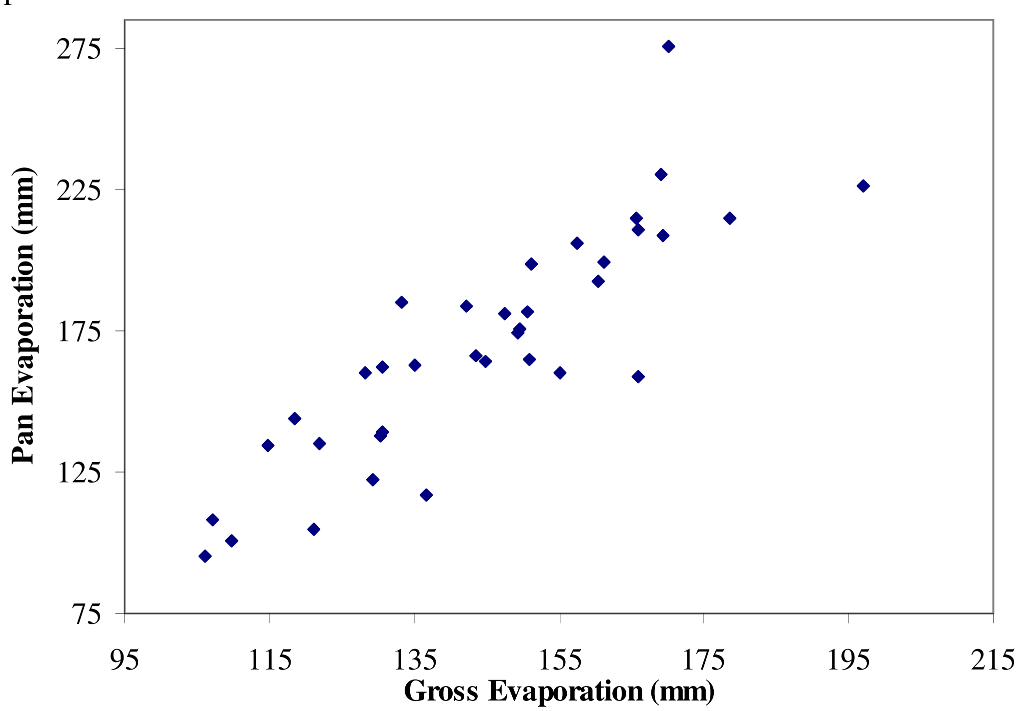

Figure D82: Scatter graph of pan evaporation vs. gross evaporation at Swift Current in September (r = 0.86)

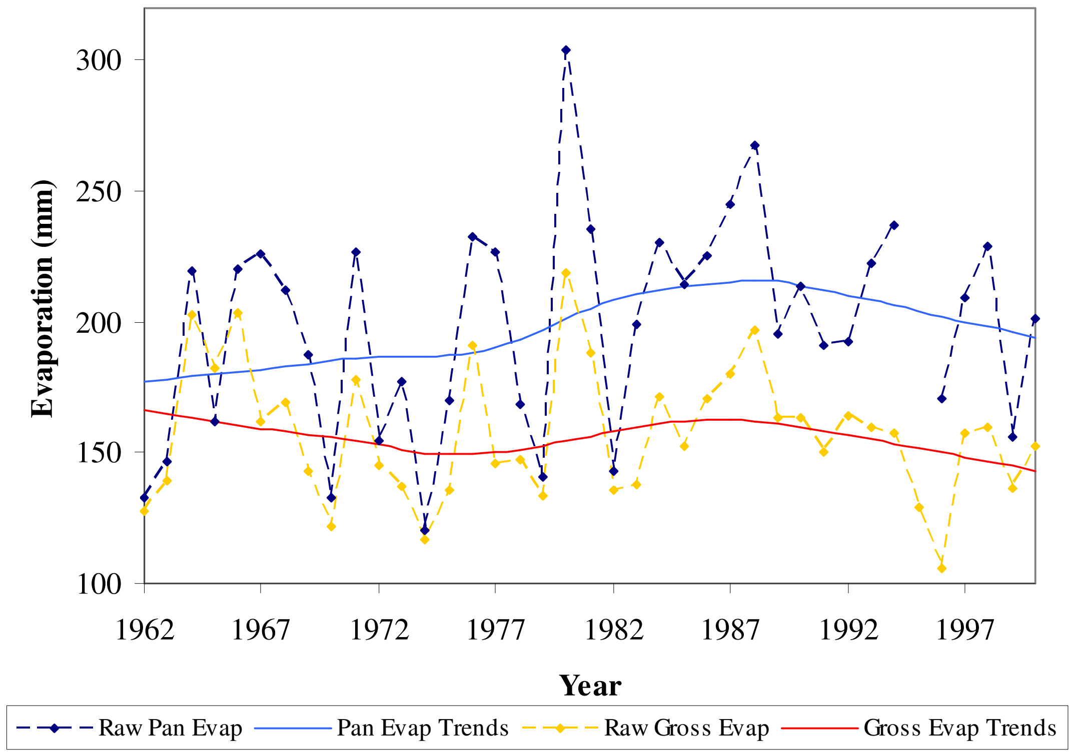

Figure D83: Comparison of Weyburn pan evaporation and Regina gross evaporation in May - Type 3

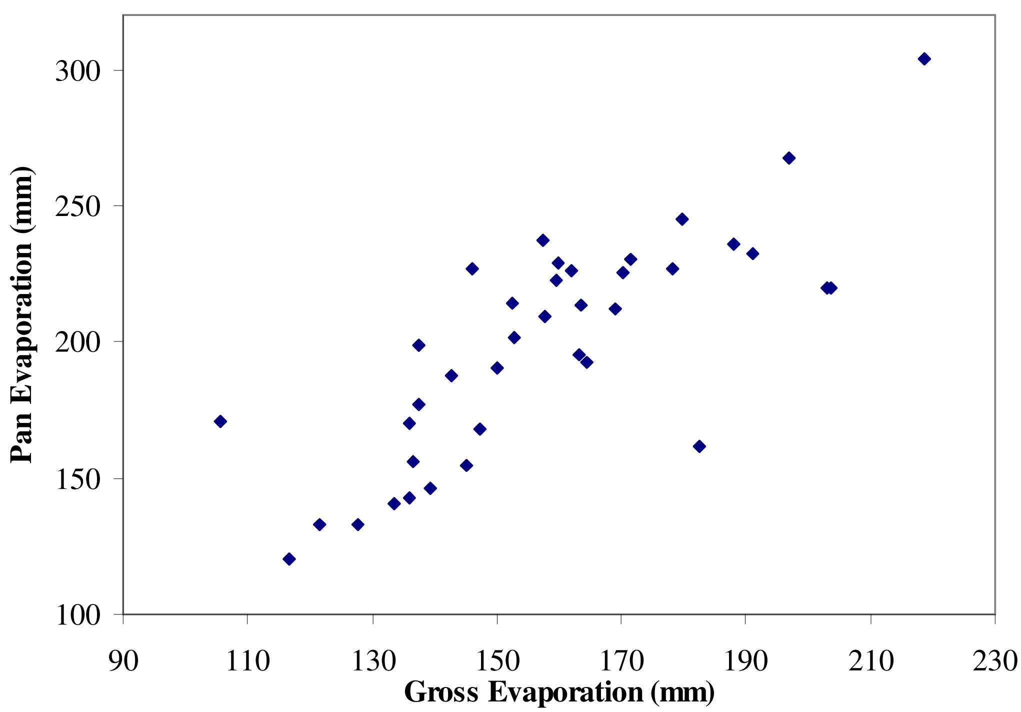

Figure D84: Scatter graph of pan evaporation at Weyburn vs. gross evaporation at Regina in May (r = 0.79)

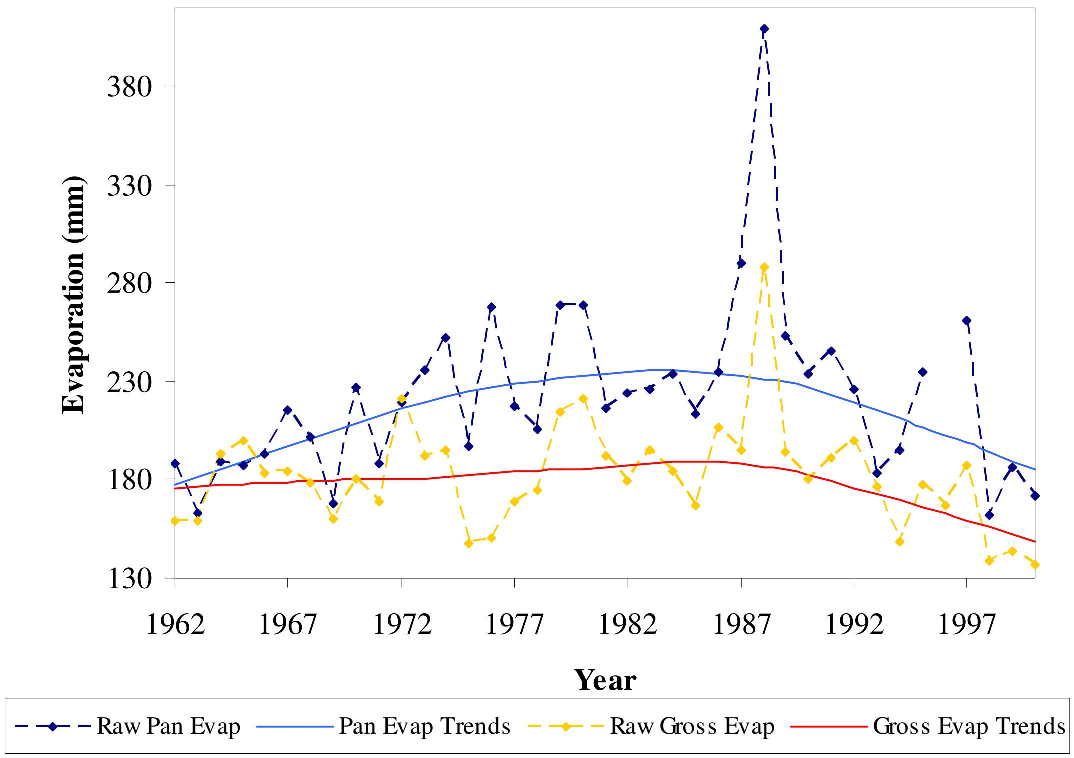

Figure D85: Comparison of Weyburn pan evaporation and Regina gross evaporation in June – Type 5

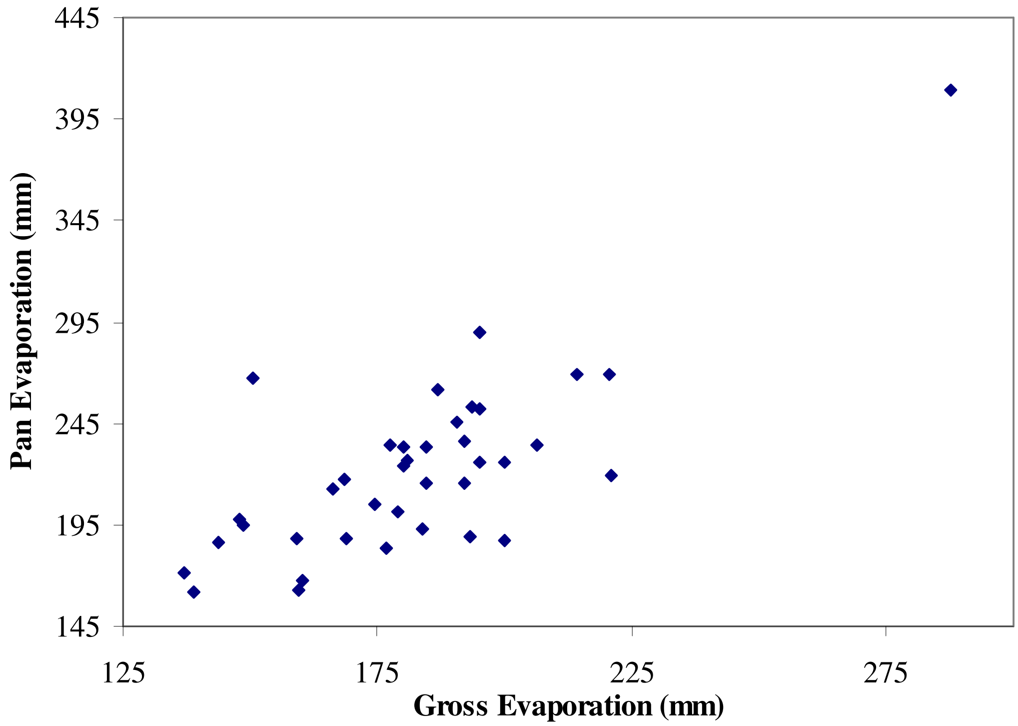

Figure D86: Scatter graph of pan evaporation at Weyburn vs. gross evaporation at Regina in June (r = 0.77)

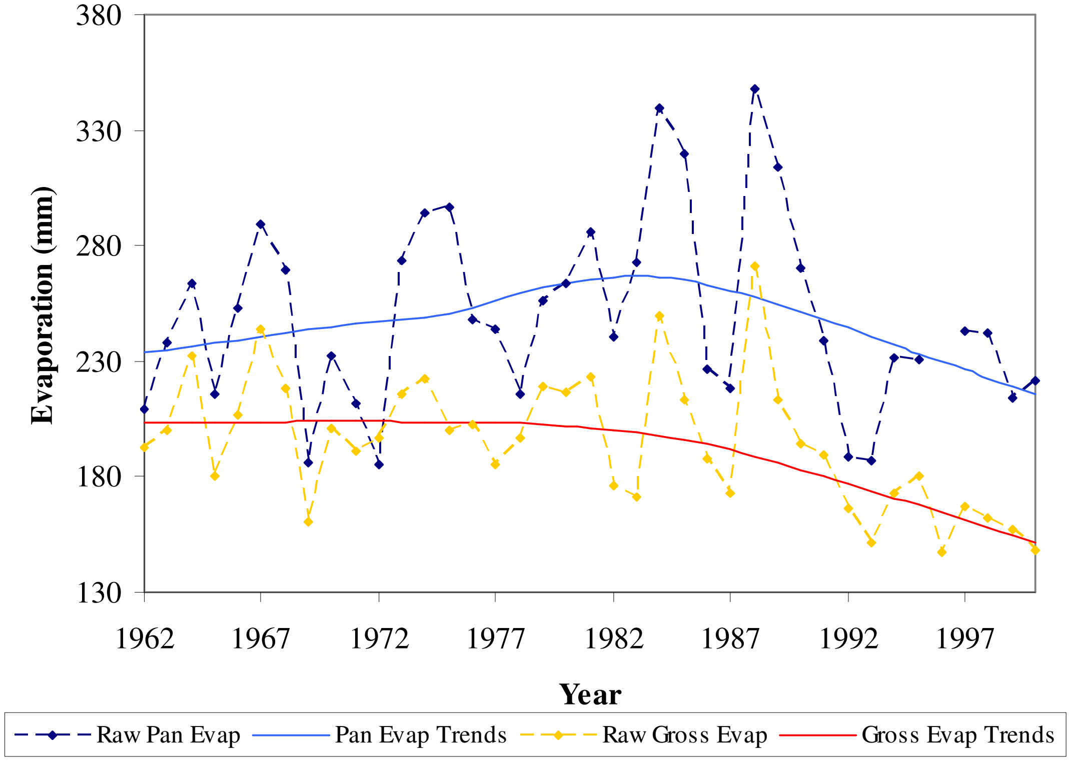

Figure D87: Comparison of Weyburn pan evaporation and Regina gross evaporation in July – Type 1

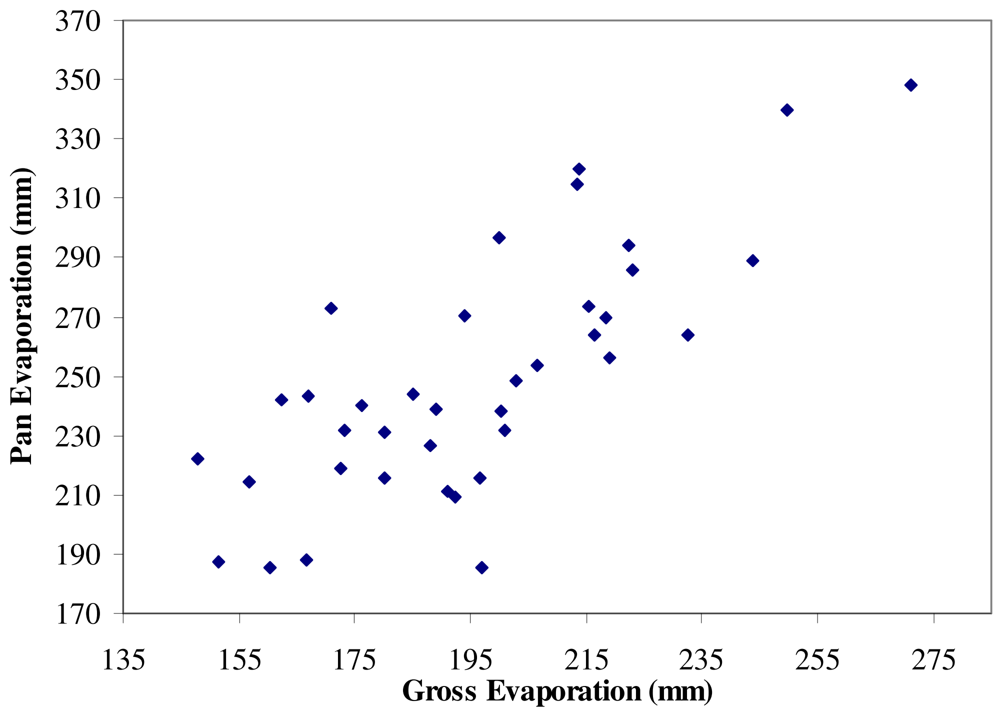

Figure D88: Scatter graph of pan evaporation at Weyburn vs. gross evaporation at Regina in July (r = 0.77)

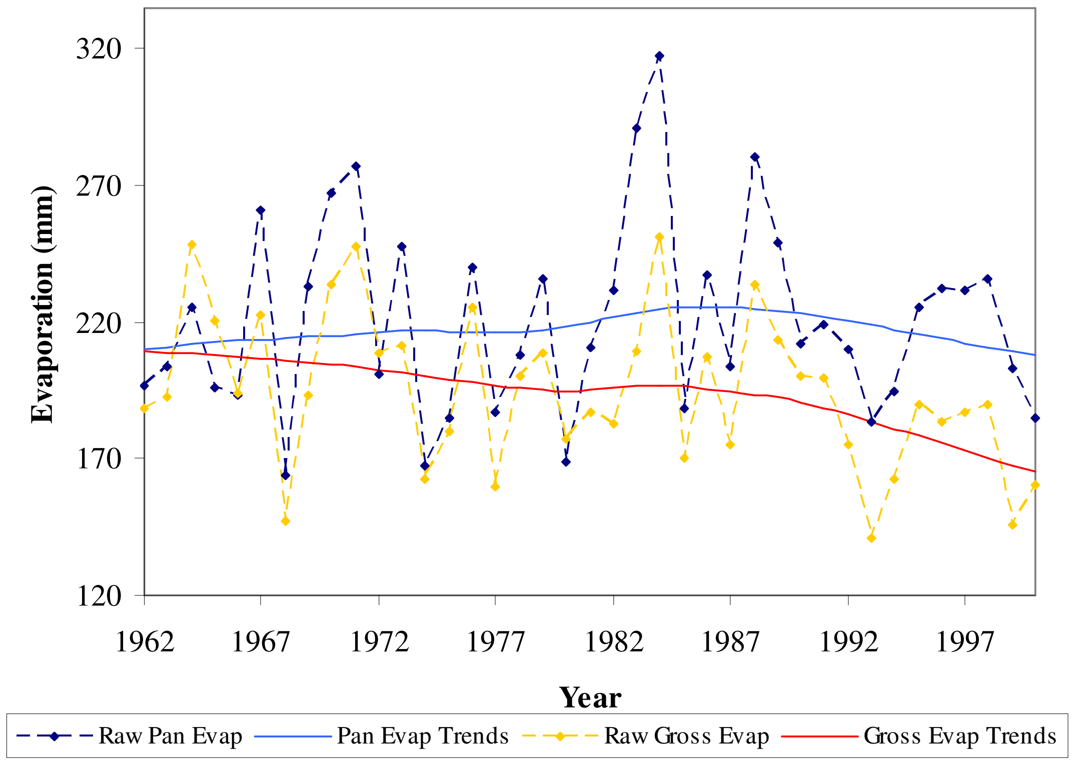

Figure D89: Comparison of Weyburn pan evaporation and Regina gross evaporation in August – Type 1

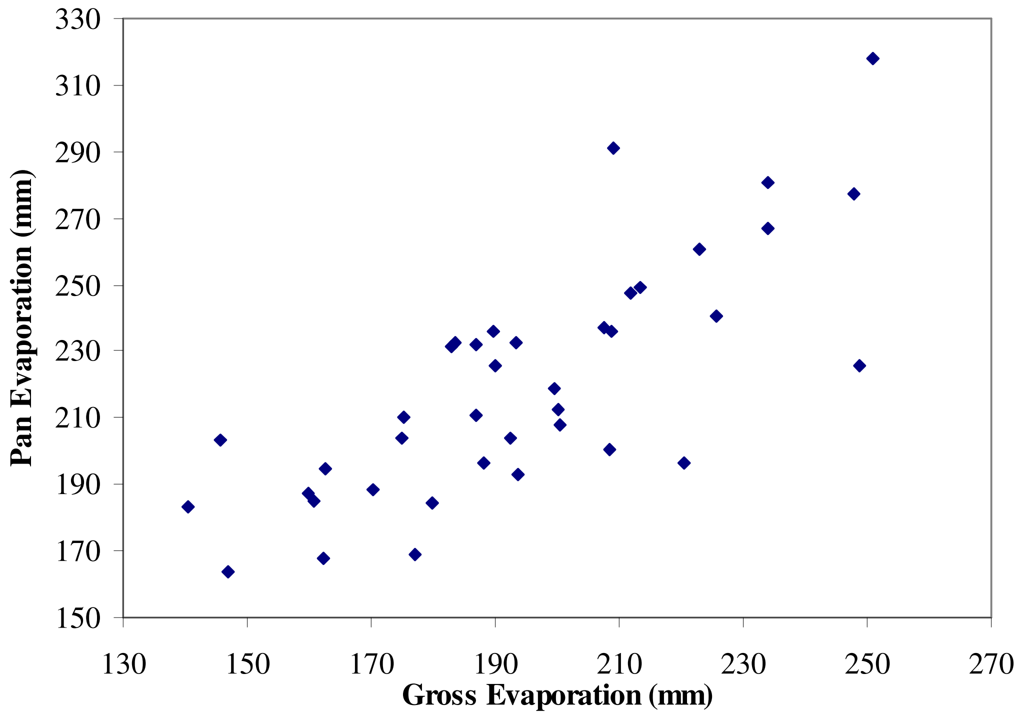

Figure D90: Scatter graph of pan evaporation at Weyburn vs. gross evaporation at Regina in August (r = 0.77)

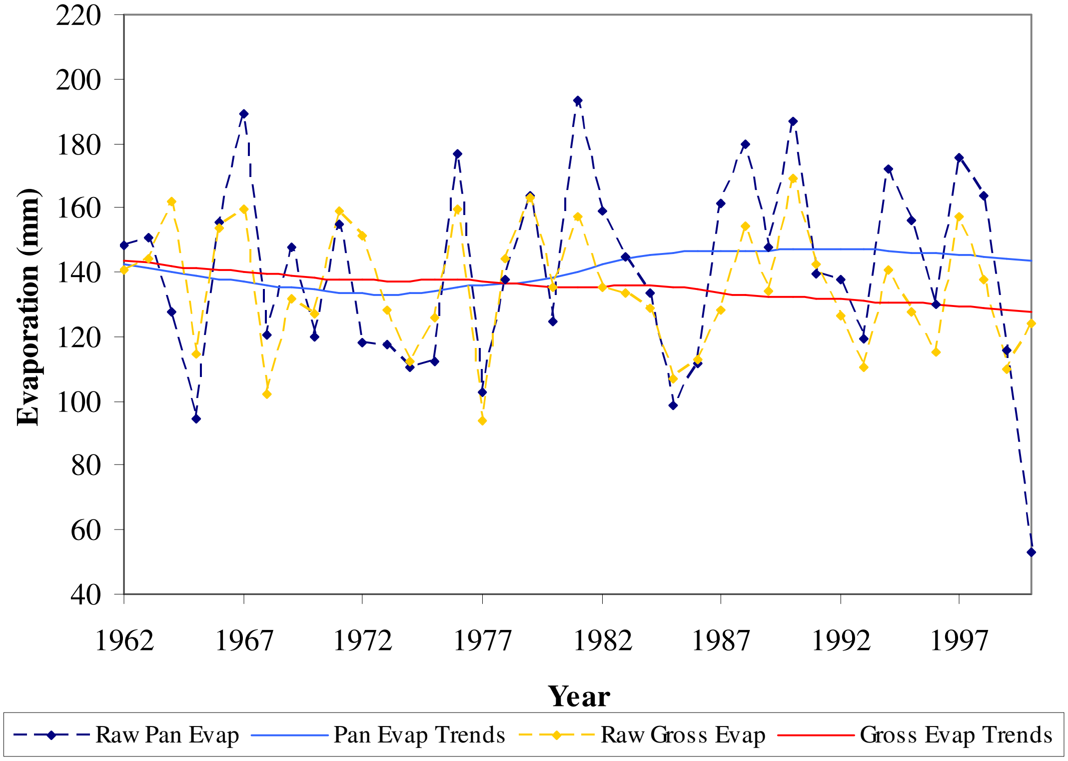

Figure D91: Comparison of Weyburn pan evaporation and Regina gross evaporation in September – Type 3

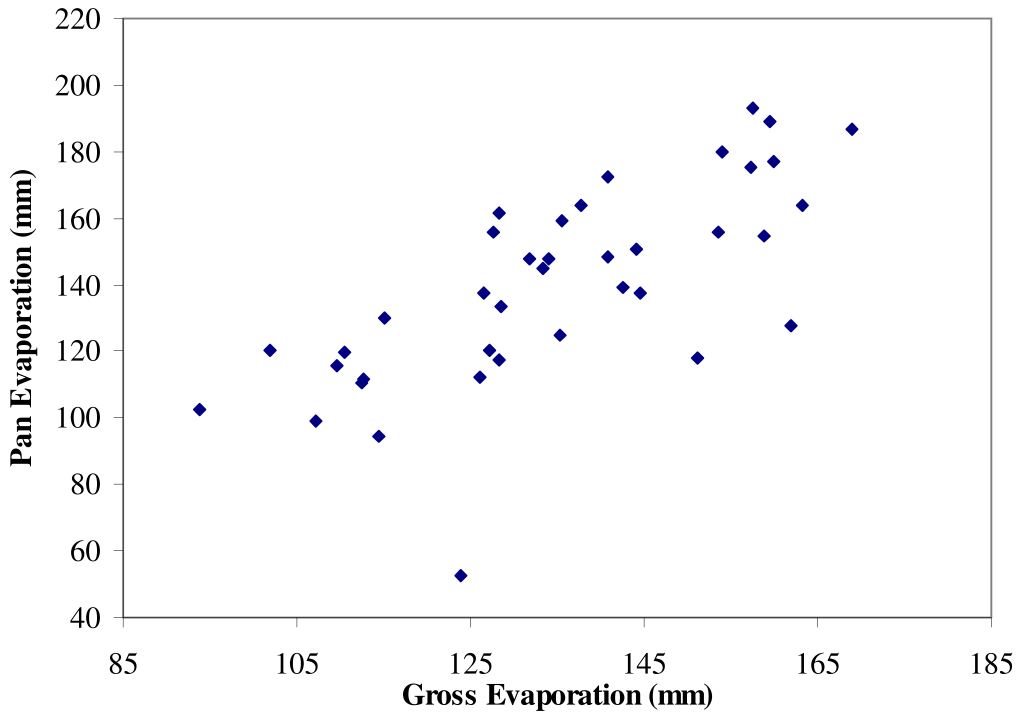

Figure D92: Scatter graph of pan evaporation at Weyburn vs. gross evaporation at Regina in September (r = 0.72)

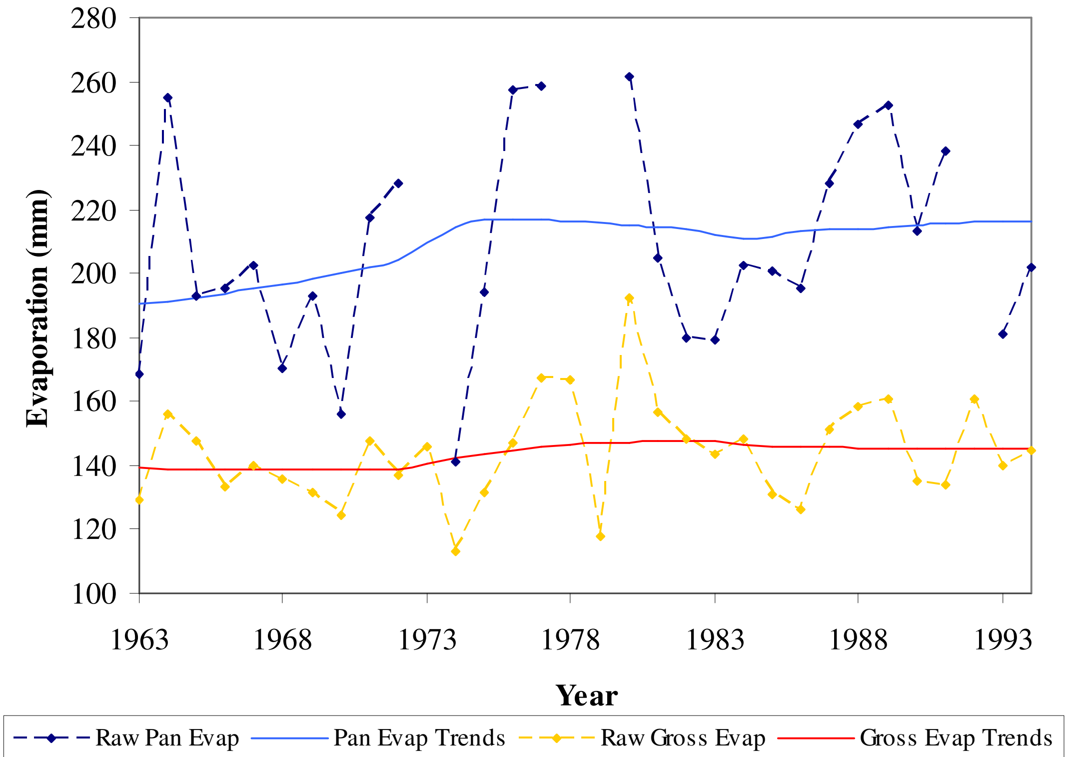

Figure D93: Comparison of Winnipeg pan evaporation and gross evaporation in May – Type 3

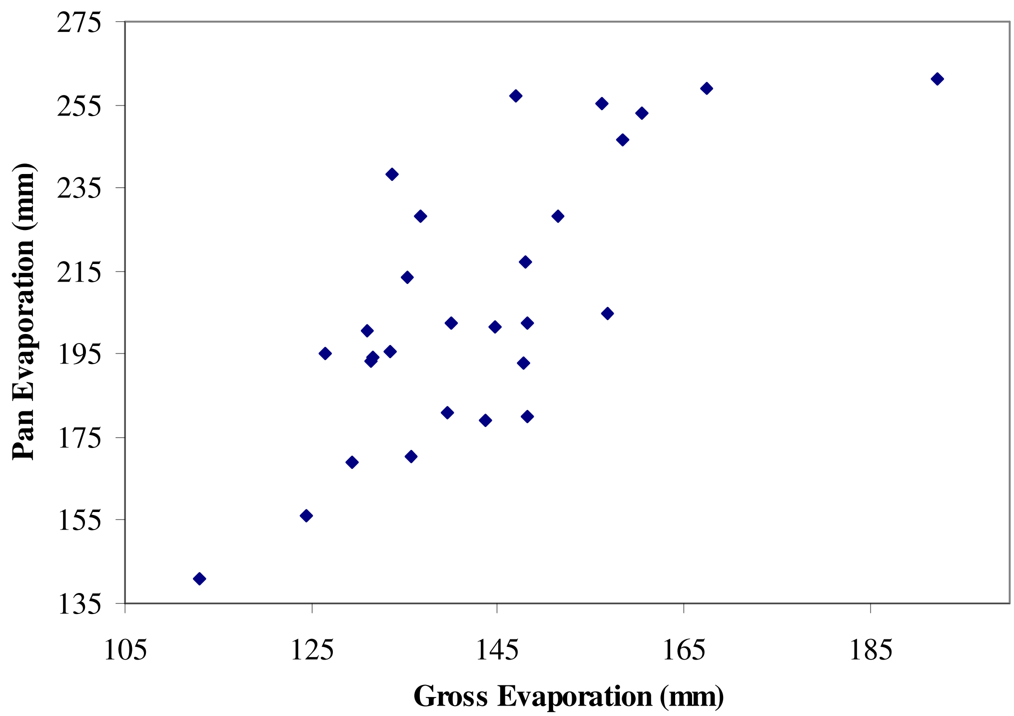

Figure D94: Scatter graph of pan evaporation vs. gross evaporation at Winnipeg in May (r = 0.73)

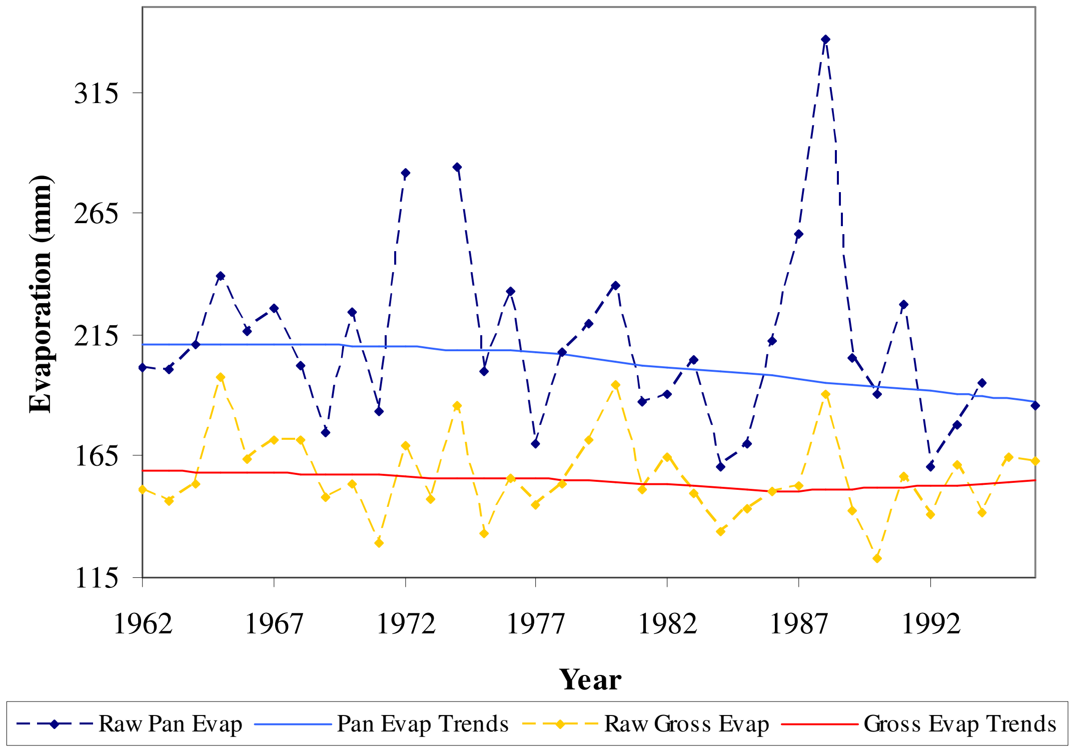

Figure D95: Comparison of Winnipeg pan evaporation and gross evaporation in June – Type 3

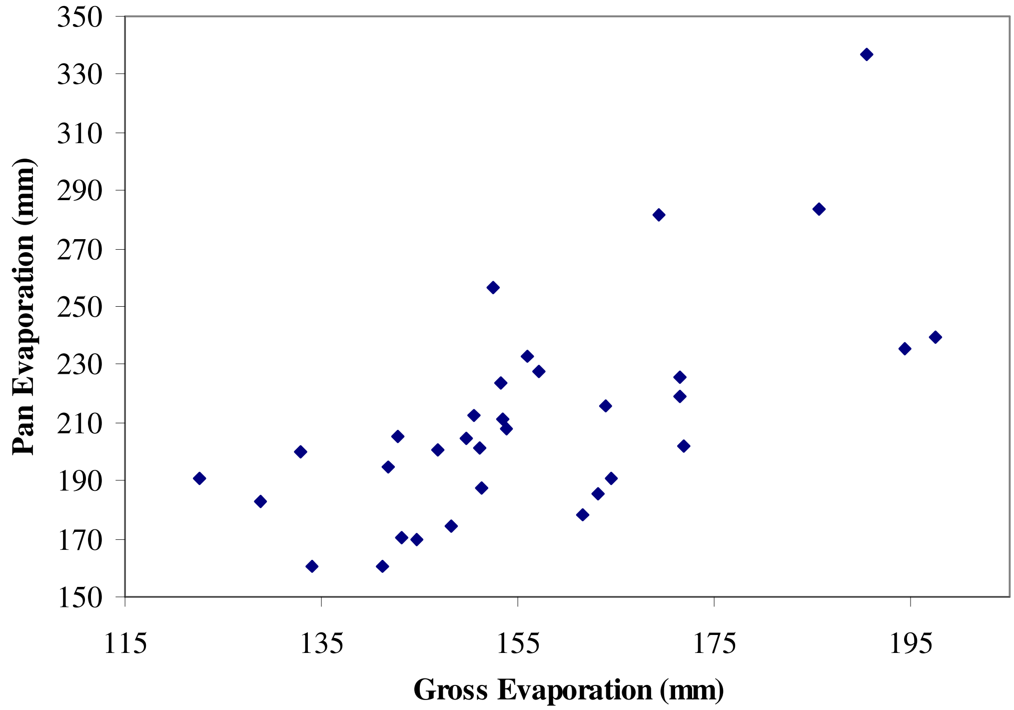

Figure D96: Scatter graph of pan evaporation vs. gross evaporation at Winnipeg in June (r = 0.67)

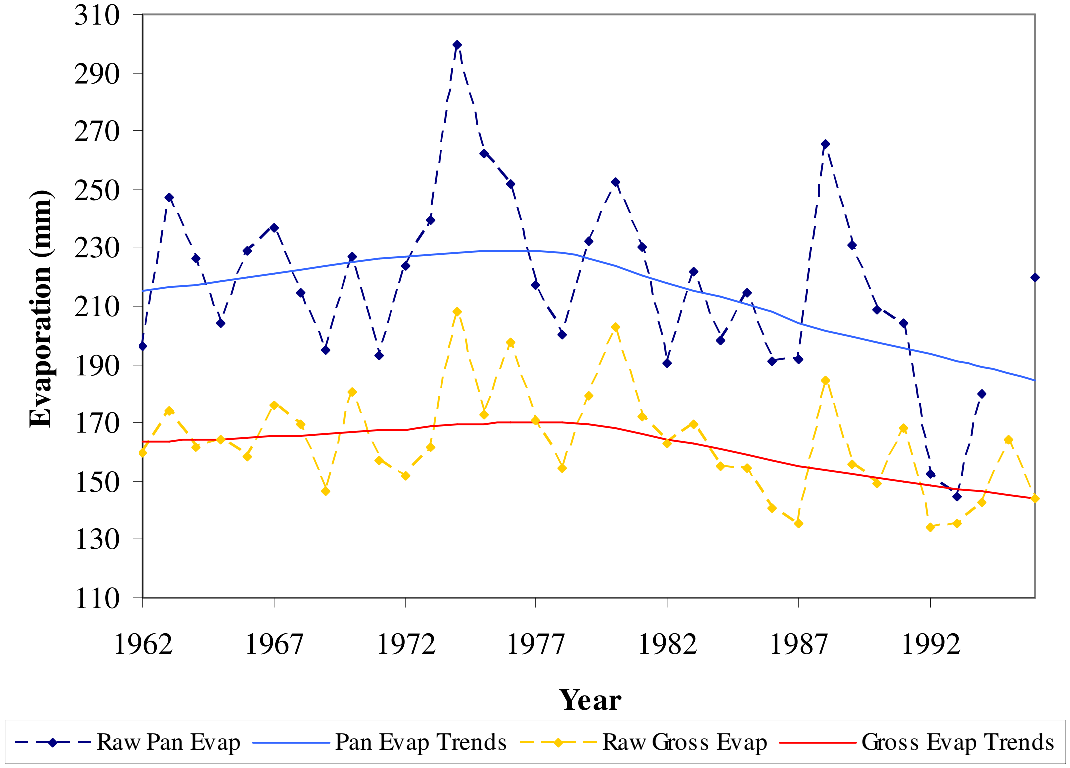

Figure D97: Comparison of Winnipeg pan evaporation and gross evaporation in July – Type 3

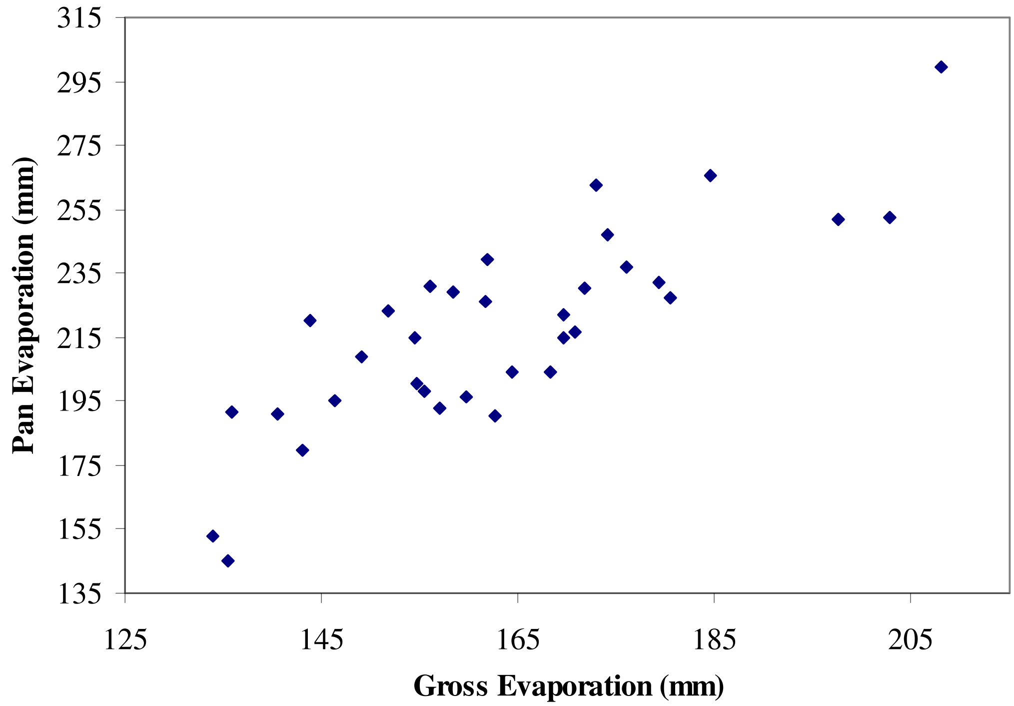

Figure D98: Scatter graph of pan evaporation vs. gross evaporation at Winnipeg in July (r = 0.83)

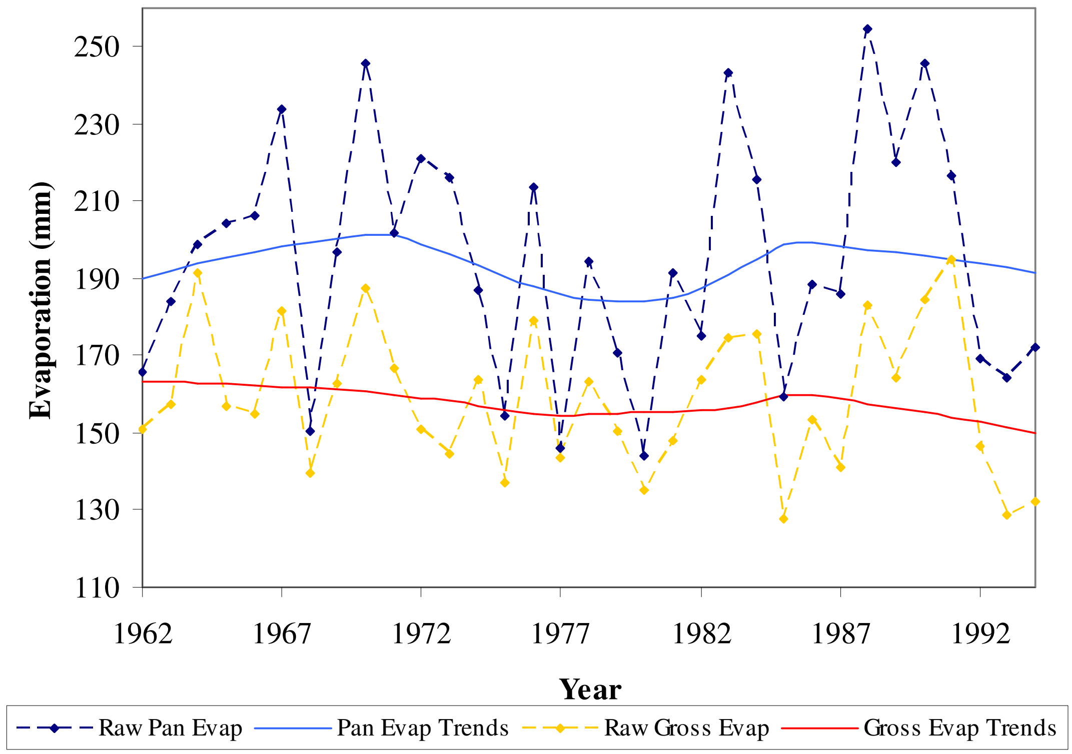

Figure D99: Comparison of Winnipeg pan evaporation and gross evaporation in August – Type 3

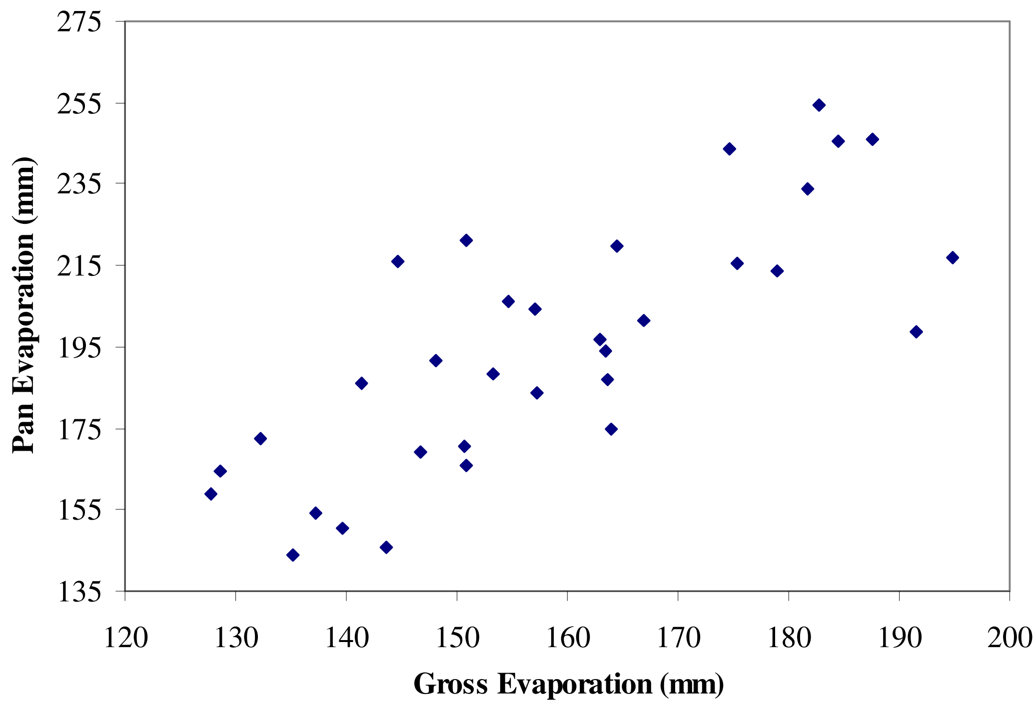

Figure D100: Scatter graph of pan evaporation vs. gross evaporation at Winnipeg in August (r = 0.78)

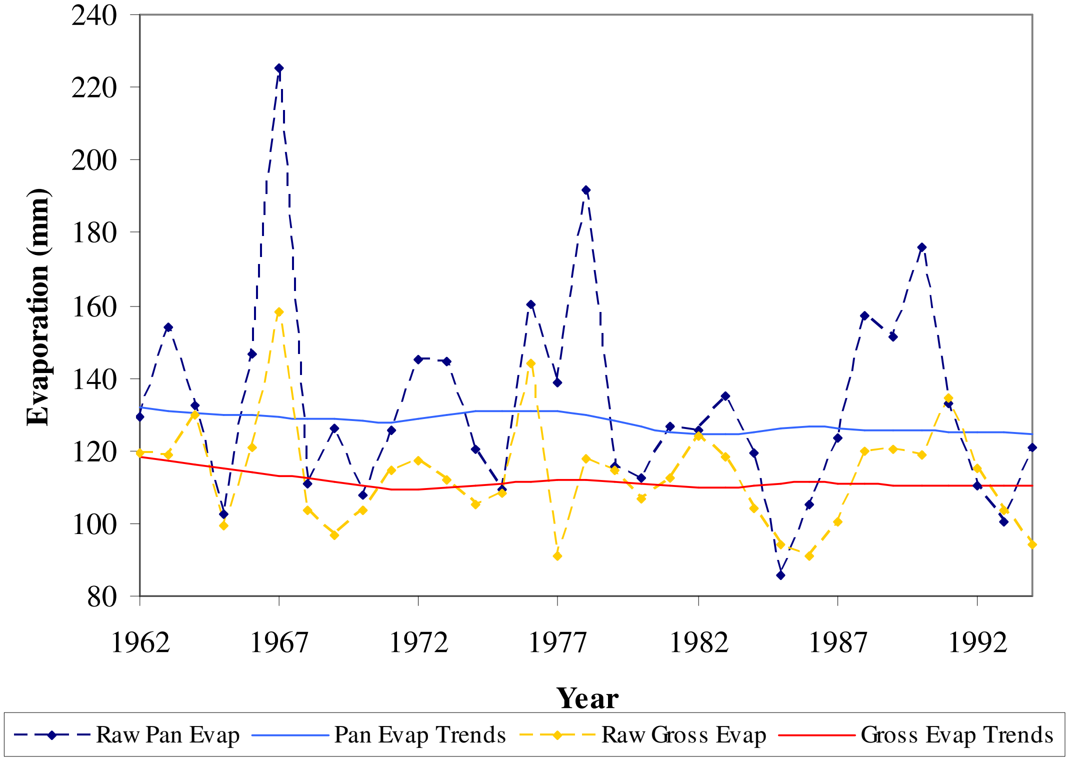

Figure D101: Comparison of Winnipeg pan evaporation and gross evaporation in September – Type 3

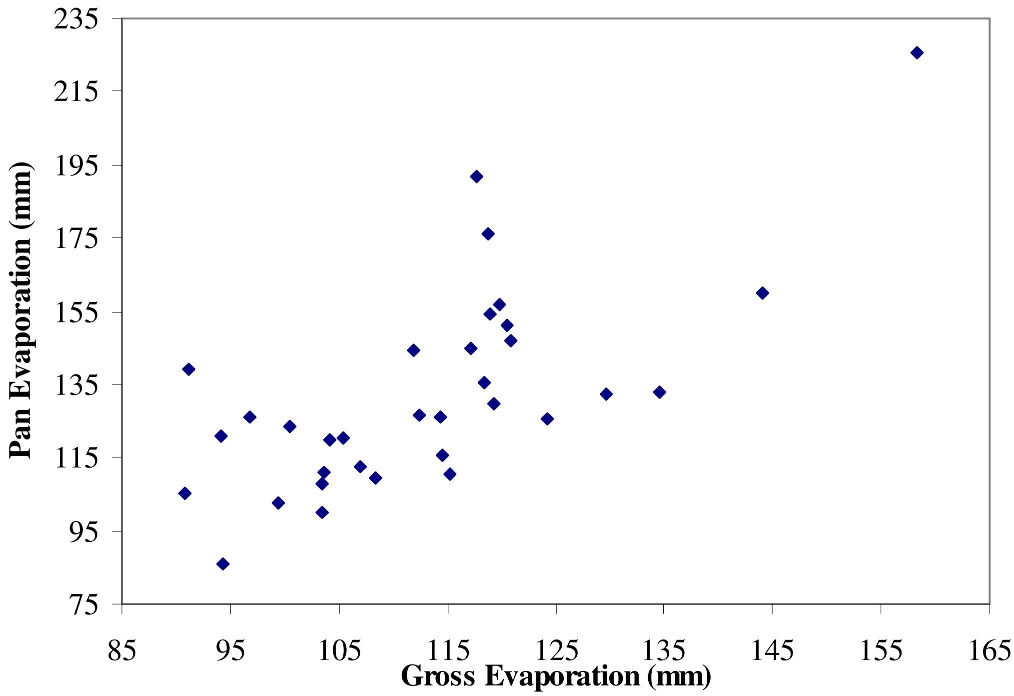

Figure D102: Scatter graph of pan evaporation vs. gross evaporation at Winnipeg in September (r = 0.71)

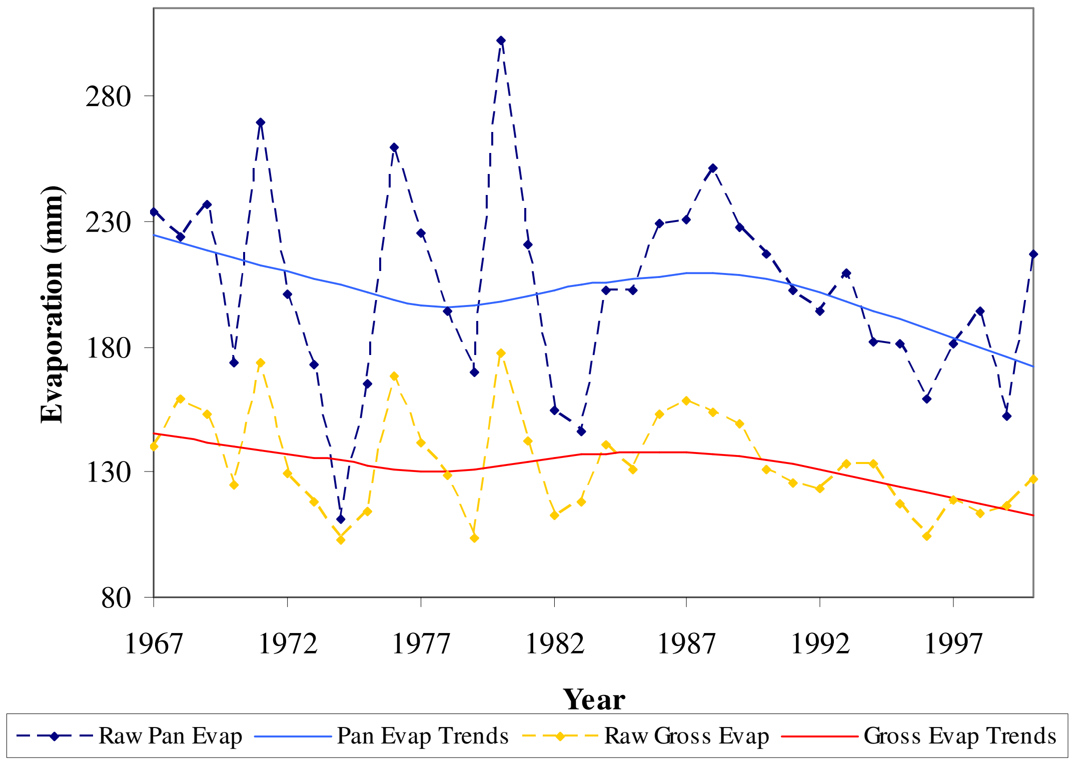

Figure D103: Comparison of Wynyard pan evaporation and gross evaporation in May – Type 2

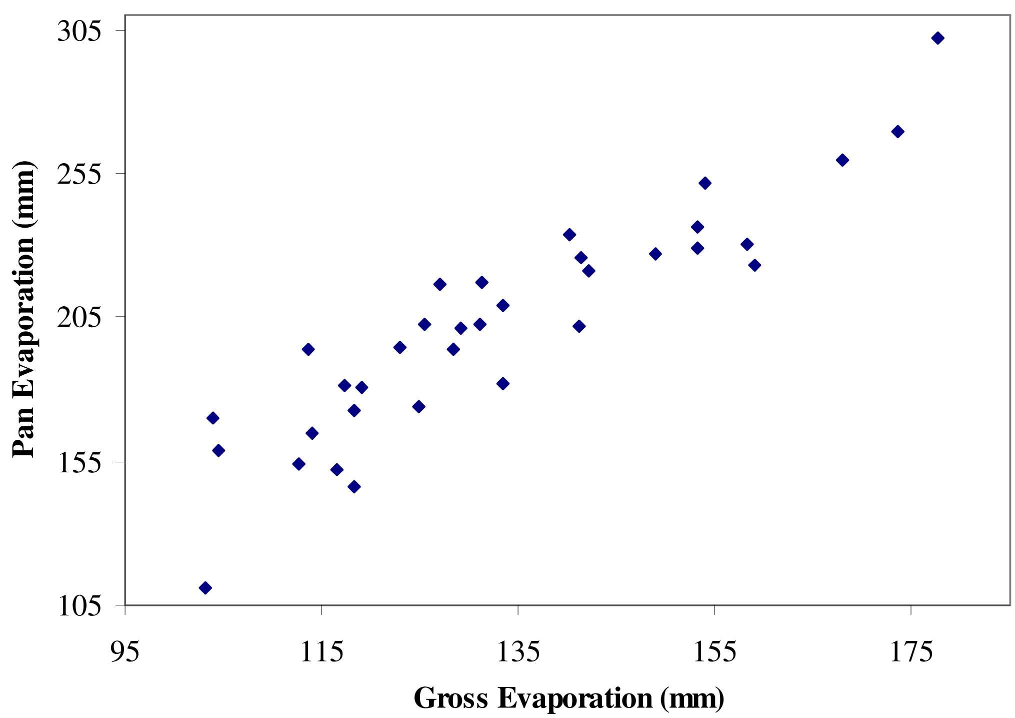

Figure D104: Scatter graph of pan evaporation vs. gross evaporation at Wynyard in May (r = 0.91)

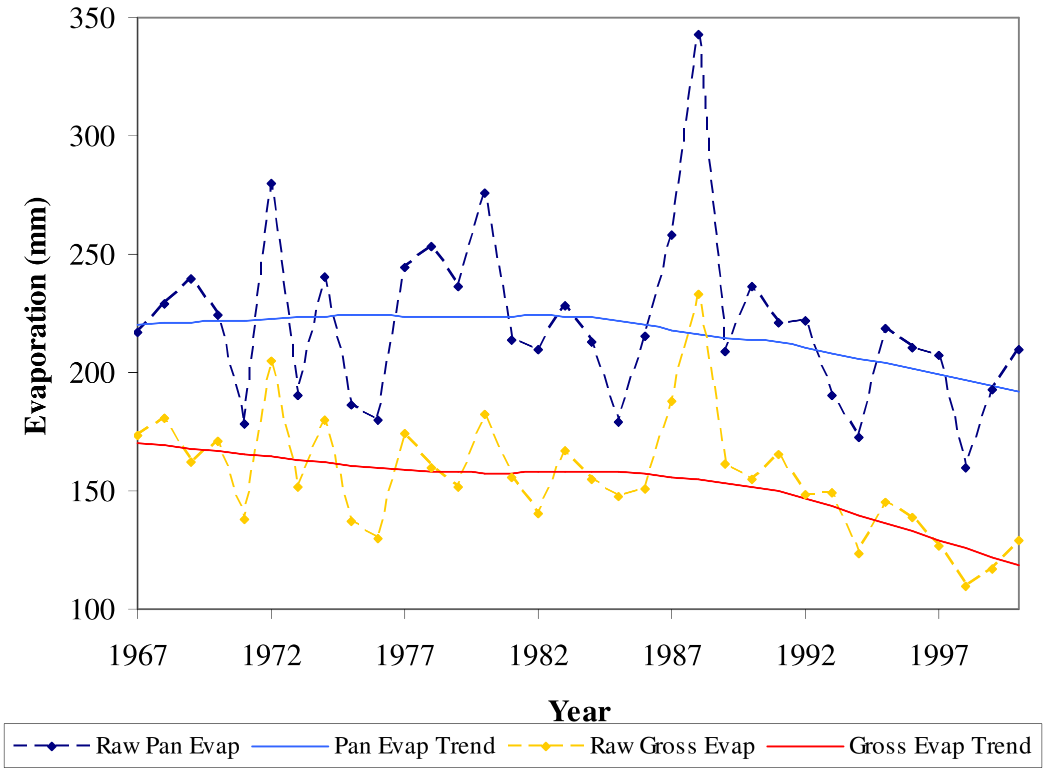

Figure D105: Comparison of Wynyard pan evaporation and gross evaporation in June – Type 3

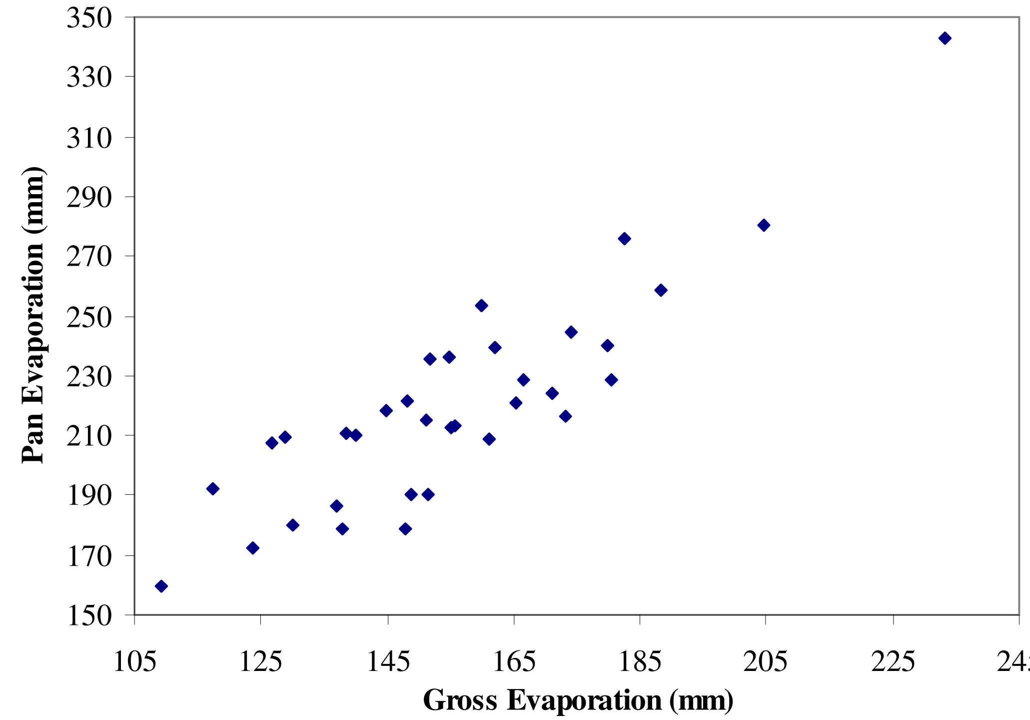

Figure D106: Scatter graph of pan evaporation vs. gross evaporation at Wynyard in June (r = 0.88)

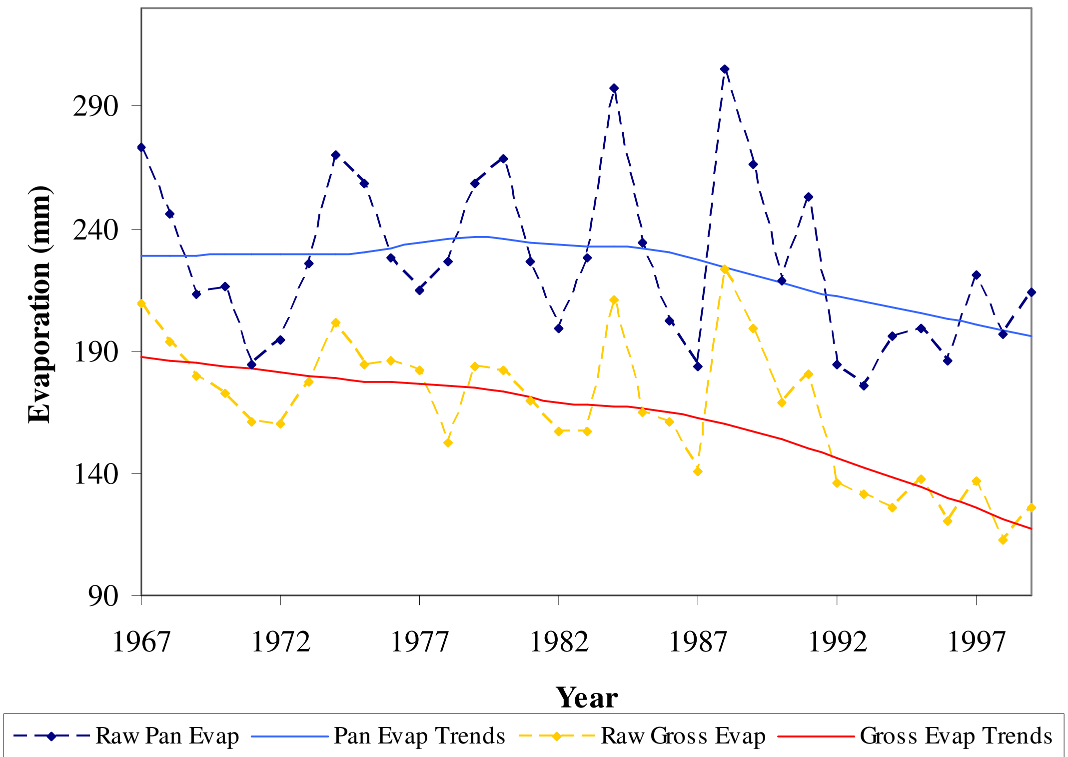

Figure D107: Comparison of Wynyard pan evaporation and gross evaporation in July – Type 2

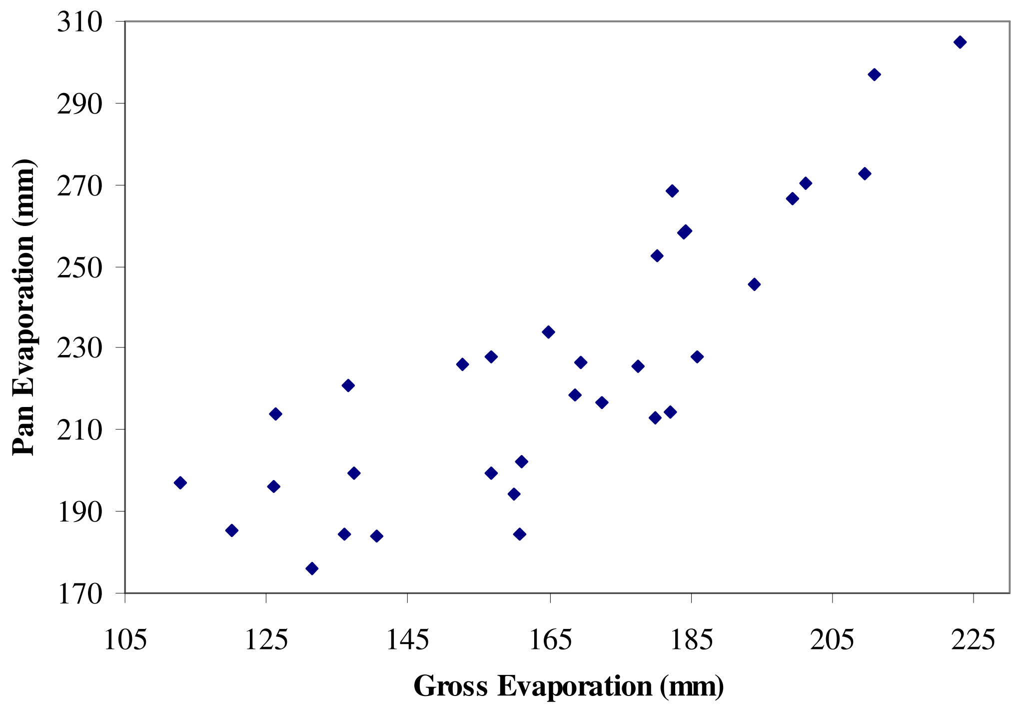

Figure D108: Scatter graph of pan evaporation vs. gross evaporation at Wynyard in July (r = 0.84)

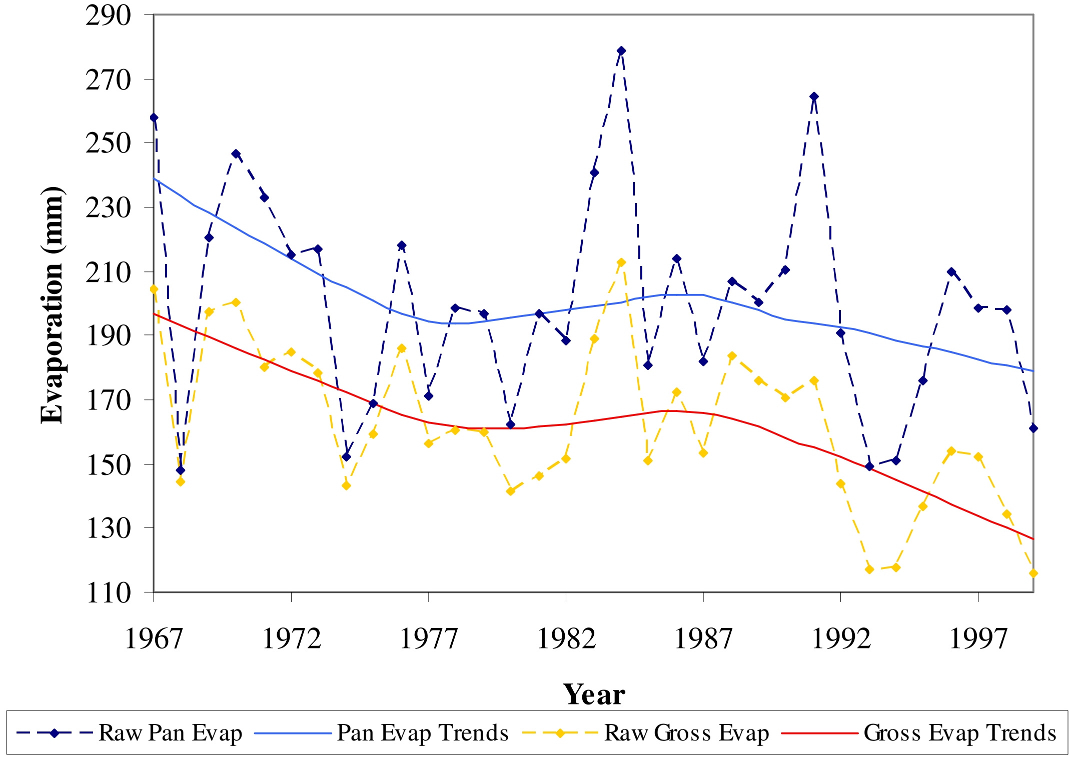

Figure D109: Comparison of Wynyard pan evaporation and gross evaporation in August – Type 2

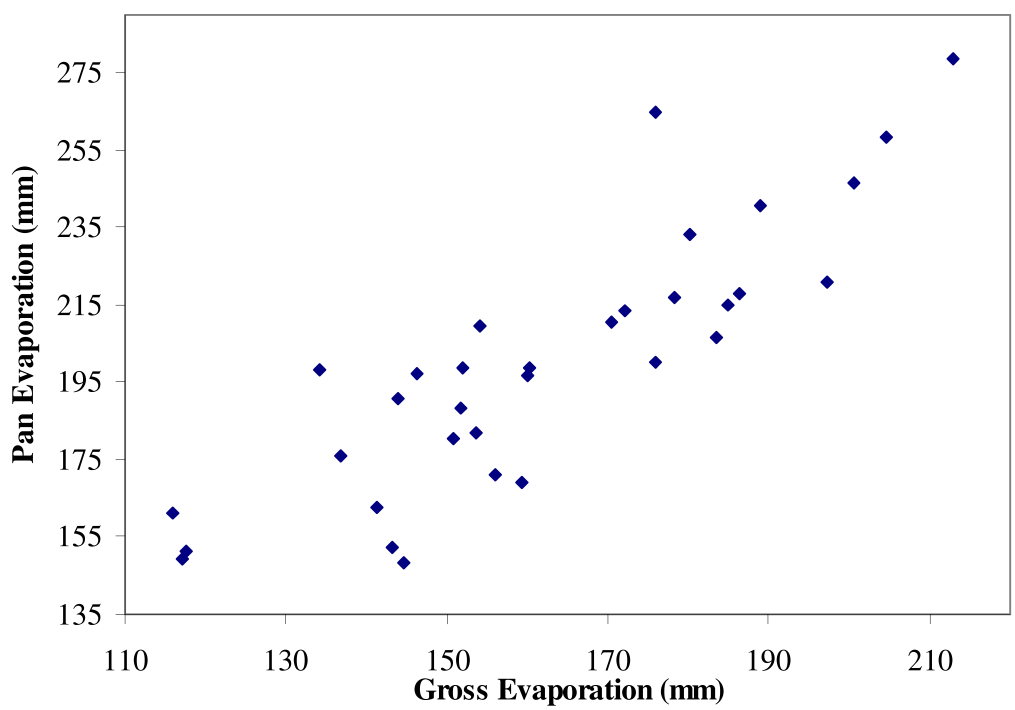

Figure D110: Scatter graph of pan evaporation vs. gross evaporation at Wynyard in August (r = 0.86)

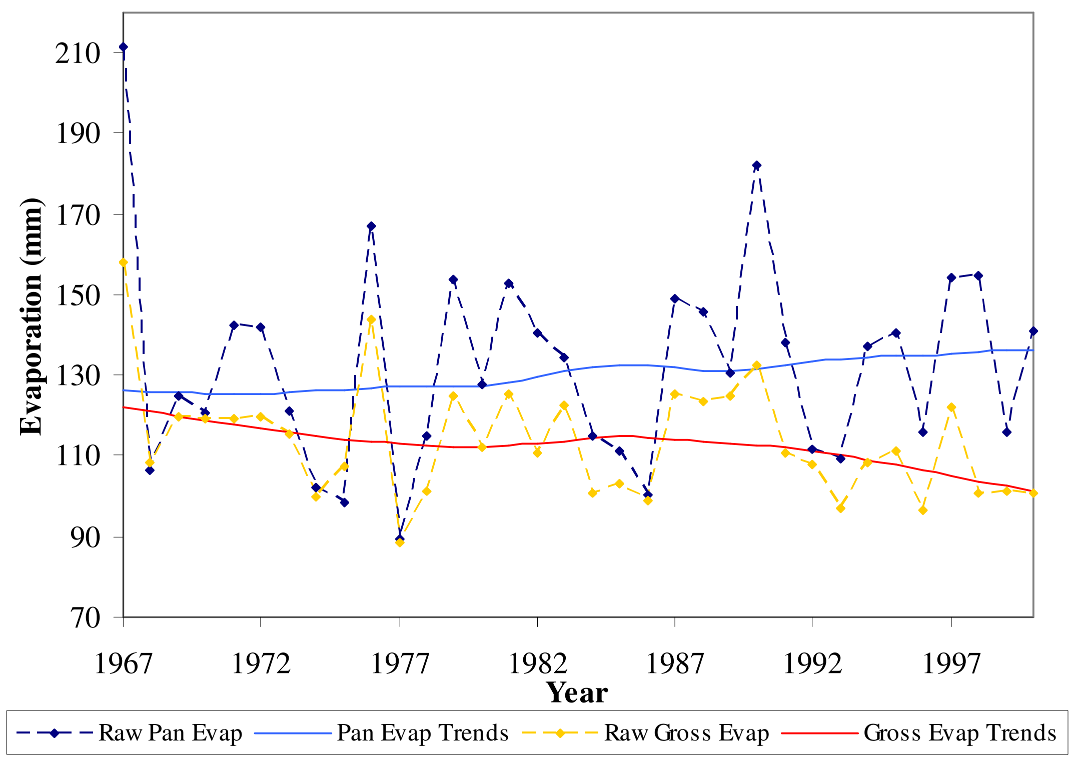

Figure D111: Comparison of Wynyard pan evaporation and gross evaporation in September – Type 1

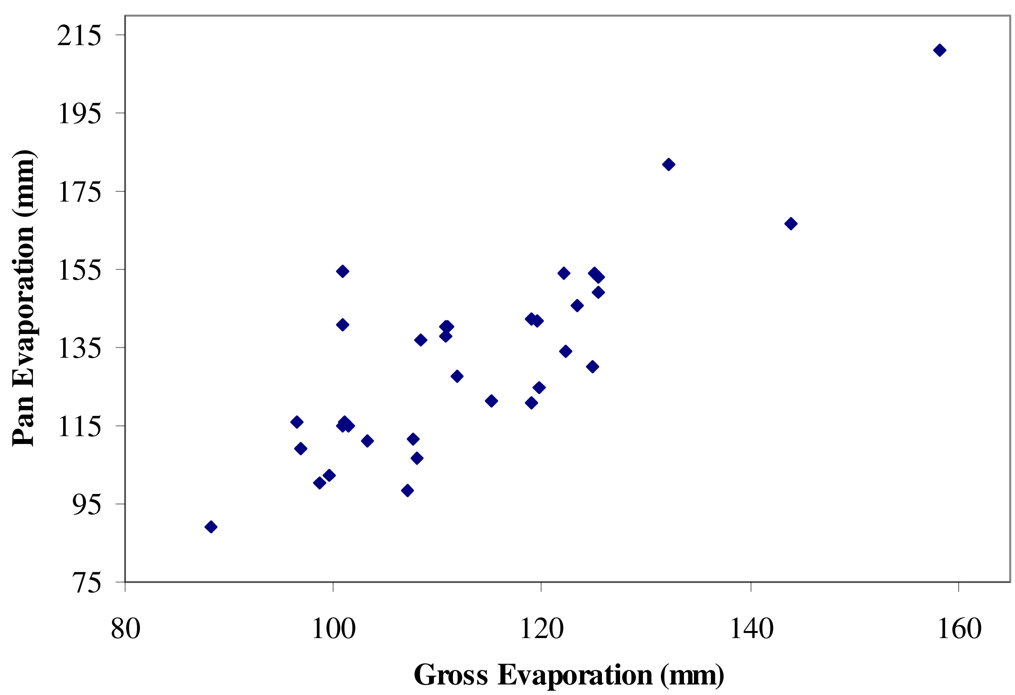

Figure D112: Scatter graph of pan evaporation vs. gross evaporation at Wynyard in September (r = 0.83)