Estimation of the Influence of Elevation on Evaporation in Southeast Alberta and Southwest Saskatchewan

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Table of Contents

List of Figures

List of Tables

Introduction

In the calculation of inter-provincial water apportionment of Lodge and Middle Creeks for the Prairie Provinces Water Board (PPWB), reservoir evaporation is computed using 0.7 times the gross pan evaporation at Altawan less precipitation at either Altawan or Eagle Butte, depending on the proximity of each reservoir to one of these climate stations. Thus, precipitation data for Altawan was applied to Cressday and Jaydot reservoirs and Eagle Butte precipitation, to all other reservoirs. At PPWB Committee on Hydrology (COH) meeting No. 77, this procedure was accepted as an improvement over previous procedures which used precipitation data from just Altawan in conjunction with the Altawan pan evaporation. Also, the previous method erroneously applied the pan coefficient of 0.7 to the net pan evaporation instead of just the gross pan evaporation.

One other refinement which the COH identified was the possible use of evaporation data from the upper basin which, it was believed, would be more indicative of evaporation at the upper reservoirs. A number of the reservoirs (Bare Creek, 1137m; Greasewood, 1122 m; Massey, 1091 m; Michel, 1100 m; and Mitchell, 1122 m) have elevations around 1100 m compared to Altawan (945 m). Cressday (964 m) and Jaydot (921 m) reservoirs are located closer to Altawan and are at approximately the same elevation. The direct method would be to initiate an evaporation pan program in the upper basin at the elevation of these reservoirs. An alternative would be to apply an adjustment factor based on empirical or modelled information. The intent of this study was to determine if an elevation correction could be determined.

Approach

There were several approaches which could be used to address this question. These included:

- a review of evaporation pan data in the immediate area of southeast Alberta
- a review of elevation dependency of other evaporation pan records elsewhere in Alberta
- a search for any pan evaporation data from the top of the Cypress Hills
- estimate the elevation dependency using Morton’s model
- estimate the elevation dependency using the Meyer equation

A check with Alberta Environmental Protection revealed no other source of pan data at higher elevations in the Cypress Hills. Further, discussion with Dr. David Sauchyn (University of Regina) who conducts many research projects in the Cypress Hills, revealed that he was not aware of any pan data that had been collected there in a research mode. Lacking any direct means of establishing an elevation adjustment, various indirect methods were investigated and form the body of this report.

Local Evaporation Pan Data

Evaporation pan data from the general area of southeast Alberta and southwest Saskatchewan were reviewed. The records were summarized using the Datacat output as shown in Table 1.

Table 1. Datacat search of evaporation pan stations in southeast Alberta and southwest Saskatchewan

```
LATITUDE LIMITS= 49 , 0  TO  50 , 30
LONGITUDE LIMITS= 105 , 0  TO  112 , 0
OPERATING BETWEEN YEARS***  1900   AND   1999
PROGRAM SELECTED = EVAPORATION
3040223 ALTAWAN                       49 14 110 01 0945 1965-11 1971-02    7 | | |@|@| | | |A|
3040223 ALTAWAN                       49 14 110 01 0945 1971-09           29 | | |X|X| | | |A|
3044200+MANYBERRIES CDA               49 07 110 28 0934 1966-05           34 | | |@| |X|B| |A|
4015680 ORMISTON                      49 43 105 22 0686 1969-05           31 | | |@|@|X| | |A|
4028056+SWIFT CURRENT SRL             50 17 107 45 0762 1958-05 1963 09    6 | | |@|@| | | |A|
4028060+SWIFT CURRENT SRL FIELD       50 16 107 44 0825 1960-05           40 |H|H|@|X|X|B|D|A|
4031776+CONSUL CDA EPF                49 17 109 31      1966-05 1978-09   13 | | |@|X| | | |A|
4031776+CONSUL CDA EPF                49 17 109 31      1978-10 1982-04    5 | | |@|X| | | |A|
4031776+CONSUL                        49 17 109 31      1982-05 1983-05    2 | | |@|X| | | |A|
4031776+CONSUL                        49 18 109 32      1983-10 1985 10    3 | | |@|X|X| | |A|
4038400 VAL-MARIE                     49 15 107 44      1966-06 1970-04    5 | | |@|@| | | |A|
4038400 VAL-MARIE                     49 15 107 44      1970-05 1982-01   13 | | |@|@| | | |A|
4038400 VAL-MARIE                     49 22 107 53 0808 1982-02           18 | | |@|X|X| | |A|
```

There were no data for station 4028056 but all available daily pan evaporation data (archive element 151) for the other stations were extracted from the Canadian Climate Archive and analyzed.

The daily pan evaporation values were processed into monthly data by calculating a monthly total if only one or no days of data were missing. Occasionally this was relaxed slightly to gain more sample years. Figure 1 provided a sample of the data processed for the month of August. Just from a casual inspection of these data it was not obvious that there was an elevation dependency. Manyberries, Altawan and Consul are all located in the general area of interest but there was very little difference in elevation among them. The more distant stations to the east and northeast (see Figure 2) were at slightly lower elevations but may have been influenced more by a gradual change in the climate than by elevation differences.

This initial conclusion was supported by the detailed analysis of the data. The average July evaporation for all years was plotted against the station elevations. The regression of July evaporation on elevation explained only 10 % of the variance in the pan evaporation (see Figure 3). The regression of August pan evaporation on elevation was even poorer with an R^2 value of 0.0002 (see Figure 4). Neither relationship was significant at the five percent level. Other factors appeared to overwhelm any elevation factor if indeed elevation had any influence on pan evaporation.

Figure 1: August pan evaporation (mm) for local sites of interest

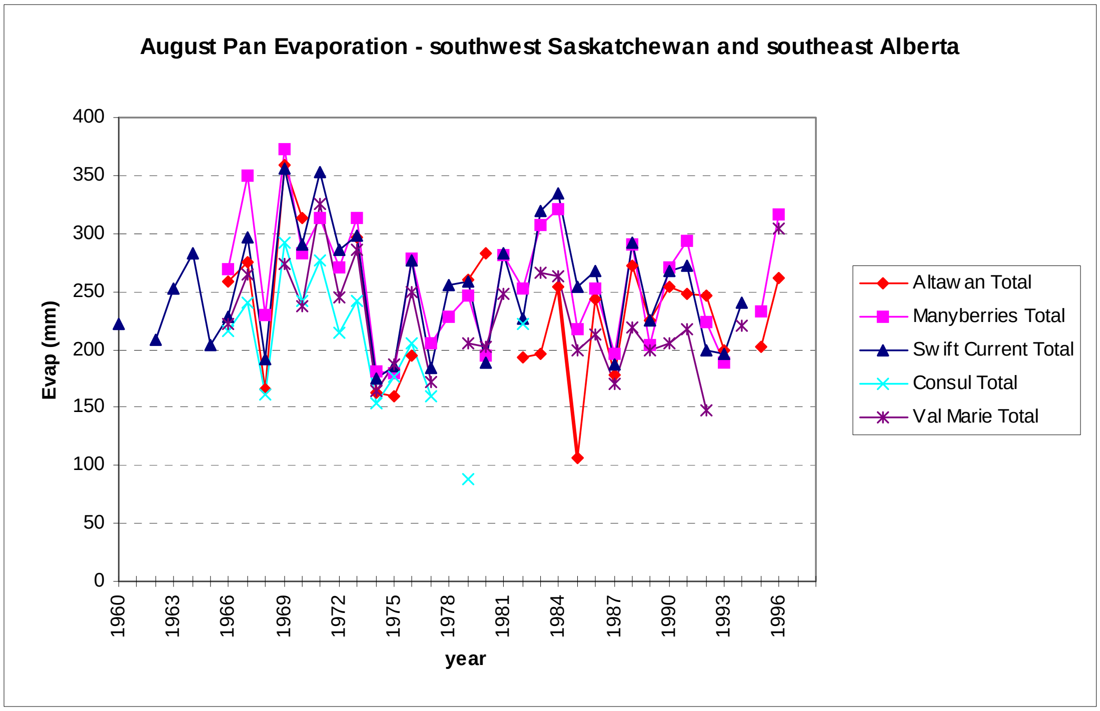


Figure 2: Location of evaporation pan stations near the Cypress Hills

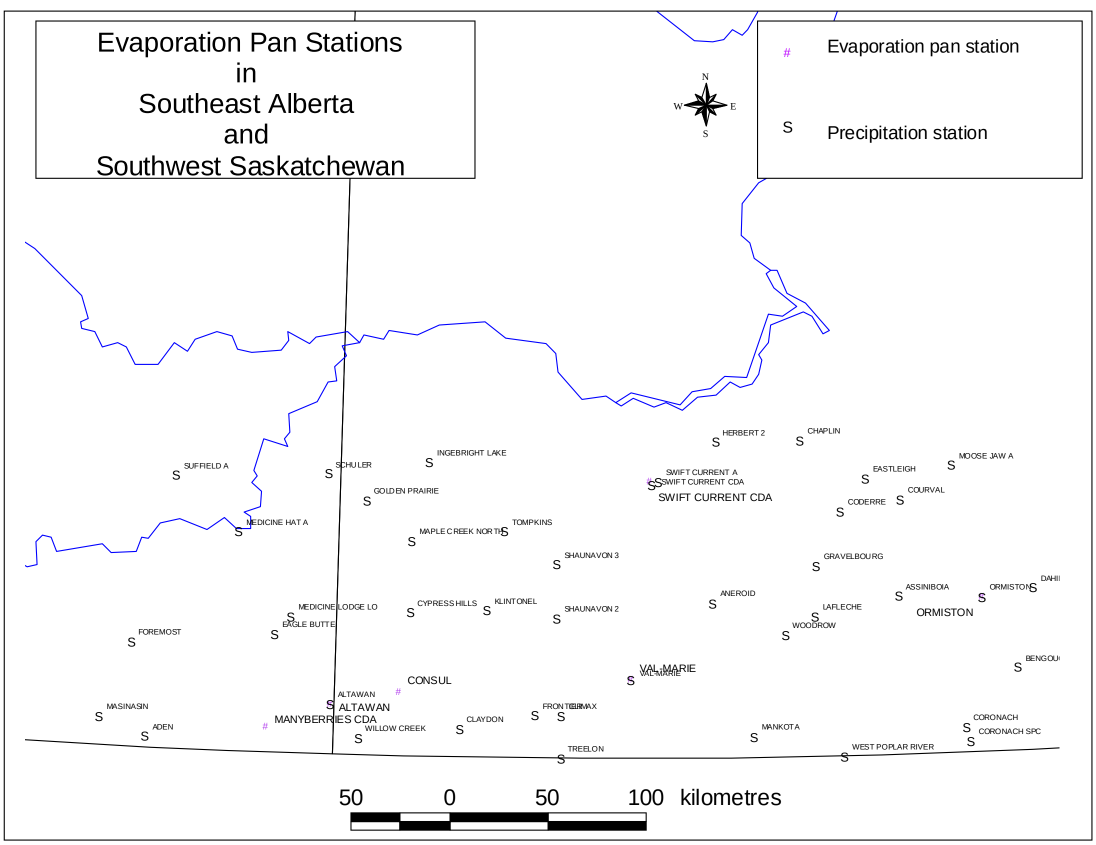


Figure 3: July pan evaporation and elevation

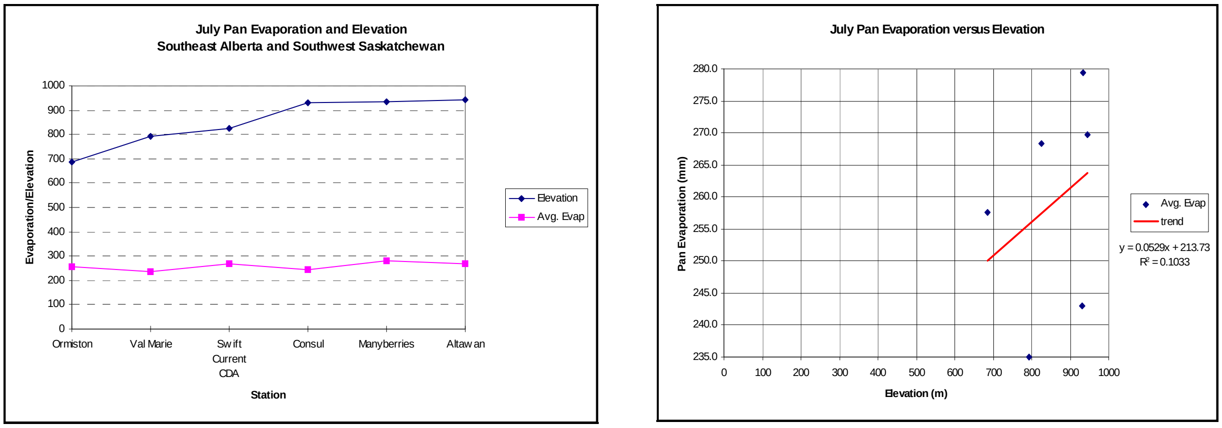
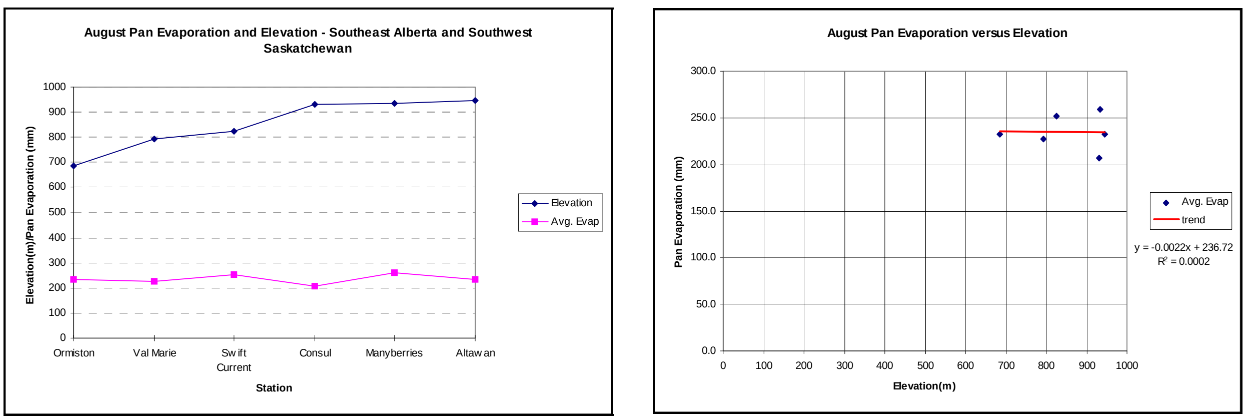


Figure 4: August pan evaporation and elevation

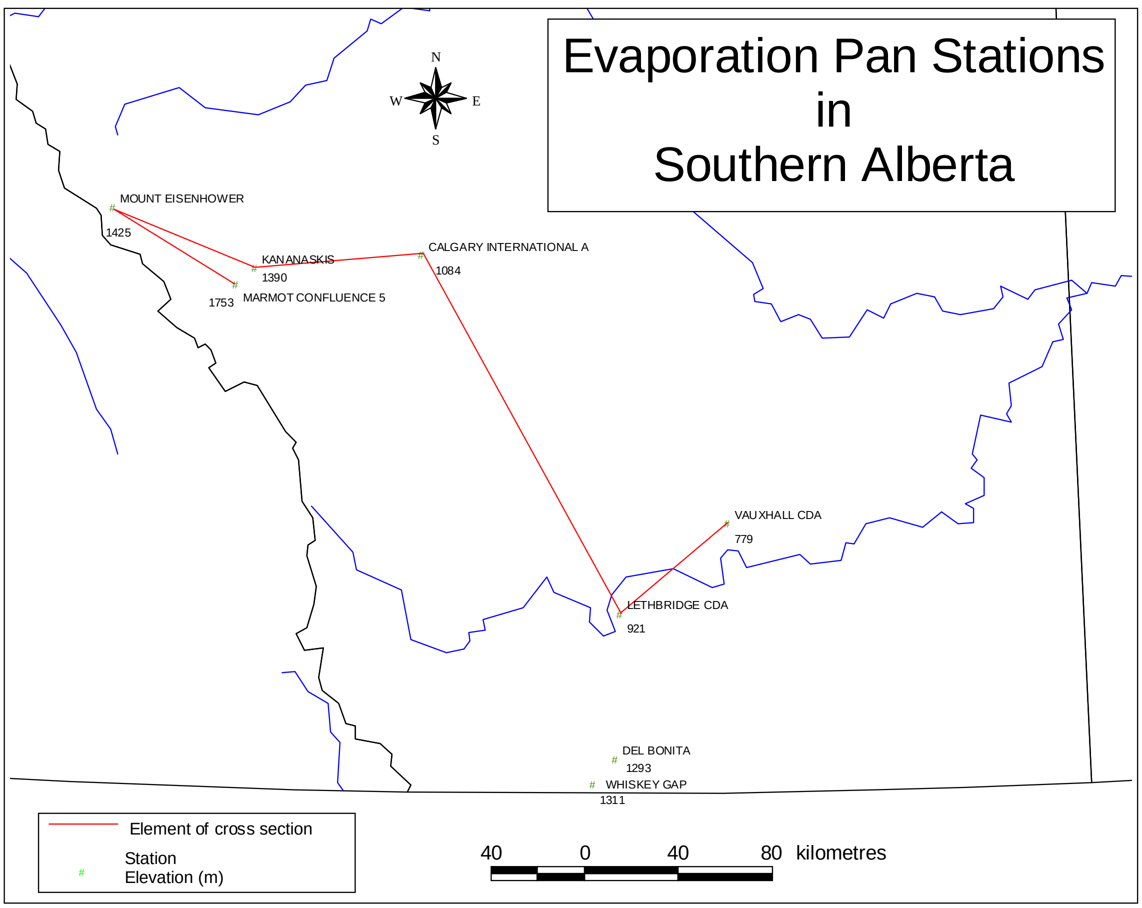


Thus, there was no apparent elevation dependency in these data. The other problem was that the sites were widely dispersed spatially. Other factors at work could be the precipitation climatology at each site which could vary appreciably from Ormiston in the east to Swift Current to the northeast of the Cypress Hills to Altawan and Manyberries in the west. Also some stations may be close to irrigated fields which would alter the local evaporation environment. Based on this analysis, no elevation adjustment would be warranted.

Southern Alberta Evaporation Pan Data

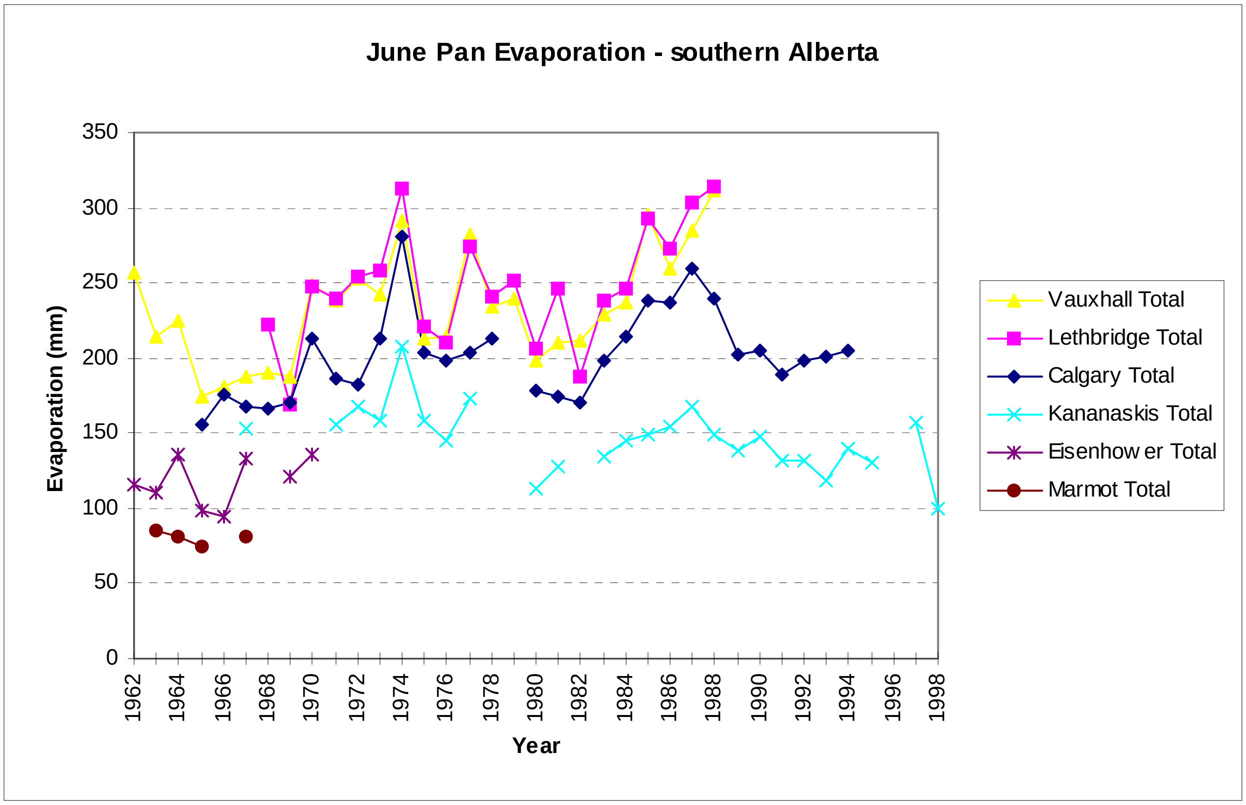
The evaporation pan data for southern Alberta were taken from sites of widely differing elevations in an attempt to discriminate evaporation rates as a function of elevation. The stations ranged from Vauxhall CDA (779 m) to Marmot Confluence 5 (1753 m) which will be referred to subsequently as just Marmot. The horizontal separation of the stations and a probable variation in climate were factors contributing to any observed difference in evaporation rates but the striking elevation differences were expected to dominate the other factors.

Figure 5: Location of evaporation pan stations in southern Alberta



As depicted in Figure 5, the stations joined by the red line segments were used to assess the evaporation rate as a function of elevation. The physical separation of the stations was comparable to those shown in the previous section but there was much greater differences in the elevations of these sites. From Figure 6, it appeared that evaporation rates were a function of elevation.

Figure 6: June pan evaporation in southern Alberta for period of record



From a detailed analysis of the pan evaporation data for these sites it was evident that elevation did play a role in explaining the differences in evaporation rates. Unfortunately not all stations had records for corresponding years. The shortest records were at Marmot (4 out of 5 possible years) and Mount Eisenhower (9 years). However, by calculating the average evaporation of all valid years for each station then regressing these values against elevation, a large portion of the variance was explained. For the months of June, July and August respectively, the regression of average pan evaporation on elevation explained 95.5, 94.1 and 95.5 % of the variance in average monthly pan evaporation. For May and September, a similar analysis could not be made because the pans could not be operated for complete months due to ice formation on the pan at the high elevation stations.

Figure 6 for southern Alberta, in contrast to Figure 1 for southeast Alberta and Southwest Saskatchewan, showed a discernible dependency of pan evaporation on elevation. Similar plots (not shown) were observed for July and August. Figure 7 depicted the average June pan evaporation as a function of elevation. While some of the difference may have been a function of gradual climate gradients due to latitude, it was clear that there was a strong association with elevation.

Figure 7: June pan evaporation and elevation - southern Alberta

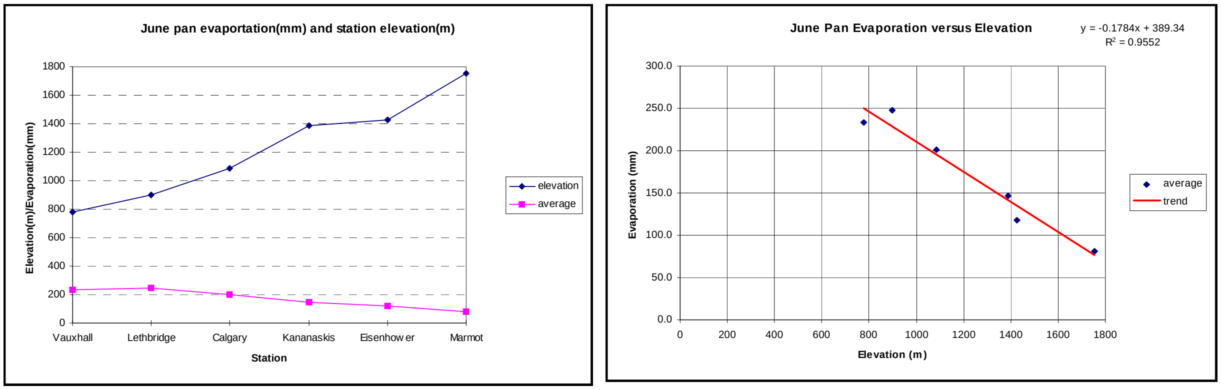


Figure 8: July pan evaporation and elevation - southern Alberta

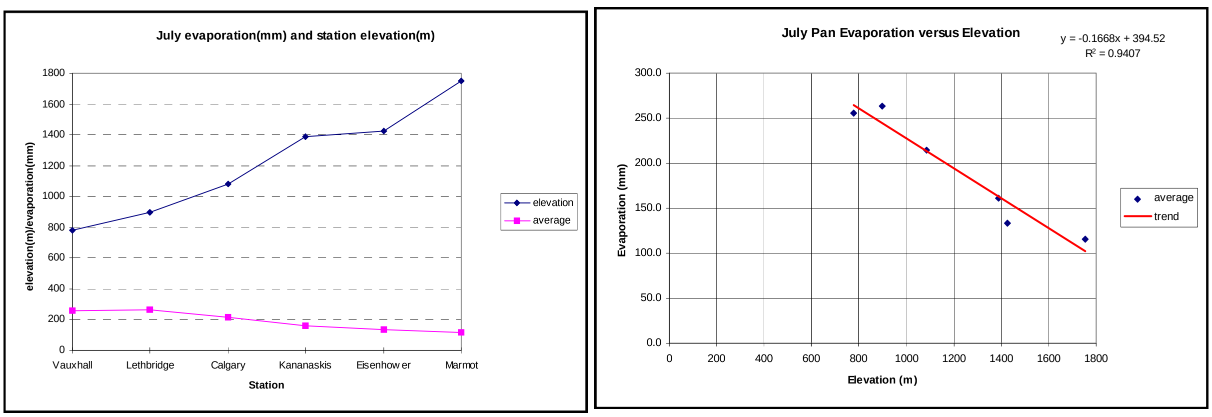
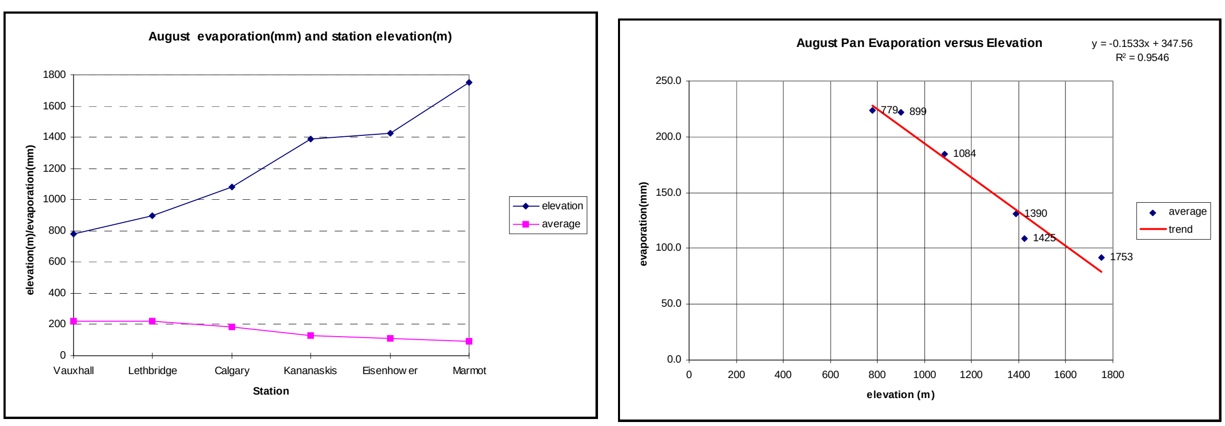


Figure 9: August pan evaporation and elevation - southern Alberta



Similarly, July and August plots of average pan evaporation against elevation showed a strong elevation factor in the pan evaporation (see Figures 8 and 9). Table 2 summarized the results of the regression analyses for June, July and August. Using

Altawan (945 m) as a base condition, it was possible to prescribe equations for June, July and August based on these analyses.

Table 2. Summary of regression analysis for southern Alberta evaporation pan data

Month	Slope	Intercept	Predicted value at Altawan	Altawan Equation	Percentage Change /100 m	R^2
June	-0.1784	389.34	225.0	225.0 - 17.8mm/100m	-7.9	0.955
July	-0.1668	394.52	236.9	236.9 - 16.7mm/100m	-7.0	0.941
August	-0.1533	347.56	202.7	202.7 - 15.3mm/100m	-7.6	0.955

The consistency of the monthly results provided some confidence that these findings were attributable to a real elevation dependency and were not just spurious. All regression equations were significant at the 99.5 % level of confidence. For Battle, Lodge and Middle creeks, one could use the measured pan evaporation at Altawan less the average slope of 16.6 mm per hundred metres times the elevation difference on a monthly basis for any month June, July or August. For shorter periods the reduction could be prorated as 5.4 and 5.8 mm/100 m for 10 or 11 day apportionment periods for the international apportionment. Another approach would be to use the percentage change per 100 m elevation difference from Altawan. Because it was not possible to establish absolute rates of evaporation as a function of elevation for the shoulder months of April, May, September and October, the relative approach was viewed with favour. Thus knowing the evaporation for any period at Altawan and the elevation of the reservoirs, it would be a simple matter in a spreadsheet to adjust the evaporation to a reservoir using an adjustment factor of -7.5 % per 100 m for any time period.

For reservoirs in the upper basin at elevations of about 1100 m, the reduction in pan evaporation from Altawan would be 11.6 %. The estimated lake evaporation would be adjusted by the same factor.

If all other factors were equal, evaporation should increase with elevation but in fact the climate changes fairly rapidly with elevation. The climate within which the evaporation pan is situated strongly influences the observed evaporation and thus the observed pan evaporation decreases with elevation because of the changing climate much more than increases due to elevation/pressure factor alone. This was evident from tundra-like climates observed at high elevations on mountains in southern Alberta. The changing plant and forest communities with elevation was another reflection of changing temperature, precipitation and humidity with elevation. The intensity of sunshine or solar radiation should increase slightly with elevation because of the reduced thickness of the atmosphere at high elevations but temperature and humidity were observed to vary more strongly.

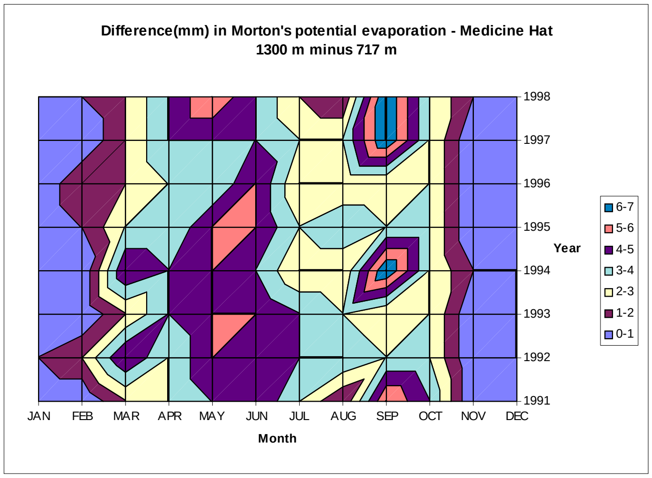
Morton's Model

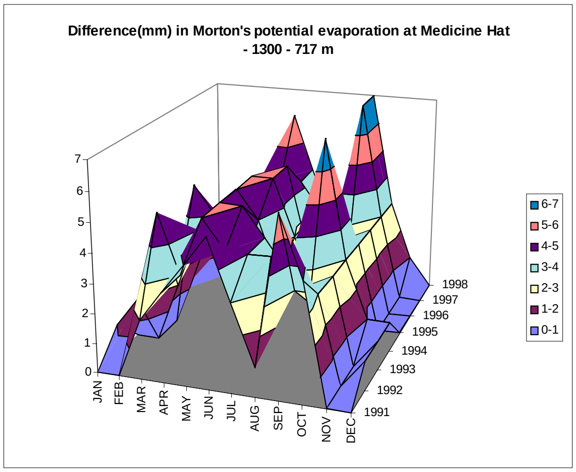
Elevation Test

Morton's lake evaporation model was tested on data for Medicine Hat for the years 1991 to 1998. The base condition was an elevation of 717 m, the elevation of Medicine Hat A. All data were held constant and the only change made was in the specification of the station elevation. Three other runs were made using a station elevation of 900m 1100 m and 1300 m. The results of each test run were compared against the base case. Morton's model has been described elsewhere (Morton, 1975,1979,1980, 1983 and 1986) and has been used extensively by Alberta Environmental Protection (1987).

The results showed an increase of evaporation with increased station elevation when all other factors were specified by the base condition. This was depicted for the 1300 m case where the difference in the two model runs was shown for the Morton potential evaporation (see Figure 10) and Morton's shallow lake evaporation (see Figure 11).

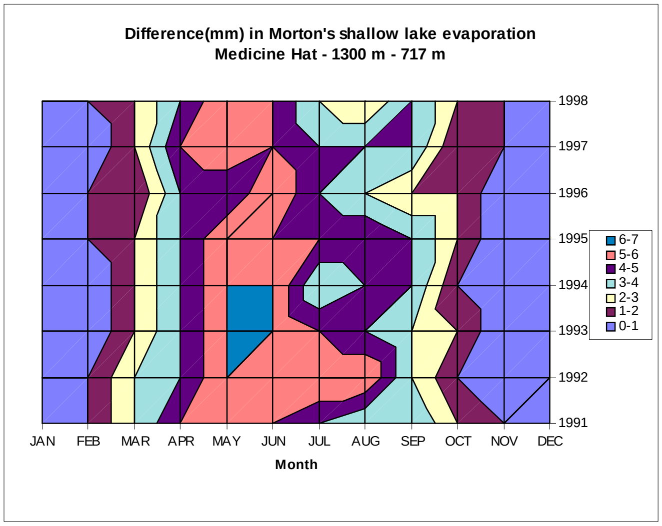
Figure 10: Difference in monthly potential evaporation (mm) between the 1300 m model run and the base case (717m) using Morton's model

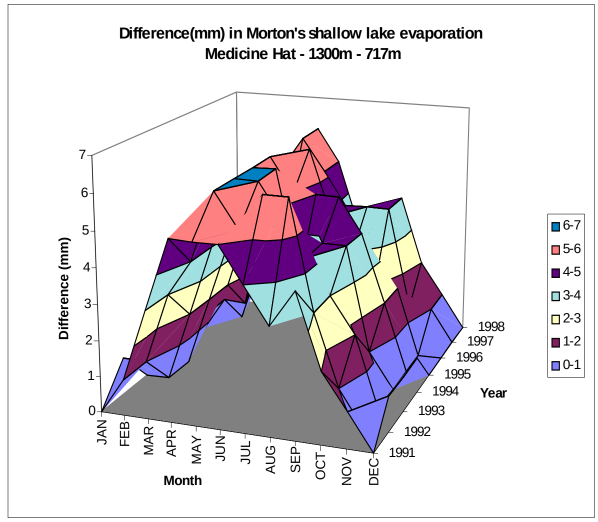




The monthly differences for summer months were typically around 4 mm per month during the open water season. The impact was more pronounced in May, June and September than in the peak summer months of July and August. A similar tendency was noted for the impact on Morton's shallow lake evaporation but the magnitude was slightly less and the higher values in September were missing.

Figure 11: Difference in monthly shallow lake evaporation (mm) between the 1300 m model run and the base case (717m) using Morton's model





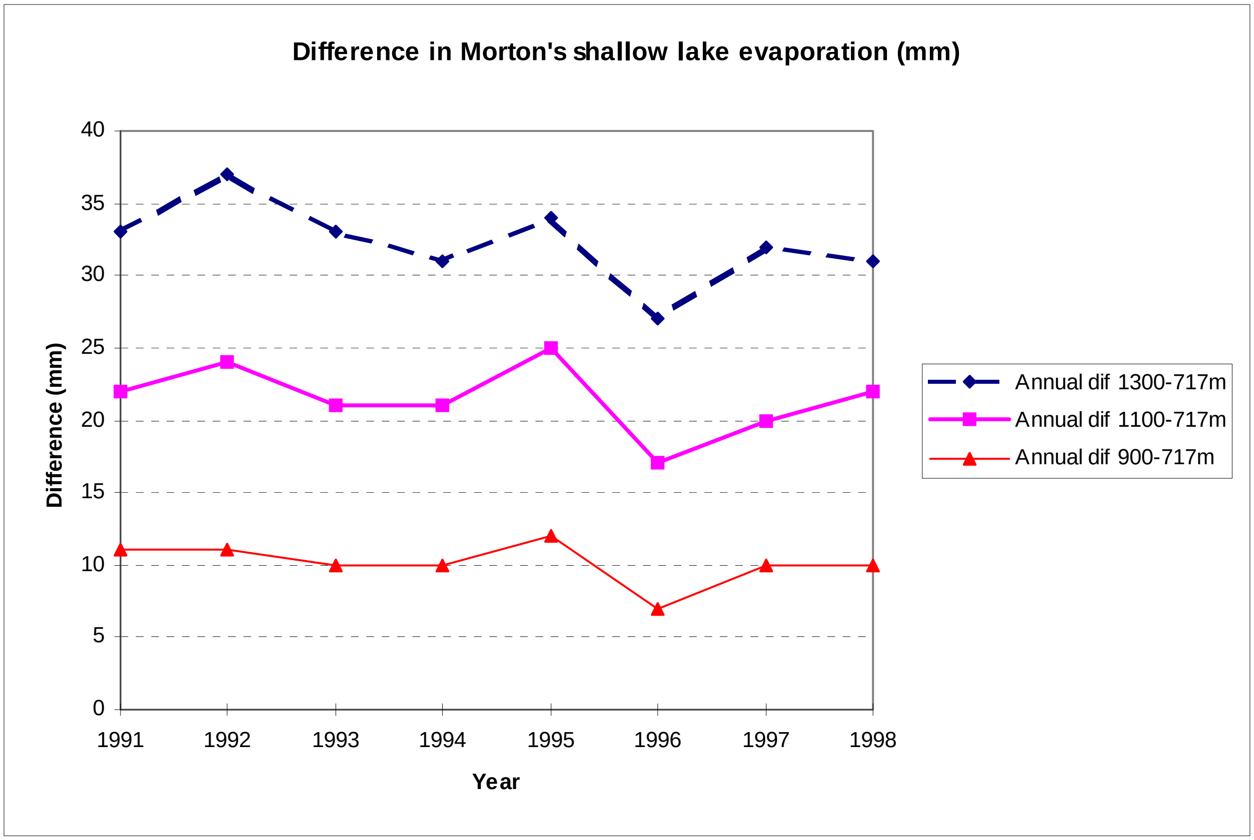
The relative change in the shallow lake evaporation in percentage was recorded in Table 3. The difference was an increase of two to four percent for the high evaporation months, June to August. On an annual basis the difference was an increase in evaporation of about four percent. Because the evaporation was much less or near zero in the months November to February, the percentage changes were not very meaningful. Not shown was the impact on the potential evaporation which was about three percent on an annual basis. The latter was explained because the magnitude of the differences were similar for the potential and shallow lake evaporation but the magnitude of the potential evaporation (average 1202 mm) was about 50 % higher than the magnitude of the shallow lake evaporation (average 812 mm).

Table 3. Percentage difference in Morton's shallow lake evaporation from increasing the station elevation to 1300 m from 717m

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual diff.
													1300-717m
1991	0	8	8	6	4	4	2	2	5	6	11	0	4
1992	17	6	7	5	5	4	4	4	5	3	0	-50	5
1993	0	0	5	5	5	4	4	3	4	6	0	25	4
1994	0	0	4	5	5	4	2	3	5	3	0	25	4
1995	0	7	5	6	5	3	3	4	5	7	0	0	4
1996	0	6	3	6	5	4	2	2	3	6	0	0	4
1997	0	0	6	6	5	3	2	3	5	4	11	0	4
1998	0	7	6	5	4	4	2	1	5	6	10	0	4

The impact on deep lake evaporation was similar to the shallow lake evaporation (about four percent annually) but the monthly pattern was shifted later in the season because of the thermal inertia of a deep lake relative to a shallow lake.

Figure 12: Difference in Morton's shallow lake evaporation (mm) caused by increasing the station elevation



As could be seen in Figure 12, there was a proportional increase in the annual shallow lake evaporation as the station elevation was increased. For the first 200 m increase, the impact was an increase in evaporation of about 10 mm; for 400 m elevation increase, the impact was an increase of about 21 mm; and for an increase in elevation of 600 m, there was an average increase in evaporation of about 32 mm.

Thus for the range of elevations of interest to this investigation, there was an increase in annual evaporation of about one per cent for every 200 m increase in station elevation - all other factors held constant. In equivalent terms, this represented about 5 mm increase in evaporation per 100 m of elevation increase.

However, the climate was known to change with elevation and the changes in the model output needed to be evaluated with actual climate data at higher elevations.

Climatology Test Including Elevation Changes

There was only one sunshine program in this area so it was assumed that the sunshine data for Medicine Hat could be applied to all stations in the area but that actual temperature and dew point data should be that measured at sites of interest. In this test, Medicine Hat at elevation 717 m was selected as the base condition. Dew point and temperature data were processed for use in Morton's model for Onefour (935 m), Eastend (1080 m) and Cypress Hills (1271m). These stations were chosen because their elevations corresponded roughly with those used in the elevation test. Thus it should be possible to discern the impact of the temperature and humidity climatology on the computed evaporation from that attributable to elevation alone.

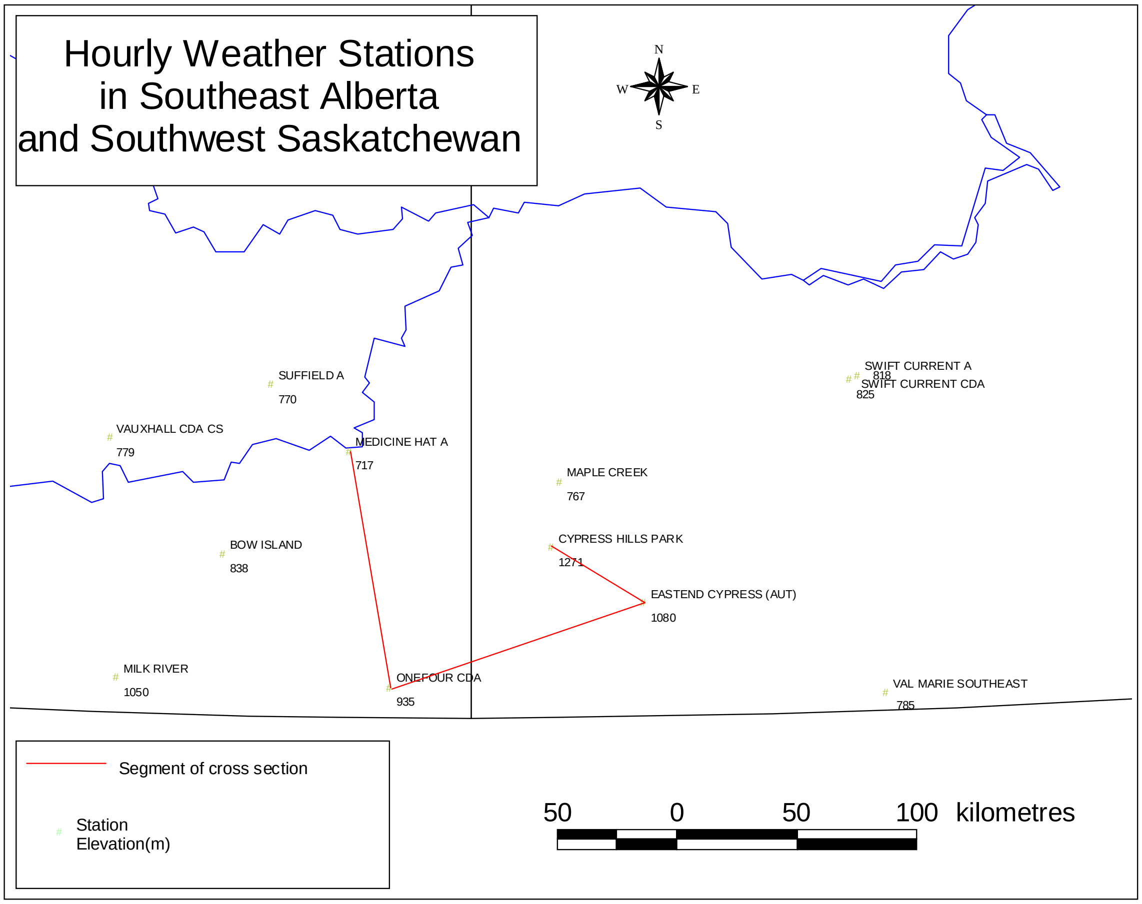
The stations with hourly data in southeast Alberta and southwest Saskatchewan have been augmented in the 1990s with a number of autostations based on Campbell Scientific dataloggers. These included Onefour (at the same location as Manyberries CDA) and Cypress Hills Park. An older style of autostation was located at Eastend. All sites measured temperature and humidity on an hourly basis and these data were stored in the Canadian Climate Archive. Other hourly stations were in this area but they were further removed from the basins of interest and the ones chosen spanned the elevation range of interest.

Table 4. Datacat search of hourly weather stations in southeast Alberta and southwest Saskatchewan

```
LATITUDE LIMITS= 49 , 0  TO  50 , 30
LONGITUDE LIMITS= 106 , 0  TO  112 , 10
OPERATING BETWEEN YEARS***  1990   AND   1999
PROGRAM SELECTED = HOURLY WEATHER
3030768 BOW ISLAND                     49 37 111 27 0838 1993-02            7 |H|H| | | |
3034480+MEDICINE HAT A                 50 01 110 43 0717 1986-04           14 |X|X|X|X|X|
3036240 SUFFIELD A                     50 16 111 11 0770 1991-01 1992 12    2 | |D|X|X| |
3036240 SUFFIELD A                     50 16 111 11 0770 1993-01            7 | |D|X|X| |
3036682 VAUXHALL CDA CS                50 03 112 08 0779 1992-08            8 |H|H|@|@| |
3044533 MILK RIVER                     49 08 112 03 1050 1988-10           12 |H|H|@|@| |
3044923 ONEFOUR CDA                    49 07 110 28 0935 1991-02            9 |H|H| | | |
4024919 MAPLE CREEK                    49 54 109 28 0767 1989-11           11 |H|H| | | |
4028040 SWIFT CURRENT A                50 17 107 41 0818 1988-10           12 |H|H|X|X| |
4028060+SWIFT CURRENT CDA              50 16 107 44 0825 1994-01            6 |H|H|@|X|X|
4031999 CYPRESS HILLS PARK             49 39 109 31 1271 1992-04            8 |H|H| | |@|
4032322 EASTEND CYPRESS (AUT)          49 26 108 59 1080 1982-11           18 |H|H| | | |
4038412 VAL MARIE SOUTHEAST            49 04 107 35 0785 1991-11            9 |H|H| | | |
```

Figure 13 depicted the locations of the stations used in this analysis. The line segments joining the chosen stations is also shown. For these runs of the Morton model, station elevation and normal precipitation were the site specific values. The processed temperature and dew point temperatures were also those measured at each location. The latitude of Medicine Hat was used for all locations to coincide with the Medicine Hat sunshine data which was used for all stations in this test.

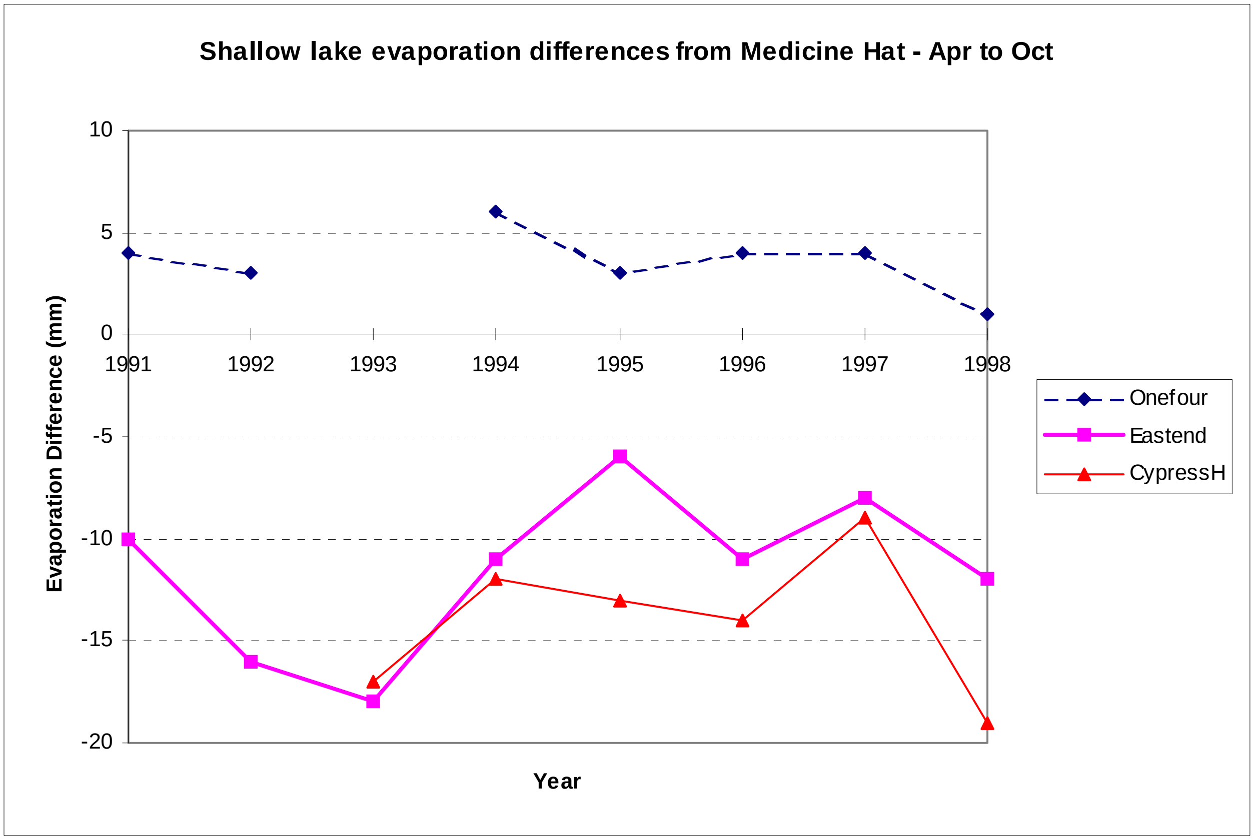
Figure 13: Location of hourly weather stations in southeast Alberta and southwest Saskatchewan



It was expected that Medicine Hat would have the greatest evaporation and Cypress Hills the least. As could be seen in Figure 14, this was true in a general sense except Onefour (Manyberries) had greater shallow lake evaporation than Medicine Hat for the open water season April to October - the period of primary interest for apportionment calculations.

Although the solar input was held constant, which may not have been totally realistic, Morton's model indicated higher evaporation at Onefour than Medicine Hat given the temperature and dew point and elevation specific to each site. Part of this was attributable to the elevation difference as shown in the previous section. The changes in temperature and dew point at Eastend and Cypress Hills Park were sufficient to override the elevation influence in the model. Using the difference between Onefour and Eastend of 13.2 mm from 935 m to 1080 m and a further 3.8 mm from Eastend to Cypress Hills (1080 m to 1271 m) for the entire summer suggested a much smaller influence than shown for the evaporation pan data in southern Alberta.

Figure 14: Difference (mm) in April to October shallow lake evaporation from Medicine Hat



A comparison of Morton's potential evaporation (see Figure 15) at these sites yielded results more comparable with the pan evaporation analysis. The difference between Onefour and Eastend was 113 mm on average for the season April to October which was about the same magnitude as the found for raw pan evaporation. The rate of decrease over the next 200 m to Cypress Hills was only an additional 35 mm. One must consider that the evaporation climates at these specific locations were not solely a function of elevation. Because the humidity of the air depended not only on the air-mass characteristics but also local evapotranspiration, localized differences in precipitation regimes could lead to anomalies on a seasonal scale. In addition, one must consider the possibility that instrumentation errors may have played a role. The best data should have been for Medicine Hat which used standard sensors which were routinely check for calibration. At Eastend, the old style autostation had similar sensors to the manned site at Medicine Hat but there were more frequent missing values and the calibration was not checked as frequently as at a manned site. The autostations at Onefour and Cypress Hills used a very different humidity sensor which yielded comparable results when the sensors were new and recently calibrated. Over the past few years , the humidity sensor at some Campbell Scientific autostations have been replaced with better quality sensors which used a different sensing system that was much less prone to degradation and calibration problems.

Figure 15: Difference (mm) in Morton's potential evaporation from Medicine Hat (April to October)

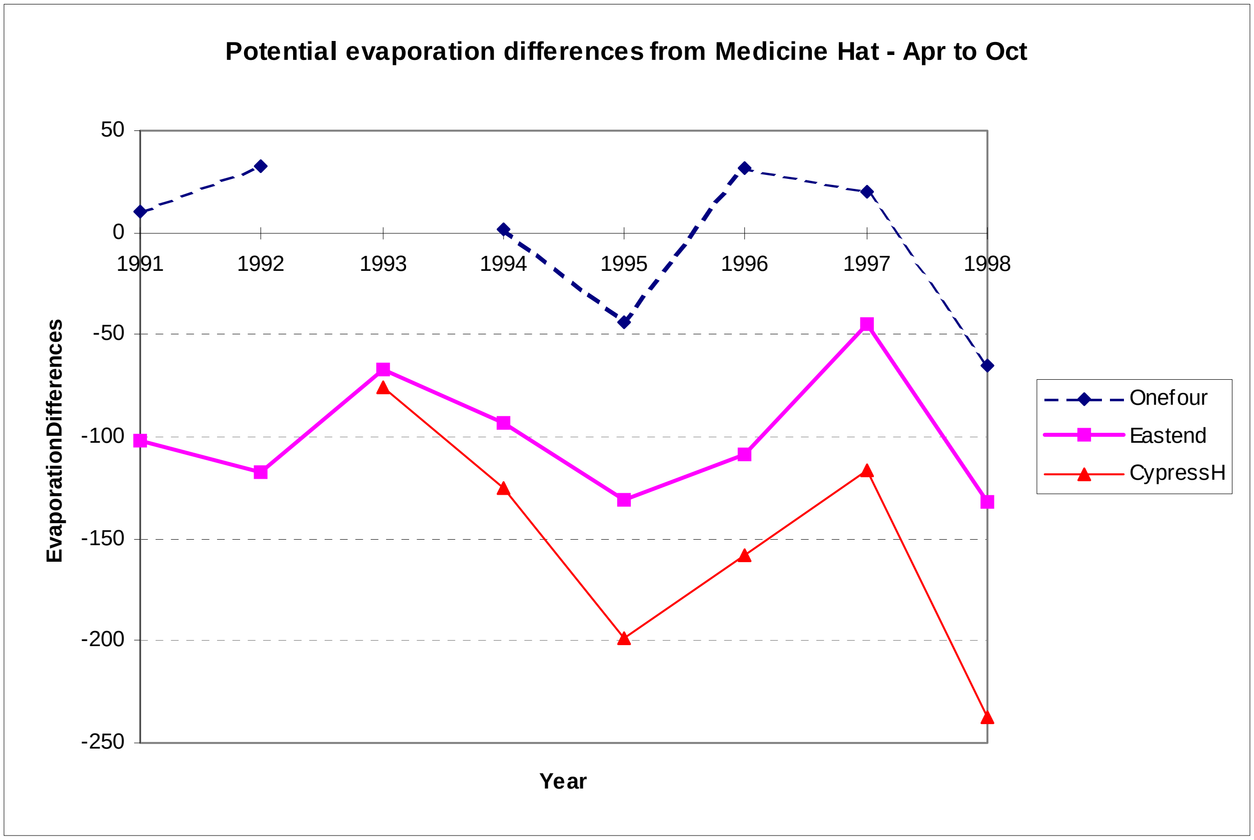
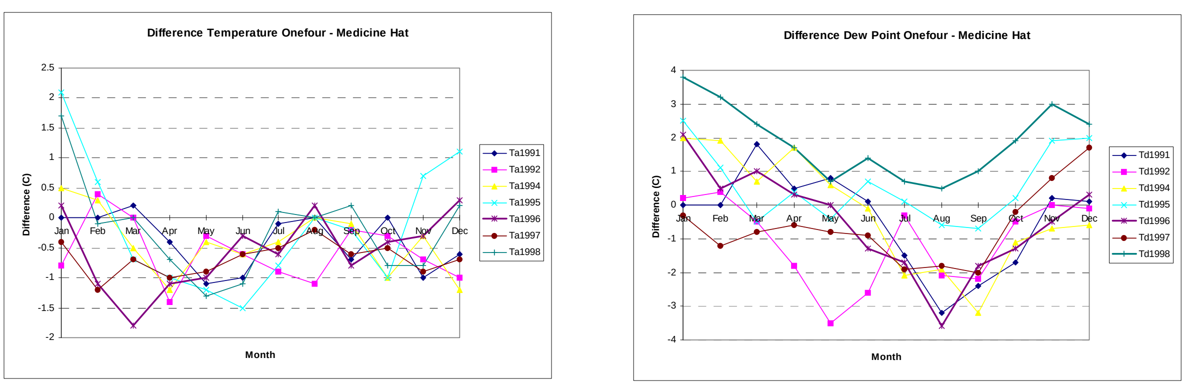


Figure 16: Comparison of dew point and temperature data for Onefour and Medicine Hat



Temperature sensors were much more stable with respect to calibration. As can be seen in Figure 16, there was fair consistency in the monthly temperature bias for the different years but the dew point relation between Onefour and Medicine Hat was much more variable. In particular, the bias in the 1998 dew point was positive for all months which suggested an instrument problem rather than a climatic factor.

Based on the results of the modelled shallow lake evaporation, only a small elevation adjustment would be warranted. The shallow lake evaporation was much less sensitive to elevation differences than either the measured pan evaporation or the Morton potential evaporation.

Meyer Equation

Using an alternative approach based on the Meyer (1915, 1942) equation and procedures refined by PFRA (1988, 1989, 1994 and 1995), it was possible to calculate evaporation at the same four sites as were investigated with respect to the Morton model in the previous section. The temperature and dew point data were utilized for the Meyer equation but in addition, wind data were required. Sunshine data were not needed for the Meyer equation. The hourly temperature, dew point and wind data were downloaded from the Canadian Climate Archive and processed into monthly average values.

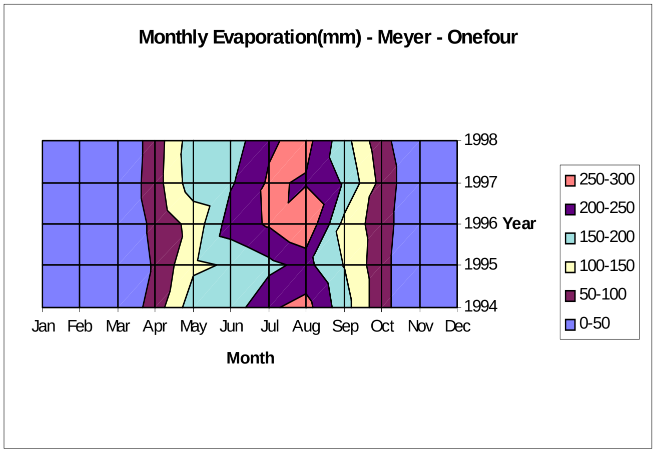
The Meyer equation included an explicit adjustment for elevation of approximately plus three percent per 1000 m. For example, if the monthly computed evaporation were 200 mm, then an elevation increase of 166 m would result in an increase of one millimetre of evaporation - all other factors held constant.

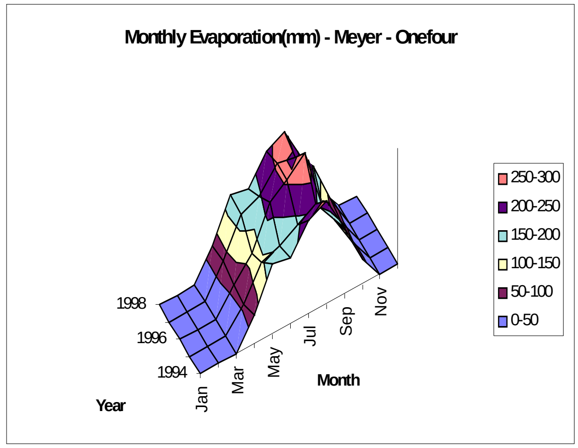
One requirement of the Meyer equation was for water temperatures to be estimated from air temperatures in the absence of measured water temperatures. PFRA developed a set of monthly water temperature equations based on measured water temperatures at a number of lakes and reservoirs across the Canadian Prairies.

The Meyer equation was easily implemented in an Excel spreadsheet. The input data were inserted in the spreadsheet and results compared for Medicine Hat, Onefour, Eastend and Cypress Hills.

Although the PFRA methodology did make provision for evaporation in March or any month for which the computed water temperature was greater than zero, this investigation was restricted to the prime open water evaporation months of April to October. Thus for this study, all evaporation values for November to March were set to zero. For Onefour, the computed values were depicted graphically in Figure 17. The patterns were similar for all stations but the magnitudes were greatest for Onefour, both monthly and seasonally. The peak evaporation was in July and August.

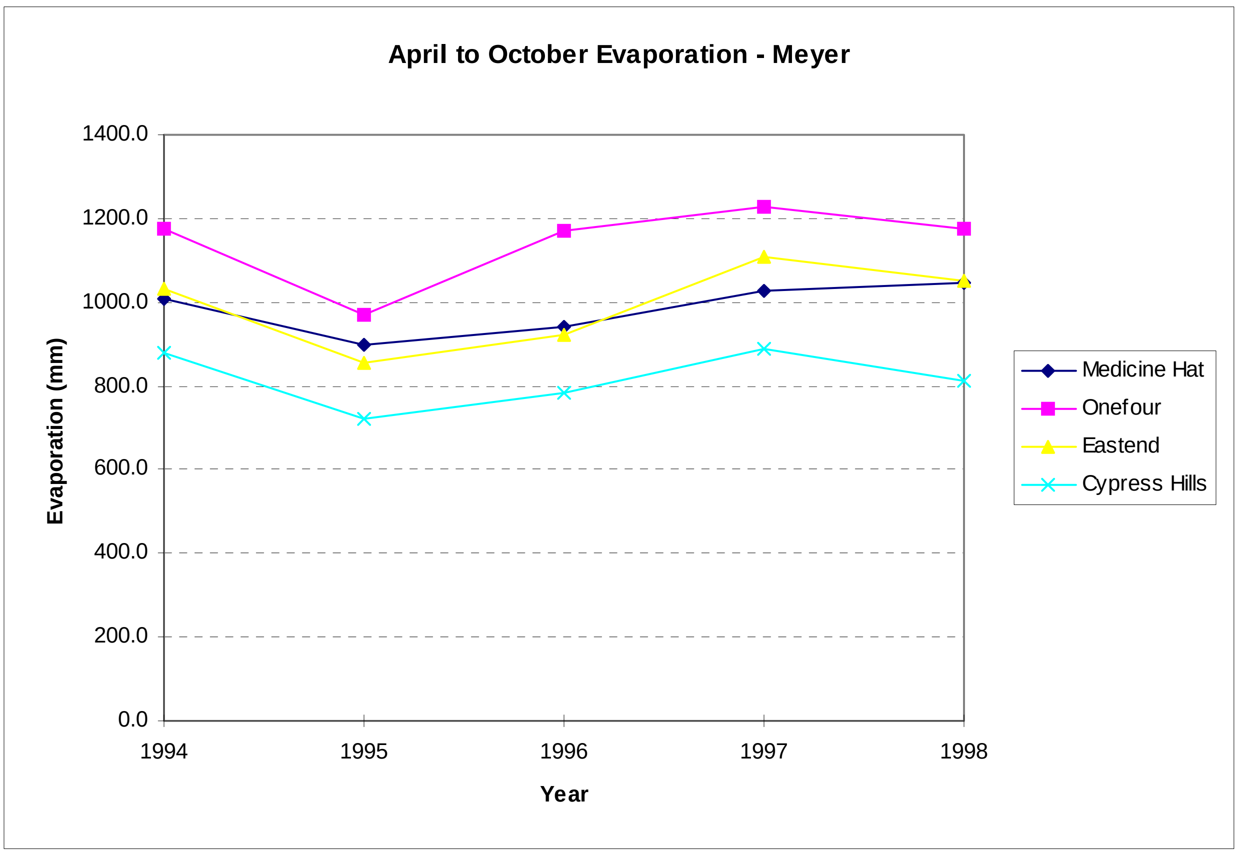
Figure 17: Meyer evaporation (mm) computed for Onefour using the PFRA methodology





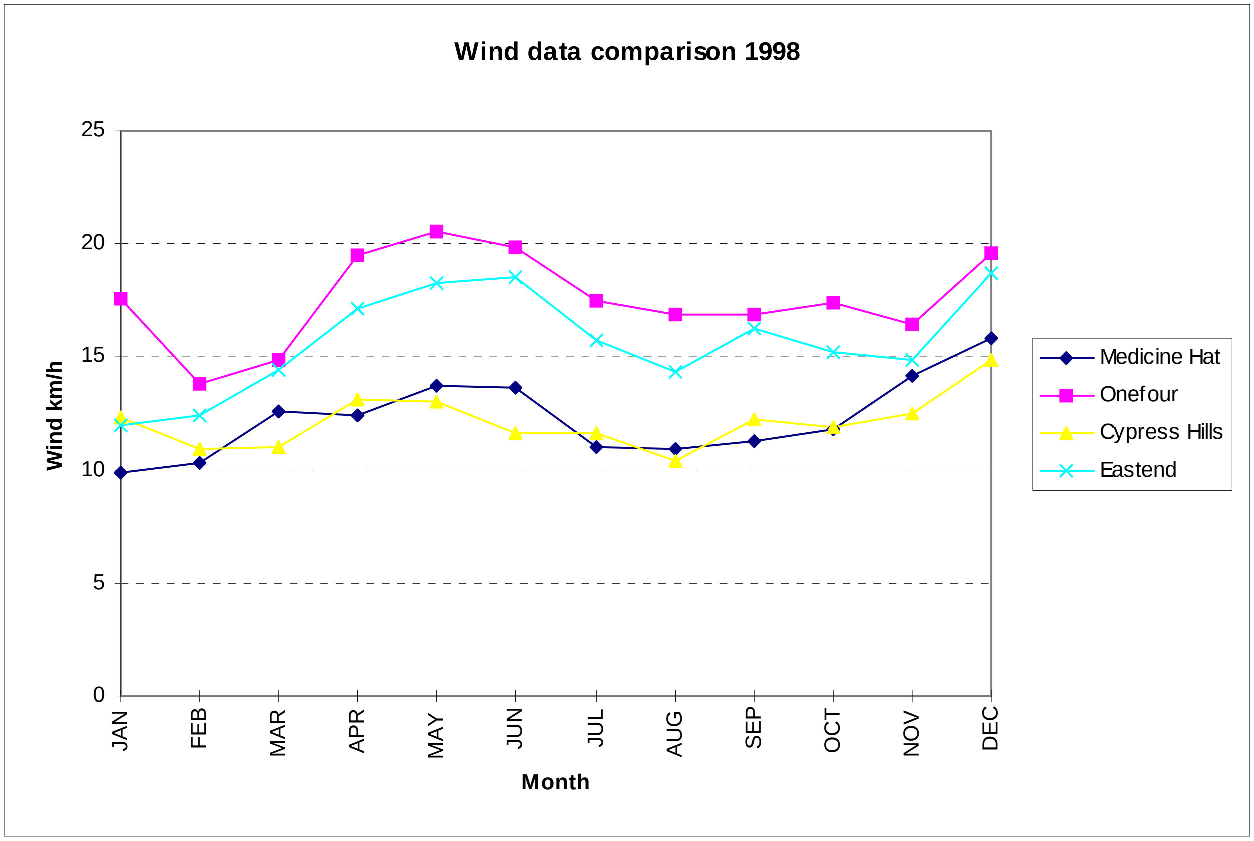
The comparative seasonal total shallow evaporation at the four sites is shown in Figure 18.

Figure 18: Meyer evaporation (mm) April to October



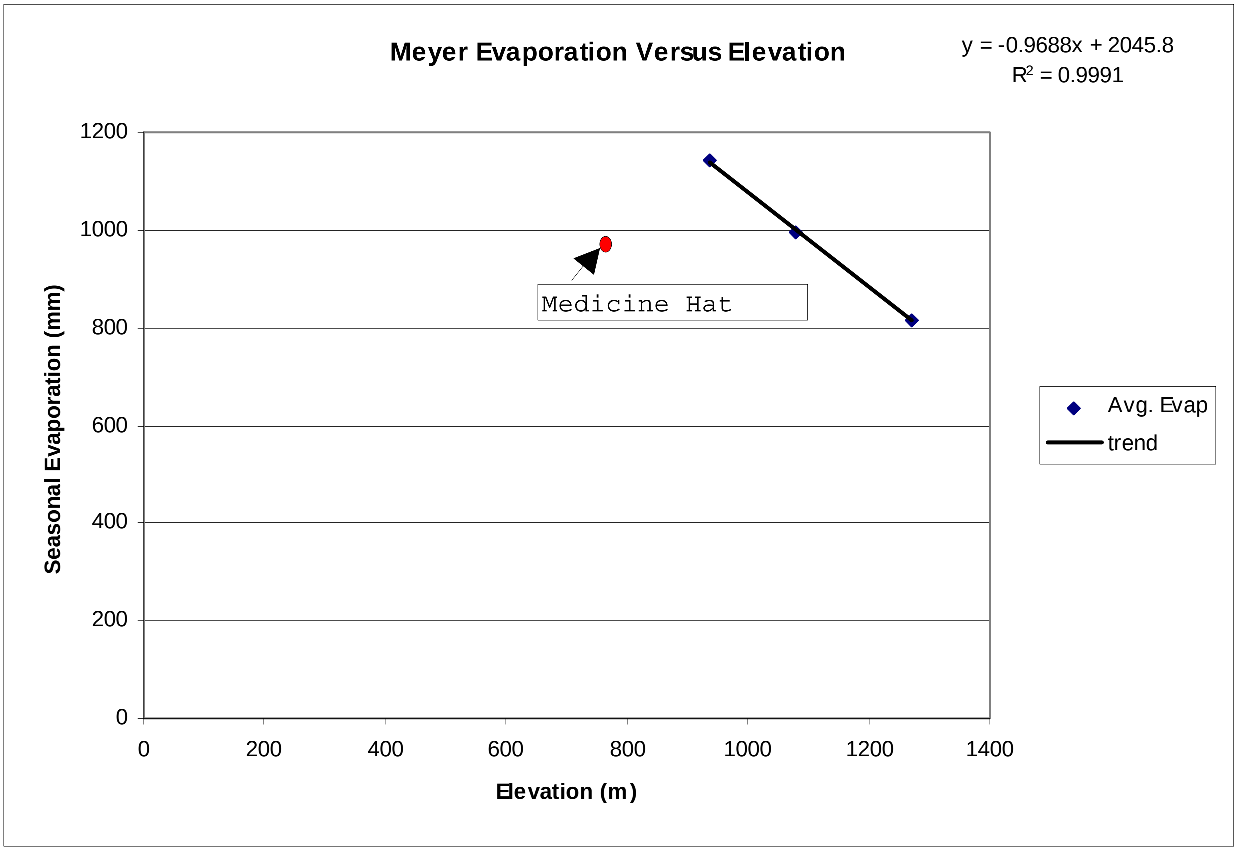
Onefour, Eastend and Cypress Hills showed a decrease of open water evaporation with elevation in a fairly regular fashion but Medicine Hat (761 m) had seasonal evaporation similar to Eastend (1080 m). Figure 13 shows that Medicine Hat was well to the north of the Cypress Hills and the other stations used in this part of the analysis. Part of the difference in the computed evaporation was attributable to the wind term (see Figure 19). On average the strongest winds were at Onefour followed closely by Eastend. The Cypress Hills Park station was probably influenced by the increased roughness of Lodgepole Pine forest whereas Medicine Hat's winds appeared to reflect a less windy regime. The Meyer equation was sensitive to wind speed which was reflected in the differences noted in the seasonal evaporation which were, in turn, a function of the differences in the wind environment at the four sites (see Figure 19).

Figure 19: Sample of monthly average wind speeds (km/h) - 1998



Excluding Medicine Hat, the rate of change of evaporation with elevation (see Figure 20) was negative 97 mm per 100 m elevation gain which was high relative to the Morton model shallow lake evaporation but similar to that noted for pan evaporation. The regression equation shown in Figure 20 excluded Medicine Hat.

Figure 20: Meyer evaporation versus elevation



Conclusions

A review of the literature indicated that some formulations suggested that evaporation should increase with elevation if all other factors remained the same because of the reduced atmospheric pressure. As shown in this study, evaporation appeared to decrease with increasing elevation for all three approaches - evaporation pan data, Morton's lake evaporation and the Meyer equation. Unfortunately there were no evaporation pan data from higher elevations in the Cypress Hills and the evaporation pan data in the local area were all from stations with approximately the same elevation. However in the different approaches, it was surprising how similar the results were.

Based on the pan measurements, a reduction of the pan evaporation of 7.5% per 100 m or 11.6 % from Altawan to the upper reservoirs would be appropriate. This could be applied seasonally, monthly or for shorter durations (15-days). To compute the net reservoir evaporation, one would take the Altawan pan evaporation and multiply by 0.884 to estimate the pan evaporation at the upper reservoirs. Then one would apply the pan coefficient of 0.70 to this figure to estimate the gross shallow lake evaporation at the upper reservoirs. From this one would subtract the Eagle Butte precipitation to yield the estimated net lake evaporation at the upper reservoirs.

Table 5. Comparison of annual/seasonal evaporation adjustment for elevation (Altawan to upper reservoirs)

Estimation Procedure	Evaporation(mm) at Altawan	Evaporation(mm) at Upper Reservoirs	Evaporation adjustment (mm)
Pan Evaporation	1041	920	-121
Pan Lake Evaporation	729	644	-85
Meyer Evaporation	1143	993	-150
Morton Potential Evaporation	1209	1078	-131
Morton Lake Evaporation	814	788	-26

Table 5 summarizes the results of this study and although the magnitudes differed, the adjustments were all of the same sign and a similar order of magnitude. The Morton lake evaporation was apparently the least sensitive to changes in elevation. There was sufficient agreement to warrant the use of an elevation adjustment in the apportionment calculations and the one based on pan data provided the most practical approach for the apportionment calculations.

Recommendations

It is recommended that the net evaporation at the upper reservoirs be determined by multiplying the Altawan pan evaporation by the elevation adjustment of 0.884 and then the pan coefficient of 0.70 before subtracting the Eagle Butte precipitation.

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