Appendix D

Air Drainage

Submitted by:
Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited
300-210
Colonnade Rd
South, Ottawa,
K2E 7L5
T: 647-205-1239
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Air Drainage Analysis for Block 1- Fruitland-Winona Block Servicing Strategy

City of Hamilton, ON, Canada

Nov 25, 2021

Glenn Clements
Senior Associate Engineer, Civil
Wood Environment & Infrastructure Solutions
NS, Canada

Executive Summary – Air Drainage Analysis Dillon Consulting Limited

The City of Hamilton requires an Air Drainage Analysis for the Block 1-Fruitland-Winona Block Servicing Strategy Area, Urban Hamilton Official Plan, Stoney Creek Boundary Expansion Block 1 (the B1-Plan) located within the City of Hamilton in southern Ontario, Canada. The desktop analysis includes a review of the area's topography and an analysis of the area's climatology.
The objective of this analysis is to study the effect of the proposed development within the Block 1 Plan on the micro-climate in the region.

Archived climate data for three nearby weather stations indicates that the predominant winds will be from the west and southwest direction. Furthermore, the data have shown December and February being the months with the highest number of fog occurrences while freezing fog was more frequent during February.

There are two types of frost conditions: advection frost and radiation frost. Advection frost is a regional frost event and it occurs when winter storm conditions which originate from northern regions move into the area. This kind of event can be understood through the analysis of climatological data and the topography of the region. Radiation frost is a micro-scale climate event and is generally site specific. Radiation frost is typically caused by cold air accumulation near the ground surface, which can occur in the winter, spring or fall.

Tender fruit plants can be damaged in the winter due to very low temperatures. The damage often includes cracking of trunks and branches, the death of flower and leaf buds or total death of grafted parts.

Following the desktop analysis of the microclimate and the topography in the area contained by the current B1-Plan (Figure 3), the proposed development is not expected to block the south-westerly-to-north-easterly direction air flow. The new development is not expected to impede the natural air movement and may assist in mixing the boundary air layer (a layer near the ground) by creating eddies (turbulences), thus aid in streaming any cold air descending from the Niagara Escarpment, i.e. preventing air stagnation. Meanwhile, the roads (existing and proposed), the Watercourses and the natural open spaces outlined in the B1-Plan will help to channel the air downstream toward Lake Ontario.

Dr. Diar Hassan

DiarHassan

Sr. Scientist, Product and Business Development
300-210 Colonnade Rs South,
Ottawa, ON, K2E 7L5
Cell: +1 647-205-1239

Contents

1. Introduction

The City of Hamilton requires an Air Drainage Analysis for the Block 1-Fruitland-Winona Block Servicing Strategy Area, Urban Hamilton Official Plan, Stoney Creek Boundary Expansion Block 1 (hereafter called the B1-Plan) area in Ontario, Canada. The subject lands are shown in Figure 1 and are generally bounded by Barton Street to the north, Highway 8 to the south, Fruitland Road to the West, and Jones Road to the East.

Wood is conducting a desktop Air Drainage Analysis for a proposed development on the subject lands. The analysis evaluates the effect of the proposed development on the micro-climate in the region.

Topography influences the air flow movement and microclimatology of any area. Nocturnal cooling caused by radiation (emission of longwave radiation from the ground) is the main reason for cold air draining from mountains or higher elevations into valleys or lower ground under the influence of gravity. A katabatic wind is a term used to describe downslope air movement (e.g. downslope air movement from the Niagara Escarpment toward Lake Ontario). Solar et al. (2002) found that within an hour after sunset, larger variations in surface temperature developed with localized cooling were found in wind sheltered locations. The authors also found that stronger stratification conditions and weaker air flow produce deeper drainage current.

Downward heat fluxes and intermittent turbulences are expected to break down the air drainage flow few times during a single night. Boundary layer flow acceleration and the reduction of Richardson number (buoyancy to flow shear ratio) are likely to increase mixing of the air near the ground with the air several meters higher (Solar et al. 2002).

New urban developments can alter the natural air flow pattern by blocking and/or affecting the air mixing and turbulences in the area. Such changes can, therefore, affect the micro-climate in that area. To study such effects, it is important to analyze the topography, current air flow, and climate conditions of the area.

Data from three nearby weather stations: Vineland, Burlington Piers, and Hamilton Airport, were collected for this purpose. Based on the archived data availability, the Burlington Piers and Vineland data were compiled for the period of January 2003 through the end of December 2015, whereas the Hamilton Airport data was compiled for the period of December 2011 through the end of December 2015.

The following sections will provide a geographical overview of the area, the B1-Plan, climatological maximum and minimum temperatures, prevailing winds, topography, and summary and conclusions of the air drainage analysis.

2. Stoney Creek Urban Boundary Expansion (Block 1)

The Stoney Creek community is located in the eastern part of the City of Hamilton, also known as Hamilton East, in southern Ontario, Canada. The community is situated between Lake Ontario to the north, the Niagara Escarpment to the south, the Hamilton city center to the west, and the Town of Grimsby to the east as shown in Figure 1 below. The unique climate and rich soil conditions in the area are favorable to the cultivation of fruits and vegetables.

Figure 1. Stoney Creek Urban Boundary Expansion (Block 1) area in light shaded yellow. © Google Earth.

The Niagara Escarpment and Lake Ontario play a major role in moderating the temperature during winter and summer producing almost ideal climate conditions for wine and ice wine production in the area. In addition to the wine industry, the area is also well known for a variety of fruit crops including peaches, cherries, grapes, apples, pears, and strawberries. Figure 2 below shows the proposed development area in relation to the 2005 Greenbelt Area (dark green) produced by the Ministry of Agriculture and Food, Ministry of Municipal Affairs and Housing and Ministry of Natural Resources.

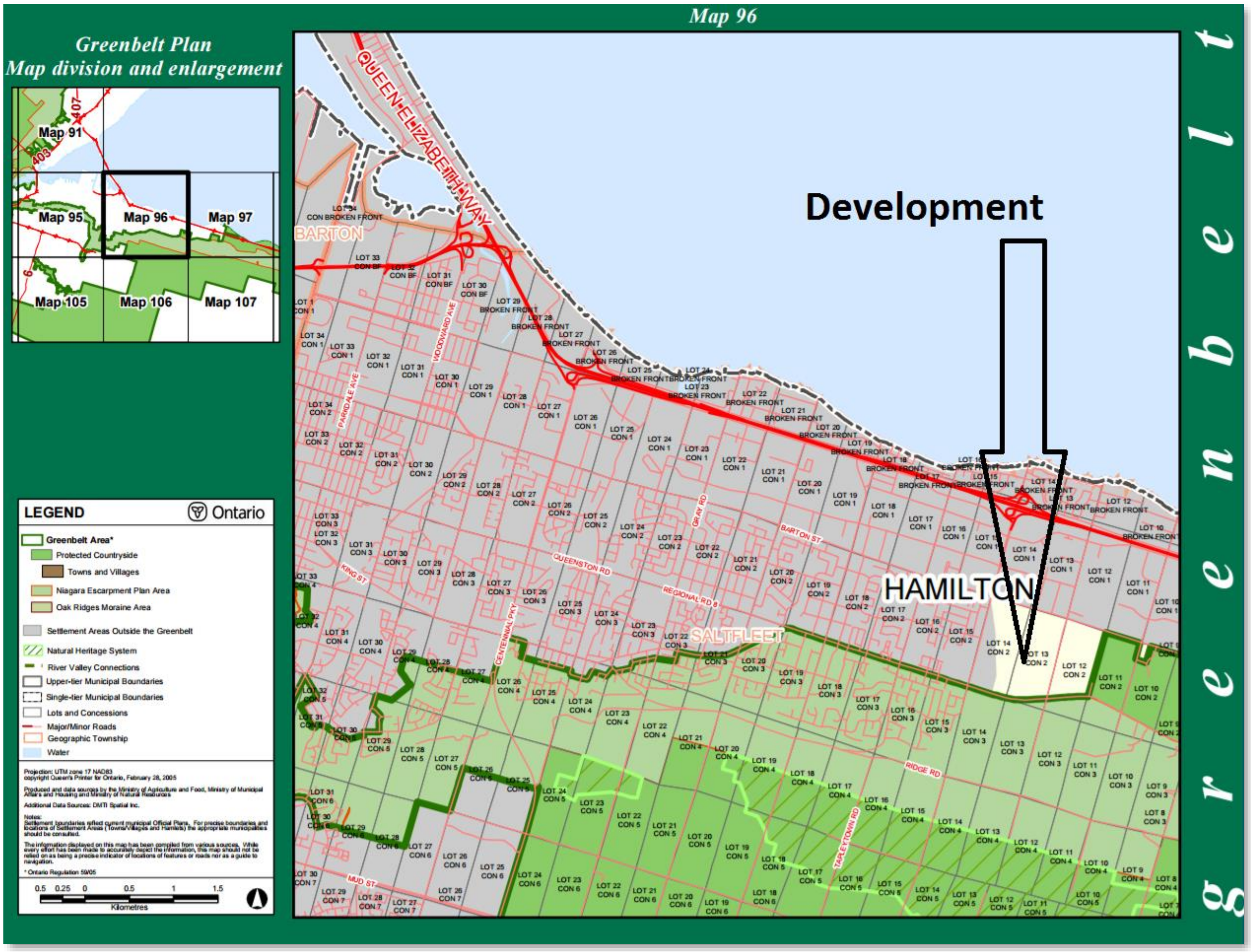


Figure 2. Map showing the Greenbelt Plan produced by the Ministry of Agriculture and Food, Ministry Affairs and Housing and Ministry of Natural Resources (2005).

3. Block-1 Fruitland Winona Block Servicing Strategy (B1-PLAN)

The proposed development inside the B1-Plan consists of dwelling development in the area bounded by Barton Street to the north, Highway 8 to the south, Fruitland Road to the west, and watercourse WC6 to the east. Figure 3 shows the Block 1-Fruitland-Winona Block Servicing Strategy map. The major roads have north-north-east to south-south-west alignment (Fruitland Road, Gordon Dean Avenue, and Jones Road) and east to west alignment (Street B, Barton Street, Highway No. 8).

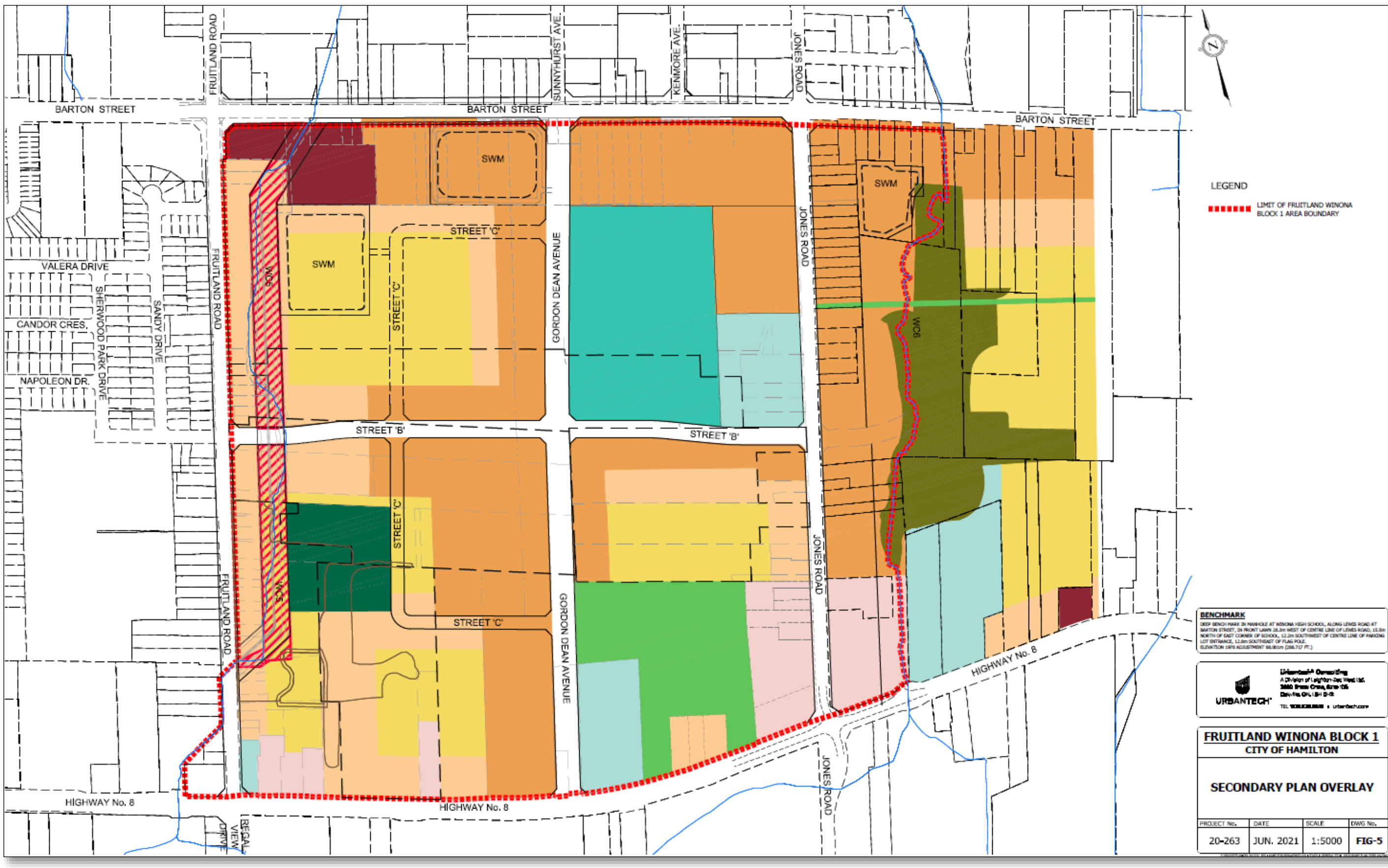


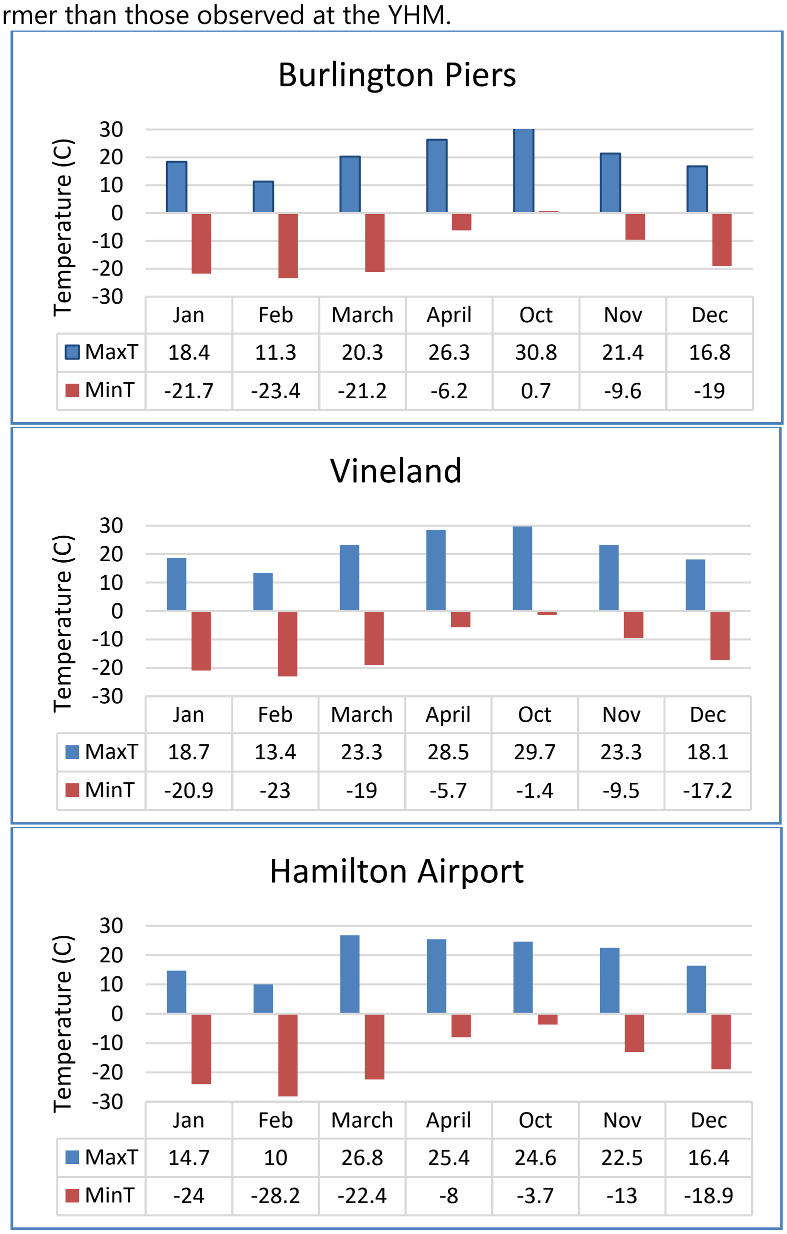
Figure 3. Stoney Creek Urban Boundary Expansion (Block 1) Plan.

The proposed land uses in the B1-Plan are primarily mixed residential units (low and medium density), other land uses include commercial, Parklands, Stormwater Management (SWM) facilities, institutions, two main watercourses to the west and east of the development, and Natural Open Spaces. The plan also features a new Gordon Dean Avenue (aligned south-south-west to north-north-east) approximately in the middle of the development, as well as a new east-west aligned, Street B, connecting Fruitland Road to Jones Road.

4. Temperature Distribution

Climatological data from Environment and Climate Change Canada (ECCC) from three nearby weather stations were used in this analysis. Internal software was used to quality check the validity of the data and to produce several figures that are used in the analysis and presented in this document.

The two primary features in this area are the landscape – notably the Niagara Escarpment with lowlands near Lake Ontario, and Lake Ontario itself. These are among several features that contribute to the spatial temperature variation in the area. Figure 4 below depicts spatial temperature variations during fall, winter, and spring. When comparing the data from Vineland Weather Station (XVN) with the data from the Hamilton Airport Weather Stations (YHM), the effect of the warmer marine environment and topography on the Vineland area is noticeable with observed maximum and minimum temperatures generally warmer than those observed at the YHM.



Burlington Piers

	Jan	Feb	March	April	Oct	Nov	Dec
MaxT	18.4	11.3	20.3	26.3	30.8	21.4	16.8
MinT	-21.7	-23.4	-21.2	-6.2	0.7	-9.6	-19

Vineland

	Jan	Feb	March	April	Oct	Nov	Dec
MaxT	18.7	13.4	23.3	28.5	29.7	23.3	18.1
MinT	-20.9	-23	-19	-5.7	-1.4	-9.5	-17.2

Hamilton Airport

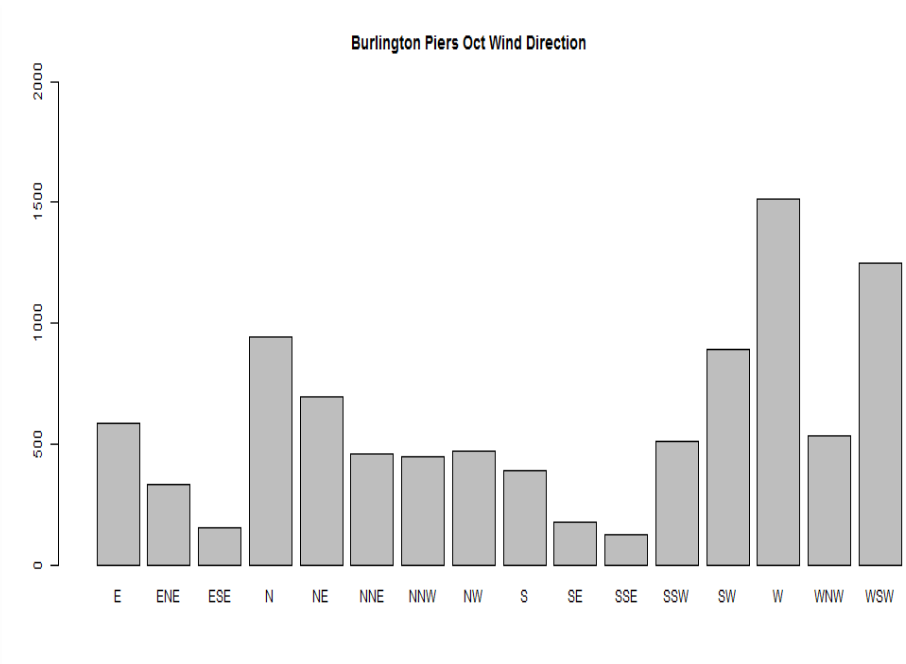
	Jan	Feb	March	April	Oct	Nov	Dec
MaxT	14.7	10	26.8	25.4	24.6	22.5	16.4
MinT	-24	-28.2	-22.4	-8	-3.7	-13	-18.9

Figure 4. Maximum and Minimum Temperatures from the three weather station for the period starting January 2003 and ending December 2015.

5. Winds

I. Prevailing Winds

To determine the prevailing orientation of the wind in the area, hourly data of wind direction collected from the three weather stations are plotted for the months of October through April. Figures 5 to 7 show the prevailing winds on a monthly basis at the three locations. The prevailing winds at Burlington Piers are westerly and southwesterly, while the north to the northeast is considered the second most common wind direction (Figure 5). Similarly, the Vineland prevailing winds are from the west and southwest during the winter season, while a north-to-east component of the winds become as prevalent during spring (Figure 6). The Hamilton station data also show that the prevailing winds are from the west and southwest direction (Figure 7).


Burlington Piers Oct Wind Direction
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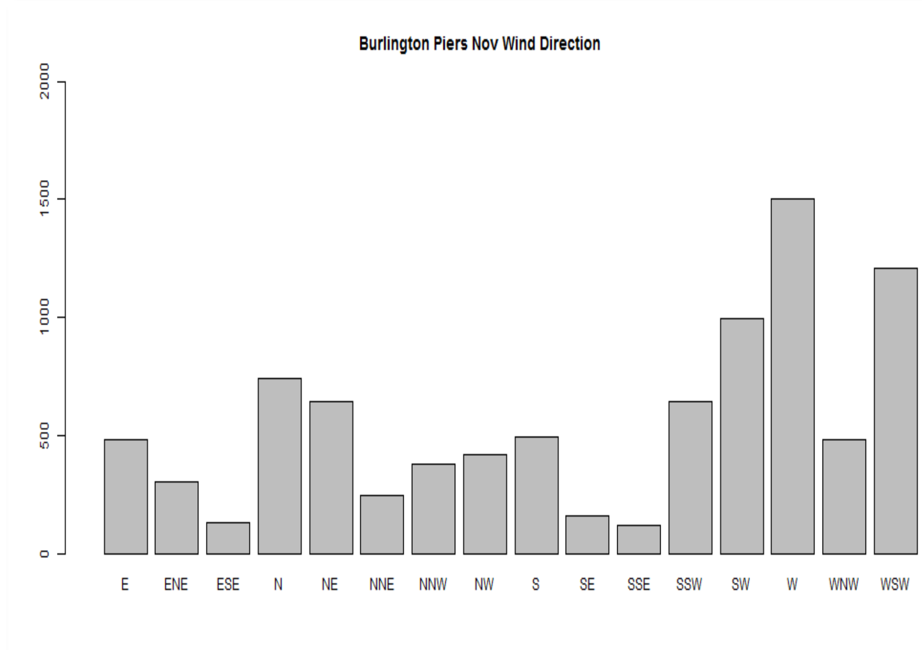
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Burlington Piers Nov Wind Direction
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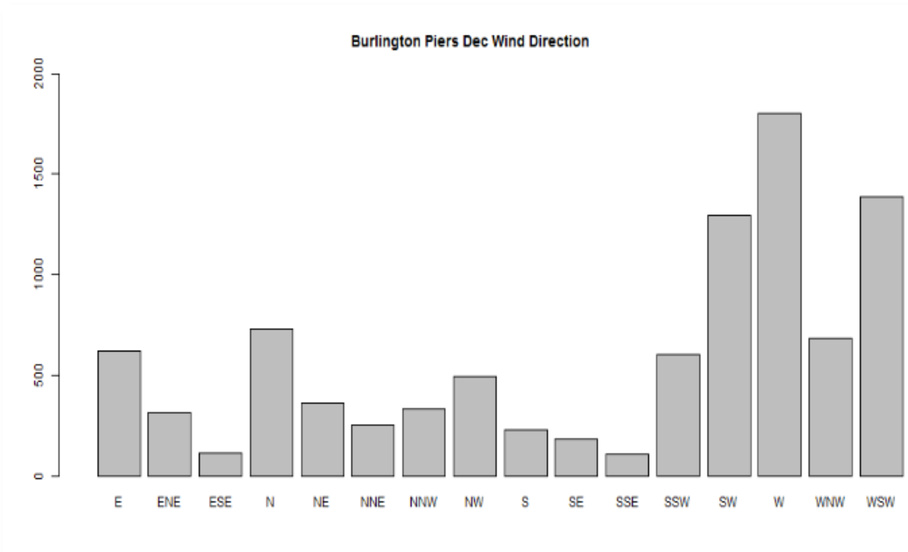
Burlington Piers Dec Wind Direction
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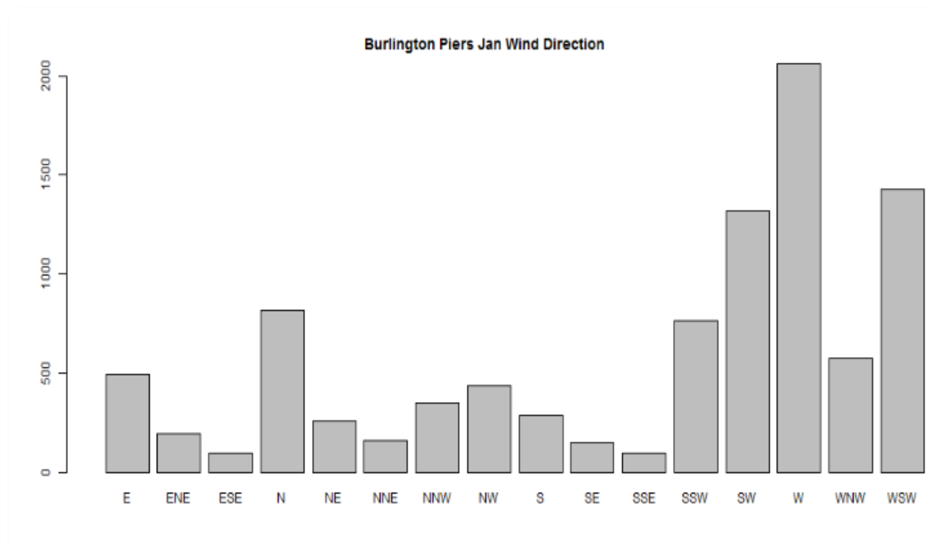
Burlington Piers Jan Wind Direction
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E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW

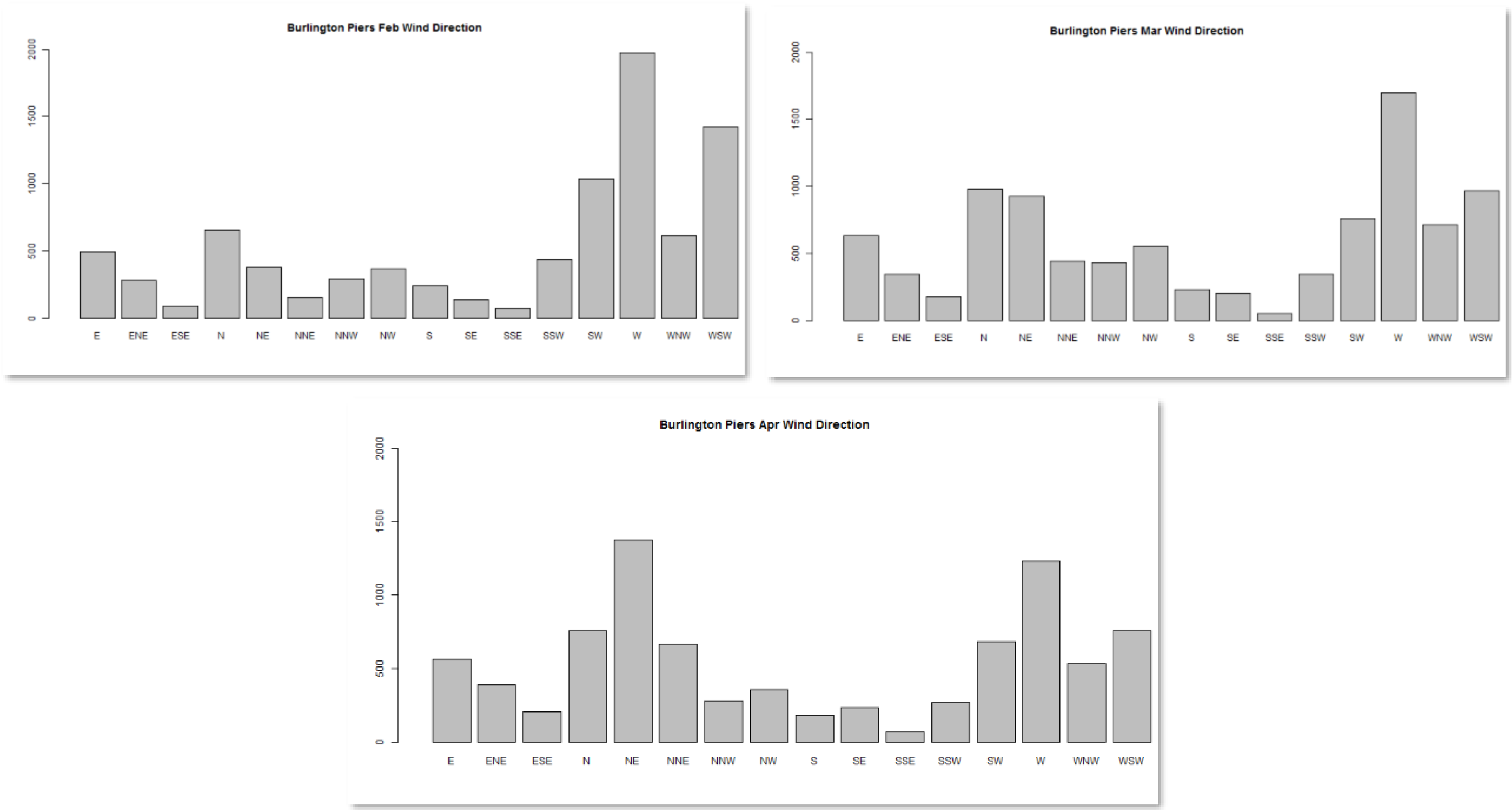
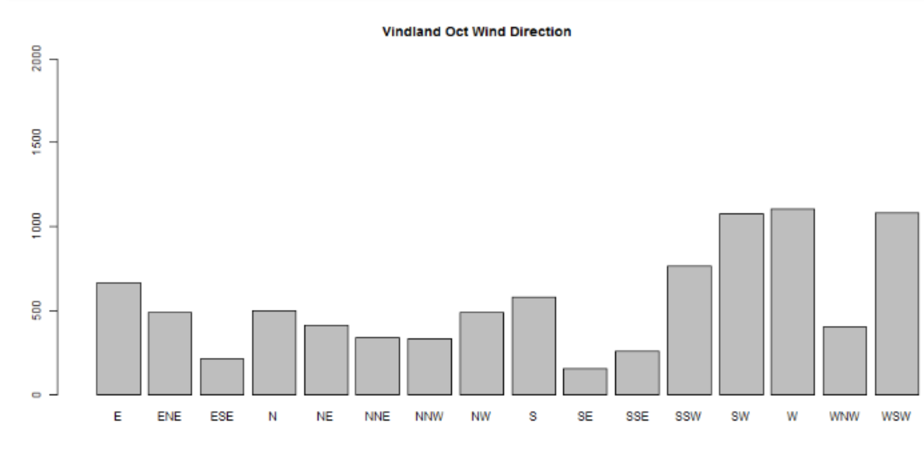


Figure 5. The prevailing winds from Burlington Piers weather station for the months of October through April (2003-2015).


Vindland Oct Wind Direction
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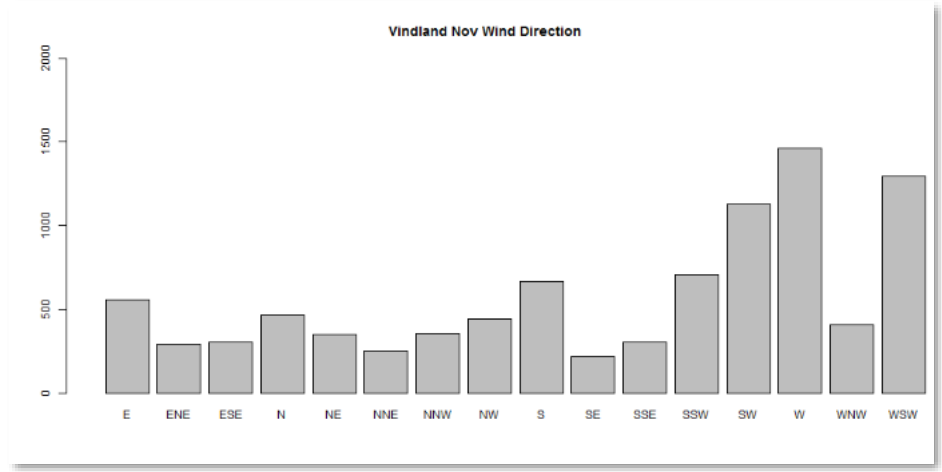
Vindland Nov Wind Direction
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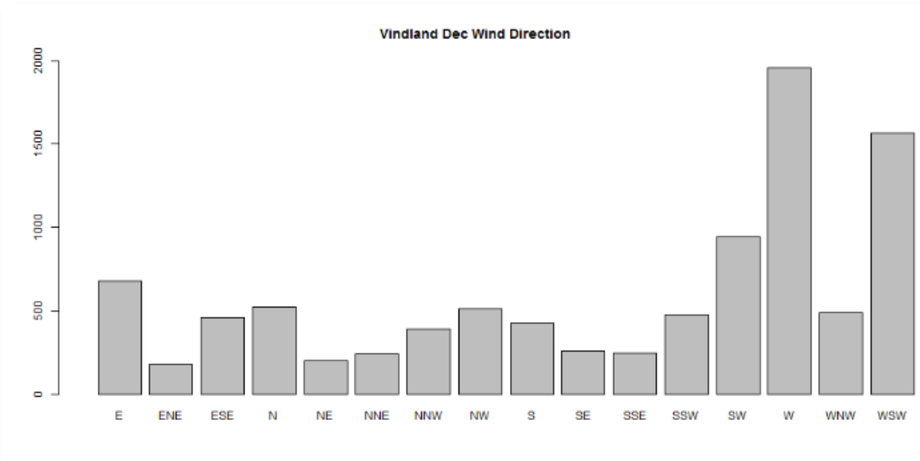
Vindland Dec Wind Direction
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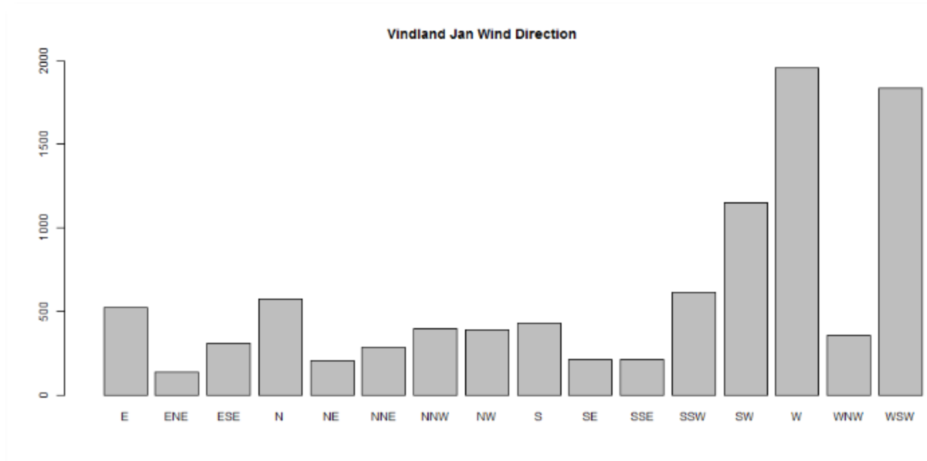
Vindland Jan Wind Direction
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E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW

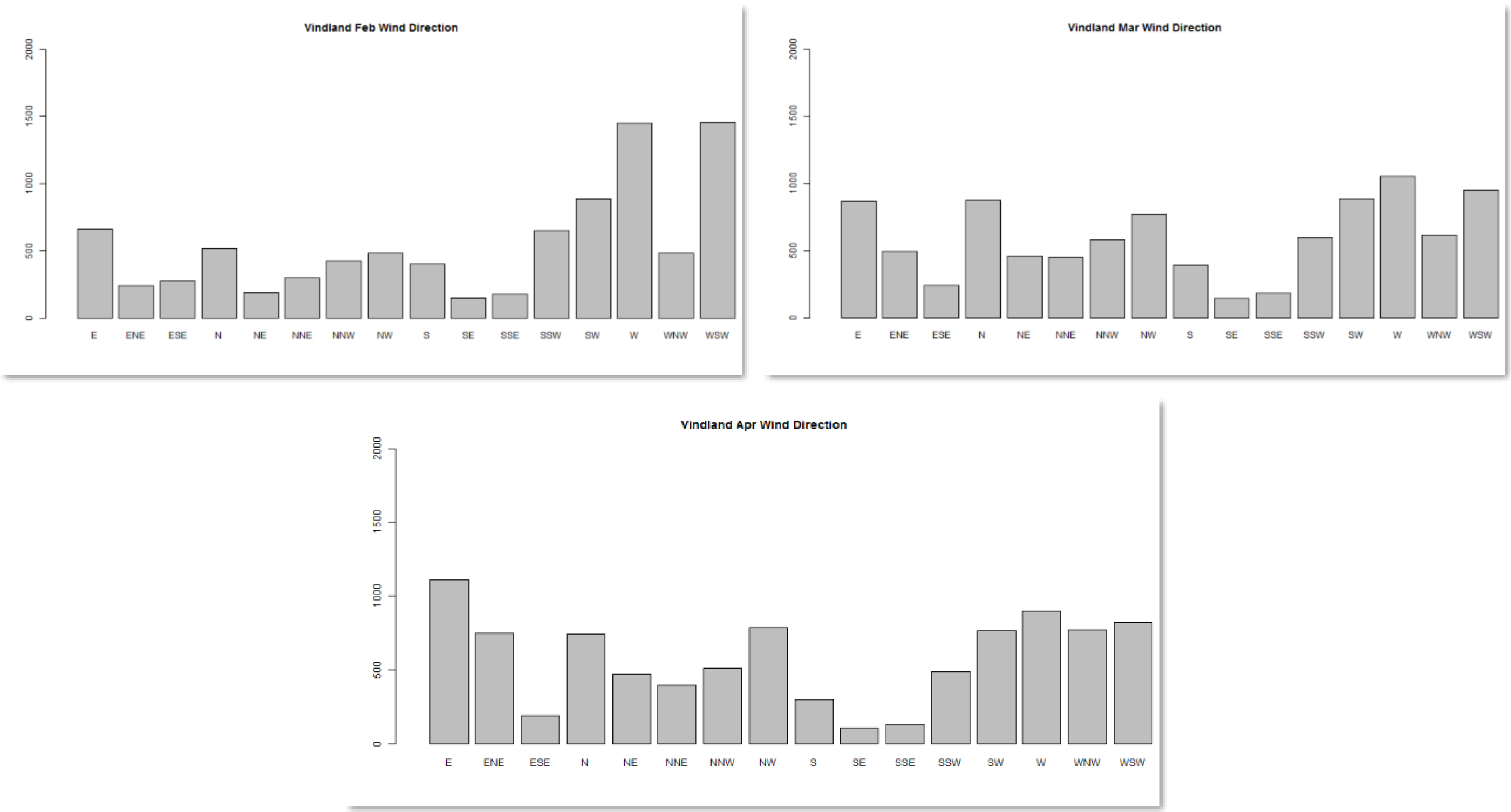
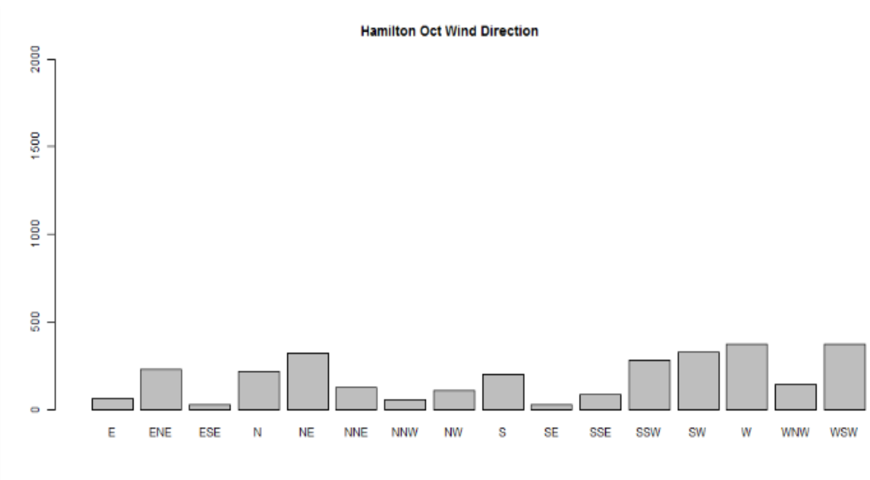


Figure 6. The prevailing winds from Vineland weather station for the months of October through April (2003-2015)


Hamilton Oct Wind Direction
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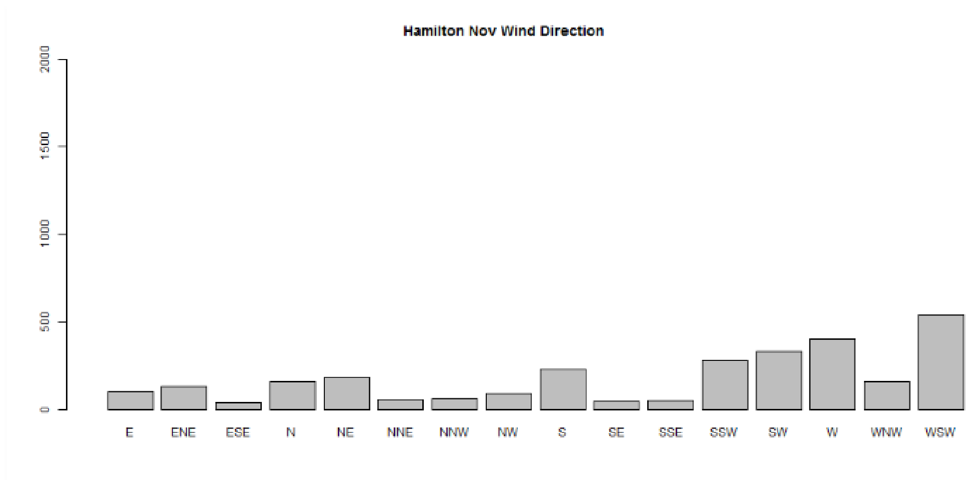
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Hamilton Nov Wind Direction
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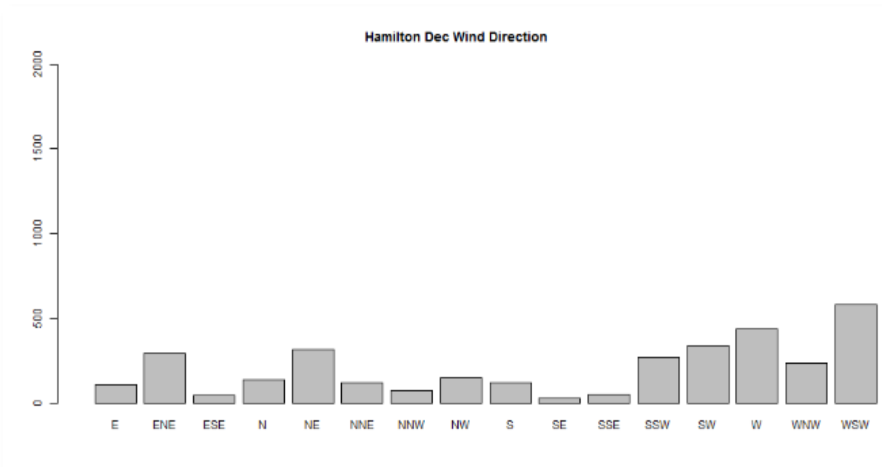
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Hamilton Dec Wind Direction
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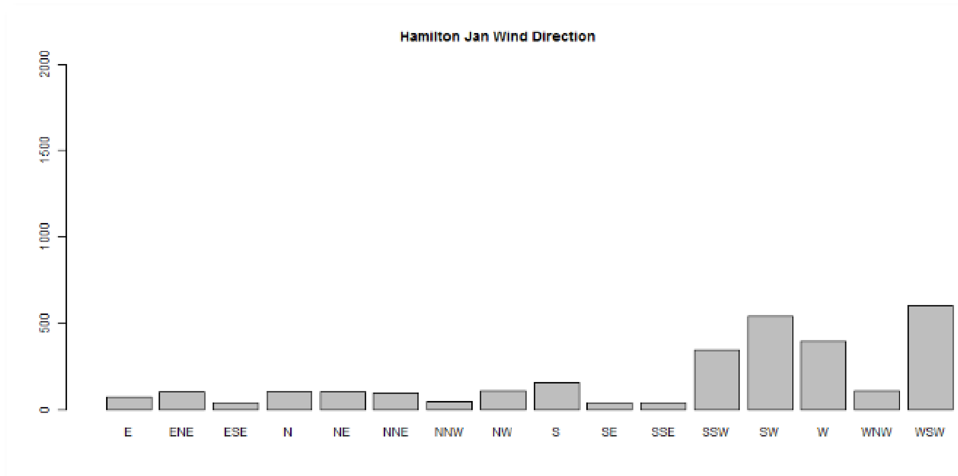
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Hamilton Jan Wind Direction
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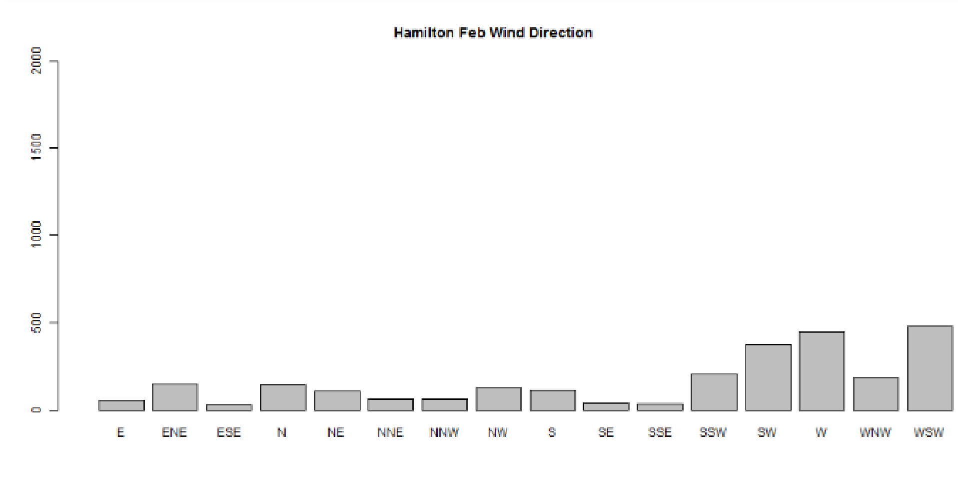
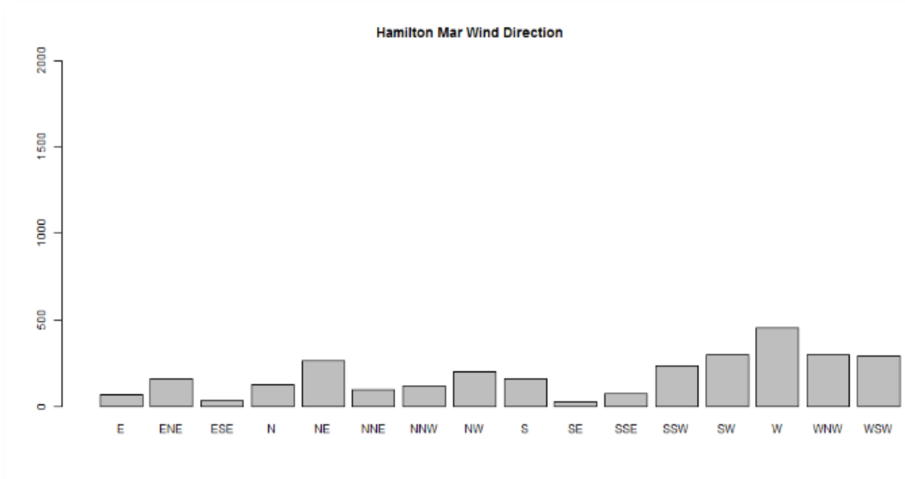
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW





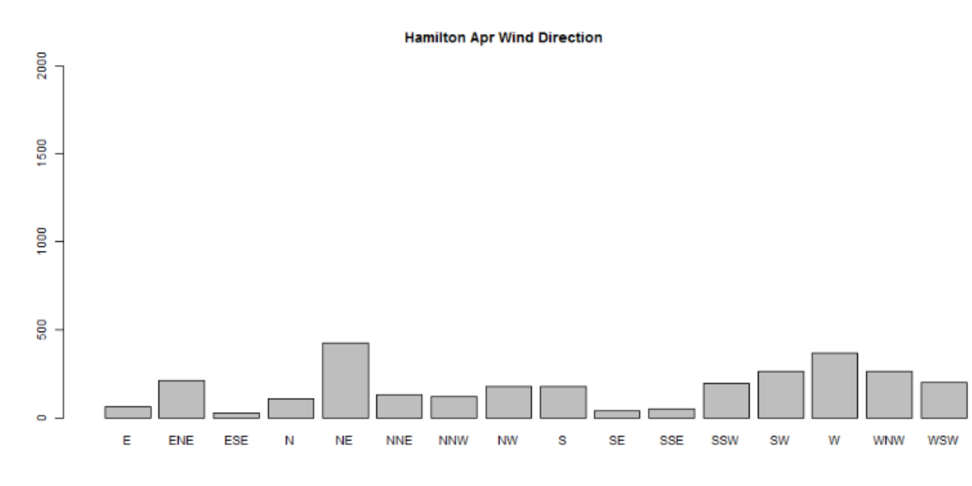
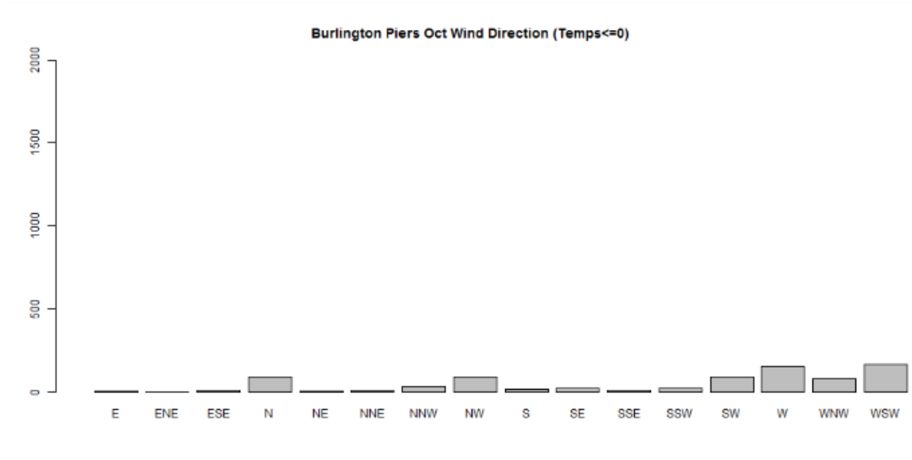


Figure 7. The prevailing winds from Hamilton Airport weather station for the months of October through April (2011-2015).

II. Prevailing Winds Under Freezing and Sub-Freezing Temperatures

The tender fruits in the area are mostly affected by sub-freezing temperatures. The dataset used in the section above were filtered for temperatures at or below freezing to show the prevailing winds during such conditions.

The monthly prevailing wind direction at or below freezing point is shown in Figure 8 below. Westerly to south-westerly winds are prevailing at Burlington Piers and Hamilton during such conditions. Meanwhile, winds from the west to west-south-west are prevailing in the Vineland area during late fall and through early spring under freezing and sub-freezing temperatures. The data shows that generally winds are less frequent in early spring (Mar-Apr) than winter (Dec-Jan-Feb) across the three stations.


Burlington Piers Oct Wind Direction (Temps<=0)
0
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1000
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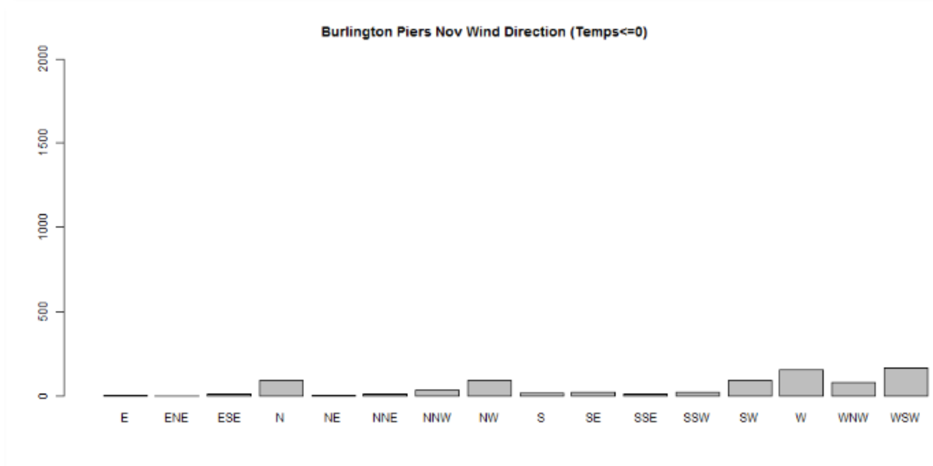
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Burlington Piers Nov Wind Direction (Temps<=0)
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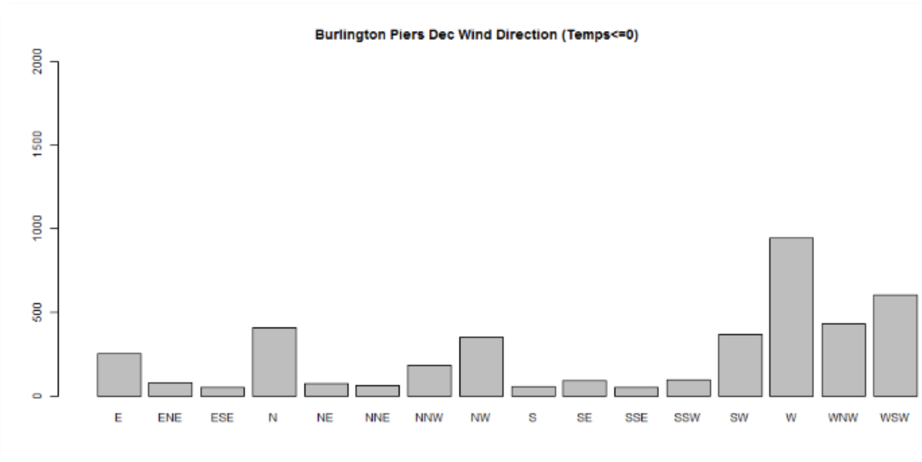
Burlington Piers Dec Wind Direction (Temps<=0)
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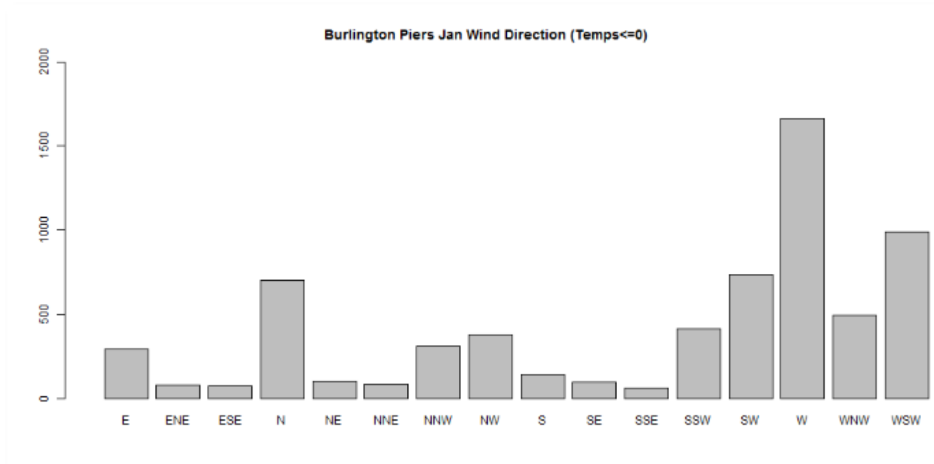
Burlington Piers Jan Wind Direction (Temps<=0)
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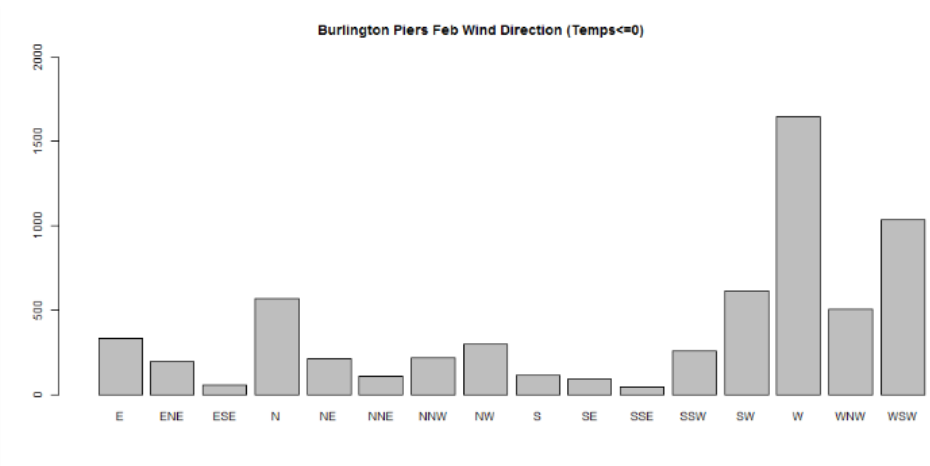
Burlington Piers Feb Wind Direction (Temps<=0)
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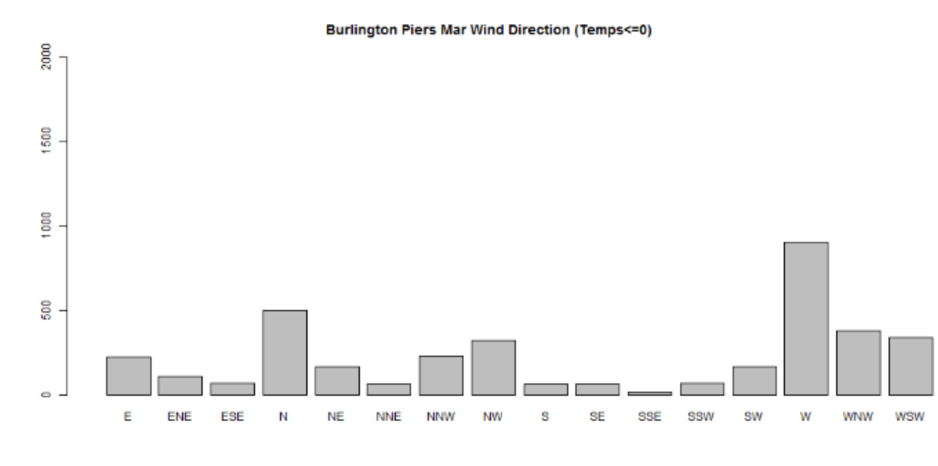
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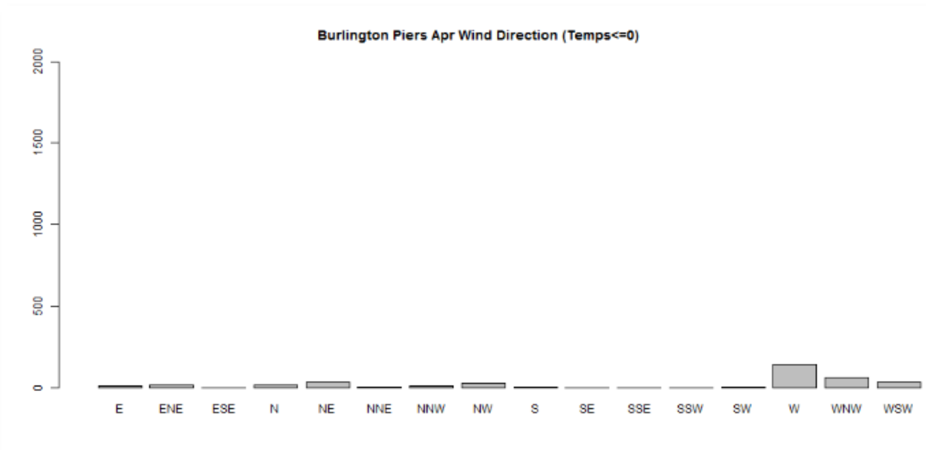
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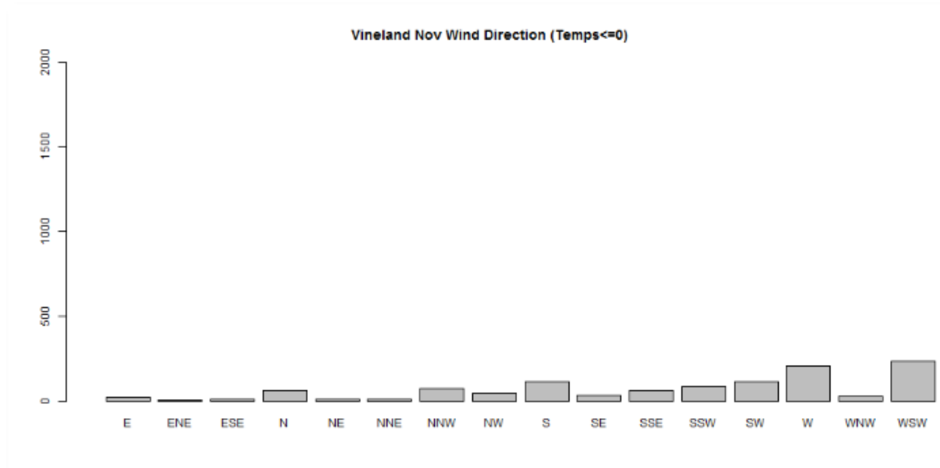
Vineland Nov Wind Direction (Temps<=0)
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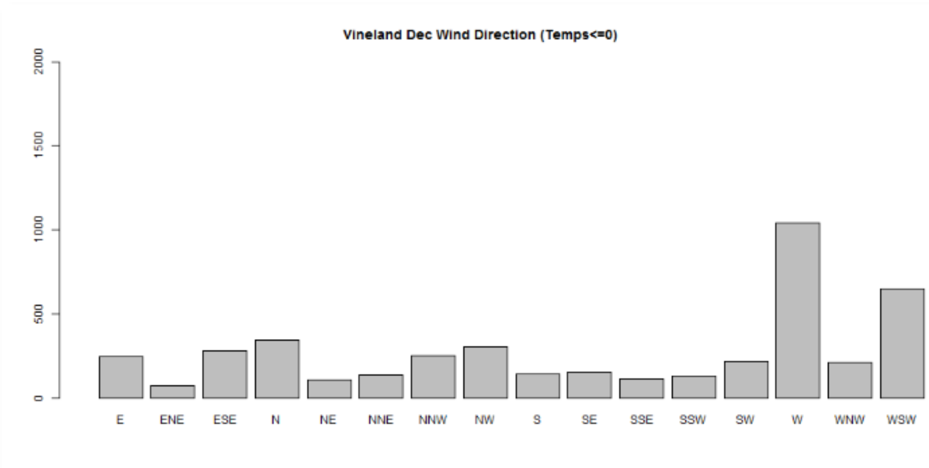
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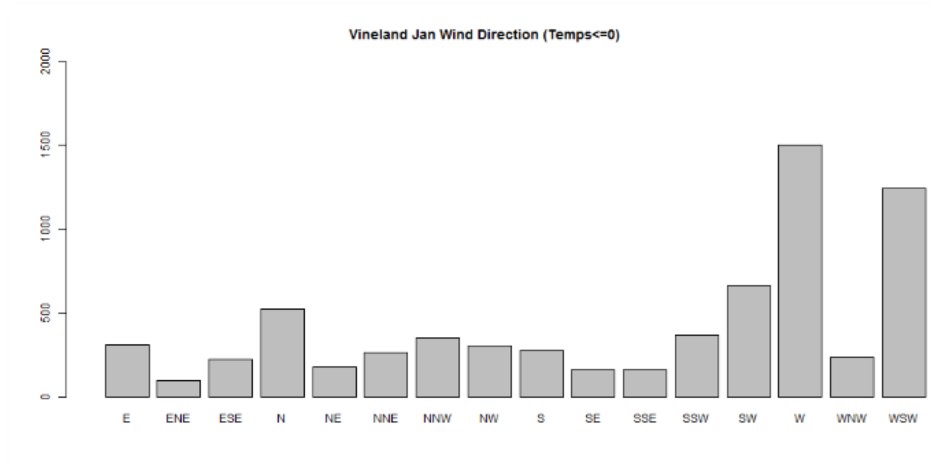
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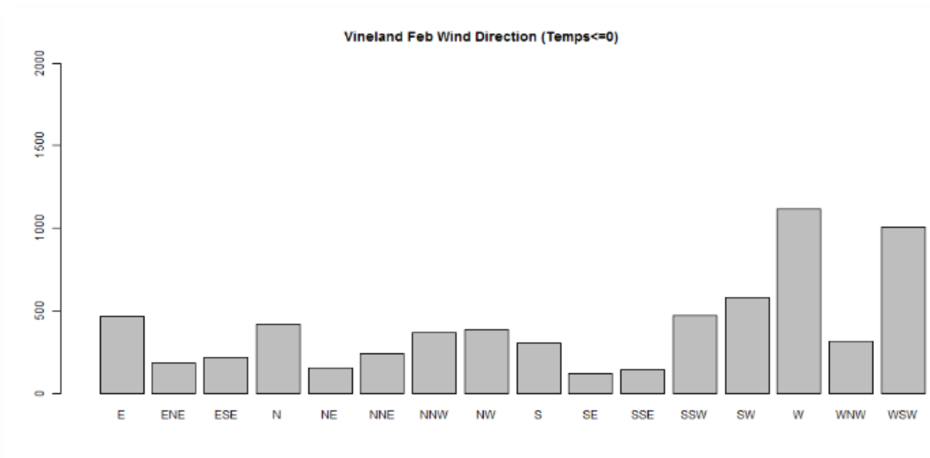
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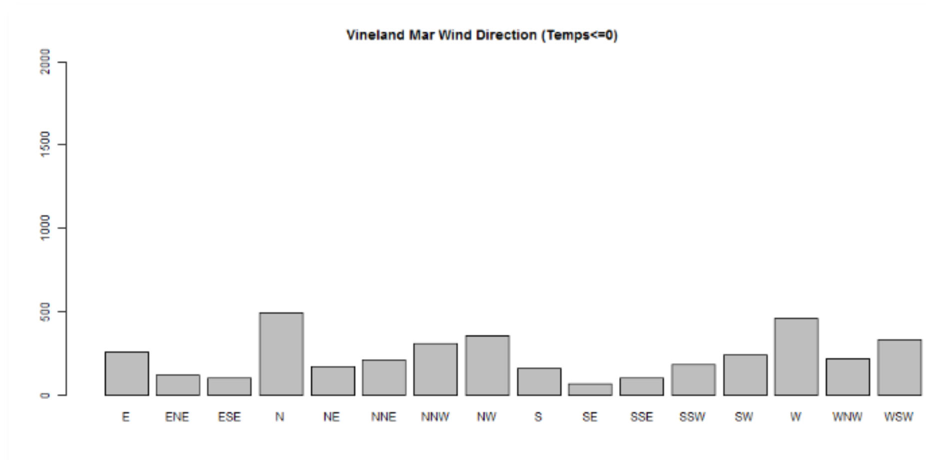
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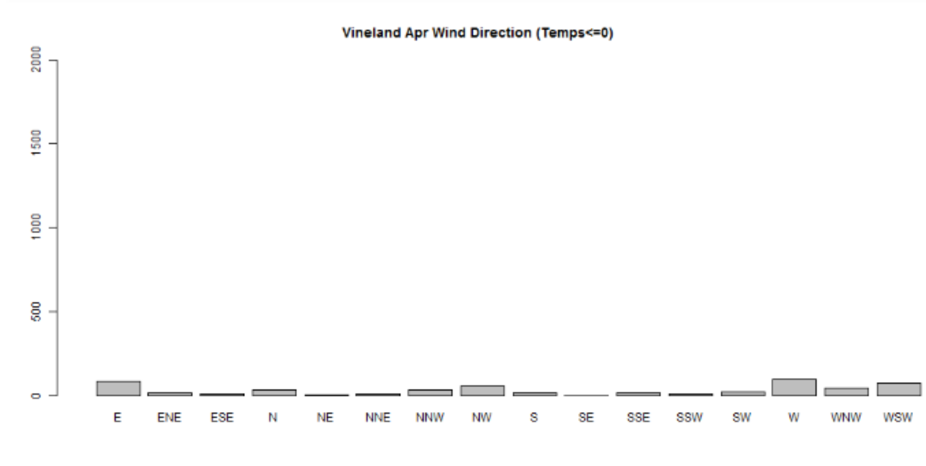
Vineland Apr Wind Direction (Temps<=0)
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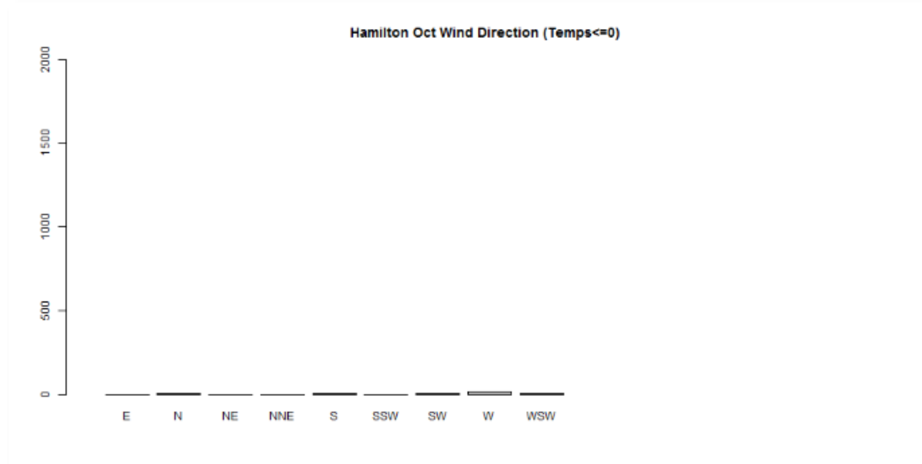
Hamilton Oct Wind Direction (Temps<=0)
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500
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S
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SW
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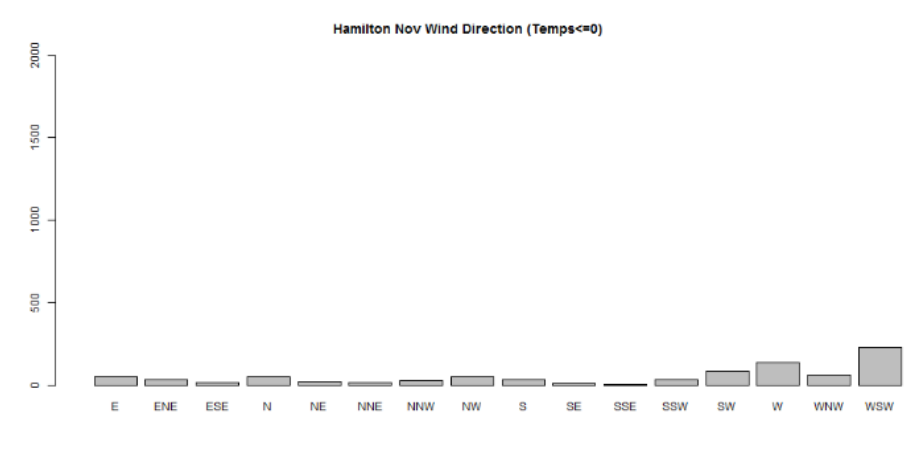
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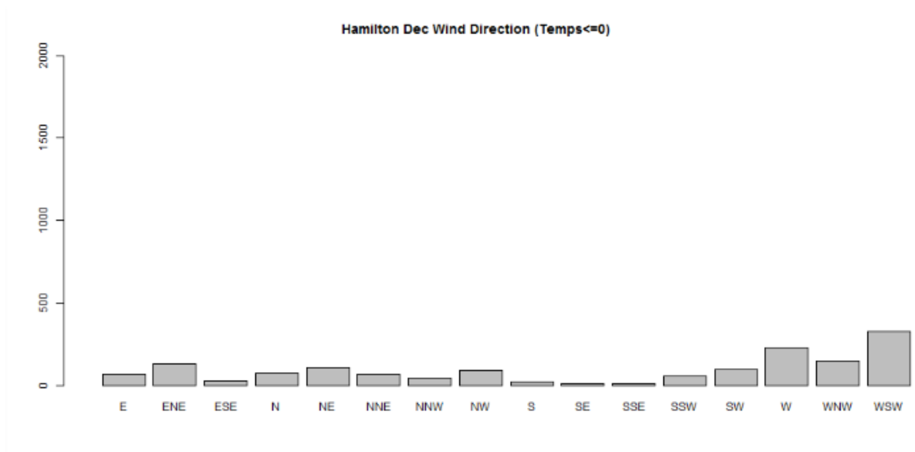
Hamilton Dec Wind Direction (Temps<=0)
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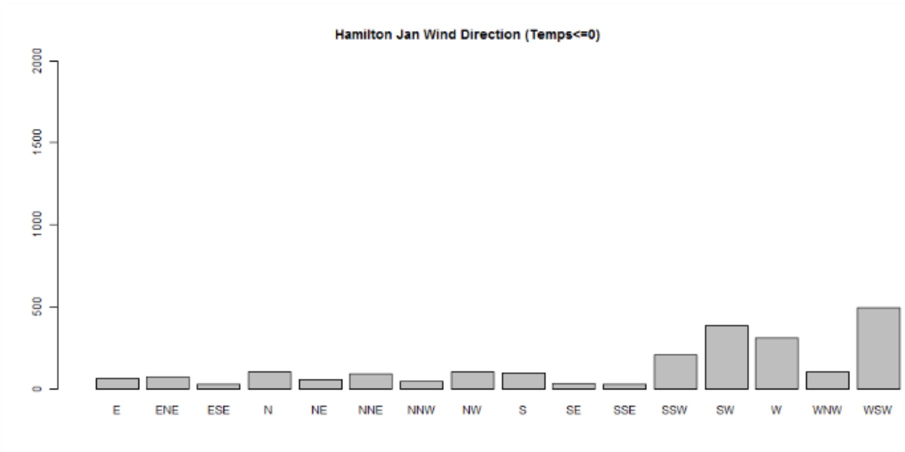
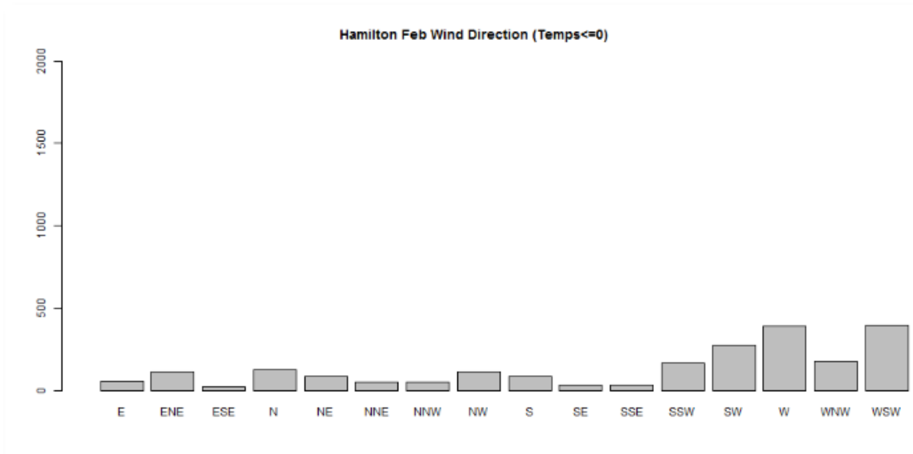
2000
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Hamilton Jan Wind Direction (Temps<=0)
0
500
1000
1500
2000
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW


Hamilton Feb Wind Direction (Temps<=0)
0
500
1000
1500
2000
E ENE ESE N NE NNE NNW NW S SE SSE SSW SW W WNW WSW

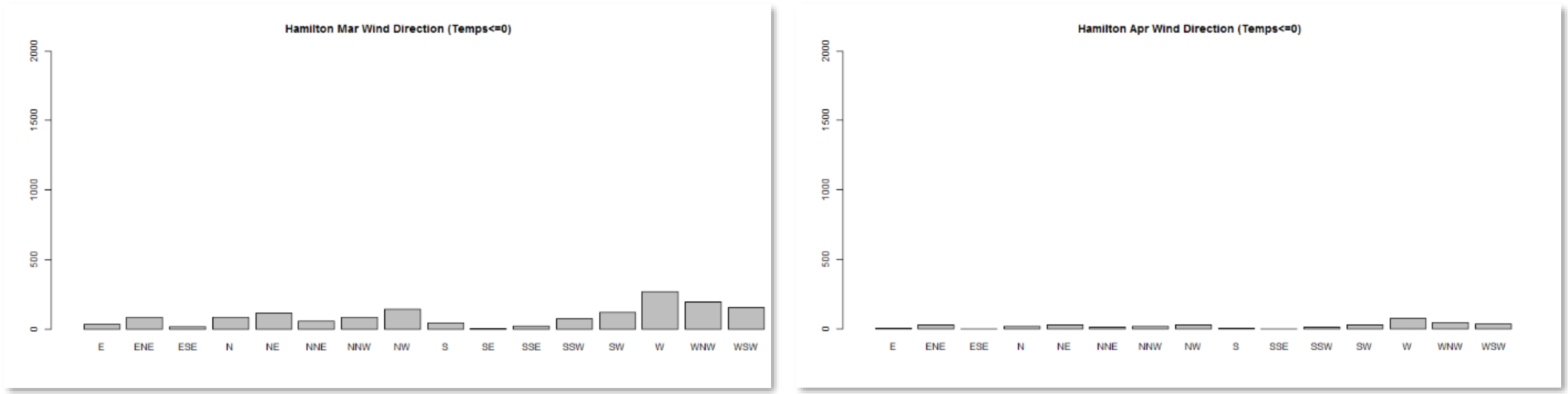


Figure 8. Late fall, winter, and mid-spring (Nov-Apr) prevailing winds from the Burlington Piers weather station, the Vineland weather station, and Hamilton Airport weather station at or below freezing temperatures.

III. *Probability of Frost Occurrence*

Frost is considered one of the main causes of significant losses to fruit crops. Cloud cover plays a major role in frost development along with other weather parameters. The Burlington Piers and Vineland weather stations are automatic reporting stations and lack any reports of cloud cover or weather condition reports (e.g. precipitation type, fog, freezing fog). To draw a generalized idea about the frequency of frost occurrence in the area, data from the three weather stations were filtered using ideal conditions for frost development (e.g. relative humidity ≥ 90%, air temperature ≤ 0°C), and calm wind conditions ≤ 4 km h^{-1}). It is worth noting that frost development requires soil temperature, but none of the weather stations reports this parameter. The database from the Hamilton Airport weather station contains hourly weather reports which will be discussed later.

Figures 9 through 11 show the time in hours versus the relative humidity at the Burlington Piers, Vineland, and Hamilton Airport weather stations. Although the results in the three figures below show that the area is prone to frost events, the Vineland region can be considered more susceptible to frost events due to its low elevation and geographical location in relation to the other sites (the median of the box and whisker plot of the Vineland area have higher frequency at or near the 90% relative humidity during evening and overnight hours). The figures also show that the frost potential extends longer in the Vineland region at the end of fall and early spring (i.e. November and March).

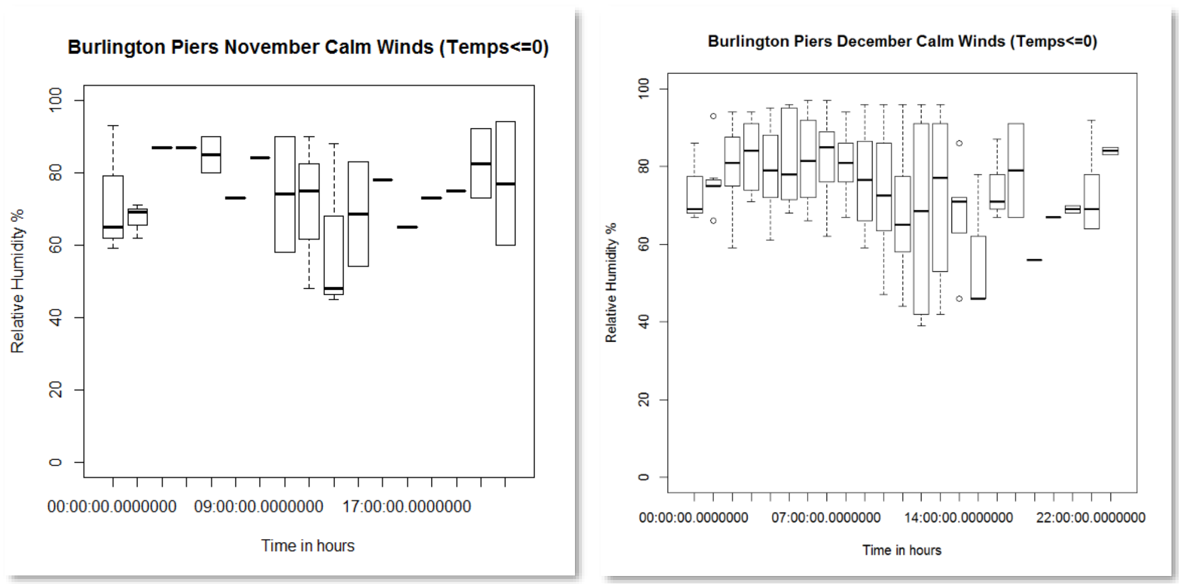


Figure 9 continues to the next page

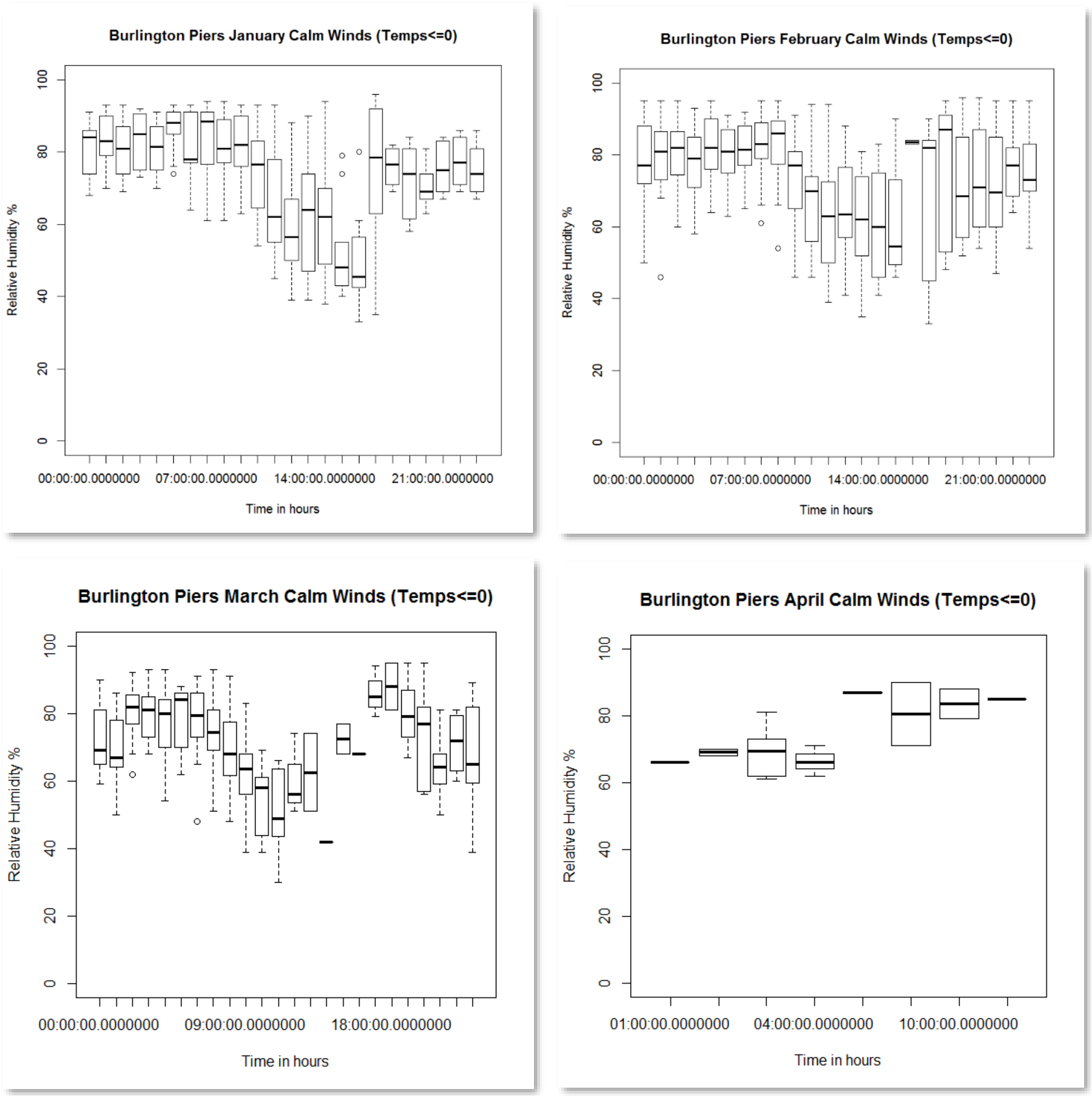


Figure 9. The temporal probability of frost occurrence for the Burlington Piers weather station (Nov-Apr) with calm winds and at or below freezing temperatures conditions.

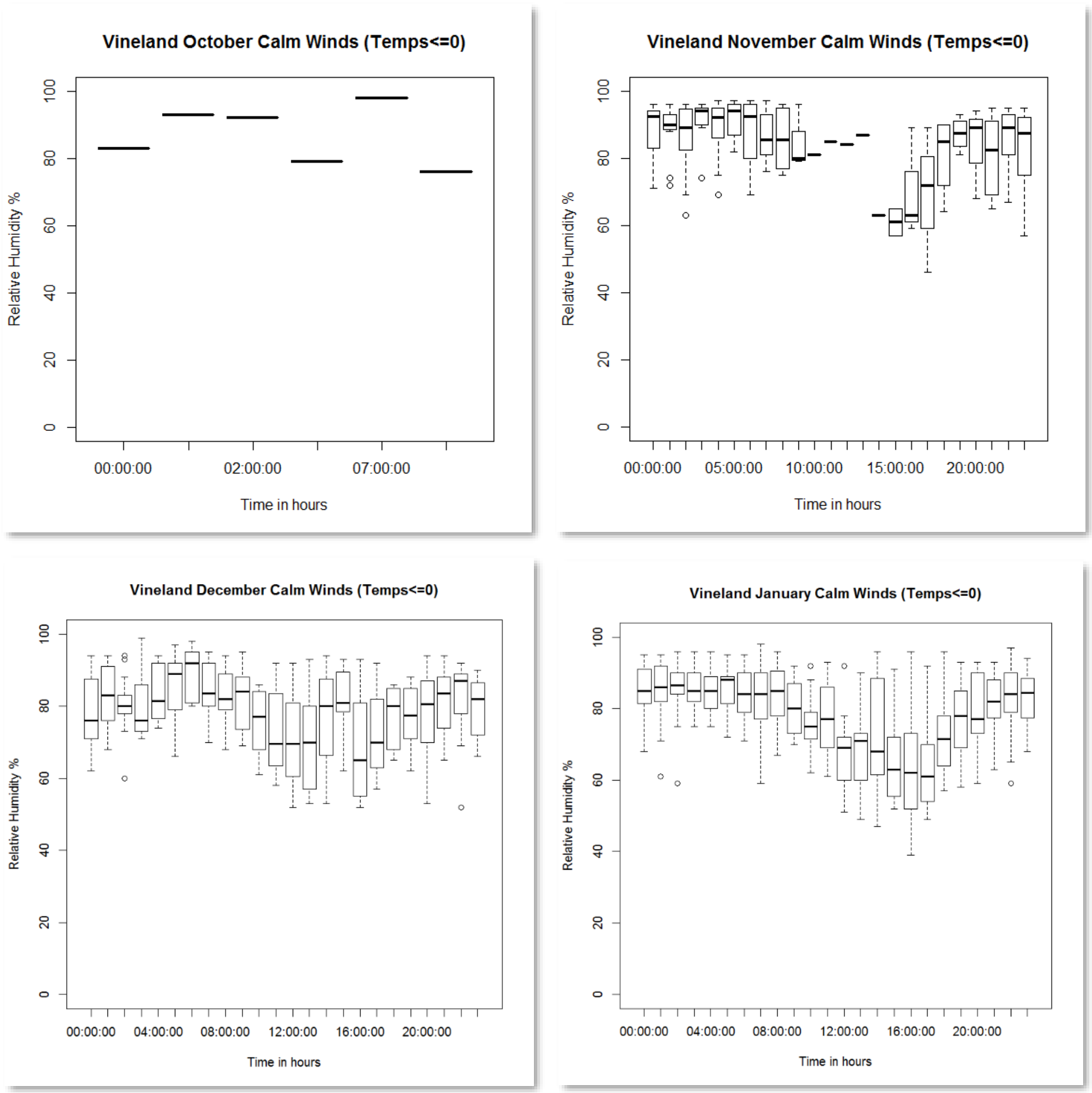


Figure 10 continues to the next page

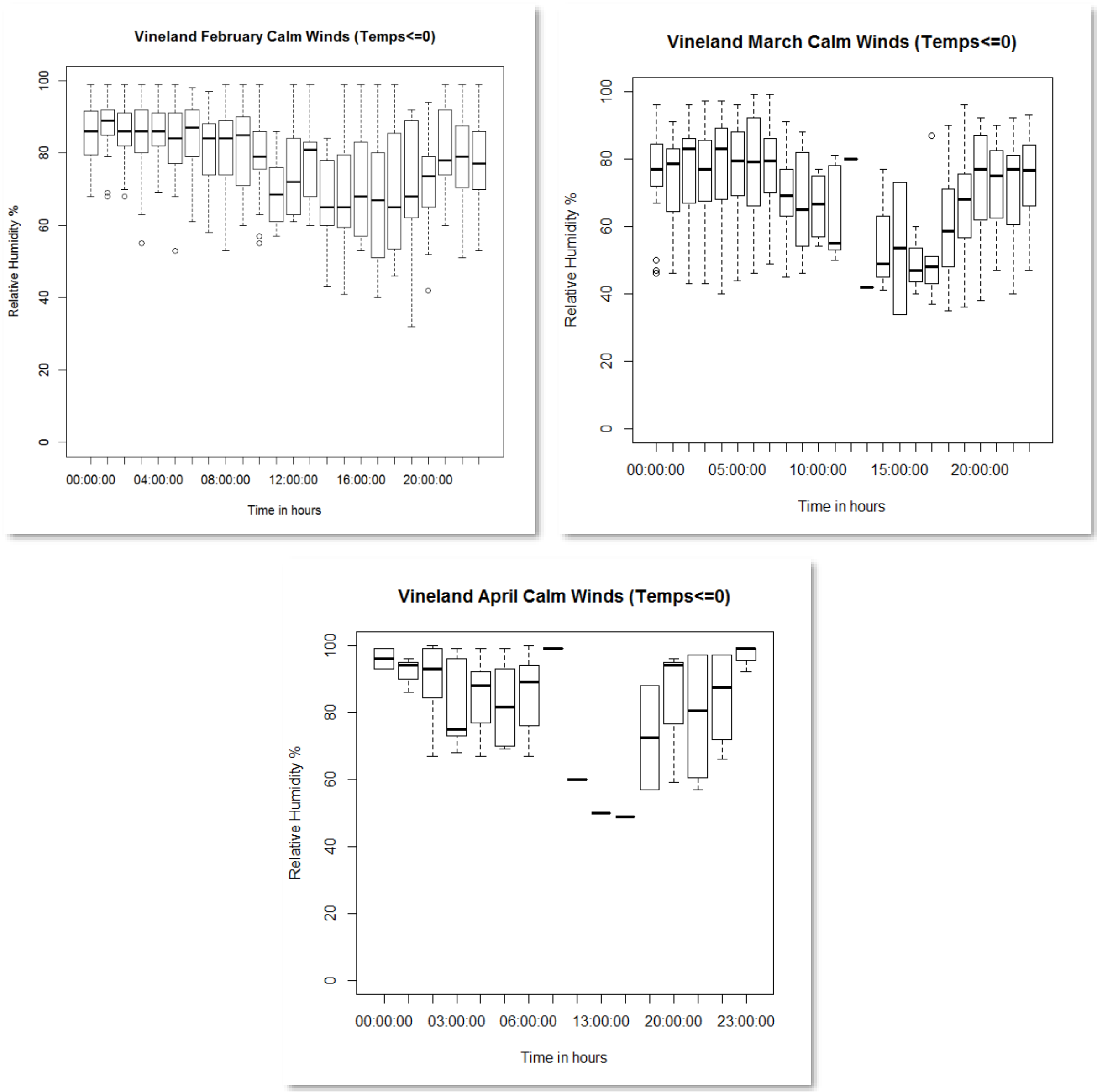


Figure 10. The temporal probability of frost occurrence for the Vineland region (Nov-Apr) with calm winds and at or below freezing temperatures conditions.

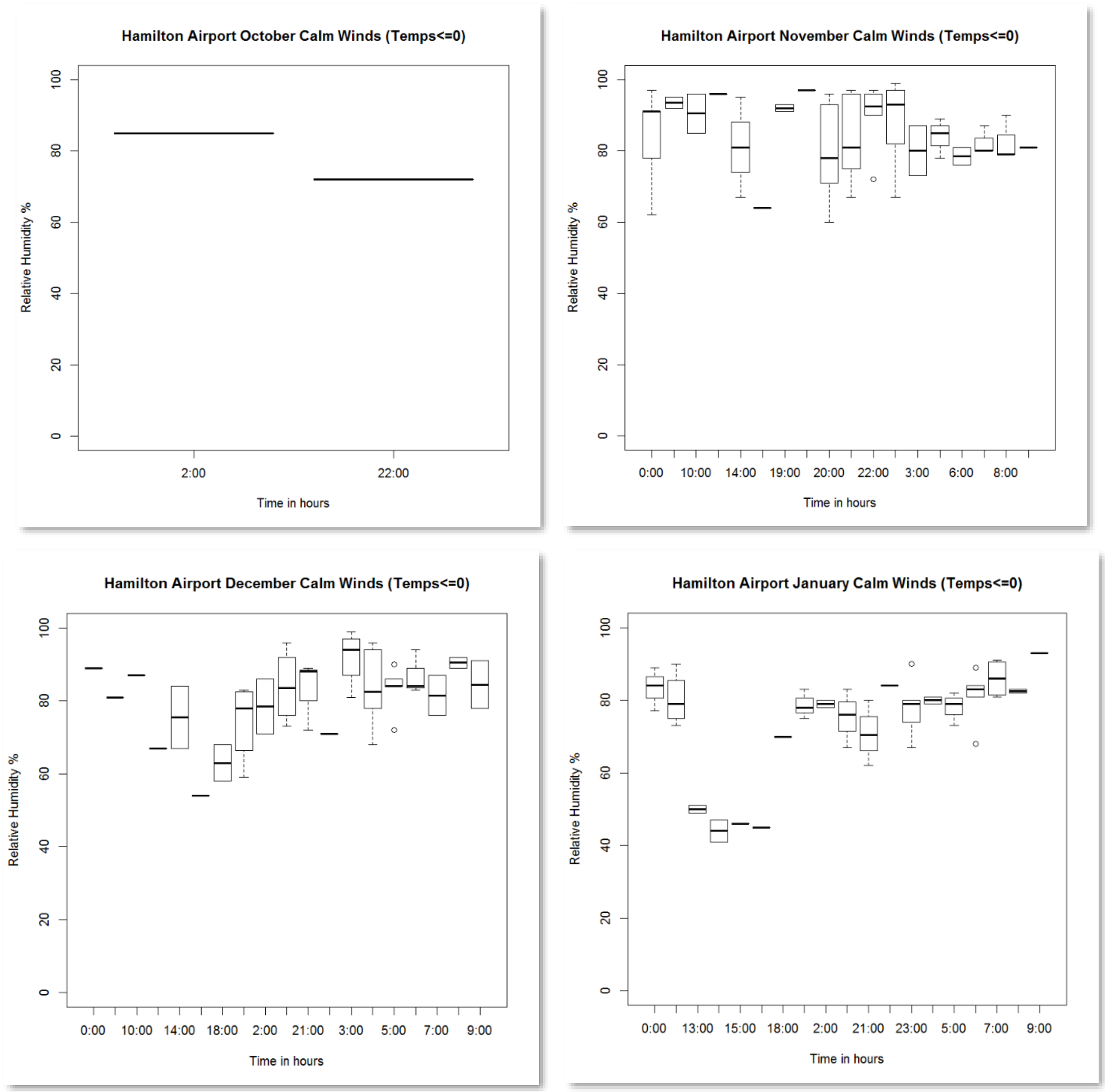


Figure 11 continues to the next page

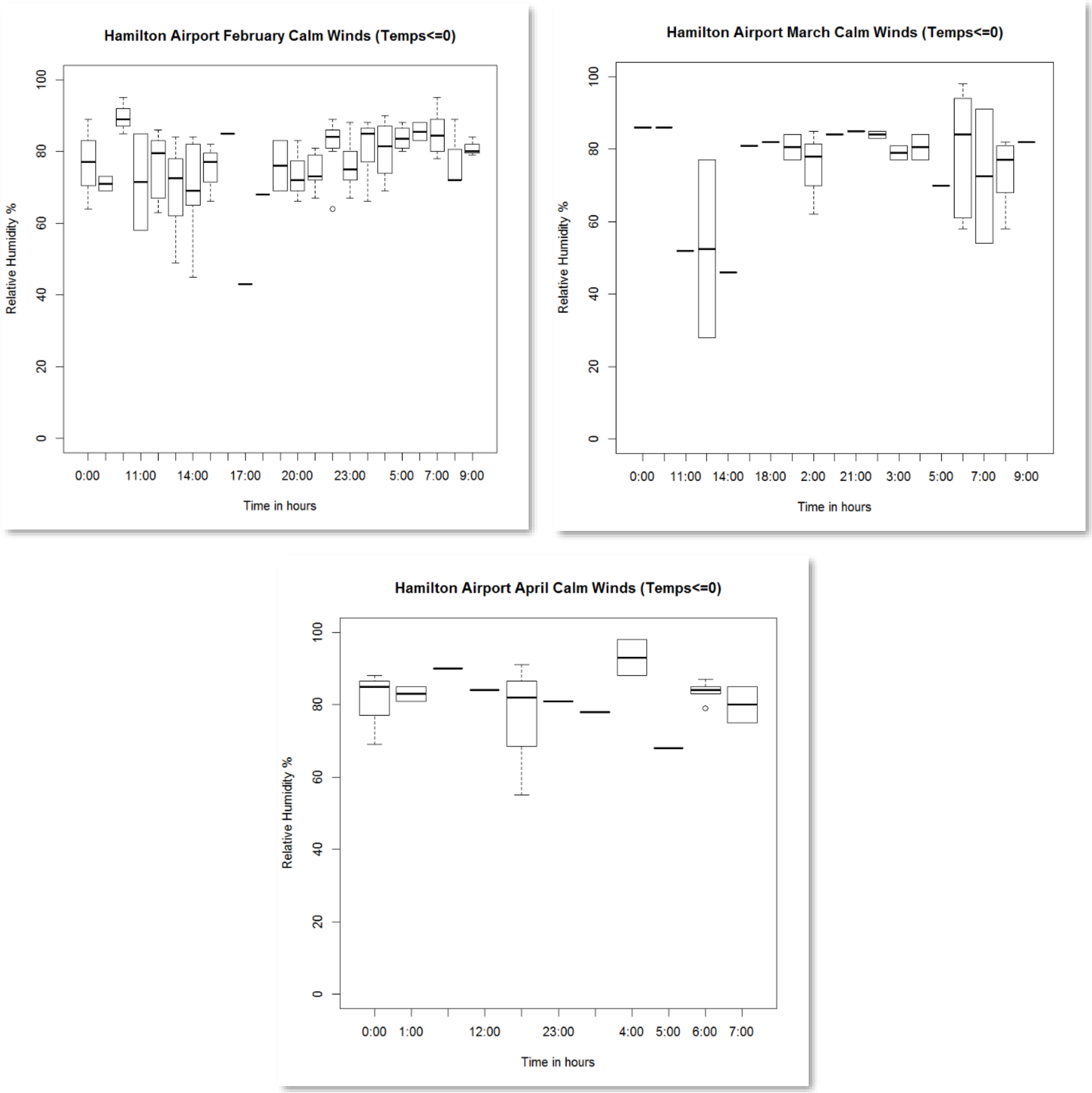


Figure 11. The temporal probability of frost occurrence for the Hamilton Airport weather station (Nov-Apr) with calm winds and at or below freezing temperatures conditions.

IV. Fog and Freezing Fog

As mentioned earlier, the Hamilton Airport weather station reports hourly weather conditions. Figure 12 shows the westerly and south-westerly winds are more common during fog incidences. In addition to the south-westerly to west-south-west wind component, the north-easterly winds are also common during freezing fog cases as seen in the figure to the left. Higher frequency of fog was reported during December and February, followed by November and January with lesser reports during March, April, and October, respectively, as seen in figure 13. Whereas, higher occurrences of freezing fog were recorded in February, with lesser reports during November, January, and December, respectively. The historical weather data also shows that the majority of the reported fog and freezing fog incidences were associated with movement of larger weather systems and distinct air masses as indicated by the higher wind speeds.

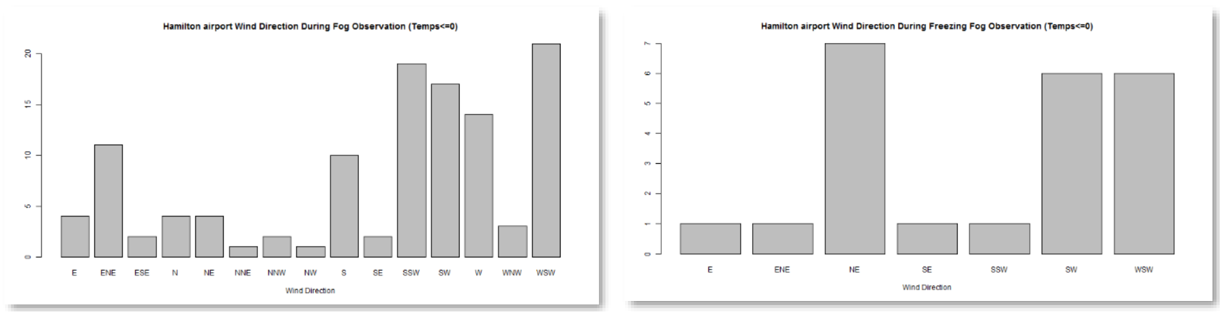


Figure 12. Wind directions during fog (right) and freezing fog (left) observations at the Hamilton Airport weather station (2011-2015).

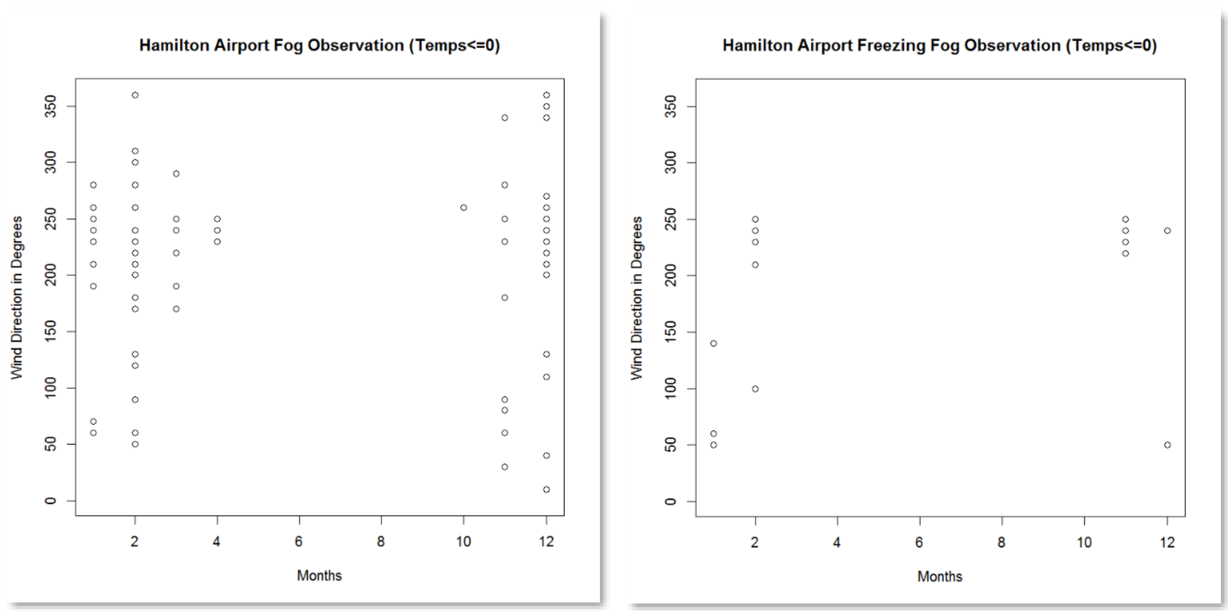


Figure 13. Fog (right) and freezing fog (left) observation during each month at the Hamilton Airport weather station (2011-2015).

6. Topography

The area under proposed development in the B1-Plan is approximately 1.05 km^2 as shown in the gray shaded region below in Figure 14. The area is located between the Niagara Escarpment to the south and Lake Ontario to the north. The area bounded by the Niagara Escarpment and the B1-Plan is much steeper than the area between the development and Lake Ontario. The ground at the top of the Niagara Escarpment is standing at ~200 m above mean sea level (MSL) and the ground elevation descends steeply northward towards the B1-Plan area. The ground elevations within the PLAN are ranging between 95 m (south facing) to 88 m (north facing) above MSL. There is a gradual decrease in the landscape elevation starting from the northern boundary of the B1-Plan toward the railway track (86 m above MSL) and ending at ~80 m above MSL at the shorelines of Lake Ontario.

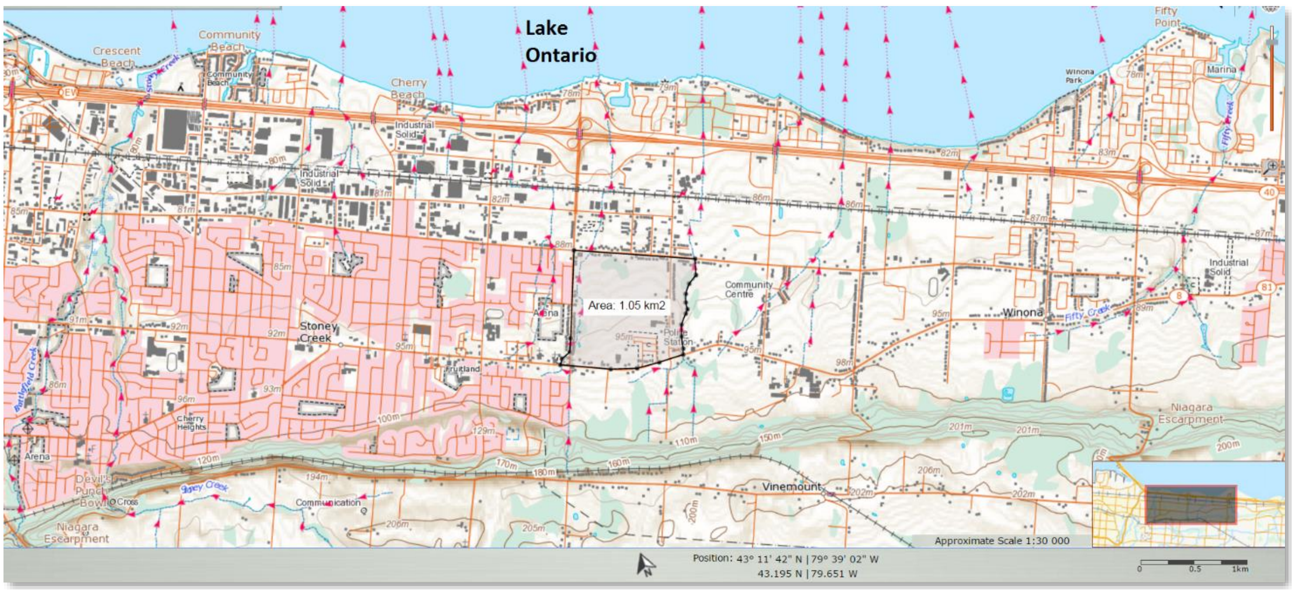


Figure 14. Topographical map of the area. ©Natural Resources Canada.

7. Summary and Conclusion

The Block 1-Frutiland-Winona Servicing Strategy Block Plan (B1-Plan) outlines the development of low to medium density dwelling units, Neighbourhood Park, SWM facilities, institutions, two main water courses to the west and east of the development, and natural open spaces. The developed area is expected to feature a new south-north Gordon Dean Avenue, approximately in the center of the development in addition to another new east-west aligned road, Collector Road B, connecting Fruitland Road to Jones Road.

The analysis of the weather data obtained from the three nearby weather stations (Vineland WS, Burlington Piers WS, and Hamilton Airport WS) suggests the following:

- Prevailing winds are from the west and southwest direction
- The Vineland area has the most moderate temperatures among the three stations
- Based on archived observations from the Hamilton Airport WS, the highest fog incidences happened during December and February, with February being the month with the highest number of reported freezing fog events.
- The westerly and south-westerly winds were the dominant direction during fog events whereas north-easterly, south-westerly, and west-southwest winds were the dominant directions during freezing fog events.

Based on the microclimate and topography in the area as evaluated in this desktop review:

- The proposed development as shown in Figure 3, is not expected to block the south-westerly to north-easterly direction air flow as it may assist in mixing the boundary air layer by creating eddies (turbulences), thus aid in streaming any cold air descending from the Niagara Escarpment, i.e. prevent air stagnation.
- The proposed development is not expected to significantly impede the natural air movement in the area due to the alignment of the current and proposed roads and watercourses.
- The Fruitland Rd, Gordon Dean Ave, and Jones Rd, in collaboration with Street B and Street C are considered the main channels to facilitate the air flow within the development.

8. References

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- Natural Resources Canada (http://atlas.gc.ca/toporama/en/)
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- Soler, M. R., C. Infante, P. Buenestado, and L. Mahrt, 2002. Observations of nocturnal drainage flow in a shallow gully, Boundary-Layer Meteorology V.105. pp. 253–273, doi:10.1023/A:1019910622806.