METRO VANCOUVER

CLIMATE CHANGE (2050) ADJUSTED IDF CURVES: METRO VANCOUVER CLIMATE STATIONS

FINAL

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May 6, 2009

Project No: 0431-006

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Dear Mr. Burton,

Re: **Climate Change (2050) Adjusted IDF Curves: Metro Vancouver Climate Stations**

Please find attached a copy of our above referenced Final report dated May 6, 2009.

Should you have any questions or comments, please do not hesitate to contact me at the number listed above.

Yours sincerely,

BGC ENGINEERING INC.
per:

Matthias Jakob, Ph.D., P.Geo.
Senior Geoscientist

EXECUTIVE SUMMARY

This study provides adjusted Intensity Duration Frequency curves for ten Metro Vancouver climate stations that consider changes in winter precipitation intensity for the 2050 time horizon (2040's-2070's) due to predicted effects of global warming. These adjusted curves form a useful step towards estimating changes in design runoff events used in a variety of applications, including the planning and design of water and wastewater management infrastructure.

Predicted changes in future rainfall amount were based on two model runs of the Canadian Regional Climate Model (CRCM), using the A2 emission scenario for the 2050 horizon. The A2 scenario, which uses very conservative (high) emission assumptions, suggests that monthly fall and winter precipitation in the Metro Vancouver area will increase in magnitude by 10% to 21% by approximately the 2050's. Herein, the more conservative 21% value was used for analysis and presentation of results.

Predicted changes in future rainfall intensity were obtained by identifying a statistical relationship between rainfall amount and intensity for existing data, and then using this relation to estimate future rainfall intensity based on a 21% increase in rainfall amount. The estimated fractional changes in rainfall intensity were used to adjust IDF values. Results suggest that the frequency of extreme rainfall intensity events will significantly increase, with forecasted 50 year rainfall intensities approximately equal to or greater than the current 100 year rainfall intensity at most stations.

This study is exploratory in nature as it is limited to a single time horizon, one emission scenario, and two model runs of the CRCM that are based on the same Global Circulation Model (GCM). Of the over fifty Metro Vancouver rain gauges in Metro Vancouver, ten gauges were selected for analysis that are active stations with the most complete data record. In a subsequent study, it may be possible to add additional stations if they also show a statistically significant historical relationship between rainfall amount and intensity and if existing analogue precipitation data be transcribed into digital format. Further work is required to address these limitations, quantify uncertainties and to establish regional IDF curves for various zones within the Metro Vancouver area.

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LIMITATIONS OF REPORT

BGC Engineering Inc. (BGC) prepared this report for the account of Metro Vancouver. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a third party makes of this report, or any reliance on decisions to be based on it are the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Results presented herein are based on the October to March period. According to information provided by Metro Vancouver, the fall and winter period is normally associated with the highest rainfall intensities and runoff volumes, and thus places the most strain on the stormwater drainage system. Potential increases in rainfall intensities (due to climate change) outside of this period are not considered in this report. Intense storms during the summer months are typically associated with convective cells (heat transfer by massive upwardly directed motion within the atmosphere) that are not currently captured by global or regional climate change models and are not considered in this report.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts from or regarding our reports and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC's written approval. Notwithstanding, BGC understands that Metro Vancouver will post final reports on their website which is accessible to the public. BGC also understands that final reports are shared with the municipalities that make up Metro Vancouver.

If this report is issued in an electronic format, an original paper copy is on file at BGC Engineering Inc. and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from our documents published by others.

1.0 INTRODUCTION

1.1 Overview

Intensity-duration frequency (IDF) curves are graphical representations of the probability that a given average rainfall intensity will occur at various event return periods. They are routinely used in water management and form the basis for urban storm water drainage calculations and sizing of culverts, drain pipes and other municipal waste-water infrastructure. Much of this infrastructure is designed to function for a half a century or more.

IDF curves are based on historic precipitation at a particular climate station and depend on the statistical principle of data stationarity: that the mean and variance of data will not change significantly over time and that past precipitation patterns can be used to predict future events. However, this assumption of data stationarity is no longer considered valid because climate and associated precipitation patterns are currently changing on a human time scale (IPPC 2007).

Changes in the globe's water system may disrupt the equilibrium of the hydrologic cycle and lead to increased frequency and magnitude of extreme events such as heavy rainfall, floods, and droughts. Metropolitan areas are particularly vulnerable as they can experience significant economic losses during extreme climatic events due to high development densities.

Future increases in rainfall intensities associated with climate change could eventually lead to underdesign of urban sewer systems, causing urban flooding and sewage spills to receiving waterbodies during extreme hydroclimatic events. Under this scenario, updated IDF curves become necessary to ensure correct sizing of the stormwater and sewerage systems during scheduled replacements.

A study was completed in 2008 for Metro Vancouver in a jointly-funded effort with Engineers Canada and Natural Resources Canada to examine the consequences of climate change on municipal infrastructure (KWL and Associated Engineering, 2008). The authors of this study were severely hampered by the lack of short duration rainfall predictions stating: "the lack of data contributed to the limited ability of the study team to make quantitative estimates of the effect of climate on infrastructure". Uncertainty was addressed by application of professional judgement in accordance with a protocol developed by Engineers Canada.

Despite the inability of the 2008 study to provide a quantitative assessment of the impacts of climate change on short duration rain events, potential climate change remains a topic of concern for Metro Vancouver with respect to wastewater infrastructure. Therefore, BGC Engineering Inc. (BGC) has been retained by Metro Vancouver to make quantitative estimates of climate change on rainfall intensities. Details and results of this assessment are provided herein.

1.2 Background on Rainfall Intensity Studies for Metro Vancouver

Metro Vancouver retained KWL in 2002 to conduct a comprehensive study of all Metro Vancouver and Meteorological Survey of Canada (MSC) rain gauges (14 in total) that measure short duration rainfall in the Metro Vancouver area. That study, published as a peer reviewed paper by Jakob et al. (2003) and a follow-up study by the Pacific Climate Impacts Consortium (2007), did not identify persistent long-term trends in rainfall intensities. The studies noted that observed discontinuous trends may be a legacy of phase shifts in the Pacific Decadal Oscillation (PDO) cycle.

The above study was unable to confidently predict changes in precipitation intensities for the future because of biased data, data records of insufficient lengths, and poor and fragmented trends that appear to be influenced by cyclic temperature fluctuations at decadal scales. Without climate modelling that can confidently be downscaled to yield reliable rainfall intensity forecasts, climate change impacts on municipal infrastructure are fraught with considerable uncertainty.

A recent study (Jakob and Lambert, 2008) investigated potential changes in landslide activity under various climate change scenarios. A product of the study was that monthly rainfall amounts can be correlated with rainfall intensities over a variety of durations. Longer durations (i.e. greater than 6 hours) generally yielded better correlation coefficients than shorter durations. This conclusion is very important because the finest temporal resolution that climate change models currently forecast changes in precipitation for Canada is on a monthly basis. The correlation between monthly rainfall and rainfall intensities over various durations used by Jakob and Lambert (2008) would then allow prediction of rainfall intensities for durations of less than 1 month, which is pursued in this report.

Climate change models are also becoming increasingly complex, with increased spatial and temporal resolution. The development of the Canadian Regional Climate Model (CRCM) allows a closer grid forecast (45 km grid length) for British Columbia for different time horizons and for individual months or seasons.

1.3 Other Studies

This section provides a brief overview of studies for a variety of locations that have investigated changes in IDF curves. Notably Ontario and Quebec appear to have spent significant effort in the development of upgraded IDF curves. This section is not meant to be an exhaustive literature search, but rather highlights the increasing awareness and research into a subject with significant financial implications.

Hanush (2008) demonstrated that a *decreasing* trend in rainfall in Australia affected IDF curves, particularly for shorter durations. He showed that rainfall intensities with a rainfall return period of 50 years may change to a 100-year return period in a matter of decades. Hanush pointed out that these changes are important for flood risk estimation and associated engineering design for flood risk mitigation works. This work is interesting because – unlike the present study – it provides an example how in some areas of the globe rainfall amounts and intensities can decrease leading to *lower* flood risk.

A study by Prodanovic and Simonovic (2007) titled “Development of rainfall intensity duration frequency curves for the City of London under the changing climate” generated IDF curves for three scenarios: simulated historic climate (no climate change), wet climates, and dry climates. The authors used non-parametric weather generators to produce short duration rainfall predictions. The weather generator combines historic information with GCM (Global Circulation Model) output and produces climate information through sophisticated perturbation algorithms. Similar to Monte Carlo analysis, the weather generator produces climate data beyond the historical record including extremes not previously encountered. The authors used the Canadian GCM model outputs CSIROM2kb and CCSRNIES and the B1 and B2 emission scenarios. The B1 scenario describes rapid global change towards service and information-based economies, while the B2 scenario emphasizes local solutions of economic, social and environmental well being and anticipates technological adaptation towards an environmentally friendly goal. Interestingly, the authors emphasize that wet and dry scenarios are equally likely, which is not the case for the wet season in south coastal British Columbia (see Section 3).

Prodanovic and Simonovic (2007) note that rainfall magnitude and intensity will be different than historically observed. The climate change scenario recommended for use in the evaluation of storm water management design standards (i.e., the wet scenario) revealed a significant increase in rainfall intensity for a range of durations and return periods. The authors state that this increase will significantly impact the design, operation and maintenance of municipal water management infrastructure. For example, they found that sizes for small storm drains and sewer overflows will increase by 8 to 15%, and major systems will require increases in sizes of 14 to 17% and the design of flood control facilities such as ponds and detention basins may increase by 10 to 23% in volume.

Nguyen et al. (2006) developed a spatial-temporal approach for the construction of IDF curves using climate change scenarios simulated by GCMs applied to different regions of Québec. They used a two-step procedure that combines statistical downscaling with temporal downscaling using generalized extreme value distributions of annual maximum precipitation derived from the British HadCM3A2 model. The approach was applied for time horizons of 2020, 2050 and 2080. As an example, results for the City of Dorval showed no changes for 2020 and decreases in annual maximum precipitation for 2050 and 2080. Signs of change were found to be different for varying durations and return periods. At McGill, for example, the annual maximum 5-minute and 24-hour precipitations for 2020 increase for short return periods, but decrease for long return periods. Annual maximum 5-minute precipitation for the 2050s was found to be greater than the current period, while those for 2080 were less than the current period. In short, this study provided inconclusive results.

Mailhot et al. (2007) used the Canadian Regional Climate Model (CRCM) to model climate in southern Québec for the 2041 to 2070 time horizon. Comparison of current regional estimates with the GCM model output revealed that return periods of 2-hour and 6-hour precipitation events will approximately halve in the future and decrease by a third for the 12-hour and 24-hour events. Based on their analysis, Mailhot et al. proposed regional IDF curves at the grid and station scales. Their work also suggested that future annual extreme rainfall events may result increasingly from convective weather systems rather than larger frontal systems.

An ongoing study by Ness et al. (2008) is seeking to develop regional IDF curves after the 2005 Toronto flood where 183 mm of rain fell in the course of a day and resulted in $500 million of insured losses. This work is based on a pilot study where clusters of rain gauges have been placed in Southern Ontario and aims to develop new IDF curves for durations up to 24 hours.

2.0 SCOPE OF WORK

The overall objective of this study is to generate IDF curves and tables that have been adjusted for predicted effects of climate change. Metro Vancouver requested that the estimated IDF curves be adjusted for approximately the year 2050 (corresponding to the period 2040's - 2070's), and that the climate change assumptions should be consistent with those used in a recent report on the vulnerability of Metro Vancouver's stormwater system to climate change (KWL and Associated Engineering, 2008). That report used the A2 emission scenario and the CRCM 4.2 ADJ and 4.2 ADL model scenarios, which contain some of the highest values in temperature and other changes in the family of emission scenarios (see Section 3.1.2).

The scope of the proposed work according to BGC's November 5, 2007 proposal is summarized in Table 2-1.

Table 2-1. Overview of Proposed Work Tasks

Task No.	Work Component	Individual Work Task Descriptions
1	Review and Data Compilation	• Review and compile climate station data • review and compile IDF curve data
2	Rainfall Intensity Relationships	• Construct rainfall intensity – monthly rainfall regression curves for various durations and for each station • Analysis of projected changes in monthly precipitation for 2050, based on the IPCC 2007 "A2" emission scenario using the Canadian Regional Climate Model (CRCM) • Analysis of projected changes in rainfall intensity
3	Climate Change Adjusted IDF Curves	• Adjustment of IDF curves to reflect projected changes in rainfall intensity and duration to approximately the year 2050
4	Deliverables and Reporting	• Climate change adjusted IDF curves and supplementary tables for each climate station as hard copy and digital files • Reporting of methodology and results

The proposal did not specify the exact number of stations to be analysed as this depended on data availability and budget. After receipt of IDF and climate data from Metro Vancouver, the following ten stations were chosen for analysis: Bu07, CW09, DN25, QT10, VA01, VA04, VA13, VA28, VA30, and VW14 (Drawing 1). These stations have the relatively longest and most continuous record of all the climate stations in Metro Vancouver. Evaluation of the potential and need to analyze additional station data would form part of the development of regional IDF curves for the Metro Vancouver area, as recommended in Section 5.0.

3.0 METHODS

The basic assumption of this study is that monthly precipitation can be correlated with rainfall intensities over a variety of durations. Accordingly, because GCMs can provide data on the change in precipitation in future climates on a monthly time-step, it should be possible to predict changes in precipitation intensities. The methods used in this study are tailored towards this goal and can be summarized as follows:

1. Obtain precipitation data from the Canadian Regional Climate model for the fall and winter months for the 2050 time frame (runs CRCM 4.2 ADJ and 4.2 ADL)
2. Use existing precipitation data for Metro Vancouver stations to regress monthly precipitation against precipitation intensities for variable durations.
3. Use the regression equations to determine changes in precipitation intensity durations from one hour to 24 hours for the stations selected.

3.1 Data Sources

3.1.1 Precipitation Data

Metro Vancouver provided BGC with IDF curves and monthly climate summary reports in Excel and pdf format (hard copy scans) for 57 climate stations in Metro Vancouver. All data contained monthly total rainfalls and maximum monthly precipitation intensities for durations up to 24 hours[1]. The Excel data was formatted and integrated with data already on file at BGC; pdf scans were not used[2]. Of this data, BGC selected the 10 active stations with the longest and most continuous winter data record as the highest priority stations for analysis. Table 3-1 provides an overview summary of data recorded and available at these stations. Table 3-2 provides further breakdown of the number of months of data available for the October-March period used in analysis.

IDF data provided by Metro Vancouver included graphs for short durations (5 minutes to 24 hours) and long durations (1 hour to 72 hours). BGC only used storms with durations of 1 hour to 24 hours to adjust the IDF curves because durations less than 1 hour resulted in regression equations with low explained variance.

[1] Some but not all climate monthly summaries also provided 48 and 72 hour maximums.
[2] Manual transcription of data on hard copy scans would significantly improve the data record for some stations, but was outside the scope of work for this study.

Table 3-1. Stations Used in Analysis

Station		Sewerage Area	Period of Record		Recorded Duration (excluding missed months)		Recorded Data Available to BGC
			From	To	# Years	# Months	# Months
VA	1	Vancouver	1957	present	48	576	525
VA	4	Vancouver	1959	present	49	588	520
BU	7	Fraser	1959	present	48	576	133
QT	10	Fraser	1959	present	49	588	528
CW	9	Fraser	1959	present	46	552	273
VW	14	North Shore	1959	present	46	552	522
DN	25	North Shore	1964	present	44	528	486
VA	13	Vancouver	1959	present	42	539	539
VA	28	Vancouver	1988	present	19	228	204
VA	30	Vancouver	1988	present	19	228	214

Table 3-2. Number of Months of Data Available for the October-March Period used in Analysis

Station	Precipitation Duration (# Months)				
	1 hr	2 hr	6 hr	12 hr	24 hr
VA30	111	111	111	111	111
BU7	71	71	71	71	71
CW09	142	142	142	142	142
DN25	254	254	254	254	254
QT10	269	269	269	269	269
VA01	212	212	212	212	212
VA13	268	268	234	234	234
VA28	102	102	102	102	102
VW14	262	262	93	93	94
VA4	259	259	178	178	178

3.1.2 Climate Model Data

Global circulation models (GCMs) provide users with continuously improving tools to model various facets of climate change. GCMs combine fluid mechanics, atmospheric physics and chemistry with related sciences to discretize earth-ocean-atmosphere interaction in three-dimensional cells at various scales. It is well known that small spatial scale processes influence larger scale processes (recall the famous folk analogy of a butterfly's wing movement in Asia influencing weather in North America). Many of these process interactions have been observed but have not been adequately quantified mathematically. This obstacle has been addressed by temporal and spatial downscaling from GCMs but this practice is associated with large uncertainty and thus error (Prodanovic and Simonovic, 2007).

GCMs only provide monthly climate outputs and their spatial resolution is typically 100 x 100 km (10,000 km^2), which is typically well in excess of the spatial scales of a city. Metro Vancouver could be approximated as a 10 km x 20 km (200 km^2) grid, or two orders of magnitude smaller than what is offered by GMCs. Furthermore, Vancouver is characterized by extreme differences in annual precipitation amounts ranging from less than 1000 mm in southern Richmond to over 3000 mm on Cypress Mountain. These topographic differences cannot be accounted for in GCMs.

In a previous study (KWL and Associated Engineering, 2008), Ouranos[3] was retained to update climate modelling data for the Metro Vancouver area. In their report, appended to the KWL and Associated Engineering report, Ouranos used the Canadian Regional Climate Model (CRCM). This model produces time series of physically coherent climate variables including precipitation, and focuses on a narrower area than GMCs (45 km x 45 km grids). As noted by Ouranos (2008), precipitation events are better simulated by RCMs than GCMs. Further information and details on the model runs used and the accuracy associated can be found in Ouranos (2008).

Ouranos used two model runs (CRCM 4.2 ADJ and 4.2 ADL). The difference between those two models is the grid size of the simulation. The ADJ simulation uses the CGCM3.1 model with a resolution of 3.75 degrees to calculate boundary conditions, while the ADL simulation uses a 2.8 degrees resolution.

Ouranos used only one emission scenario in their analysis (A2). The A2 scenario is an extreme simulation resulting in some of the highest values in temperature and other changes in the family of emission scenarios. It is defined as “a scenario family describing a very heterogeneous world. The underlying theme is self-reliance and preservation of local identifies. [Human] fertility pattern across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines” (Nakicenovic et al. 2000). To paraphrase, the A2 emission scenario is one in which individual country leaders cannot agree on concerted efforts to vigorously reduce greenhouse gas emissions keeping their own country’s interests above those of the globe. Correspondingly, greenhouse gas emissions continue at a level in which temperatures will continue to increase rapidly. If the past 10 years are an indication of the future, the A2 scenario may be, despite its conservative assumptions, reasonably accurate.

Predicted changes in precipitation used in this report are summarized in the Precipitation Table of Ouranos (2008) (the report contains no numbering) and are reproduced below in Table 3-3. The Ouranos model runs are based on quarter-year time-steps.

[3] Ouranos is a research consortium on regional climatology and adaptation to climate change. It is a joint initiative of the Government of Quebec, Hydro-Quebec, and the Meteorological Service of Canada.

Table 3-3. Changes in Average Total Precipitation for Quarter-Year Periods for the 2050 Time Horizon Using the CRCM 4.2 ADJ and ADL Model Runs (after Ouranos, 2008)

Time Period	Change (2050) ADJ (% change)	Change (2050) ADL (% change)
Annual	12	16
Dec, Jan, Feb (DJF)	**9**	**28**
Mar, Apr, May	18	13
Jun, July, Aug	4	-7
Sept, Oct, Nov (SON)	**12**	**14**

This table indicates a relatively wide range of rate of change for the relevant months of October to March. Averaging the DJF-SON periods results in a 10.5% increase in average precipitation for the ADJ scenario, while averaging the same period for the ADL scenarios results in a 21% increase. Herein, adjusted IDF curves are provided for the more conservative 21% increase.

3.2 Assumptions and Limitations

The analyses carried out in this study are based on the following assumptions and limitations:

1. The highest intensity rainfall occurs in the "wet months" between October and March when precipitation is primarily due to synoptic scale weather (not localized convective storms).
2. At each station, the IDF curves provided by Metro Vancouver adequately represent the likelihood of a particular rainfall intensity and duration (e.g. no review was undertaken of the accuracy of the IDF curves provided);
3. The Canadian Regional Climate Model can adequately predict precipitation changes for the future.
4. The statistical correlation between monthly precipitation and precipitation intensity remains reasonably constant over time.
5. The "2050" year scenario refers to modelled precipitation conditions for approximately the period 2041 - 2070 (Ouranos, 2008).
6. Estimated relative change in precipitation is based on a small spectrum of all model outcomes, due to the complex multiplicative effect of combining various alterations of model runs, GCMs and emission scenarios. Model outcomes considered include:
    a. Two simulations of the same regional climate model
    b. Two runs of the same Global Circulation Model (GCM) CGCM3
    c. The same emission scenario (SRES A2)

3.3 Data Analysis

3.3.1 Forecasted Short Duration Rainfall

Current climate models have difficulty forecasting rainfall intensity of short durations. However, they do seem able to produce reasonable simulations of monthly rainfall. Consequently, a statistical technique is required to relate historic short duration rainfall with monthly rainfall data. Miles and Associates (2001) compared annual rainfall and rainfall intensities and found good correlations for a large number of stations for return periods between 2 and 100 years. This result suggests that a correlation between short duration precipitation and monthly precipitation may be used to statistically estimate future rainfall intensity based on monthly rainfall forecasted by physically based models.

BGC plotted short duration rainfall amounts observed at the stations listed in Table 3-1 over periods of 1 to 24 hours against monthly rainfall totals, for the period October-March (inclusive). In order to extract a relation between the short duration precipitation and the monthly precipitation, power law curves of the following form are fitted to the data:

$$P_{short} = AP_{month}^{K} \qquad \text{[Eq. 1]}$$

where P_{short} is the shot duration precipitation and P_{month} is the monthly precipitation. A and K are parameters obtained by fitting a power law curve to the data.

This relationship can be manipulated to express fractional changes in the short-term precipitation as a function of fractional changes in the monthly precipitation:

$$\frac{\Delta P_{short}}{P_{short}} = K\,\frac{\Delta P_{month}}{P_{month}} \qquad \text{[Eq. 2]}$$

Station CW09 is shown for example in Figure 3-1, where the curves show the power law fit for precipitation durations of 1 hour to 24 hours. For each year of data, monthly precipitation totals for the October to March period were plotted against the maximum rainfall intensity in that given month for each of the durations under consideration (1, 2, 6, 12, and 24 hours). The inset of the figure gives the resulting equation and the variance explained. Except for short rainfall durations (1 hour and 2 hours), the fitted curves explain most of the variance, suggesting that there is a fairly robust relationship between monthly precipitation and short duration rainfall: that is, increased short duration precipitation intensity results in increased monthly precipitation. Results shown in Figure 3-1 are for the October to March period.

For each duration (1, 2, 6, 12, and 24 hours) at a particular climate station, the regression equation was used to solve for the fractional change in precipitation intensity, given a 1.21 fractional change in monthly rainfall. At CW09, for example (Figure 3-1) the increase in intensities for the 1, 2, 6, 12, and 24 hour periods were calculated at 8%, 9%, 12%, 14%, and 15%, respectively.

3.3.2 Adjusted IDF Curves

Rainfall intensity duration frequency values computed from the Gumbel distribution were adjusted by multiplying the existing values by the fractional change in precipitation intensity for each rainfall duration. Power regression lines were then fitted to the adjusted values to obtain adjusted IDF curves for each return period.

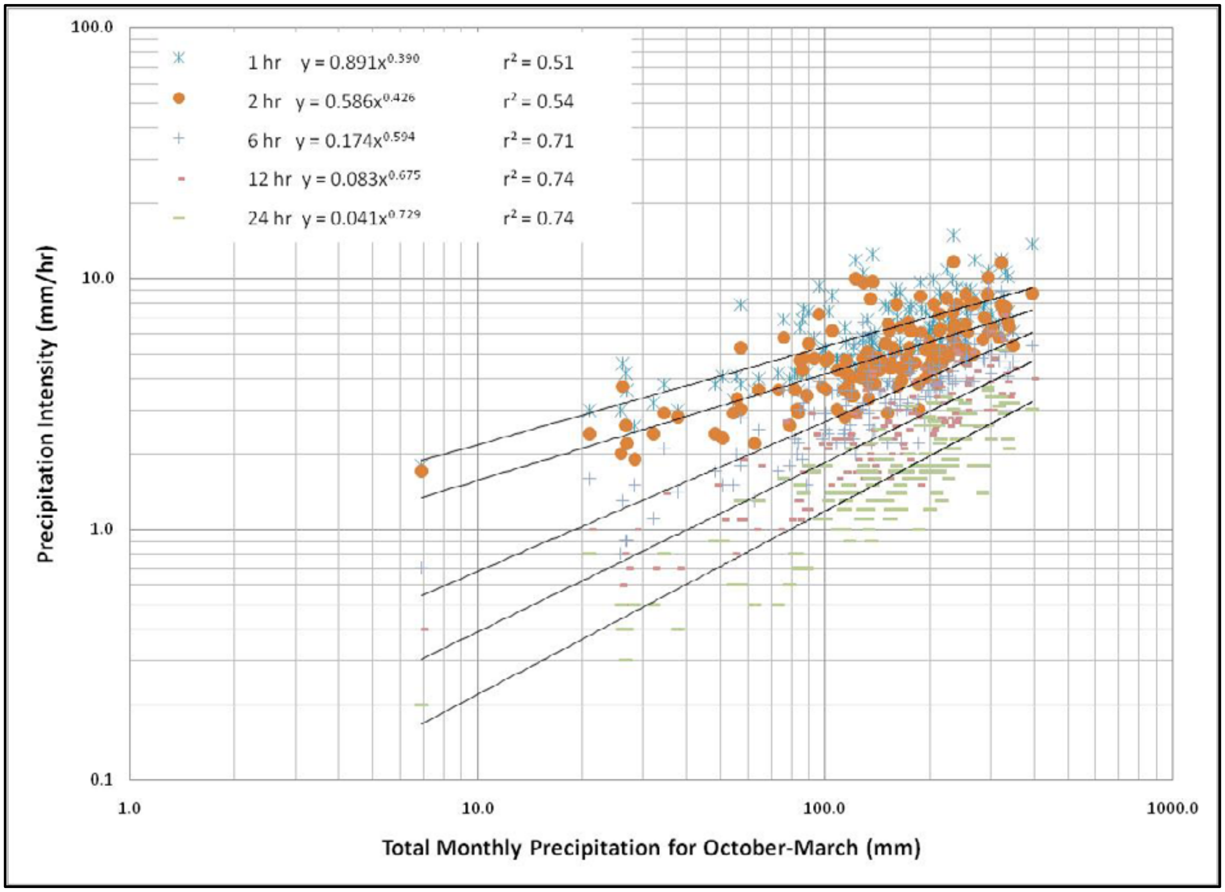

Figure 3-1. Precipitation Intensity versus Total Monthly Precipitation, Station CW09

4.0 RESULTS

Regression equations of monthly precipitation versus rainfall intensity are provided in Appendix I for each of the durations investigated (1, 2, 6, 12 and 24 hours). Fractional changes in rainfall intensity based on the two climate change scenarios are also tabulated in Appendix I. Adjusted IDF data and curves are shown in Drawings 2-11 for the same stations.

For the ADL scenario (21% increase in monthly rainfall), the predicted return periods approximately halve for most rainfall durations and climate stations. At station BU07, for example, the current 100-year return period, average 24 hour rainfall intensity is 6.6 mm/hour. Under the ADL scenario, the adjusted 50 year intensity is 6.7 mm/hr.

5.0 SUMMARY AND RECOMMENDATIONS

This study has examined potential changes in rainfall intensity for durations of between 1 and 24 hours as a second-order effect of global warming. It is argued that global warming will lead to an enhanced hydrologic cycle, which, for south coastal British Columbia, will lead to more rain during the fall, winter and spring months and drier conditions for the summer months.

A non-linear correlation was found between monthly rainfall and rainfall intensities at variable durations. Longer durations generally resulted in better explained variance. This empirical relationship is convenient as it avoids the sophistication and cumulative uncertainties that are introduced by other methods such as artificial weather generators.

Two model runs of the CRCM were used for the A2 emission scenario for the 2050 time frame, which produced an estimated range in increased average monthly fall and winter precipitation of 10% to 21%. These values were subsequently substituted in the regression equations of monthly rainfall and rainfall intensities to yield predicted changes in rainfall intensities for durations of 1 to 24 hours, for the more conservative 21% projected increase in rainfall. The analysis was repeated for ten Metro Vancouver climate stations.

This work, though not yet comprehensive, has closed an important gap in the understanding and prediction of climate-change impacts on municipal sewerage and stormwater infrastructure.

This study is exploratory in nature as it is limited to only one emission scenario and two model runs of the CRCM that are based on the same GCM. Furthermore, IDF curves were only produced for the 2050 time horizon, and for only 10 out of the over 50 rain gauges that measure short duration rainfall in Metro Vancouver. In addition, no attempt has been made to produce regional IDF curves based on the spatial distribution of IDF curves at individual climate stations or to provide maps showing zones of applicability for particular curves.

BGC recommends the following work within the Metro Vancouver study area:

1. Development of regional IDF curves for existing conditions; and
2. Development of regional IDF curves for the 2050 conditions considered herein.

BGC further recommends the following additional work to improve the data record and to provide further understanding of uncertainties associated with the forecasted effects of climate change on rainfall:

1. Examine the sensitivity of the climate-adjusted IDF curves to alternative forecasted changes in precipitation associated with different emissions scenarios or models;
2. Transcribe pdf scans of climate data to improve the electronic data record for Metro Vancouver climate stations;
3. Use different runs of the CRCM to span a broader spectrum of modelled outcomes;

4. Use more emission scenarios to explore the sensitivity of emission scenarios on predicted changes in rainfall intensities;
5. Expand the prediction time horizon to 2100;
6. Complete a more detailed statistical analysis of relative differences in forecasted changes to short versus longer term rainfall intensity (sub 1 hour to 72 hours); and
7. Explore the possibility of completely different model approaches such as weather generators to compare the empirical results in this study with different methodologies. This approach would likely result in better confidence of expected changes and would help test the hypothesis that the precipitation amount-intensity relations remain reasonably constant with changing precipitation amounts.

6.0 CLOSURE

We hope that the foregoing satisfies the requirements of the assessment you requested. Please do not hesitate to contact the undersigned if you have any questions or require additional information.

Thank you for the opportunity to undertake this assessment.

BGC ENGINEERING INC.
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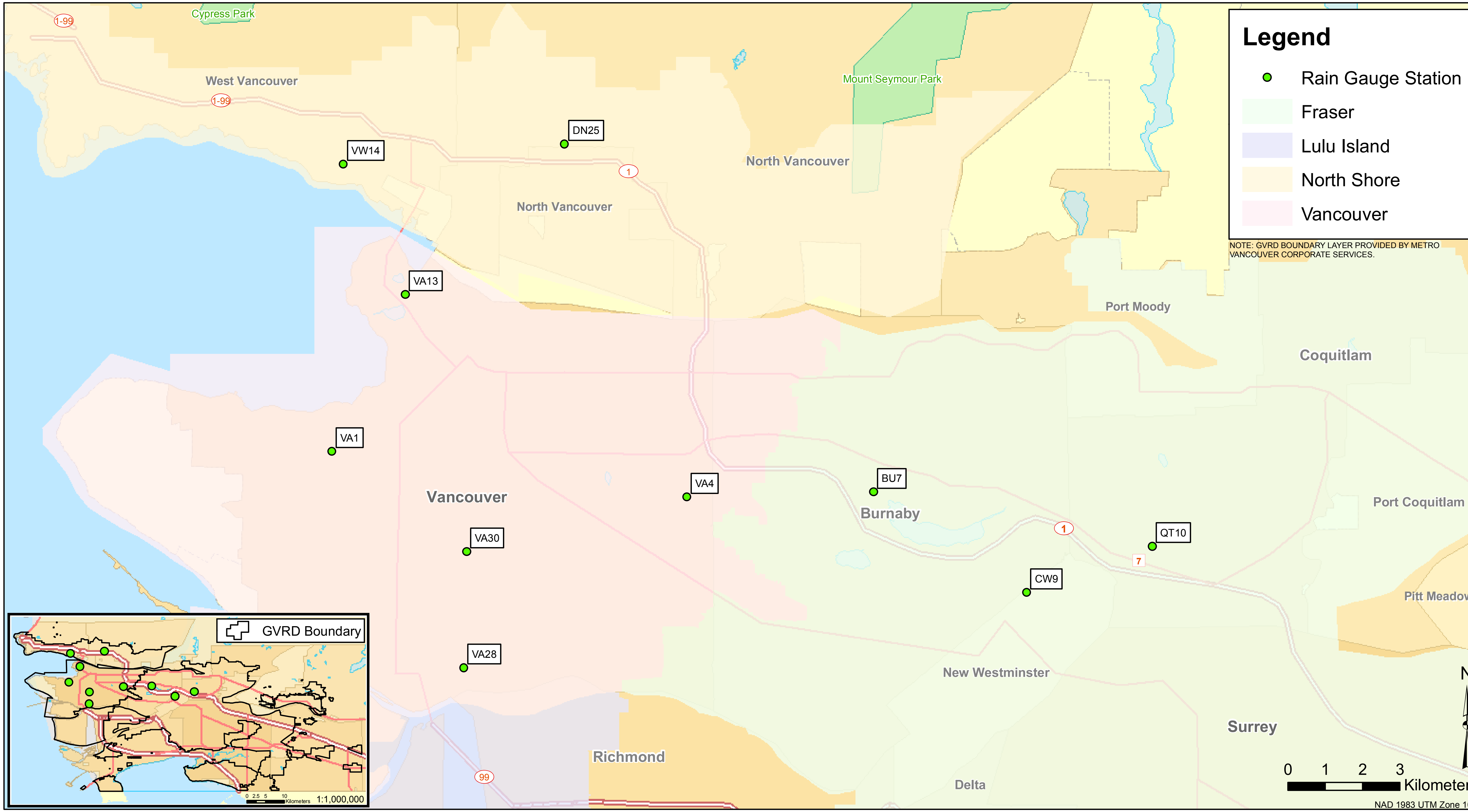
APPENDIX I
REGRESSION EQUATIONS AND FRACTIONAL CHANGES IN RAINFALL INTENSITY

Station	Month	Equation	R^2	Fractional Change in Intensity, 21% rain increase	Equation	R^2	Fractional Change in Intensity, 21% rain increase	Equation	R^2	Fractional Change in Intensity, 21% rain increase	Equation	R^2	Fractional Change in Intensity, 21% rain increase	Equation	R^2
BU07	Oct-March	y = 1.2585 x^ 0.3258	0.44	1.064	y = 0.7056 x^ 0.3983	0.60	1.079	y = 0.2121 x^ 0.5712	0.63	1.115	y = 0.1128 x^ 0.6220	0.68	1.126	y = 0.0565 x^ 0.6776	0.6378
CW09	Oct-March	y = 0.891 x^ 0.3902	0.51	1.077	y = 0.5863 x^ 0.4256	0.54	1.085	y = 0.1737 x^ 0.5937	0.71	1.120	y = 0.0826 x^ 0.675	0.74	1.137	y = 0.0412 x^ 0.7286	0.74
DN25	Oct-March	y = 1.2005 x^ 0.3385	0.33	1.067	y = 0.7387 x^ 0.3924	0.37	1.078	y = 0.2907 x^ 0.502	0.56	1.100	y = 0.1297 x^ 0.5949	0.64	1.120	y = 0.0557 x^ 0.6784	0.69
QT10	Oct-March	y = 1.2065 x^ 0.3267	0.32	1.064	y = 0.7578 x^ 0.371	0.41	1.073	y = 0.2558 x^ 0.51	0.59	1.102	y = 0.1104 x^ 0.608	0.66	1.123	y = 0.0504 x^ 0.6792	0.68
VA01	Oct-March	y = 0.9795 x^ 0.3553	0.42	1.070	y = 0.6085 x^ 0.4055	0.48	1.080	y = 0.2578 x^ 0.5028	0.56	1.101	y = 0.1182 x^ 0.5917	0.61	1.119	y = 0.0586 x^ 0.6491	0.65
VA04	Oct-March	y = 1.1445 x^ 0.3345	0.31	1.073	y = 0.7239 x^ 0.3785	0.37	1.076	y = 0.2339 x^ 0.5251	0.58	1.110	y = 0.1148 x^ 0.6021	0.66	1.118	y = 0.0558 x^ 0.6638	0.73
VA13	Oct-March	y = 1.0496 x^ 0.3476	0.28	1.069	y = 0.6263 x^ 0.409	0.32	1.081	y = 0.2243 x^ 0.5494	0.32	1.110	y = 0.108 x^ 0.6326	0.30	1.128	y = 0.0533 x^ 0.6933	0.25
VA28	Oct-March	y = 0.7163 x^ 0.4356	0.61	1.087	y = 0.4597 x^ 0.4781	0.68	1.095	y = 0.1629 x^ 0.6040	0.73	1.122	y = 0.0725 x^ 0.6955	0.75	1.142	y = 0.0363 x^ 0.7433	0.80
VA30	Oct-March	y = 0.5967 x^ 0..4803	0.55	1.096	y = 0.4139 x^ 0.5131	0.53	1.103	y = 0.2058 x^ 0.5644	0.63	1.114	y = 0.1079 x^ 0.6246	0.63	1.126	y = 0.0448 x^ 0.7251	0.73
VW14	Oct-March	y = 1.2966 x^ 0.3128	0.31	1.061	y = 0.8361 x^ 0.3646	0.31	1.072	y = 0.1881 x^ 0.6238	0.27	1.126	y = 0.0709 x^ 0.7679	0.24	1.158	y = 0.0307 x^ 0.8692	0.19

DRAWINGS



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PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: RAIN GAUGE STATIONS

PROJECT No.:	FIG No.:	REV.:
0431-006	1	

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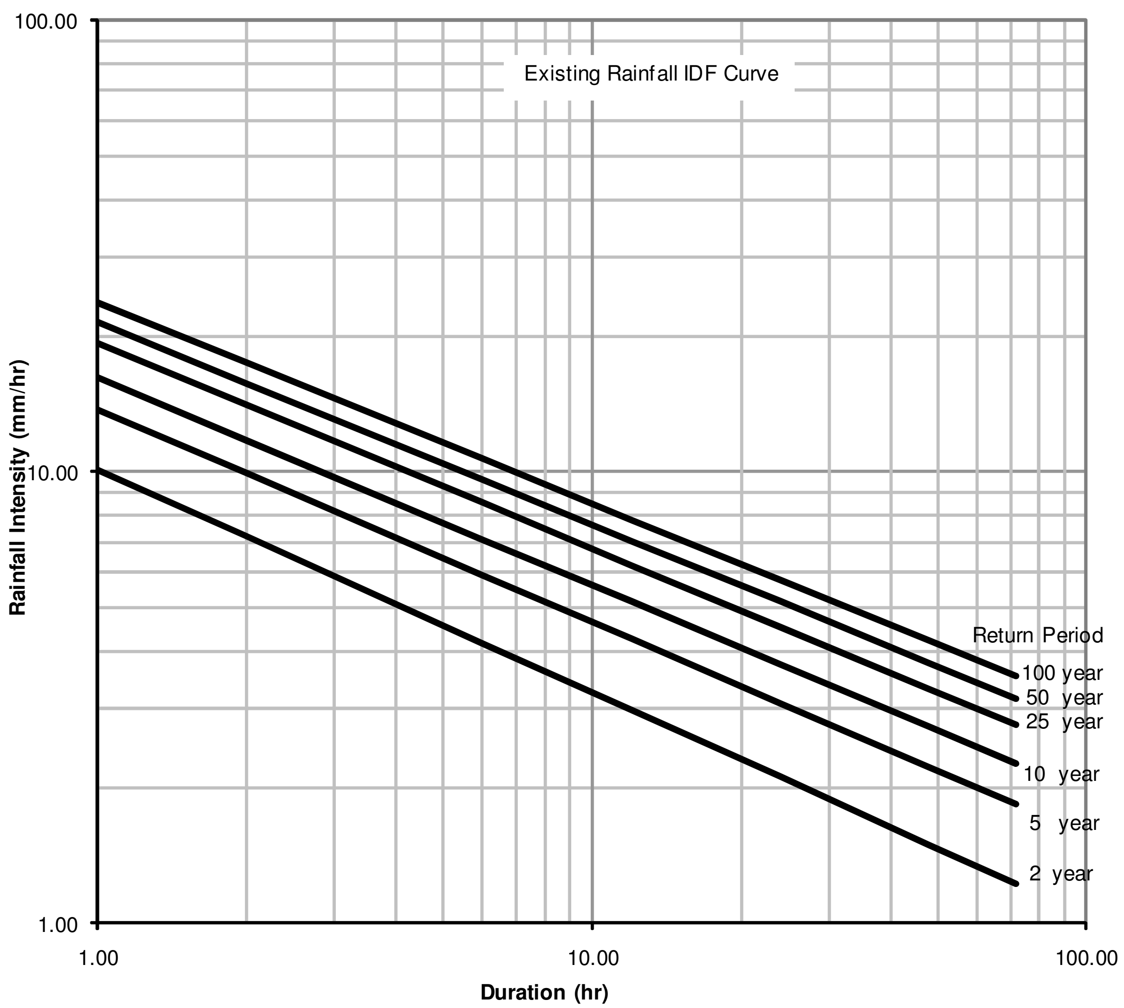

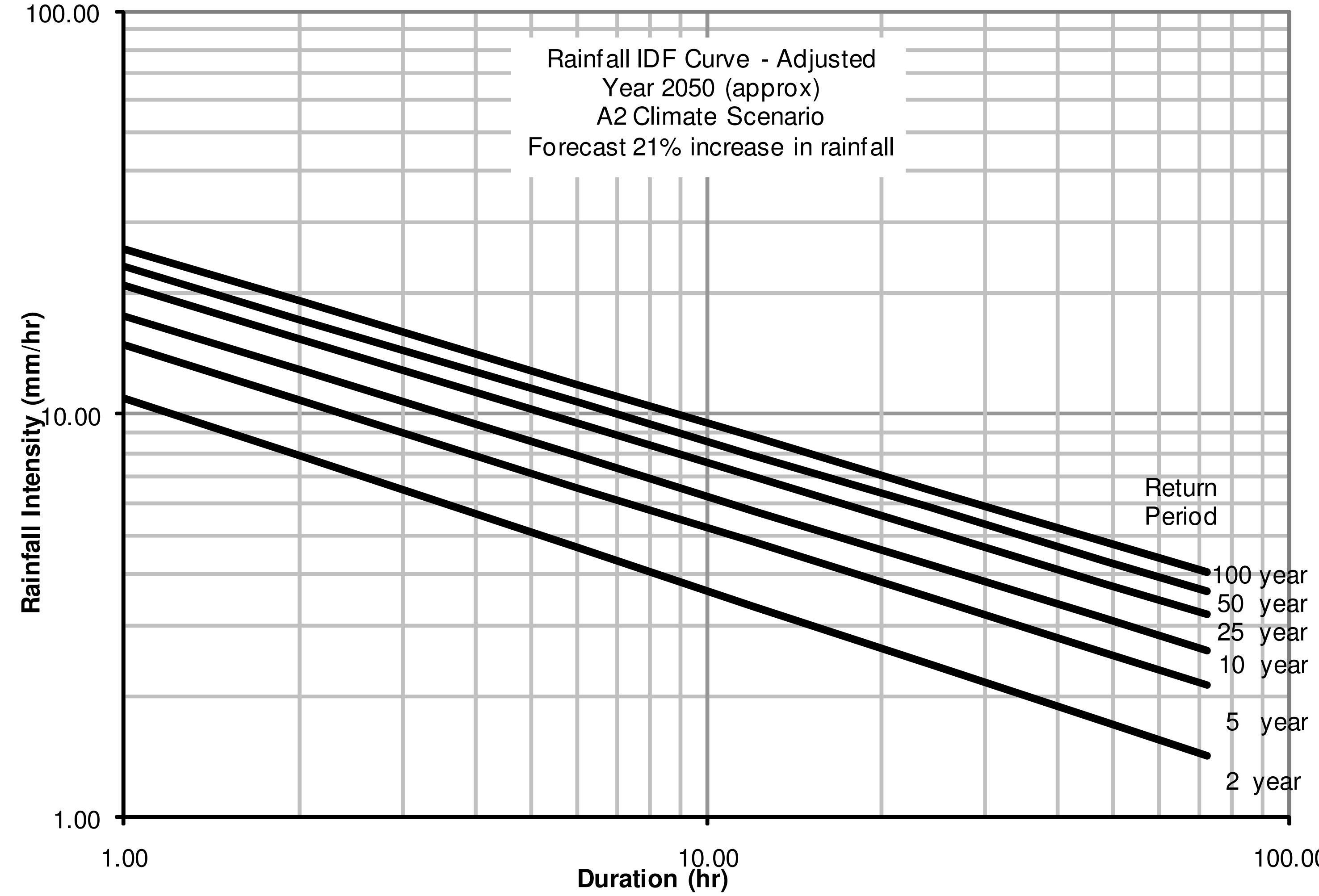

DURATION	RETURN PERIOD											
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	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	10.1	11.0	13.7	15.0	16.1	17.6	19.2	20.9	21.5	23.4	23.7	25.8
2	7.2	7.9	9.9	10.9	11.7	12.9	14.0	15.4	15.7	17.3	17.4	19.2
6	4.2	4.7	5.9	6.6	7.1	7.9	8.5	9.5	9.6	10.7	10.7	11.9
12	3.0	3.4	4.3	4.8	5.1	5.8	6.2	7.0	7.0	7.9	7.8	8.9
24	2.1	2.4	3.1	3.5	3.7	4.3	4.5	5.2	5.1	5.9	5.7	6.6
48	1.5	1.7	2.2	2.6	2.7	3.1	3.3	3.8	3.8	4.4	4.2	4.9
72	1.2	1.4	1.8	2.1	2.2	2.6	2.8	3.2	3.1	3.7	3.5	4.1

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PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: VA28 - KENT PUMP STATION

PROJECT No.: 0431-006

FIG No.: 10

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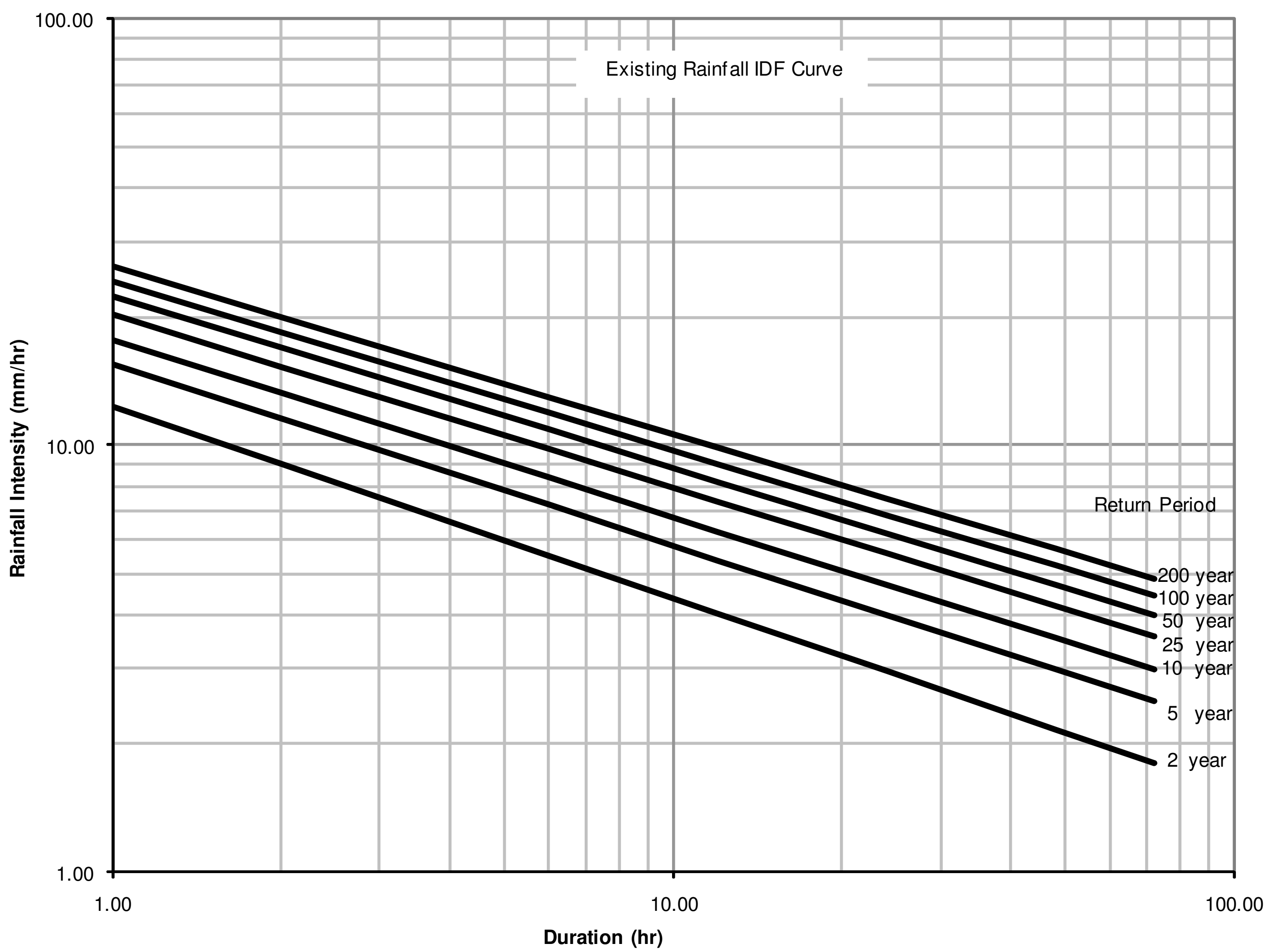

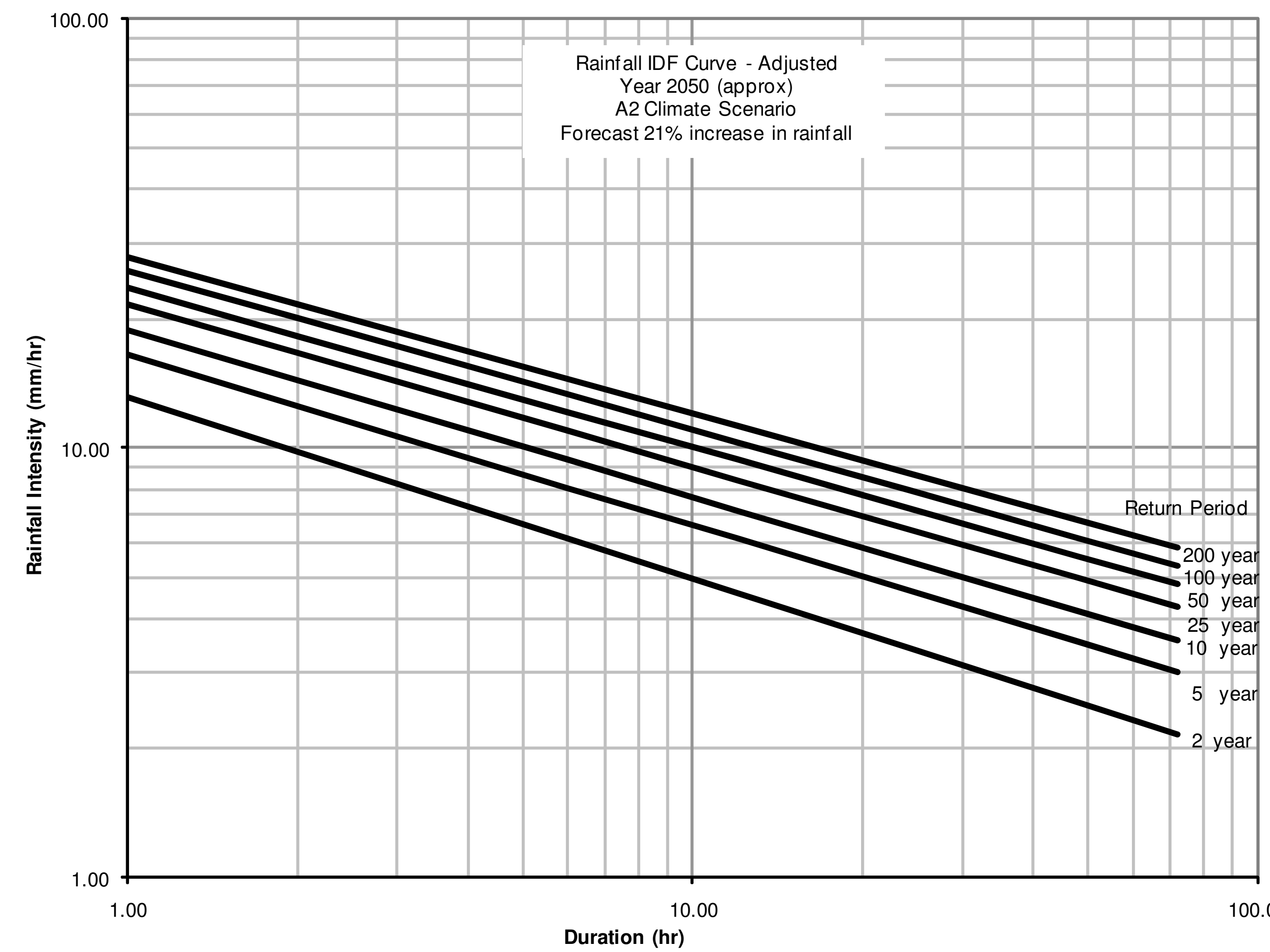

DURATION	RETURN PERIOD													
	2 year		5 year		10 year		25 year		50 year		100 year		200 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase	Existing	2050, 200 yr, 21% Monthly Rainfall Increase
1	12.3	13.1	15.5	16.5	17.6	18.8	20.3	21.6	22.3	23.7	24.3	25.8	26.2	27.9
2	9.0	9.8	11.6	12.5	13.2	14.3	15.3	16.6	16.9	18.3	18.4	20.0	20.0	21.7
6	5.5	6.2	7.2	8.1	8.4	9.4	9.8	11.0	10.9	12.2	11.9	13.3	13.0	14.5
12	4.0	4.6	5.4	6.1	6.3	7.2	7.4	8.4	8.2	9.4	9.1	10.3	9.9	11.3
24	3.0	3.4	4.0	4.7	4.7	5.5	5.6	6.5	6.2	7.3	6.9	8.0	7.5	8.8
48	2.2	2.6	3.0	3.5	3.5	4.2	4.2	5.0	4.7	5.6	5.2	6.2	5.7	6.8
72	1.8	2.2	2.5	3.0	3.0	3.6	3.6	4.3	4.0	4.8	4.5	5.3	4.9	5.9

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TITLE: VW14 - WEST VANCOUVER MUNICIPAL HALL

PROJECT No.: 0431-006
FIG No.: 9
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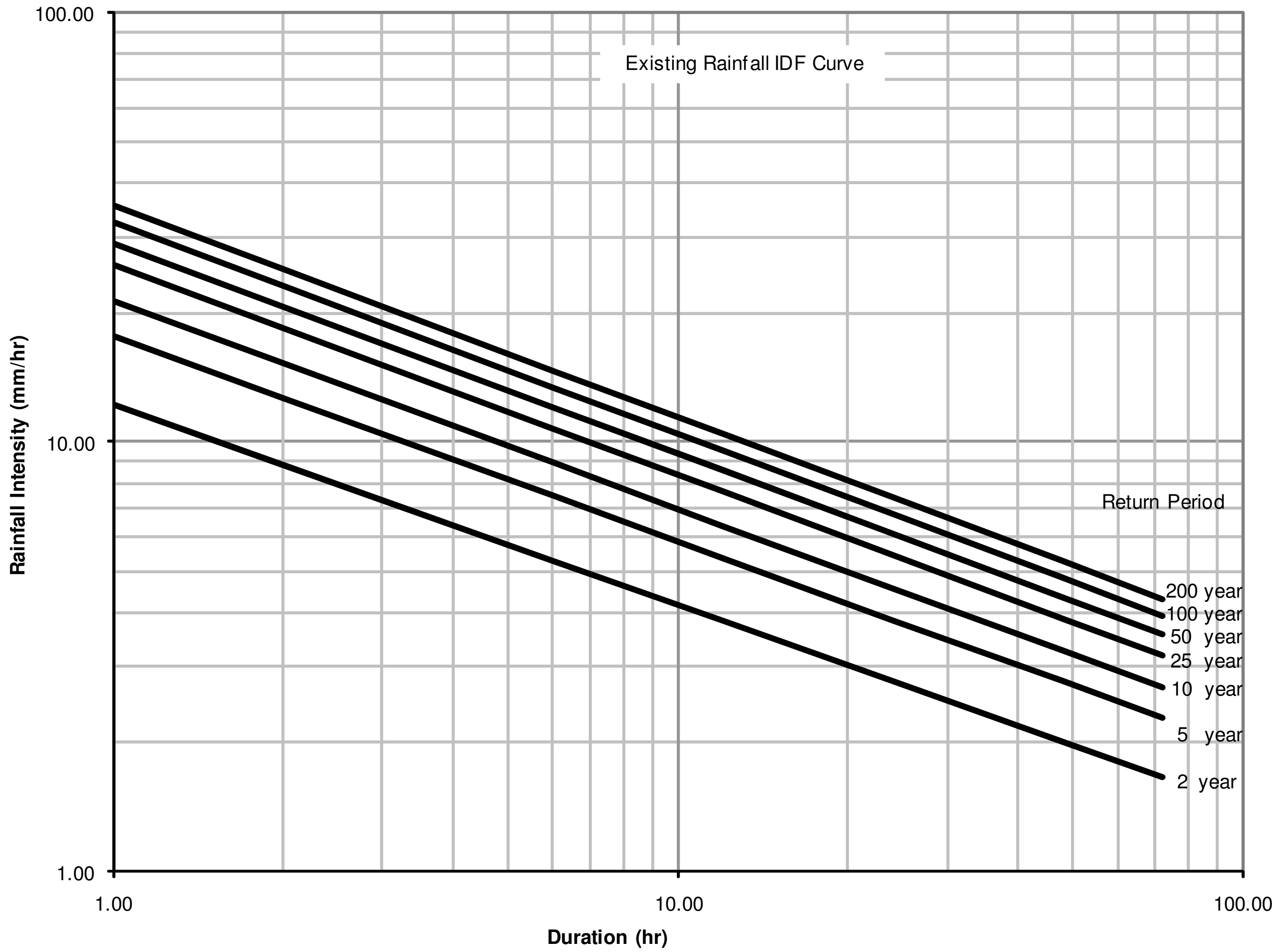

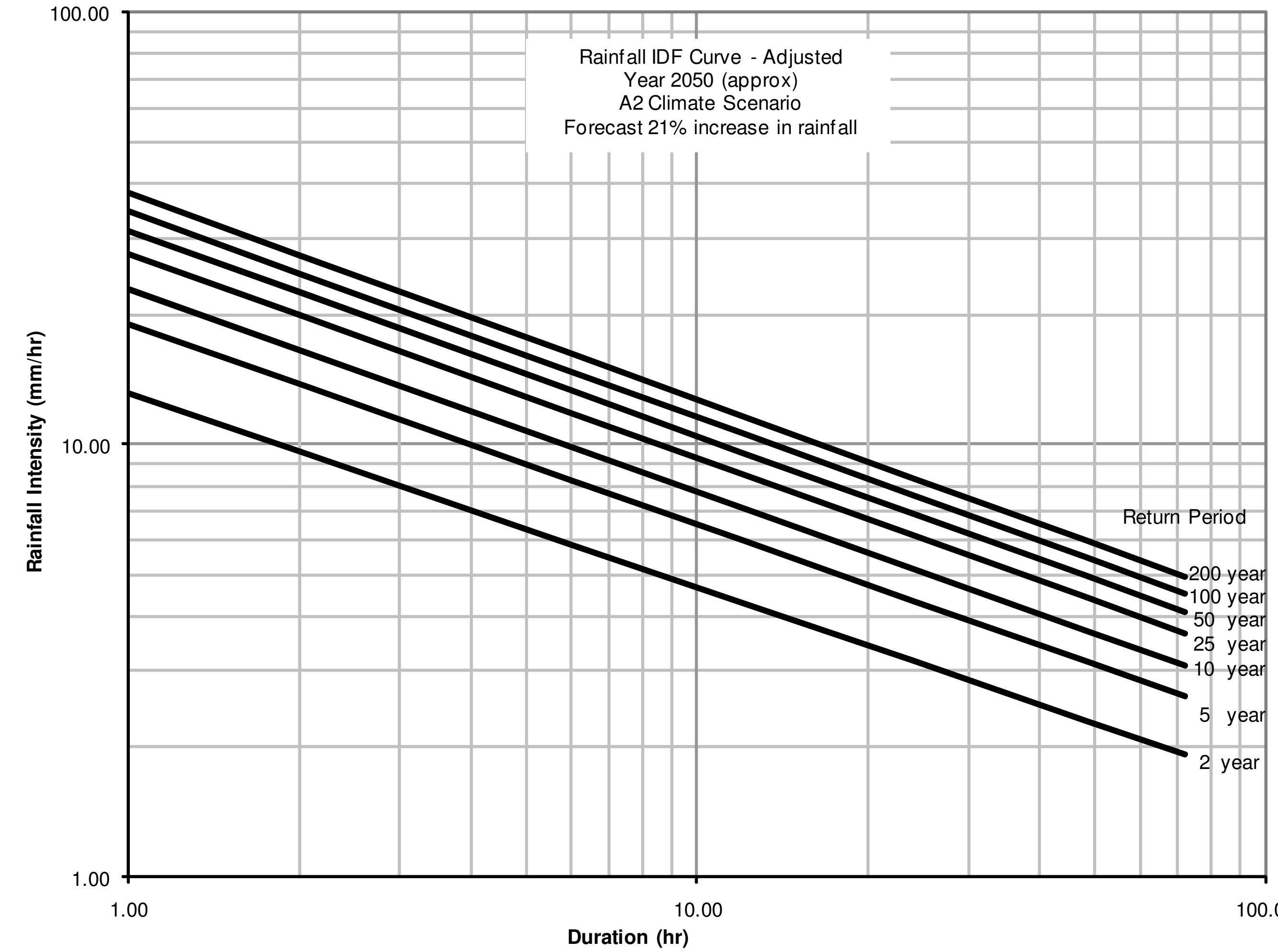

DURATION	RETURN PERIOD													
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	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase	Existing	2050, 200 yr, 21% Monthly Rainfall Increase
1	12.2	13.1	17.7	19.0	21.3	22.9	25.8	27.7	29.1	31.2	32.4	34.8	35.7	38.3
2	8.9	9.6	12.7	13.8	15.2	16.5	18.4	20.0	20.7	22.5	23.0	25.0	25.3	27.5
6	5.3	5.9	7.5	8.3	8.9	9.9	10.7	11.9	12.1	13.4	13.4	14.8	14.7	16.3
12	3.8	4.3	5.4	6.0	6.4	7.1	7.7	8.6	8.6	9.6	9.5	10.7	10.4	11.7
24	2.8	3.1	3.9	4.4	4.6	5.2	5.5	6.2	6.1	6.9	6.8	7.7	7.4	8.4
48	2.0	2.3	2.8	3.2	3.3	3.7	3.9	4.4	4.4	5.0	4.8	5.5	5.3	6.0
72	1.7	1.9	2.3	2.6	2.7	3.1	3.2	3.7	3.6	4.1	3.9	4.5	4.3	5.0

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PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: VA13 - STANLEY PARK SERVICE YARD

PROJECT No.: 0431-006

FIG No.: 8

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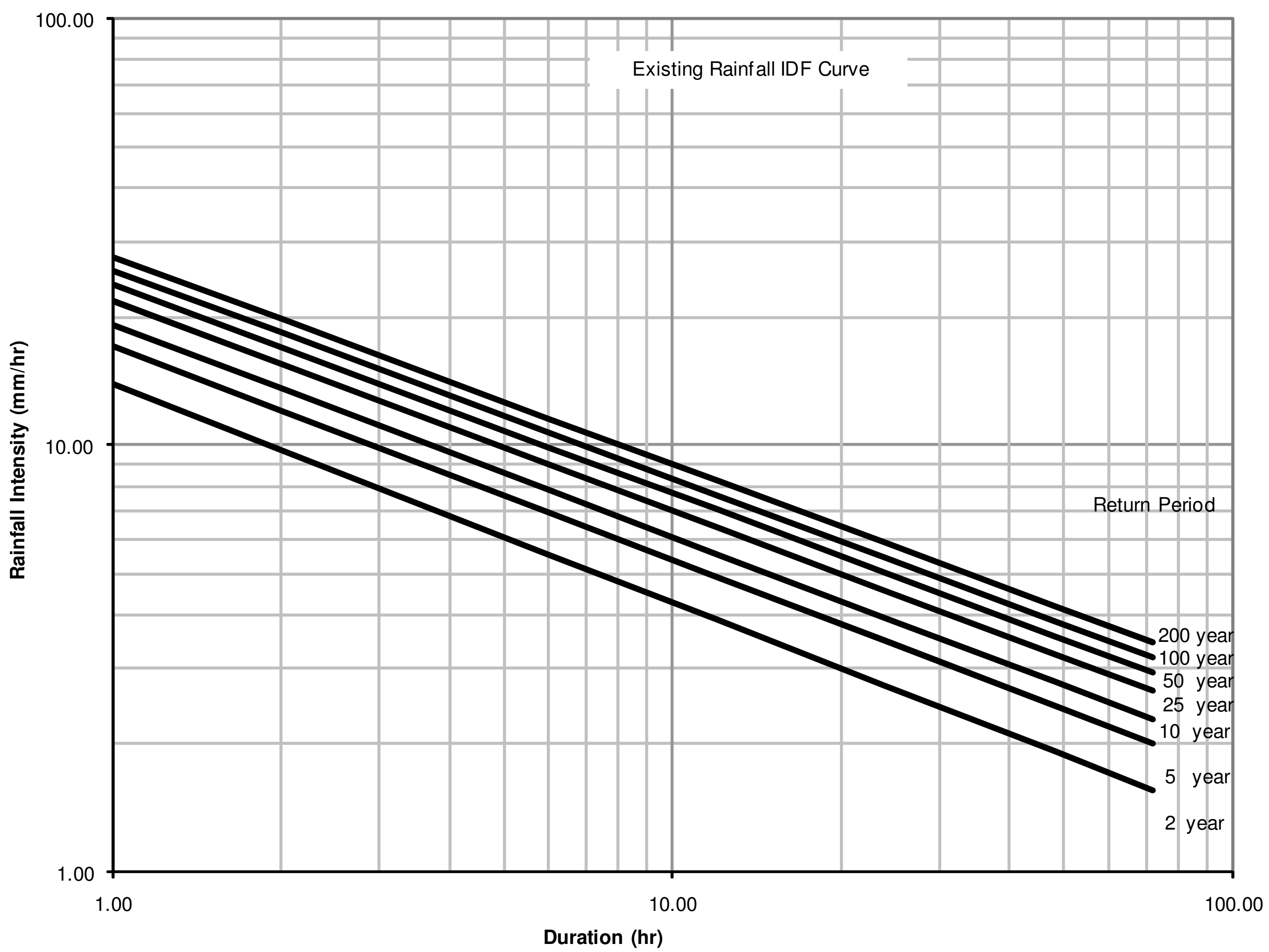

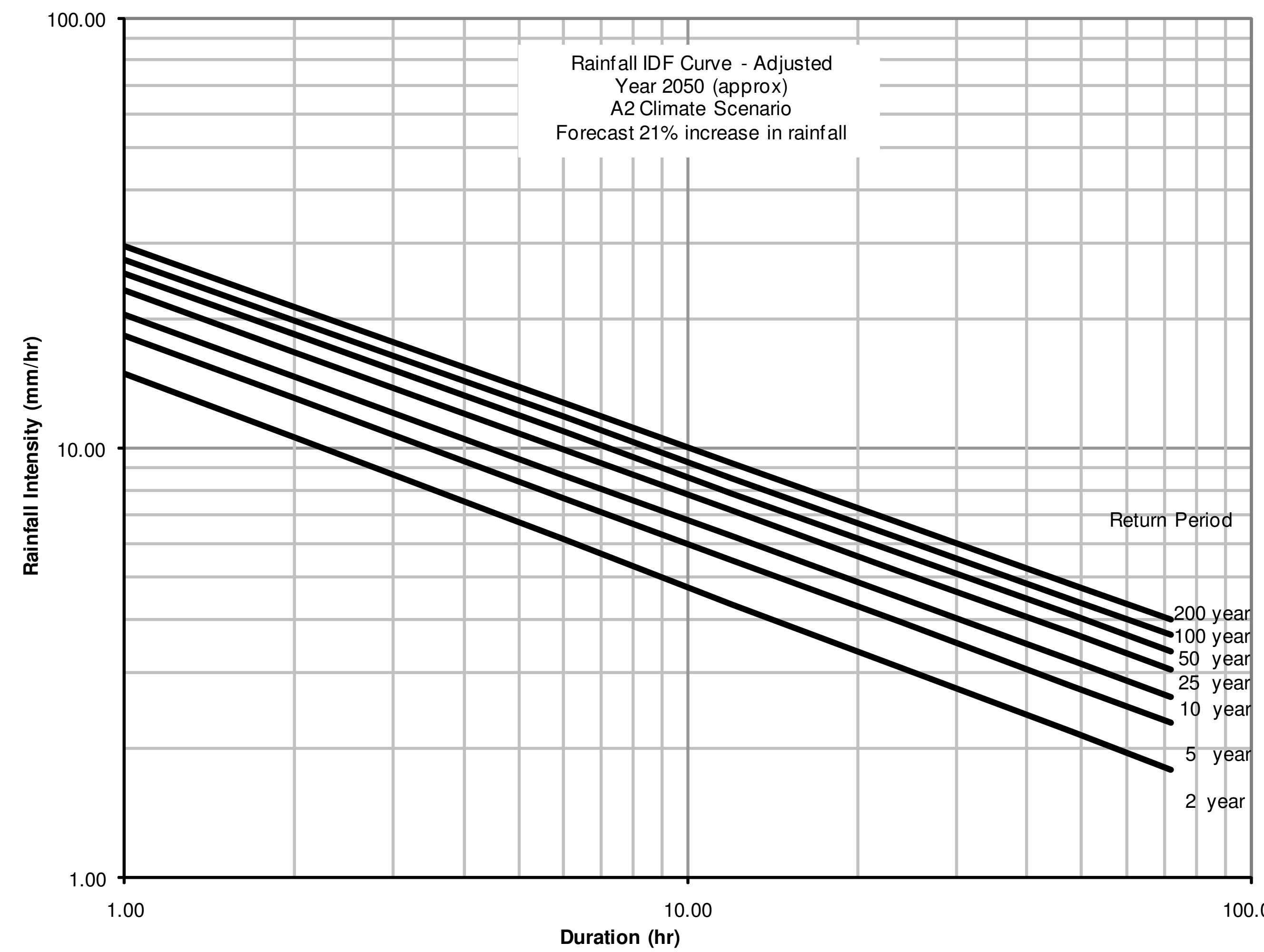

DURATION	RETURN PERIOD													
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	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall	Existing	2050, 100 yr, 21% Monthly Rainfall Increase	Existing	2050, 200 yr, 21% Monthly Rainfall Increase
1	13.9	14.9	17.1	18.3	19.2	20.5	21.8	23.4	23.8	25.5	25.7	27.5	27.7	29.6
2	9.8	10.6	12.1	13.1	13.6	14.7	15.5	16.8	16.9	18.3	18.4	19.9	19.8	21.4
6	5.6	6.1	7.0	7.7	7.9	8.7	9.0	10.0	9.9	10.9	10.7	11.8	11.6	12.8
12	3.9	4.3	4.9	5.5	5.6	6.2	6.4	7.2	7.0	7.9	7.7	8.5	8.3	9.2
24	2.7	3.1	3.5	3.9	4.0	4.5	4.6	5.1	5.0	5.7	5.5	6.2	5.9	6.7
48	1.9	2.2	2.4	2.8	2.8	3.2	3.2	3.7	3.6	4.1	3.9	4.5	4.2	4.8
72	1.6	1.8	2.0	2.3	2.3	2.6	2.7	3.1	2.9	3.4	3.2	3.7	3.5	4.0

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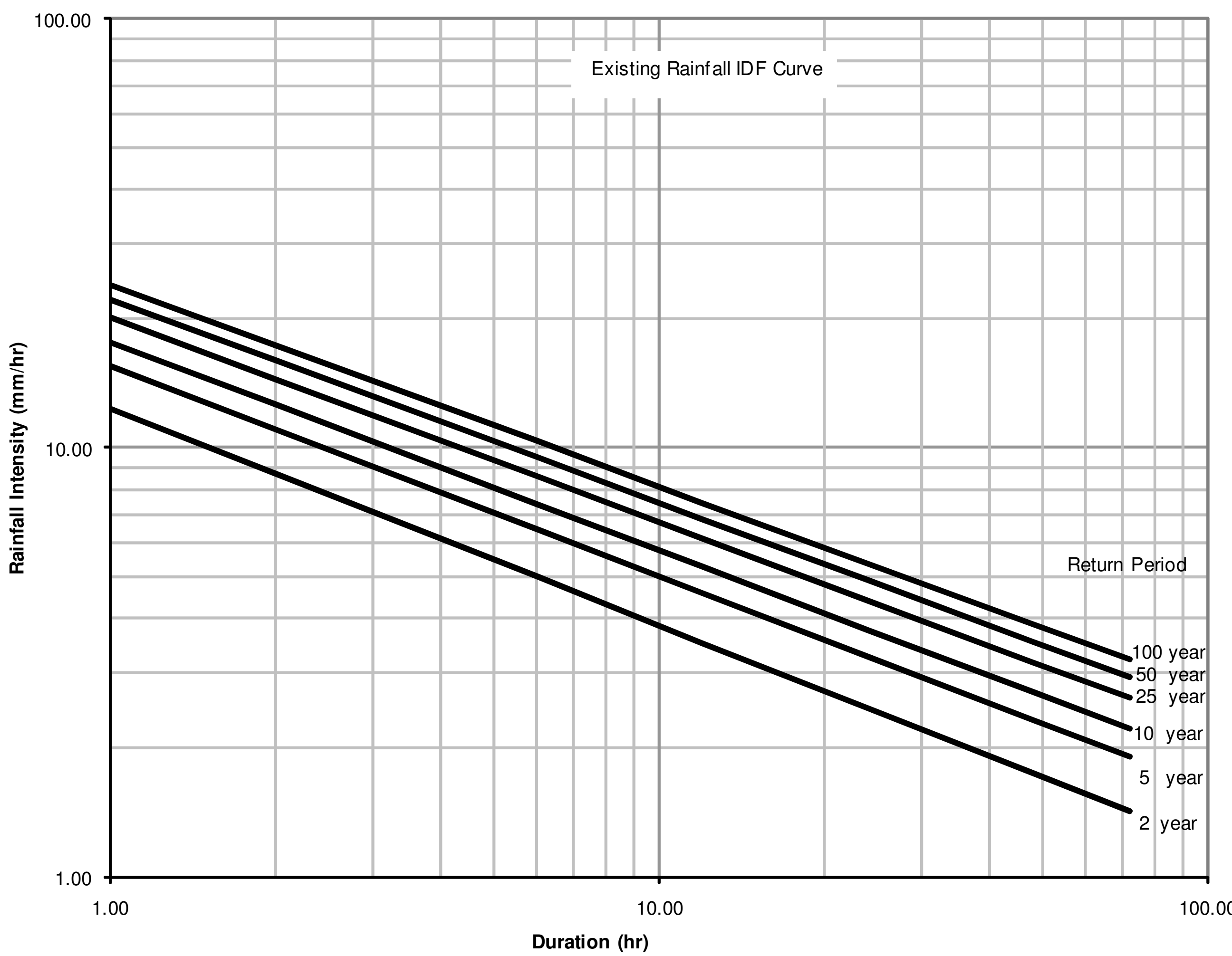
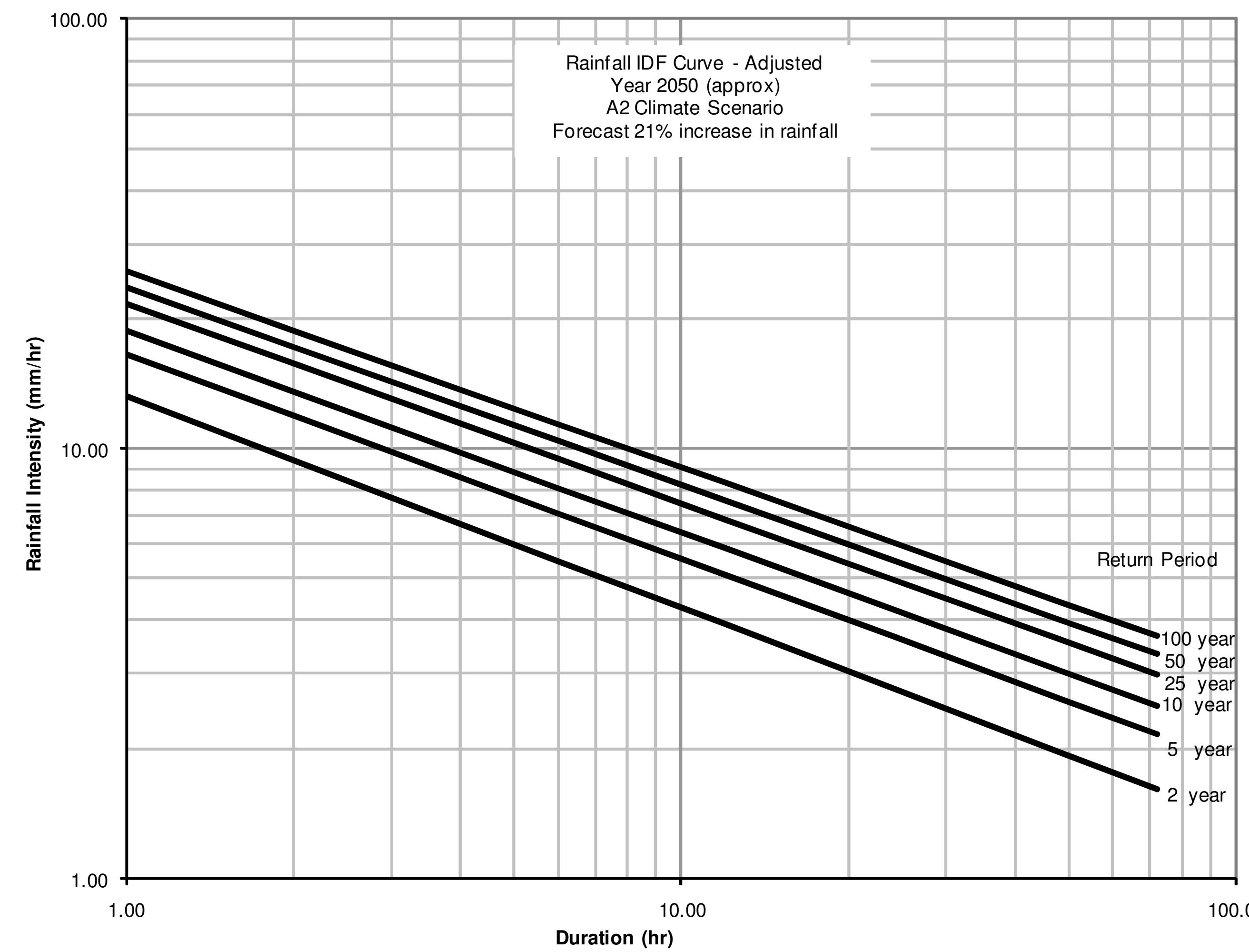
TITLE: VA04 - RENFREW ELEMENTARY SCHOOL

PROJECT No.: 0431-006

FIG No.: 7

REV.:





DURATION	RETURN PERIOD											
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	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	12.3	13.2	15.5	16.6	17.5	18.8	20.2	21.6	22.1	23.7	24.0	25.8
2	8.7	9.4	11.0	11.9	12.6	13.6	14.5	15.7	15.9	17.2	17.3	18.8
6	5.0	5.5	6.4	7.1	7.4	8.1	8.6	9.4	9.5	10.4	10.3	11.4
12	3.5	3.9	4.6	5.1	5.3	5.9	6.2	6.9	6.8	7.6	7.5	8.3
24	2.5	2.8	3.3	3.7	3.8	4.2	4.4	5.0	4.9	5.5	5.4	6.0
48	1.7	2.0	2.3	2.6	2.7	3.1	3.2	3.6	3.5	4.0	3.9	4.4
72	1.4	1.6	1.9	2.2	2.2	2.5	2.6	3.0	2.9	3.3	3.2	3.7

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REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

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PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: VA01 - KITSILANO HIGH SCHOOL

PROJECT No.: 0431-006
FIG No.: 6
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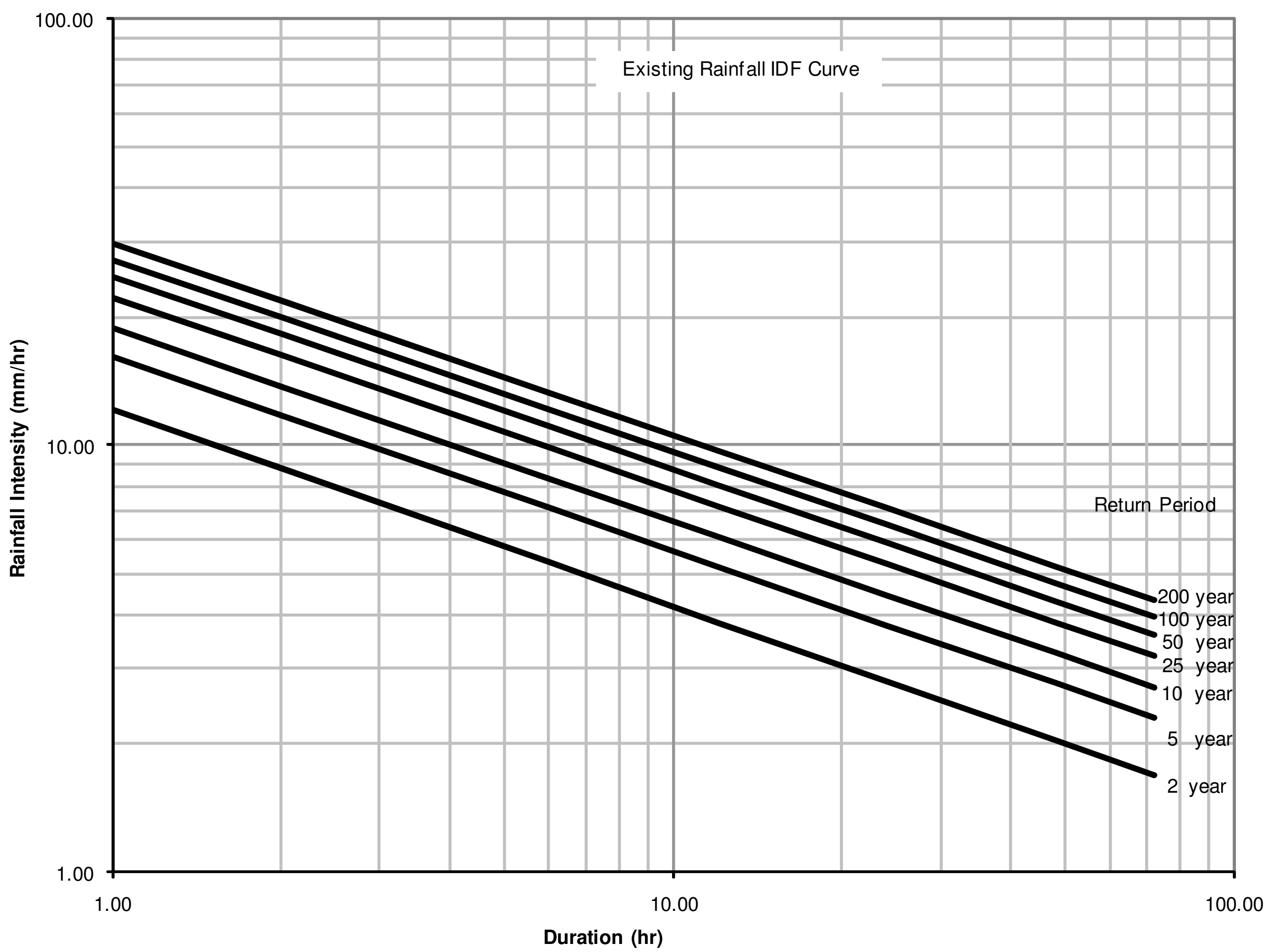

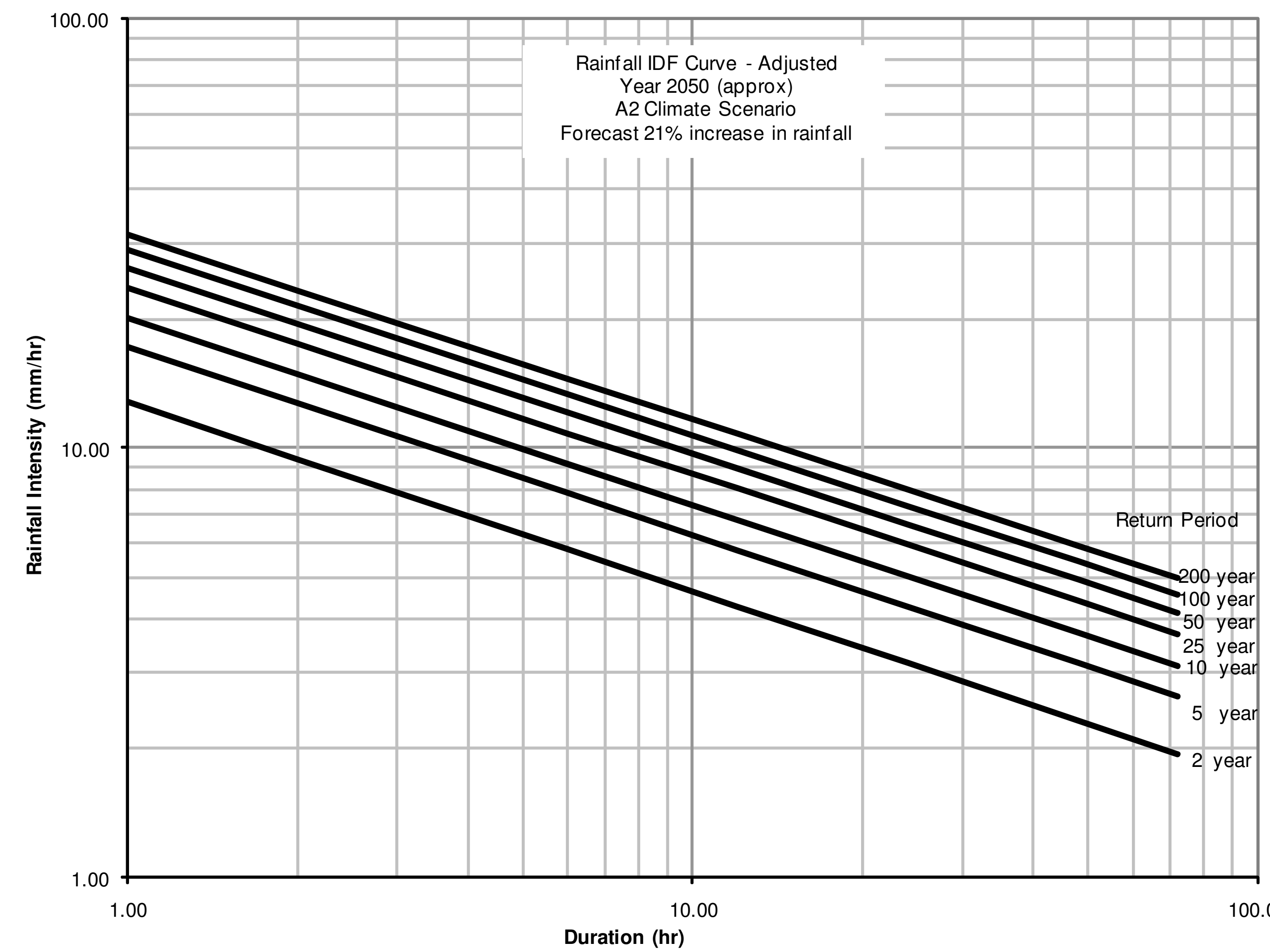

DURATION	RETURN PERIOD													
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	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase	Existing	2050, 200 yr, 21% Monthly Rainfall Increase
1	12.1	12.9	16.2	17.2	18.9	20.0	22.3	23.6	24.8	26.3	27.2	28.9	29.7	31.6
2	8.8	9.5	11.8	12.7	13.8	14.8	16.3	17.5	18.1	19.5	19.9	21.5	21.8	23.4
6	5.3	5.8	7.1	7.9	8.4	9.2	9.9	10.9	11.0	12.1	12.2	13.4	13.3	14.6
12	3.9	4.3	5.2	5.8	6.1	6.8	7.2	8.0	8.1	9.0	8.9	9.9	9.7	10.8
24	2.8	3.2	3.8	4.3	4.5	5.0	5.3	6.0	5.9	6.7	6.5	7.3	7.1	8.0
48	2.0	2.3	2.8	3.2	3.3	3.7	3.9	4.4	4.3	4.9	4.8	5.4	5.2	6.0
72	1.7	1.9	2.3	2.6	2.7	3.1	3.2	3.7	3.6	4.1	4.0	4.6	4.3	5.0

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PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: QT10 - COQUITLAM MAILLARDVILLE

PROJECT No.: 0431-006
FIG No.: 5
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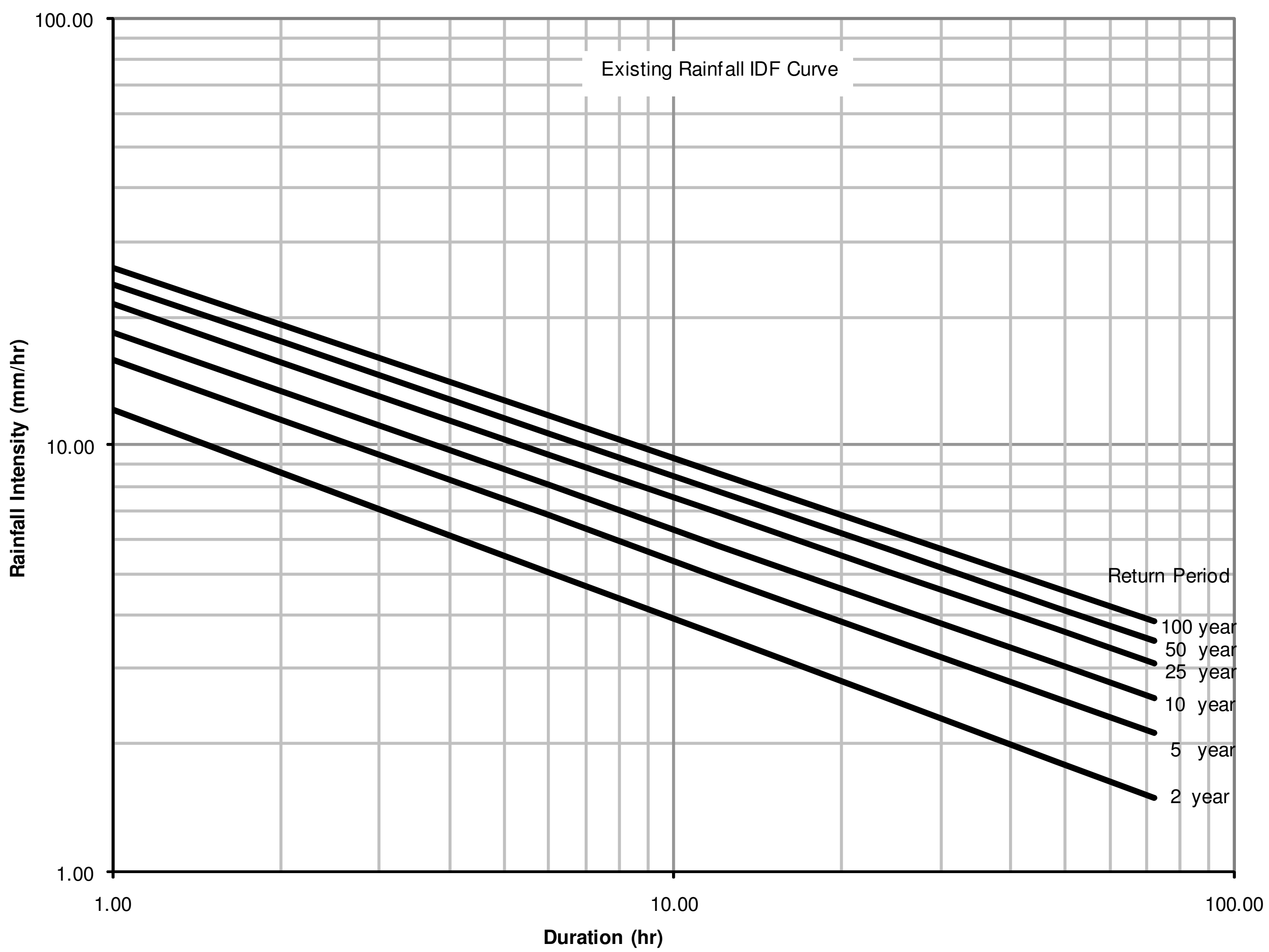
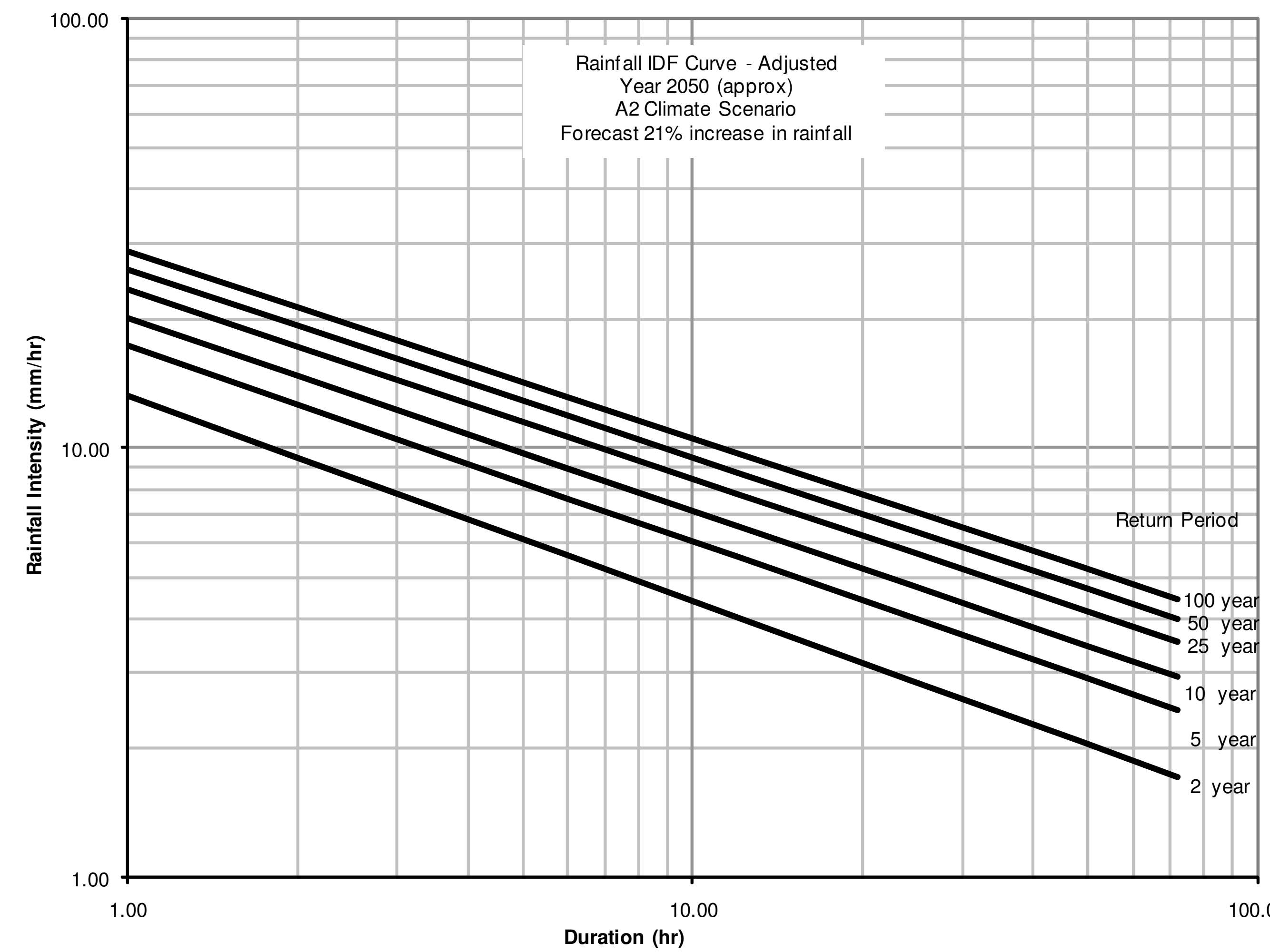




DURATION	RETURN PERIOD											
	2 year		5 year		10 year		25 year		50 year		100 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	12.1	13.2	15.9	17.4	18.4	20.1	21.5	23.6	23.9	26.1	26.2	28.7
2	8.6	9.5	11.5	12.6	13.3	14.7	15.7	17.3	17.5	19.3	19.2	21.2
6	5.0	5.6	6.8	7.6	8.0	9.0	9.5	10.7	10.7	11.9	11.8	13.1
12	3.6	4.0	4.9	5.6	5.8	6.6	7.0	7.8	7.8	8.8	8.6	9.7
24	2.6	2.9	3.6	4.1	4.2	4.8	5.1	5.8	5.7	6.5	6.3	7.2
48	1.8	2.1	2.6	3.0	3.1	3.5	3.7	4.2	4.2	4.8	4.6	5.3
72	1.5	1.7	2.1	2.5	2.6	2.9	3.1	3.6	3.5	4.0	3.9	4.5

X:\Projects\0431 GVRD\Design\20090206_IDF_Curves\IDF_VA30_Kersland.mxd

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:
DATE: FEB 2009
DRAWN: GLT
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

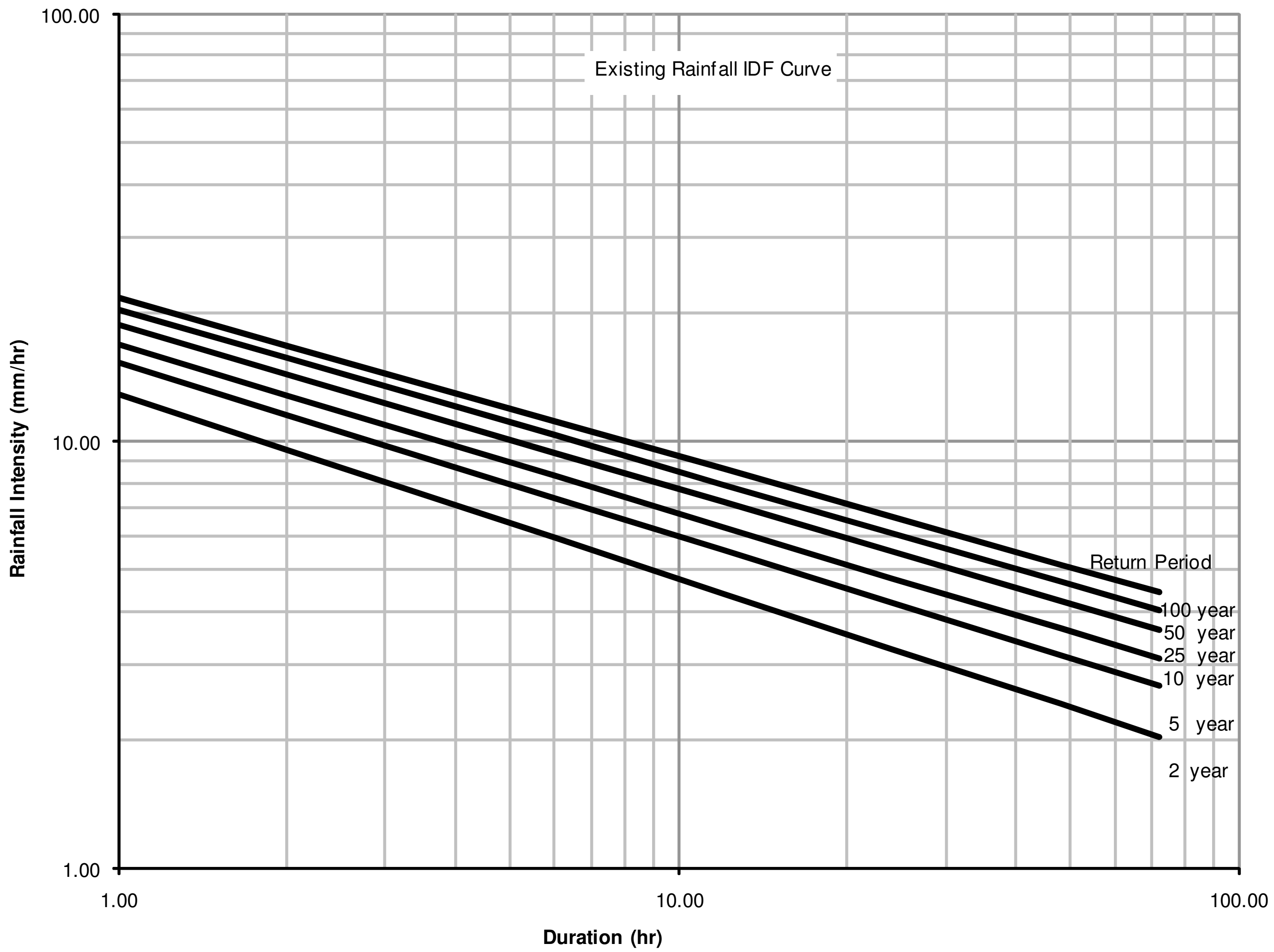
BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

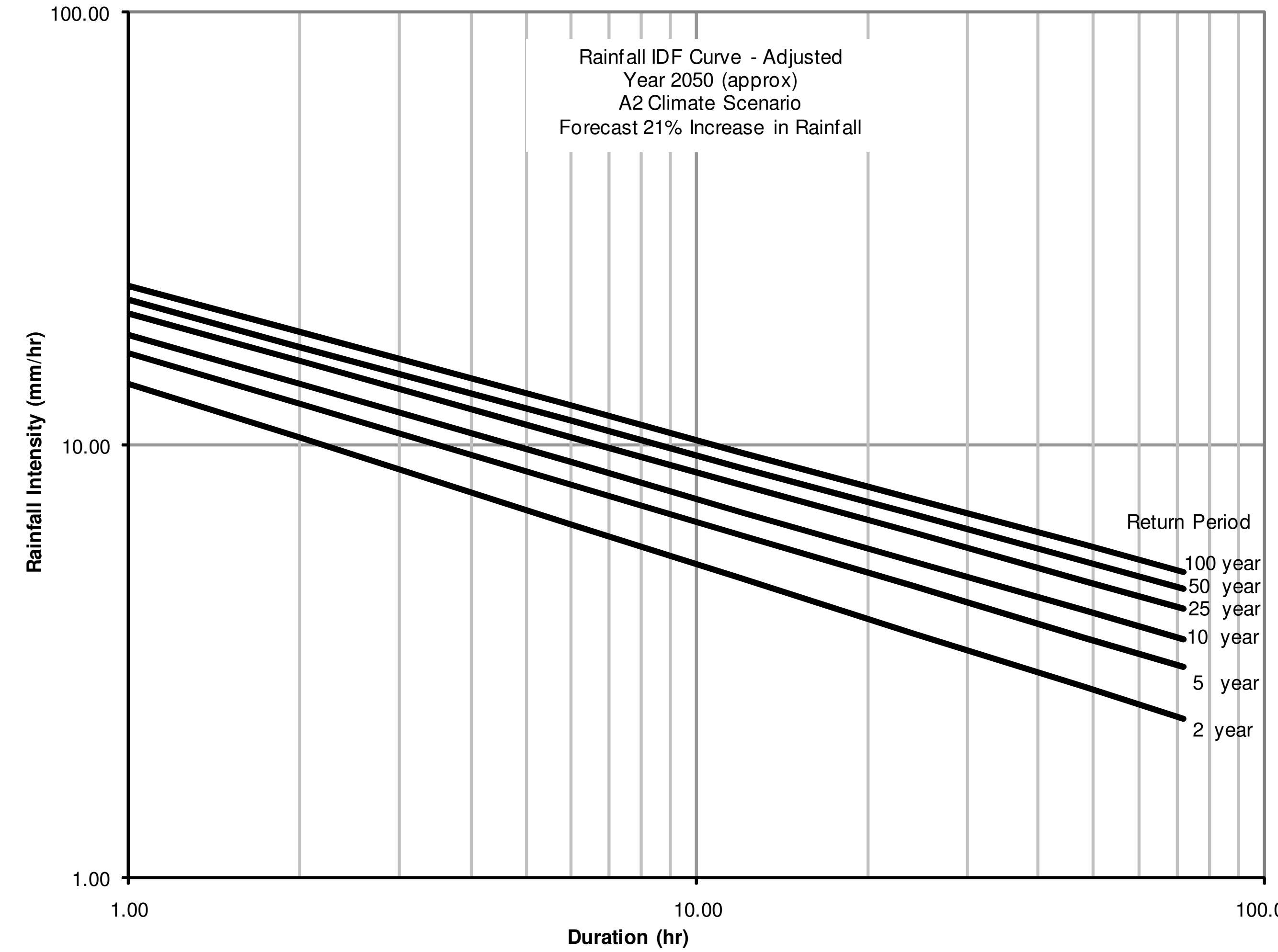
CLIENT: GVRD

PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: VA30 - KERSLAND RESERVOIR

PROJECT No.: 0431-006
FIG No.: 4
REV.:





DURATION	RETURN PERIOD											
	2 year		5 year		10 year		25 year		50 year		100 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	12.9	13.8	15.2	16.3	16.8	18.0	18.8	20.1	20.3	21.7	21.7	23.3
2	9.6	10.4	11.5	12.4	12.8	13.8	14.4	15.6	15.6	16.9	16.8	18.2
6	5.9	6.6	7.3	8.1	8.3	9.1	9.4	10.4	10.3	11.4	11.2	12.3
12	4.4	4.9	5.5	6.2	6.3	7.0	7.2	8.1	7.9	8.8	8.6	9.6
24	3.3	3.7	4.2	4.7	4.8	5.4	5.5	6.3	6.1	6.9	6.7	7.5
48	2.4	2.8	3.1	3.6	3.6	4.1	4.2	4.8	4.7	5.4	5.1	5.9
72	2.0	2.3	2.7	3.1	3.1	3.6	3.6	4.2	4.0	4.6	4.4	5.1

X:\Projects\0431 GVRD\Design\20090206_IDF_Curves\IDF_DN25_NorthVanDH.mxd

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:
DATE: FEB 2009
DRAWN: GLT
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
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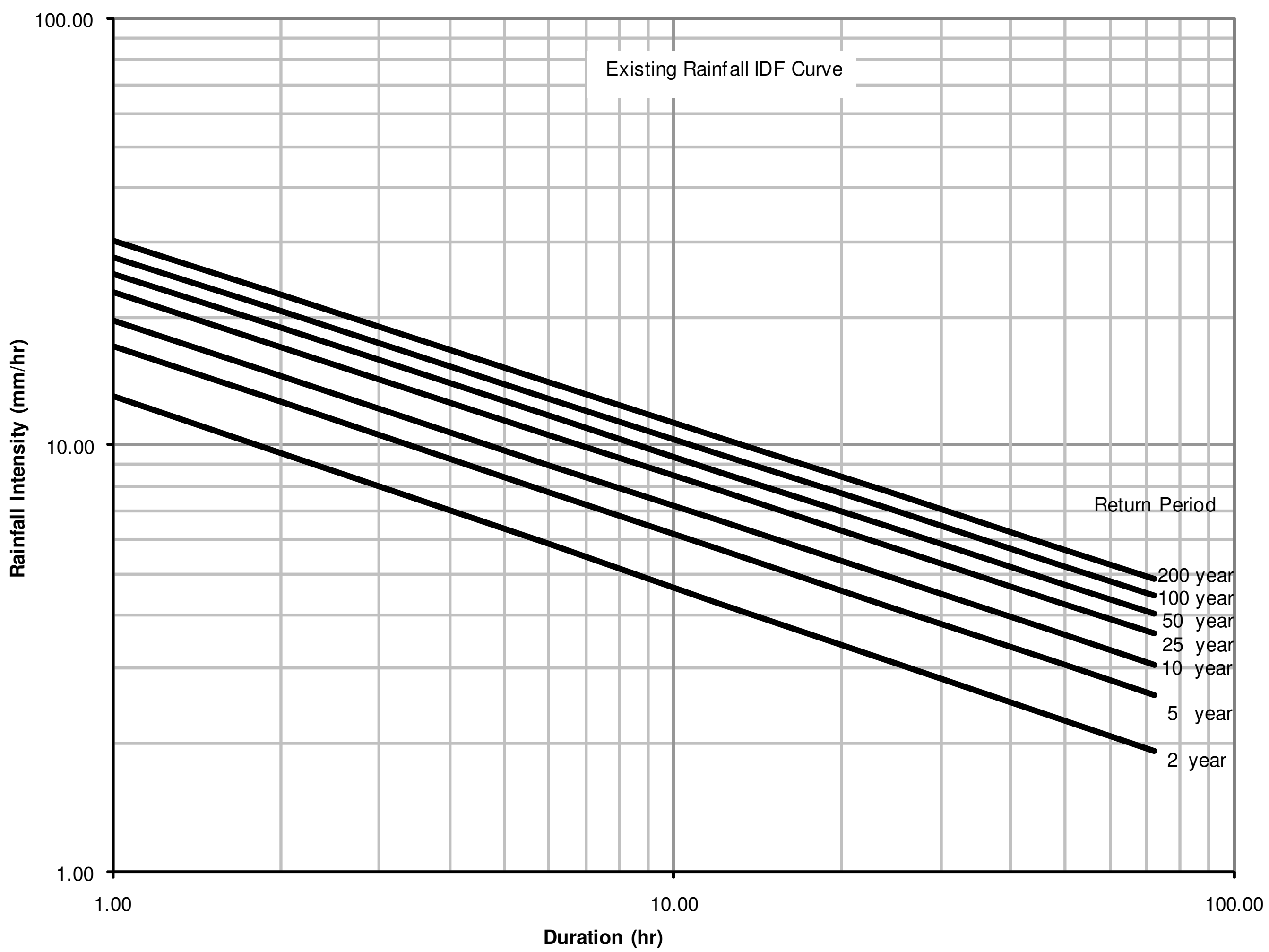
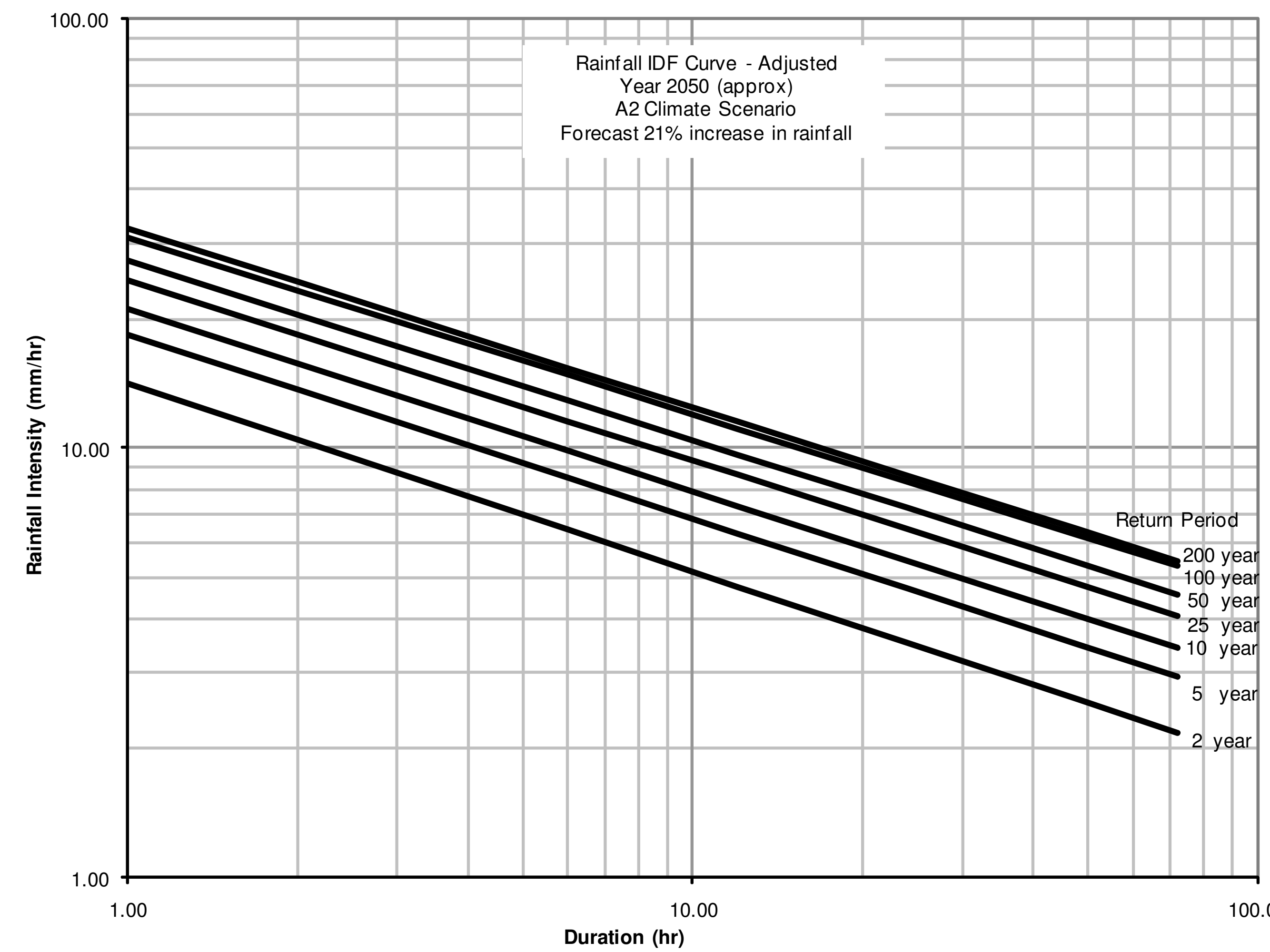
CLIENT: GVRD

PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: DN25 - NORTH VAN DISTRICT HALL

PROJECT No.: 0431-006
FIG No.: 3
REV.:





DURATION	RETURN PERIOD													
	2 year		5 year		10 year		25 year		50 year		100 year		200 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase	Existing	2050, 200 yr, 21% Monthly Rainfall Increase
1	13.1	14.1	17.0	18.4	19.6	21.2	22.9	24.7	25.3	27.3	27.7	31.0	30.1	32.5
2	9.6	10.4	12.6	13.6	14.5	15.8	17.0	18.4	18.8	20.4	20.6	23.3	22.4	24.3
6	5.9	6.5	7.8	8.5	9.0	9.9	10.6	11.6	11.7	12.9	12.9	14.8	14.0	15.4
12	4.3	4.8	5.7	6.3	6.7	7.4	7.8	8.7	8.7	9.6	9.6	11.1	10.4	11.5
24	3.2	3.5	4.2	4.7	4.9	5.5	5.8	6.5	6.5	7.2	7.1	8.4	7.8	8.7
48	2.3	2.6	3.1	3.5	3.6	4.1	4.3	4.8	4.8	5.4	5.3	6.3	5.8	6.5
72	1.9	2.2	2.6	2.9	3.1	3.4	3.6	4.1	4.0	4.5	4.5	5.3	4.9	5.5

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:
DATE: FEB 2009
DRAWN: GLT
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
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CLIENT: GVRD

PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: CW09 - PORT MOODY PUMP STATION

PROJECT No.: 0431-006
FIG No.: 2
REV.:

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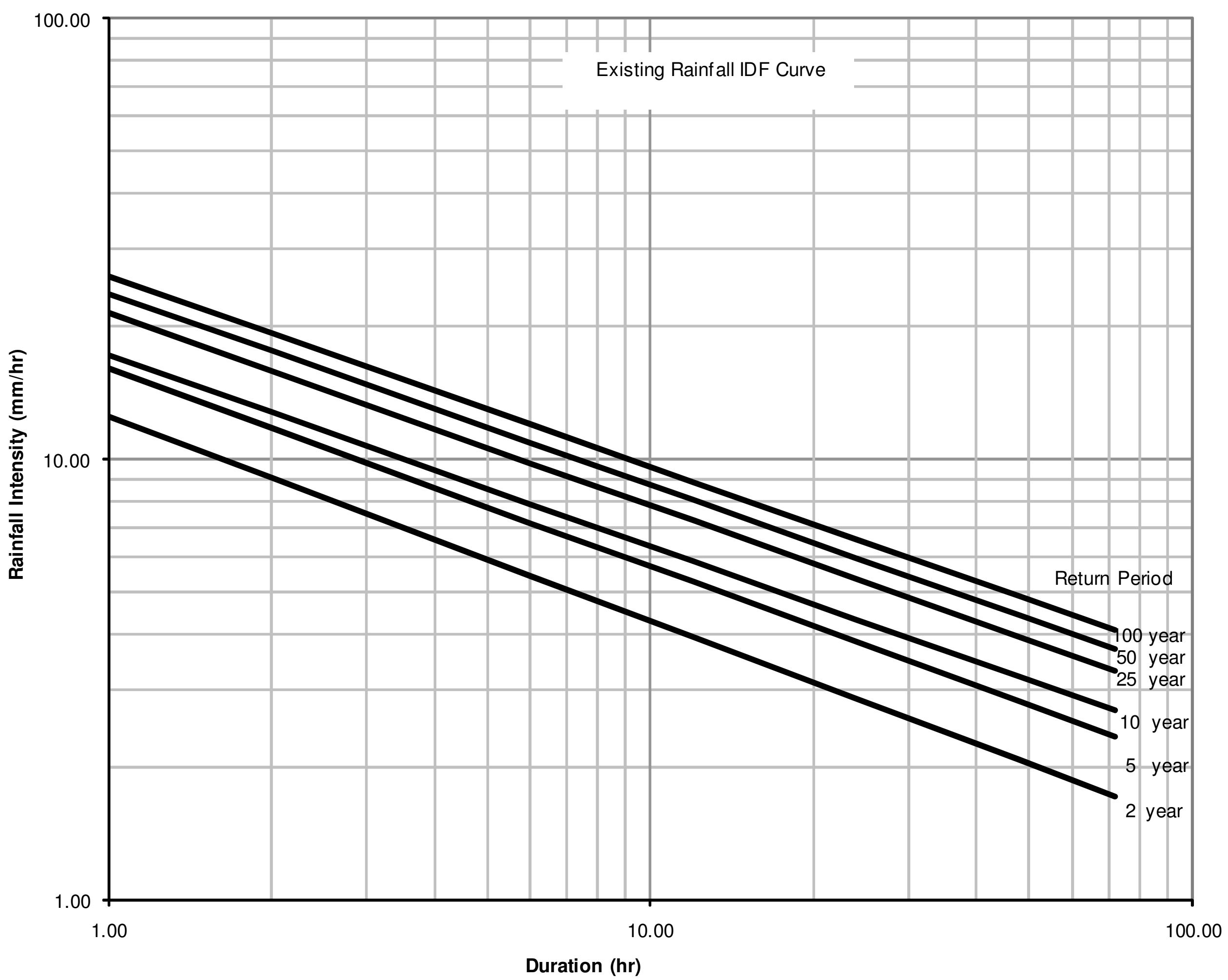

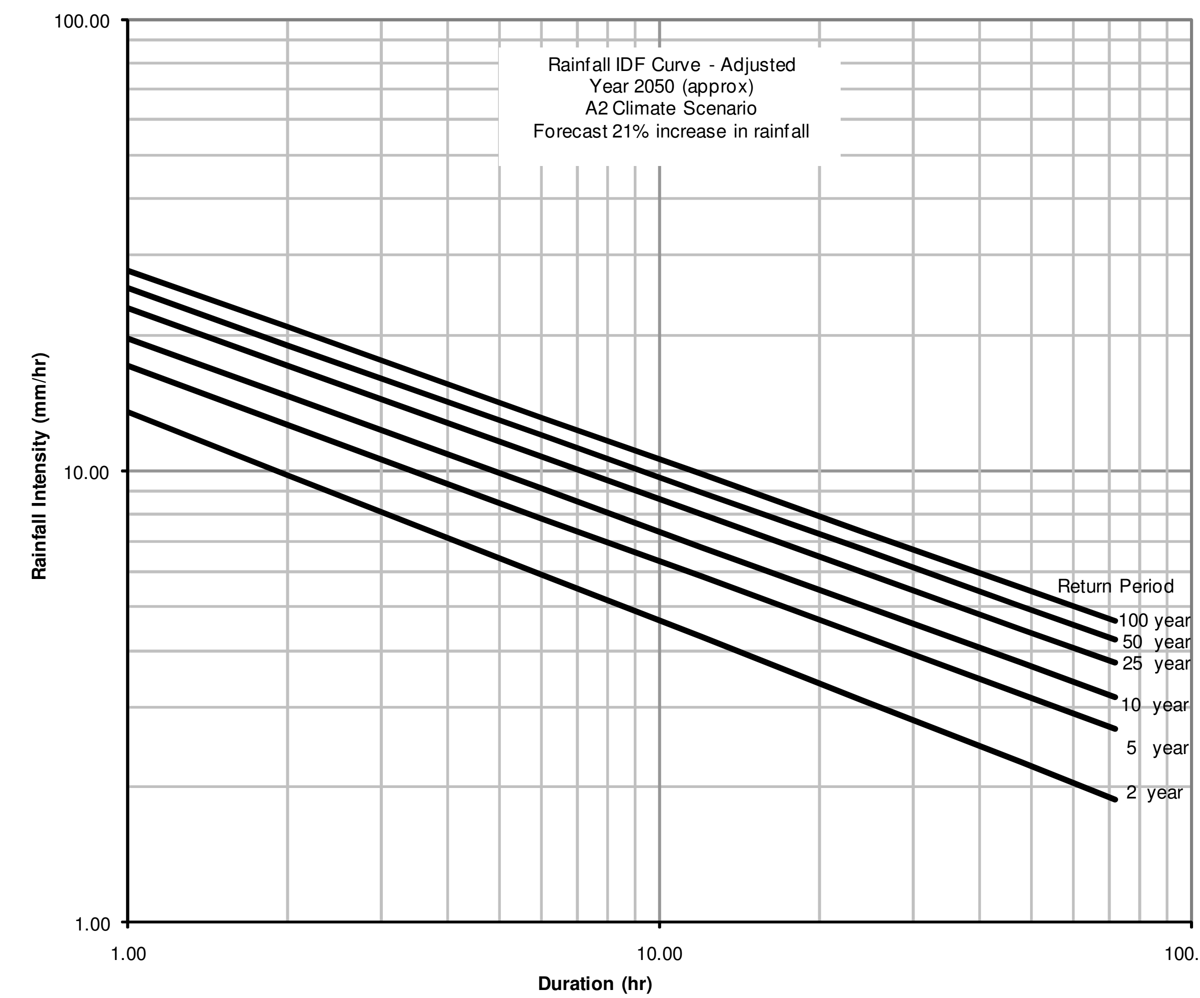

DURATION	RETURN PERIOD											
	2 year		5 year		10 year		25 year		50 year		100 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	12.4	13.5	16.1	17.2	17.2	19.7	21.5	23.0	23.8	25.4	26.0	27.8
2	9.0	9.8	11.8	12.7	12.7	14.7	15.9	17.2	17.6	19.0	19.3	20.8
6	5.4	5.9	7.2	7.9	7.9	9.2	9.8	10.8	10.9	12.0	12.0	13.2
12	3.9	4.3	5.3	5.8	5.8	6.8	7.2	8.0	8.1	9.0	8.9	9.9
24	2.8	3.1	3.9	4.3	4.3	5.1	5.3	6.0	6.0	6.7	6.6	7.4
48	2.1	2.3	2.8	3.2	3.2	3.8	3.9	4.5	4.4	5.0	4.9	5.5
72	1.7	1.9	2.4	2.7	2.7	3.2	3.3	3.8	3.7	4.2	4.1	4.7

X:\Projects\0431 GVRD\Design\20090206_IDF_Curves\IDF_BU07_Sperling.mxd

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:
DATE: FEB 2009
DRAWN: GLT
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: GVRD

PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: BU07 - SPERLING AVE. PUMP STATION

PROJECT No.: 0431-006
FIG No.: 11
REV.: