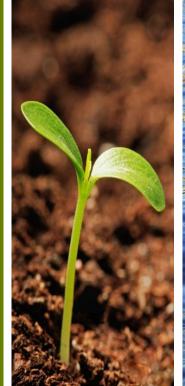
Climate Change: Current and Future Impacts on Erosive Rainfall in Calgary Alberta







My Climate Change Story

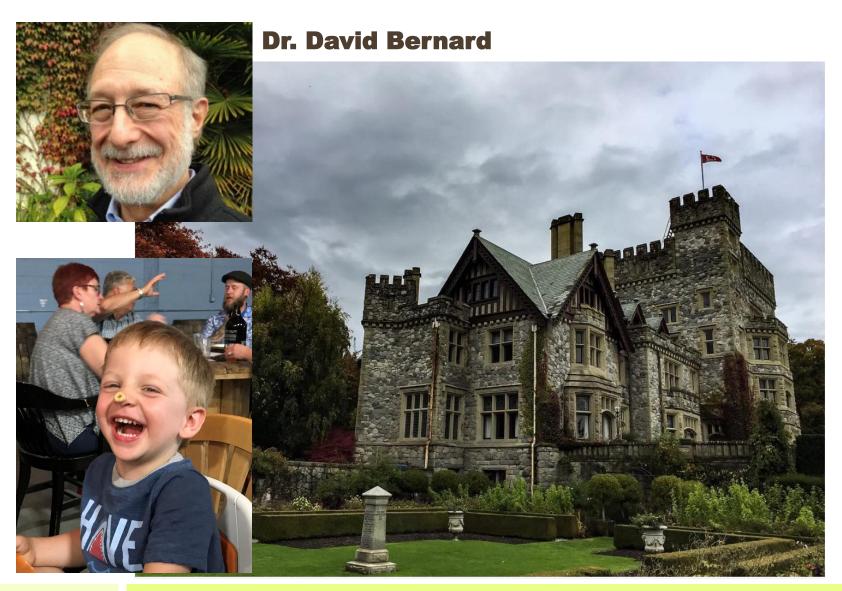


# BEN ETHIER

Masters Of Science Graduate

Erosion Control Technician – City of Calgary

### Royal Roads University



# Calgary, Alberta



# Why Is This Happening?









# A=R\*K\*LS\*C\*P

A= Average Annual Soil Loss

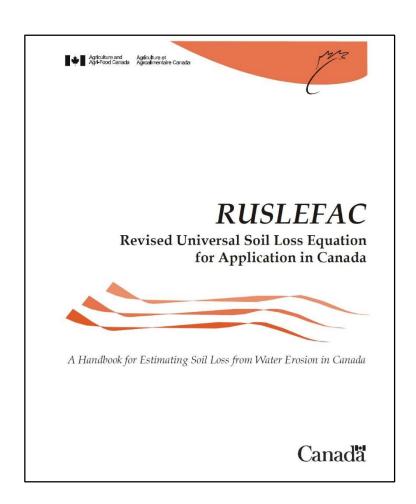
R= Rainfall factor (Constant?)

K= Soil Erodibility (Measured on site)

LS= Length Slope (measures on site)

C= Cover factor (based on practices)

P= Protection factor (based on practices)



# Why This Matters? – Impacts To Rivers



#### Why This Matters? – Impacts To Storm ponds and Pipes



# Why This Matters? – Impacts To Storm ponds and Pipes





# Why This Matters – Drinking Water



# Why This Matters – Recreation and Fish Health



#### Research and Literature Review

Journal of Hydrology 548 (2017) 251-262



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#### Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

#### Research papers

Towards estimates of future rainfall erosivity in Europe based on and WorldClim datasets

Panos Panagos 3.4, Cristiano Ballabio 3, Katrin Meusburger 5, Jonathan Spinoni 3, Chri Pasquale Borrellia,

\*European Commission, Joint Research Centre, Directorate for Sustainable Resources, Via E. Fermi 2749, I-21027 Ispra (VA), Italy
\*Environmental Geosciences, University of Basel, Switzerland

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Georgakakos, Editor-in-Chief, with the
assistance of Jennifer Guohong Duan,
Associate Editor

Keywords. R-factor Rainfall intensification Storminess

#### ABSTRACT

The policy requests to develop trends in soil erosion changes can be res narios of the two most dynamic factors in soil erosion, i.e. rainfall ero recently developed Rainfall Erosivity Database at European Scale (REDI to spatially interpolate rainfall erosivity data have the potential to be future rainfall erosivity based on climate scenarios. The use of a thorou (Gaussian Process Regression), with the selection of the most appropri tion temperature datasets and bioclimatic layers) allowed to predict tion, temperature datasets and blockmant layers, anowed to predict mate change scenarios. The mean rainfall erosivity for the European U to be 857 MJ mm ha<sup>-1</sup> h<sup>-1</sup> yr<sup>-1</sup> till 2050 showing a relative increase (2010). The changes are heterogeneous in the European continent der of most erosive months (hot period: April-September). The output resu tion of future rainfall erosivity taking into account the uncertainties of © 2017 The Authors, Published by Elsevier B.V. This is an open access ar

#### 1 Introduction

Soil erosion is one of the main European environmental threats, particularly in Southern Europe (Panagos et al., 2015a). Its prevention and mitigation is a key ecosystem service to monitor and access spatially and temporally (Guerra et al., 2016). Accelerated soil erosion may lead to a decrease of ecosystem stability, land productivity, land degradation in general and a loss of income for farmers (Salvati and Carlucci, 2013). Soil erosion and more generally land degradation is driven by unsustainable land management due to increasing human pressure enhanced by climate change (Helldén and Tottrup, 2008). The extent, frequency and magnitude of soil erosion in Europe is expected to increase due to a general increase of extreme rain fall events caused by climate change (Pruski and Nearing, 2002; Deelstra et al., 2011)

The prediction of soil erosion changes in the future are mainly dependent on modeling future rainfall erosivity, land use changes and impacts of policies on soil loss. The most commonly used erosion models are the the various types of the Universal Soil Loss

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Equation (USLE) originally develor (1978). In the proposed algorithms proportional to rainfall erosivity (I input factors. While rainfall erosiv rainfall in soil erosion, the soil eroc the soil properties defining the sus the cover management (C-factor) ta and management in agricultural land ness (LS-factor) accounts for the top port practices (P-factor) consider measures. A modified version of the Soil Loss Equation (RUSLE), was or et al. (1997), and has been recently a for the estimation of soil loss by (Panagos et al., 2015a). Among other past Pan-European soil erosion asse rates the option of running climate

policy scenarios. Rainfall erosivity is a multi-annu rainfall kinetic energy and intensity d on sheet and rill erosion (Wischme fall erosivity of a given storm in RUSI

#### Potential changes in rainfall erosivity in the U.S. with climate change during the 21st century

M.A. Nearing

ABSTRACT: The erosive power of rainfall can be expected to change as climate changes. Such ADSTRACT: The evisible power of rainflat can be expected to know, a student configuration for evisive changes are likely to have significant impacts on local and national soil conservation strategies. This study uses results of climate change scenarios from two coupled Atmosphere-Ocean Global Climase Models to investigate the possible levels and patterns of change that might be ex-pected over the 21st century. Results of this study suggest the potential for changes in rainfall erosivity across much of the continental United States during the coming century. The magnitude of change (positive or negative) across the country over an 80 year period averaged between 16–58%, depending upon the method used to make the predictions. Some areas of the country showed increases and others showed decreases in erosivity. Spatial distributions of calculated erosivity changes indicated areas of both consistency and inconsistency between the two climate

Keywords: Atmosphere-ocean global climate models, precipitation, RUSLE, soil erosion

period), and there is less than one chance

in a thousand that this observed trend

could occur in a quasi-stationary climate.

Karl et al. (1996) also observed an in

crease in proportion of the country expe-

riencing a greater than normal number of

Atmosphere-Ocean Global Climate mod-

els also indicate potential changes in rainfall patterns, with changes in both the number of

wet days and percentage of precipitation com-

ing in intense convective storms as opposed

to the product of total rainstorm energy and maximum 30 minute rainfall intensity

during a storm (Wischmeier and Smith

1978). The relationship first derived by

Wischmeier and Smith has proved to

be robust and is still used today in the

Revised Universal Soil Loss Equation

(RUSLE) (Renard et al. 1997), which is

the current technology applied in the

United States for conservation planning

and compliance. Studies using a physical-

ly-based, continuous simulation model of

erosion have also substantiated the geo-

graphic trends of published R factors for

et al. 1996).

several parts of the United States (Baffaut

A direct computation of the rainfall

erosivity factor, R, for the RUSLE model

requires long term data for rainfall amounts and intensities. Current global

circulation models do not provide details

(McFarlane et al. 1992; Johns et al. 1997).

wet days.

oil erosion rates may change in response to changes in climate for a variety of reasons, including climatic effects on plant biomass production, plant residue decomposition rates, soil microbial activity, evapotranspiration rates, soil surface sealing and crusting, and shifts in land use necessary to accommodate a new climatic regime (Williams et al. 1996). However, the most conse-quential effect of climate change on water erosion will be in changes of erosive power, or erosivity, of rainfall.

Studies using erosion simulation models (Nearing et al. 1989; Flanagan and Nearing 1995) indicate that erosion response is much more sensitive to the rainfall amount and intensity than to other environmental variables (Nearing et al. 1990). Warmer atmospheric temperatures associated with greenhouse warming are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events (IPCC 1995). Such a process may already be taking place in the United States. Historica weather records analyzed by Karl et al. (1996) indicate that since 1910 there has been a steady increase in area of the United States affected by extreme precipi tation events (> 50.8mm in a 24 hr

Mark A. Nearing is a scientist with the U.S. Department of Agriculture, Agricultural Research Service with the National Soil Erosion Research Laboratory at Purdue University in West Lafayette.

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vide scenarios of monthly and annual changes in total precipitation around the Renard and Freimund (1994) evaluated erosivity at 155 locations within the continental United States, and developed

requisite for a direct computation of R factors (McFarlane et al. 1992; Johns et

al. 1997). However, the models do pro-

statistical relationships between the R factor and both total annual precipitation at the location and a modified Fournier coefficient (Fournier 1960: Arnoldus 1977) F. calculated from monthly rainfall amounts as

$$F = \frac{\sum_{i=1}^{12} P_i^2}{P}$$
(1)

where p, (mm) is the average monthly precipitation and P (mm) is the average annual precipitation.

Derived relationships between R factor and P developed by Renard and Freimund (1994) were

R factor =  $0.04830P^{1.610}$  (r<sup>2</sup> = 0.81) (2)<sup>1</sup> R factor = 587.8 - 1.219P + 0.004105P2

and the relationships between R factor

 $(r^2 = 0.73)$  (3)

R factor =  $0.7397F^{1.847}$  ( $r^2 = 0.81$ ) (4)<sup>2</sup> R factor = 95.77 - 6.081 + 0.04770F<sup>2</sup>  $(r^2 = 0.75)$  (5)

to longer duration, less intense storms where the R factor is in units of (MJ mm Rainfall erosivity is strongly correlated

Equations 2 and 4 provided a better fit on the lower end of the data range, and equations 3 and 5 fit better on the upper end; therefore, Renard and Freimund (1994) recommended using equation 2 when P was < 850 mm and equation 3 when P was > 850 mm. Likewise, they recommended using equation 4 when F was < 55 mm and equation 5 when F was > 55 mm.

The objective of this study was to estimate potential changes in rainfall erosivity in the United States during the 21st century under global climate change scenarios generated from two coupled Atmosphere-Ocean Global Climate models.

#### **Methods and Materials**

Two coupled Atmosphere-Ocean Global Climate models from which results were used were developed by the

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erosivity in the past and future due to climate ntral part of India



Khare, Sananda Kundu

ment & Management, Indian Institute of Technology, Roorkee, India

Temporal change in rainfall erosivity varies due to the rainfall characteristic (amount, intensity, fre quency duration) which affects the conservation of soil and water. This study illustrates the variation of rainfall erosivity due to changing rainfall in the past and the future. The projected rainfall is generated by SDSM (Statistical DownScaling Model) after calibration and validation using two GCMs (general circulation model) data of HadCM3 (A2 and B2 scenario) and CGCM3 (A18 and A2 scenario). The selected study area is mainly a cultivable area with an agricultural based economy. This economy depends on rainfall and is located in a part of the Narmada river basin in central India. Nine rainfall locations are selected that are distributed throughout the study area and surrounding. The results indicate gradually increasing projected rainfall while the past rainfall has shown a declined pattern by Mann-Kendall test with statistical 95% confidence level. Rainfall erosivity has increased due to the projected increase in the future rainfall (2080 s) in comparison to the past. Rainfall erosivity varies from -32.91% to 24.12% in the  $2020_5$ , -18.82 to 75.48% in 2050 s and 20.95-202.40% in 2008. The outputs of this paper can be helpful for the decision makers to manage the soil water conservation in this study area.

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ND license (http://creativ

infall erosivity (R factor) is an imon by water, which is directly related I (Loho Frankenberger Flanagan & Rainfall erosivity has a capability to ll (van Dijk, Bruijnzeel, & Rosewell mposed by Govers (1991): Hudson Universal Soil Loss Equation (RUSLE) (Renard Foster Weesies McCool & ivity are not a linear relation to soil on the size of raindrops, intensity (Salles, Poesen, & Sempere-Torres fter high rainfall intensities to create will increase the detachment capa & Sempere-Torres, 2002), Nature of ation of intensity, amount, duration, occur due to climate change impact. d the R factor of RUSLE to ass ess the

International Research and Training Center na Water and Power Press

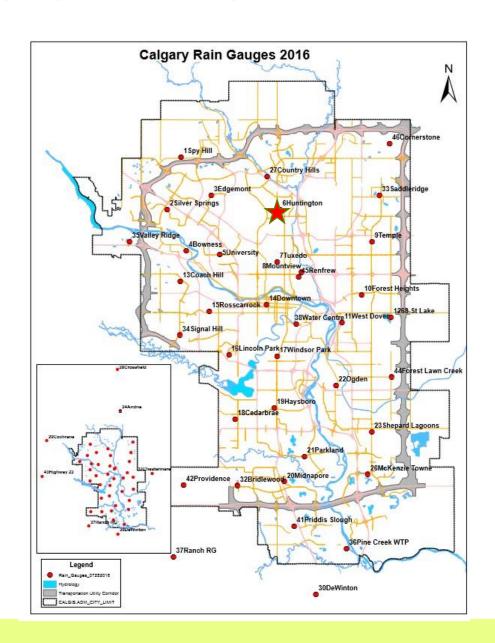
rainfall erosivity of Europe. Nearing et al. (2005) also indicated a change in the runoff and soil erosion due to changed precipitation. Rainfall erosivity is an important factor as rainfall or precipitation is considered as the main driving force of soil erosion and has direct influence on the soil particle detachment and transport of the eroded particles by runoff (Wischmeier & Smith, 1978).

Various parameters of climatic variables are used to detect the trend analysis using past historical climatic data by various statistical methods (Kumar & Jain, 2010; Kumar, Jain, & Singh, 2010; Kundu Khare Mondal & Mishra 2014: Kundu Khare Mondal & Mishra, 2015; Mondal, Khare, & Kundu, 2015; Pal & Al-Tabbaa, 2010; Sonali & Kumar, 2013; Subash, Singh, & Priya, 2013; Tabari, Talaee, Ezani, & Some'e, 2012; Wang et al., 2013; Yue & Hashino, 2003;). Different types of GCM (General Circulation Model) data are used for predicting the future rainfall and temperature (Anandhi, Srinivas, Nanjundiah, & Nagesh Kumar, 2008; Chen, Xu, & Guo, 2012; Chu, Xia, Xu, & Singh, 2010; Hassan, Shamsudin, & Harun, 2014; Mondal et al., 2014; Raje & Mujumdar, 2011; Yang, Li, Wang, Xu, & Yu, 2012). GCM data are not used directly in the hydrological model at local level study due to coarse resolution of the data. Different types of methods are used to downscale into local level using coarse resolution GCM data (Carter & Kenkyū, 1994). For climate downscaling study, different established methods are, Artificial Neural Networks (ANN), Multiple Linear Regression (MLR), Support Vector Machine (SVM) (Duhan & Pandey, 2015;

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<sup>\*</sup> Corresponding author.

### Rain gauges – Huntington Hills station



# Updating R values

•e=0.119 + 0.0873 log10 /

•E=
$$\sum_{k}^{p} e_{k} \Delta V_{k}$$

\* Units for the R-value are (MJ\*mm/Ha\*H\*Y) and were intentionally left out of both the presentation and paper for readability. This is typical for similar papers

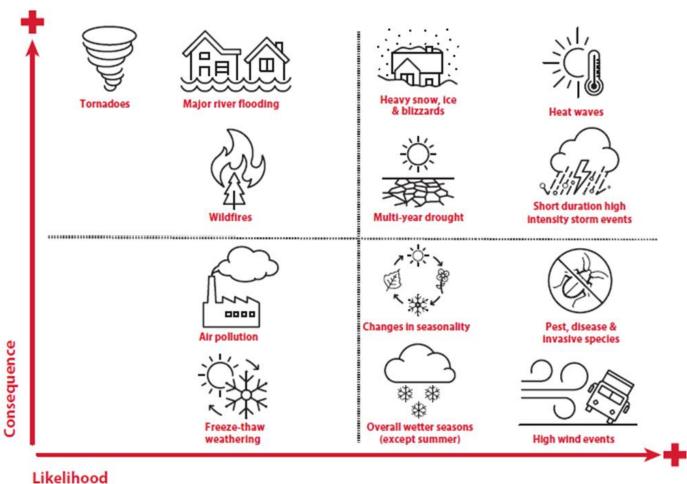
# Running the Data

1	CHANNEL # 6					
2	LOCATION: "HUNTINGTON "					
3	SUMMARY OF RECORDED RAINFALL					
4	Date	Time	Volume (mm)	6 h volume	Storm Event	15 Min Volume
5	4/21/2006					0
6	4/21/2006					0
7	4/21/2006	19:05	0			0
8	4/21/2006	19:10	0			0
9	4/21/2006	19:15	0			0
10	4/21/2006	19:20	0			0
11	4/21/2006	19:25	0			0
57354	11/6/2006	22:00	0	0		0
57355	11/6/2006	22:05				0
57356	11/6/2006	22:10	0	0		0
57357	11/6/2006	22:15	0	0		0
57358	11/6/2006	22:20	0	0		0
57359	11/6/2006	22:25	0	0		0
57360	11/6/2006	22:30	0	0		0
57361	11/6/2006	22:35	0	0		0
57362	11/6/2006	22:40	0	0		0
57363	11/6/2006	22:45	0	0		0
57364	11/6/2006	22:50	0	0		0
57365	11/6/2006	22:55	0	0		0
57366	11/6/2006	23:00	0	0		0
57367	11/6/2006	23:05	0	0		0
57368	11/6/2006	23:10	0	0		0
57369	11/6/2006	23:15	0	0		0
57370	11/6/2006	23:20	0	0		0
57371	11/6/2006	23:25	0	0		0
57372	11/6/2006	23:30	0	0		0
57373	11/6/2006	23:35	0	0		0
57374	11/6/2006	23:40	0	0		0
57375	11/6/2006	23:45	0	0		0
57376	11/6/2006	23:50	0	0		0
57377	11/6/2006	23:55	0	0		0
57378	11/7/2006	0:00	0	0		0
57379						
57380						

X30

### The Risk to Calgary and where this study fits

# Calgary's Climate Risks profile



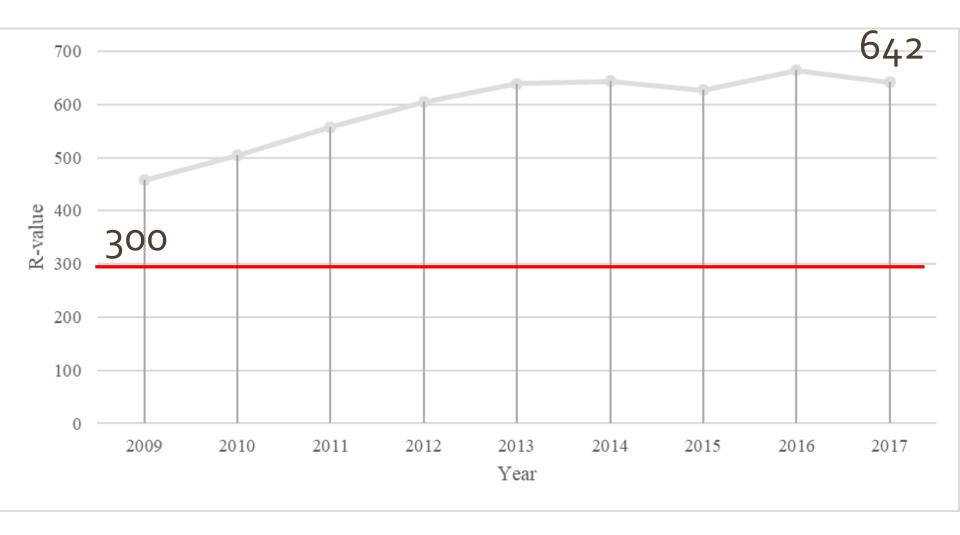
# Climate change

•F= 
$$(\sum_{i=1}^{12} pi^2)/P$$

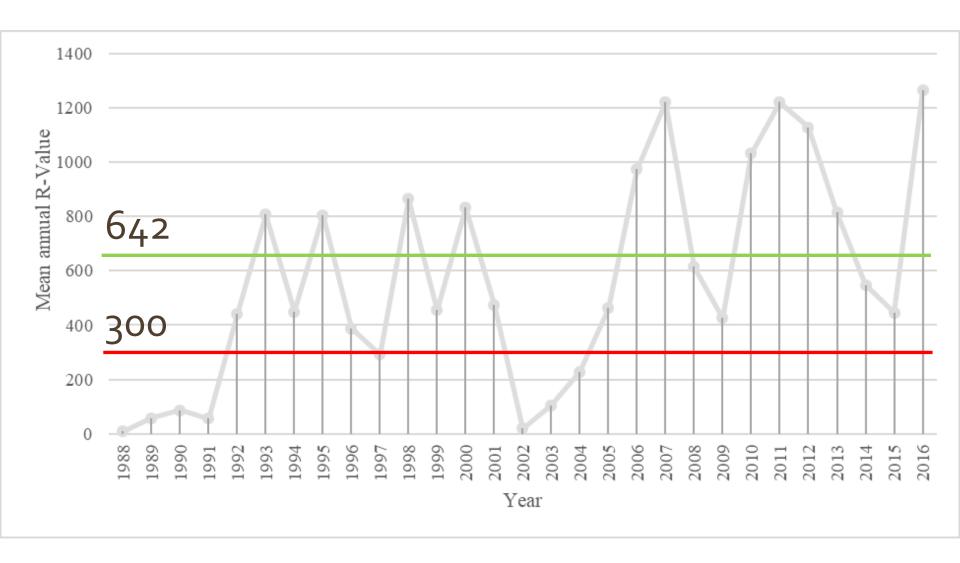
•R-value =  $0.7397F^{1.847}$ 

•R-value =  $95.77-6.081+0.04770F^2$ 

#### Findings - R-value has increased 2.14 times



#### Findings – Large Year Over Year Fluctuations in R value



#### Comparative 22 year average 4.5 to 8.5



#### Short Duration High Intensity Rainfall



- most erosive rainstorms contributed an average of 43% of erosive rainfall for the year
- second most erosive storm contributed an average of 19%

### Short Duration High Intensity Rainfall



- The statistical relationship used to predict erosive rainfall in the future may not be applicable in Calgary
- Only moderately successful when tested; tended to underrepresent R-value

# What This Means – Moving Forward



### What This Means – Estimates May Be Incorrect

Table 2

Sites approved in 2017 that meet the City of Calgary approval limit (2 tonnes/hectare/year) under accepted (300) and calculated (642) R-values

	R-Value			
Variable	Accepted (300)	Calculated (642)		
Total Number of sites	181	181		
Number of sites that pass	170	113		
Percent of total that pass	949	62%)		

Notes: only sites with the area information were included in the totals

#### What This Means – Estimates May Be Incorrect

Table 3

Difference in estimated sediment approved to enter the storm system based on accepted (300) and calculates (642) R-values

		_	
Variable	Accepted (300)	Calculated (642)	Difference
Yield with controls	1646	3521	1876
Yield without controls	30575	65431	34856
Estimated sediment kept out by controls	29093	62254	33163

Notes: only sites with years where average annual site soil loss has been calculated

### What This Means – Estimates May Be Incorrect



OR

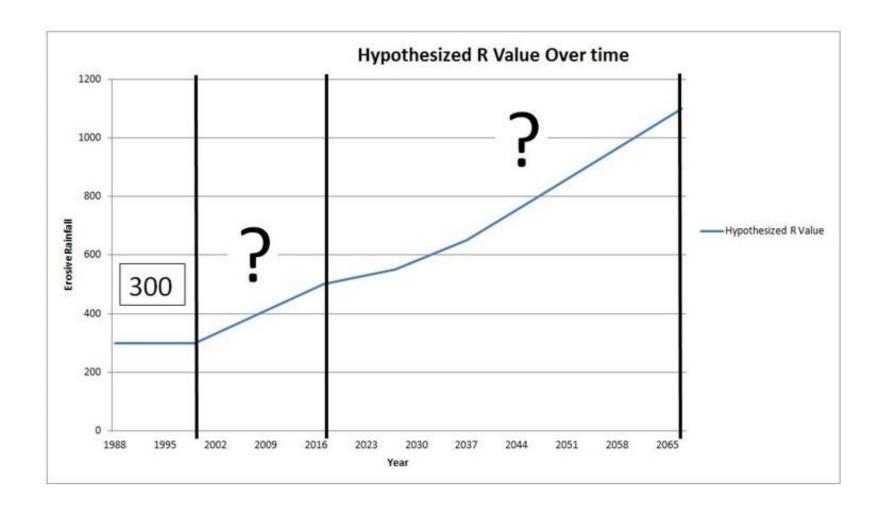
ONE





X3.3

#### What This Means – Future R-values



#### What This Means – Increased Practice Failure

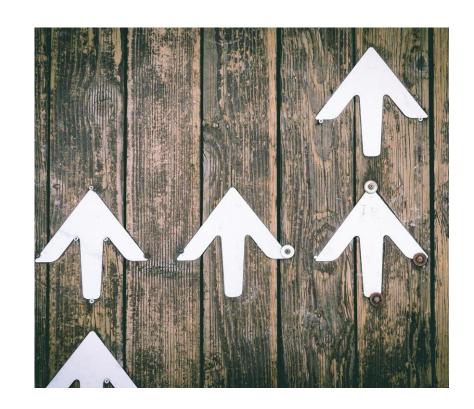


#### What This Means – Erosive Rainfall Is Likely To Increase



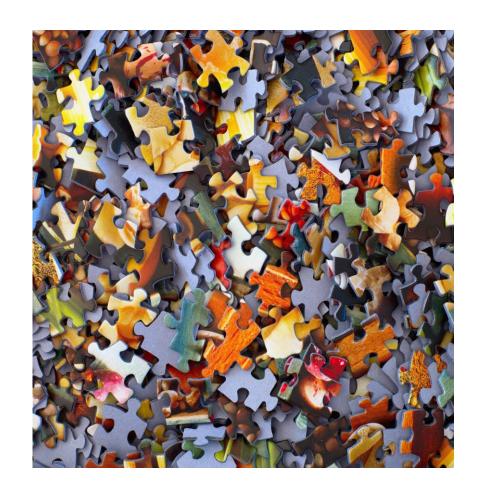
#### Conclusions

- The erosive rainfall value increased from 300 to 642. Or 2.14 times.
- Potential impact of increasing soil loss by 1,800 tns to nearly 35,000 tns
- 28% under a carbon reduced future and 31% under business as usual.
- A small proportion of storms contributed a large proportion of erosive rainfall
- Designing to a 22-year average r value may be setting a site up for annual failures.



#### My Ask of The City of Calgary

- These findings are relevant for the Huntington Hills station.
- The City of Calgary should consider carefully implementing these findings
- Care should be taken prior to implementing these findings



### My Ask of ESC Stakeholders

- Keep an open mind
- Remember what it is we are all protecting







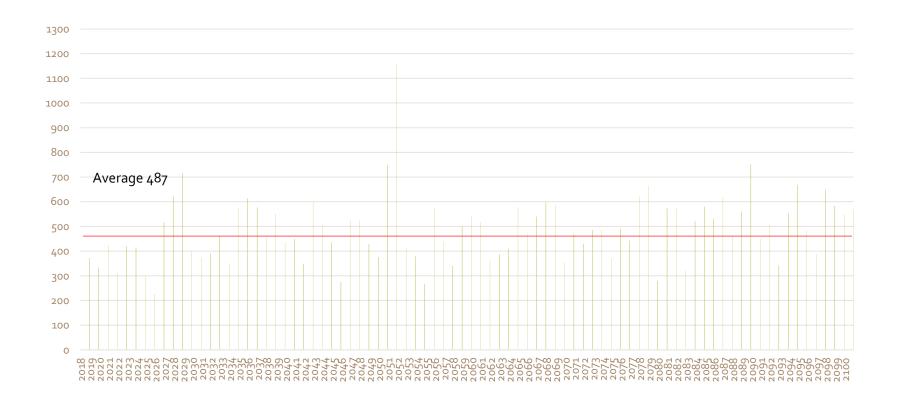
#### Questions?

#### **Contact Info**

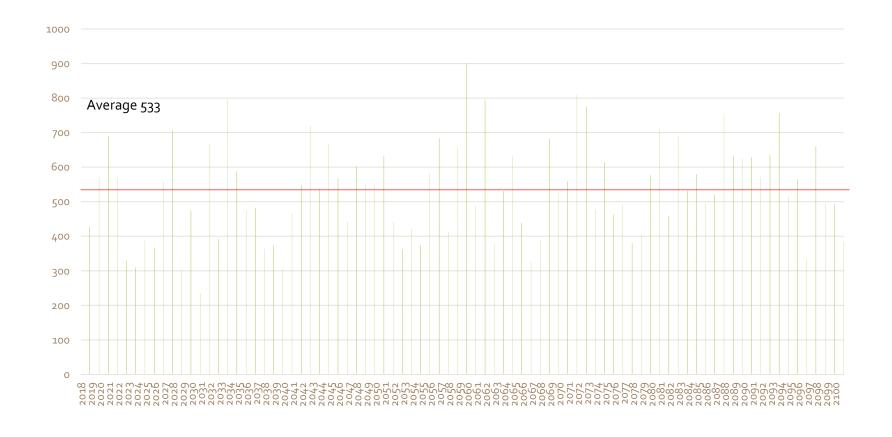


Ben Ethier 403-268-2082 Ben.ethier@Calgary.ca

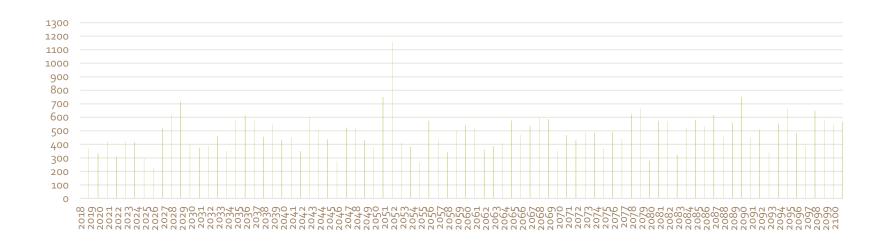
### Annualized rainfall RCP4.5

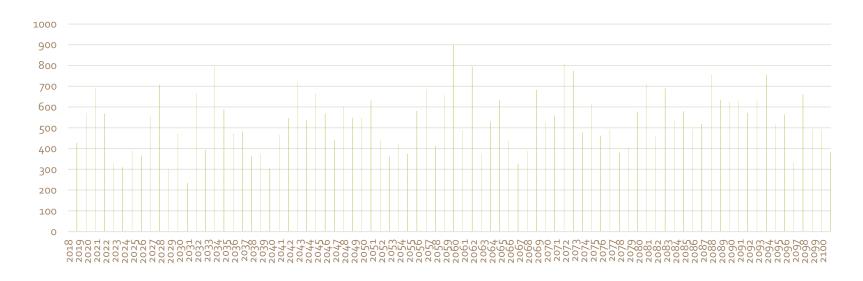


### Annualized Rainfall RCP 8.5

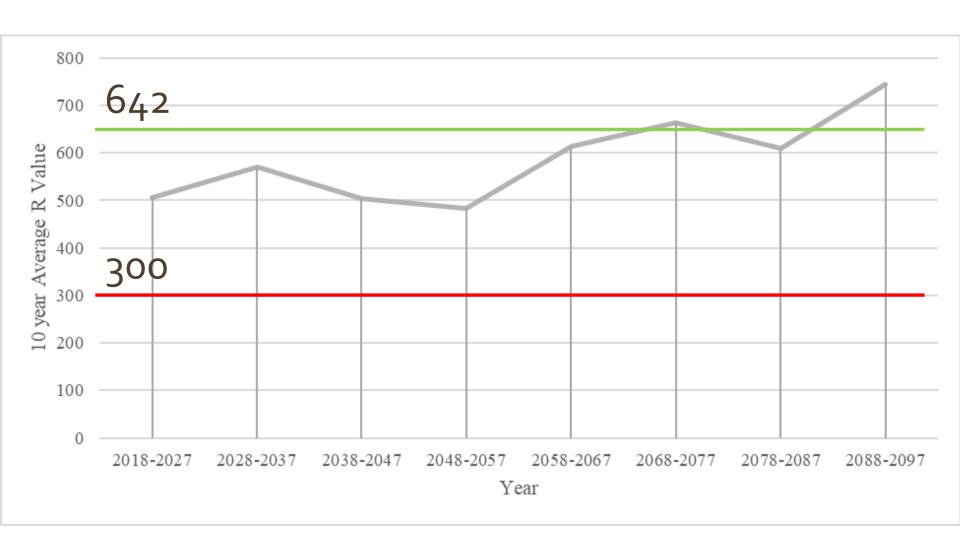


### Comparative annualized 4.5 to 8.5





### Findings- Climate Change – RCP 8.5 (Business as usual)



# Findings - Climate Change — RCP 4.5 (Climate Stabilization by 2100)

