Storslysia

Social insurance program and relocation scheme

SOCIETY OF ACTUARIES

UNSW SYDNEY

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Executive Summary

This report will be providing information on our designed social natural hazards insurance program for Storslysia against the economic losses and social impacts of the increasing number of extreme catastrophes in the country of Storslysia due to climate change. The diverse geography of Storslysia is considered in terms of the different levels of the financial impact caused by each type of disaster and how insurance products can be introduced for different geographical areas. The report also explores the feasibility of voluntary relocation programs aimed to mitigate the damage from natural disasters ahead of time.

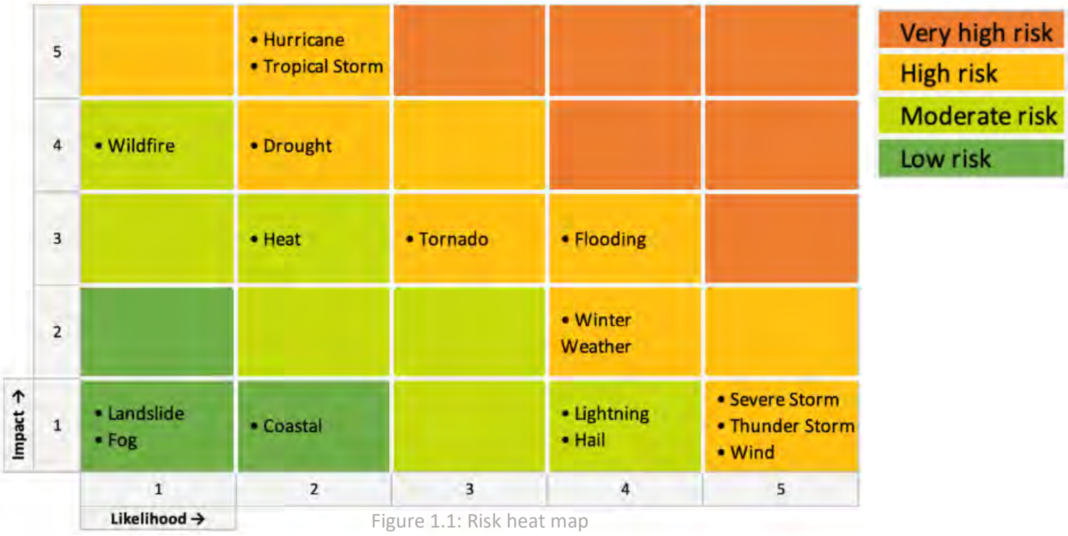
According to Intergovernmental Panel on Climate Change (IPCC), the globe is experiencing ascending frequency of extreme natural disasters. Comprehensive data analysis of the risk of catastrophe-related displacement will be provided, along with predictions on all these changes. And more importantly, our social insurance plan and relocation plan will be developed correspondingly to achieve the ultimate goal of reducing the socio-economic impact of climate change on Storslysia over the next 130 years (2020-2150).

Given the limitations and uncertainties of the data, several assumptions were made based on internal data and additional research, and the rationale and analysis are presented in the Appendix. Due to the complexity and variability of climate change, we have combined the IPCC assumptions on socio-economic development, energy use and other factors on climate change impacts and predicted the frequency of hazardous events under different SSP scenarios using the provided frequency prediction model.

1. Objectives of Analysis

1.1 Background

Storslysia has suffered through various major disasters in the past decades, and, with the fast-approaching effects of climate change, the rate and severity of these disasters appear to be ramping up. The number of cases of natural disasters reported in the past decade makes up almost a third of the total reports in the last 60 years. With the looming threat of climate change, it has become imperative to put in place proper social insurance programs that target mitigating and reducing the cost of oncoming natural disasters.



Impact ↑					
5		• Hurricane • Tropical Storm			
4	• Wildfire	• Drought			
3		• Heat	• Tornado	• Flooding	
2				• Winter Weather	
1	• Landslide • Fog	• Coastal		• Lightning • Hail	• Severe Storm • Thunder Storm • Wind
	1	2	3	4	5
	Likelihood →				

Very high risk
High risk
Moderate risk
Low risk

Figure 1.1: Risk heat map

Yet, amongst the natural hazards that occur in Storslysia, most of the events had a negligible amount of property damage, injuries, and fatalities. Henceforward, the low-risk hazards would be retained. Whilst our insurance program would be primarily designed to transfer the moderate to high-risk hazards along with relocation schemes to reduce the overall risk exposure of Storslysia to natural hazards as below.

1.2 Reserving for future disasters

A framework that predicts the consequential costs of natural hazards will be built along with thoughtful financial analysis to advise on building adequate reserves with elevated degrees of certainty to ensure our insurance program's feasibility and sustainability against extreme disasters.

1.3 Voluntary relocation program

As introduced above, our insurance program will be constructed with a relocation program that includes voluntary and post-disaster involuntary relocation. Based on our research, we would focus on relocation schemes that help reduce our exposure to flood-related disasters by a significant margin with a high degree of certainty. On the other hand, we would provide recommendations on infrastructure and private housing development to reduce the subsequent cost of other high-risk disasters.

2. Program Design

As introduced in sections 1.2 and 1.3, the two main programs will be:

1. A comprehensive social insurance program that covers many of the major causes of property damage in Storslysia.
2. A voluntary relocation program aimed at reducing costs arising from flooding-related events.

2.1 Social Insurance Program

Our suggestion is to have an overarching social insurance that covers natural disaster damages to property and possessions and temporary or permanent relocation that arises from the disaster. This program is aimed to cover the damages caused by hurricanes, tropical storms, tornados, hurricanes, flooding, winter weather and flooding-related damages. Importantly, the program was designed to exclude disasters including wildfires, drought, landslides and fog due to differences in nature and the rarity of such events leading to the lack of data to properly predict cost and frequency.

We suggest the program be mandatory for the citizens of Storslysia. Research into natural disaster insurance policies has shown that voluntary programs run the risk of “charity hazard” and have lower participation rates than expected [reference 1]. The premiums collected over the years will be placed into a government reserve. This reserve will build up over time and will be capable of paying for costs related to natural disasters when it occurs.
This insurance program will be triggered when a disaster with damage magnitude over Ᵽ15,000 has occurred. It will cover all property and possession losses caused by the disaster and the temporary relocation costs for residents affected. Upon severe disaster and infeasibility of repairment of the property, the program will provide involuntary relocation based on the original poverty value.

2.2 Voluntary Relocation Program

Alongside the social insurance program, we want to specifically aim to lower costs arising from flooding and flooding-related damages. Historically, these account for up to 30% of all total major natural disaster events. We believe that a sizeable proportion of these can be mitigated through the planned retreat from households in high-risk areas. Research from other countries has shown that properties that are in 1-in-100-year flood risk zones (expecting 1 flood every 100 years) make up 3 to 7% of the population. In Storslysia, this translates to over 200,000 housing units that will have to be relocated. This is clearly not feasible, and we will have to make further assumptions on the proportion of houses that are even higher risk, those who are potentially in 1-in-10-year flood risk zones.
In our models, we will discuss the feasibility of mitigating flood damage by offering fully subsidised voluntary relocation for households in these 1-in-10-year flood risk zone areas. However, due to the lack of geographical data, many assumptions will have to be made about Storslysia’s population. In section 3 where we will discuss our relocation models, we will give a more detailed rundown on the optimistic and pessimistic assumptions we have on the population in high-risk areas, the amount of risk mitigation and the participation rate of the program.
We plan to have the program slowly adopted over the next 10 years, aiming to move 10% of the maximum participation rate until reaching the maximum participation.

3. Pricing and Costs

3.1 Methodologies

Table 1: Methodologies

Methodology	Application	Further Support	Justification
ARIMA Modelling	Predicting the expected number of minor, medium and major disasters	Appendix B	Generally accepted method for evaluating trends in time series data
Provided SSP model	Projecting the expected number of minor, medium and major disasters into the future under different SSP scenarios	-	-
Fitting distributions	Generating possible future costs arising from natural disasters	Appendix C	Inflation adjusted cost are close to be randomly distributed over time
Compound Poisson Process and Ruin Simulation	Accessing initial reserve required for the social insurance program to succeed	Appendix D	Generally accepted method for evaluating claims data and value at risk
General Research	Researching past experiences into relocation to make assumptions on the program	References	Due to the lack of geographic and population data provided, similar data from other countries are consulted

3.2 Assumptions

The domestic economy of Storslysia has sustained a healthy level of inflation in most of the years from 1960 to 2020. Without further information on the economy, we were unable to determine the change in the relative price of property damage against income. We assume the real value of consequential poverty damages will vary at the same rate as income and GDP. Hence, past poverty damage will be analysed in form of present value from 1960 to 2020 with the provided inflation statistics and future inflation would be omitted in our analysis.

For the purpose of modelling, a number of assumptions are required due to the lack of data:

- Major disasters are assumed to increase the price of material and labour costs by the maximum possible amount under Storslysia law, 50%
- Major disasters will also assume the pessimistic assumptions of household goods loss of 75% of the property damage
- A major disaster will cause affected households to be temporarily displaced for up to 12 months after the disaster and require temporary housing. The number of households affected will be estimated by dividing the cost of the disaster by the median house price.
- There will always be enough temporary housing.
- Medium disasters are assumed to increase the price of material and labour costs moderately, increasing costs by 25% after the disaster
- Medium disasters will cause little to no damage to household goods
- Medium disasters will not cause temporary displacement
- Disasters caused by co-occurring disasters are counted as one occurrence of each.

Table 2: Relocation Assumptions

	A. Maximum Participation Rate	**B.** % of Property in 1-in-10-year Flood Risk Zones	**C.** % of Flood damage caused by 1-in-10-year Flood Risk Zone Properties
Optimistic	90%	0.05%	70%
Moderate	70%	0.1%	50%
Pessimistic	50%	0.15%	30%

For relocation, we will make the following assumptions:
A. Maximum Participation Rate: It is not expected that all populations in the flood risk areas are willing to relocate. Research has shown that the young and middle-aged working class are most willing to relocate [reference 2]. The most successful voluntary relocation program was the New Zealand Christchurch Residential Red Zone relocation program which started in 2011 and had almost reached full participation by 2015 [reference 3]. The relocation of Tacloban, Philippines had 70% participation in 6 years [reference 4]. Research in Mission Beach, Australia has shown that up to 51% of residents are open to the idea of planned retreat prior to a disaster [reference 1].

B. Percentage of Property in 1-in-10-year Flood Risk Zones: Under our model, we note that on average, the damage caused by major flood disasters annually is around 200 times the median price of properties in Storslysia. The assumption in the above table reflects the need to move about 2,000, 4,000 and 6,000 1-in-10-year flood-risk properties.

C. Percentage of Flood damage caused by 1-in-10-year Flood Risk Zone Properties: As per the definition of 1-in-10-year Flood Risk Zones, these are the properties that will be damaged by floods with lower severity than those of 1-in-100-year Flood Risk Zones. These are expected to cause the majority of the major claims.
The relocation program will be funded separately from the social insurance program and will not drain reserves from the social insurance fund.

3.3 Model Results

First, Monte Carlos simulation on the created Compound Poisson Model were used to simulate the base case of the future costs arising from natural disasters. This was run under the 4 provided SSP scenarios, with SSP5 being the more extreme scenario in terms of Atmospheric CO_2.

Total Expected Cost Arising from Natural Disasters Under SSP5 Assumption

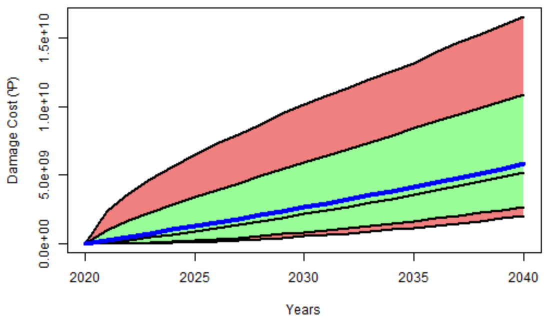


Figure 3.3.1: projected costs

Table 3: Cost Simulation Under SSP5

	Total Cost (Ᵽ 1,000)	
	2030	2040
Mean	2,641,738	5,805,094
Median	2,156,627	5,159,806
95% Percentile	5,893,088	10,856,099
99% Percentile	10,764,764	16,546,614

Total Expected Cost Arising by 2030 from Natural Disasters Under different SSP Assumptions

Table 4: Cost Simulation Under Different SSP Scenarios

	Mean (Ᵽ 1,000)	95% Percentile (Ᵽ 1,000)
SSP1 – 2.6	2,032,710	4,572,328
SSP2 – 3.4	2,049,151	4,573,764
SSP3 – 6.0	2,088,128	4,682,829
SSP5 – Baseline	2,641,738	5,893,088

Running ruin simulation on the base case with premiums the expected cost each year shows the following results:

Table 5: Probability of Ruin for SSP5 Under Different Starting Reserves

Starting Reserve (Ᵽ 1,000)	Probability of Reserve Running Out Within 20 Years
10,000,000	1.0%
5,000,000	4.5%
4,000,000	7.2%

Next, the effect under the inclusion of the relocation program under SSP5 was simulated. Note that all SSP assumptions will arrive at similar results. (Appendix E)

Comparison of Expected Cost Per Year on Disaster Claims Under SSP5

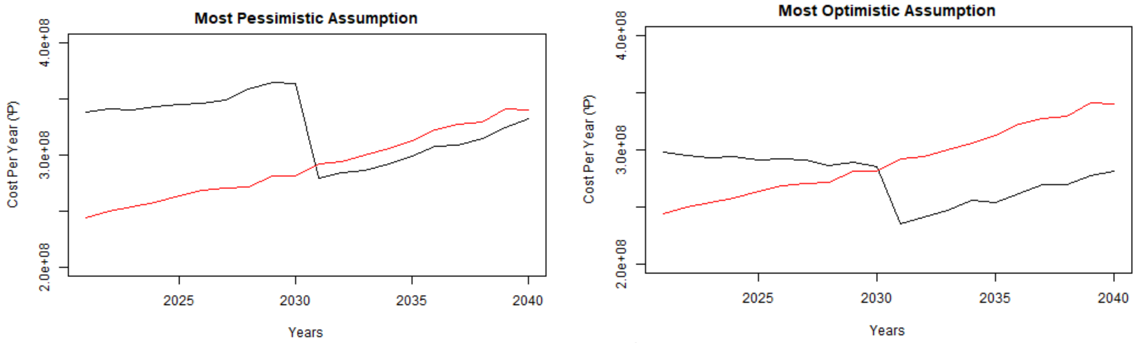


Figure 3.3.2: Comparison between estimated futural costs with and without relocation

[red: without relocation; black: with relocation]

The relocation program will result in heavier costs in the first decade, as the full subsidy program relocates citizens away from 1-in-10-year flood risk zones. For the years after the first ten years, the expected cost every year from disaster claims is expected to be lower than without the program. The cost saved over after the 10 years is expected to eventually outweigh the cost of the relocation program. The time required to break even depends on how optimistic the assumptions are from Table 2. Assumption A, the participation rate, will not affect the years needed to break-even but will affect ruin probabilities. Assumptions B and C have impacts on the cost of the program and how much cost will be saved by the program. Some selected examples of payback years are noted below.

Table 6: Expect Payback Time Under SSP5 with Different Assumptions

Assumptions	Expected Year to Break Even
Optimistic B, C	2035
Optimistic B, Moderate C	2038
Moderate B, Optimistic C	2043
Optimistic B, Pessimistic C	2048
Moderate B, C	2050
Pessimistic B, Optimistic C	2053
Pessimistic B, C	2090

Assumption B, the percentage of property in 1-in-10-year flood risk zones, directly impacts the cost to relocate the residents away from the hazard zone. If the pessimistic assumption of B is true, then this leads to much heavier costs in the first 10 years of the program.

For Assumption C, the percentage of flood damage caused by 1-in-10-year flood risk zone properties affects how much claim costs are saved in the future years from reduced flooding-related disasters.

Under the optimistic assumptions, the program will be able to break even just 5 years after the relocation program is complete. Post relocation program, Storslysia is expected to save one-sixth of the annual cost spent due to natural disasters. Assumption B increases the payback time the most, as full buyback of properties can turn out to be a very costly endeavour as the number of properties increases. However, we do believe that even under moderate assumptions, the relocation program is worth considering. Albeit unlikely, if both pessimistic assumptions on B and C are true, then the program can take a very long time to be able to see any benefits.

Table 7: Probability of Ruin for SSP5 Under Different Starting Reserves, With Relocation Program

Starting Reserve	Probability of Reserve Running Out Within 20 Years			
	No Relocation	Optimistic A	Moderate A	Pessimistic A
10,000,000,000	1.3%	0.9%	1.0%	1.2%
5,000,000,000	5.3%	4.2%	4.8%	5.0%
4,000,000,000	9.2%	6.4%	7.7%	8.1%

In our model, assumption A directly influence the amount of reduction to the number of occurrences of natural disasters. In reducing the number of occurrences, we are directly targeting the value at risk for each year. This allows the social insurance program to have a lower probability of ruin under the same starting reserve.
Assumptions B and C will not affect the ruin probability as we will be financing the 2 programs separately.

On the relocation program, the following table contains expected annual costs for the next decade under different assumptions:

Table 8: Expected Cost of Property Buyback for Voluntary Relocation

(Ᵽ 1,000)	Optimistic B	Moderate B	Pessimistic B
Optimistic A	54,381	108,762	163,143
Moderate A	42,296	84,593	126,889
Pessimistic A	30,212	60,423	90,635

3.4 Premiums

The premiums are set to be expected cost of next year’s disasters. Different areas should have different premiums based on their risk exposure. Due to the lack of geographical data, only the regional average were computed as below.

Table 9: Expected Premiums Per Household Under Different Assumptions

(Ᵽ)	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6
2021, No relocation	3.67	89.36	7.83	31.85	91.95	19.15
2031, No relocation	4.40	107.01	9.37	38.14	110.11	22.94
2021, Optimistic A	3.67	89.22	7.81	31.80	91.81	19.12
2031, Optimistic A	3.51	85.44	7.49	30.45	87.92	18.31

4. Data Limitations

Table 10: Data Limitations and Corresponding Assumptions

Data Limitation	Corresponding Assumption	Justification
Lack of Geographical Data and Flood Zone Data	Assumed a percentage of citizens that are in 1-in-10-year flood risk zones	Based on average cost of major flooding related disasters in our model
	Assume there are safer areas in each region for relocated citizens to resettle in	Due to relatively low amount of population that is assumed to require relocation, we expect there to be available areas for relocation
No Data on Acceptance Rate of Voluntary Relocation	Assumed possible optimistic, moderate, and pessimistic cases	Based on data from similar programs from other similar countries
Missing Inflation Data in 2003	Set 2003 inflation rate as the average of 2002 and 2004	Assumed to be a fault in record as -990% inflation is not feasible
No Data on Currently Available Disaster Insurance Programs in Storslysia	Assumed no comprehensive social insurance program exist in Storslysia	-
No Data on Properties in Storslysia, such as building age, material, etc	All property damage will be predicted using past disaster events	-

5. Risk and Risk Mitigation Considerations

The above analysis of our project is built based on a no change in relative pricing basis. However, it is evident that Storslysia will face market risks and other potential risks as below:

I. Market rate risk: Inflation may exceed the economic growth causing a rise in the relative cost of disasters. Nonetheless, the huge amount of reserve is extremely vulnerable to market rate fluctuation.
II. Extreme events risk: Black swan events may occur and drain or exceed the current reserve causing the collapse of the insurance program or severe damage to the economy.
III. Underwriting risk: Keeping required underwriting data up to date is challenging.
IV. Environment change risk: According to [reference 5], coastal regions had twice the growth rate compared to inland cities. Whilst coastal regions face significantly higher risk exposure to coastal floods and the sea level is expected to continue raising in the coming decades causing more areas to be exposed to coastal related risks.
V. Social attitude change risk: Satisfactory ruin probability was achieved by a large amount of initial reserve that taxpayers may feel reluctant to cover.
VI. Liquidity: Inflation and the loss in the real value of the program’s reserve urges the government to have the fund invested which may cause liquidity issues when disasters occur before the maturity date.
VII. Operational risk: Research into flood maps in the USA from the FEMA program has shown that flood maps drawn as recently as 2 decades ago are already incapable of accurately predicting the extent of flood damage. [reference 8]

Hence, the corresponding mitigation strategies below may be considered.

I. The government should be high-risk averse when managing the reserve pool to target the neutralization of impacts of inflation and secure a non-negative return.
II. The program should only be implemented with the suggested level of the initial reserve to reach the desired level.
III. Local governments of Storslysia should ensure housing and census information are up to date annually and the central government should raise financial, personnel and technological support to assist.
IV. Under planning, constructions should be advised to be located in relatively safe areas conditions on the rising sea level to reduce the potential future risk exposures.
V. Social awareness of the benefits of the program should be improved with publicization.
VI. The government of Storslysia may choose to keep the reserve and bear the potential loss caused by inflation to eliminate liquidity risk.
VII. Prompt updates on flood map with enhanced technology and potential collaboration with professional consultant firms in relative fields will be of assistance.

6. Further recommendation

In addition to the corresponding mitigation strategies for the risks mentioned above, we would like to furnish the following recommendations.

According to the risk heat map (figure 1.1), hurricanes, storms, tornadoes, winter weather and drought are high-risk hazards in Storslysia as well. Yet, without further geographical data provided, the feasibility of reducing risk exposure with the relocation cannot be assessed. Accordingly, the government of Storslysia may consider the following development advice:

- Flood-resilient and storm-resilient buildings should be encouraged in risky regions[Appendix F]. Import tax on relevant material may be reduced. Companies that are capable of building and civilians ordering such houses should receive benefits.
- Temporary or permanent flood embarkment should be constructed upon the relocation progress in certain regions.
- Infrastructure development for improved water supply and gas supply should be reviewed. , Our team would like to offer a detailed scheme with additional data on winter weather and drought damages.
- Warnings on wind or storm hazards should be easily accessible to citizens. The government may refer to the Japanese earthquake notification system [Appendix G] for advisory.

Nonetheless, the government should take moral and attitudinal hazards into consideration. The full coverage of social insurance is likely to reduce citizens' initiatives of investing in private hazard protections and increase the likelihood of having misreported poverty damages. The government of Storslysia should enhance the supervision and offer premium reductions for households that actively improve their own private hazard protections.

Most importantly, our simulation established that our constructed program has a high-level of certainty to reduce the economic damages caused by natural hazards. However, monitoring the yearly disasters and level of reserve is essential to this program. As a consequence of severe disasters happening in the early years after the implementation and the burnout of existing reserves, adjustment on future premiums and voluntary relocation progression will be necessary. Nevertheless, periodical monitoring of Value at Risk (VaR) and the ruin probability of the program computed with simulation should be conducted.

Conclusion

The social insurance program and voluntary relocation scheme are expected to be financially beneficial to the Storslysia government based on our analysis introduced above. Our pricing system offers a range of scenarios based on a variety of assumptions that cover the potential outcomes of our scheme after implementation that proved the feasibility of this program.

Yet, further monitoring and tailoring are indispensable. And a review of the enclosed limitations of our program and recommendations followed up with additional information from the government of Storslysia would be instrumental to the improved effectiveness of this program.

Appendix and Methodology

APPENDIX A – Inflation Adjustment

In order to have property damage more accurately reflect the price at the time of occurrence, the property damage data is adjusted for inflation. The yearly inflation data of Storslysia is provided, however the 2003 data appeared to be corrupted (showing a value of -990%). We use the average inflation between 2002 and 2004 to replace this data.

APPENDIX B – ARIMA Modelling

To determine the initial input value for the frequency projection model, the expected number hazard events in 2020 are required. ARIMA model is used for predicting the expected occurrence of minor, medium, and major hazard events for 2020 based on the historical data from 1960 to 2019.

Section B-1: Quarterly vs. Annual Modelling

The ultimate goal is to predict the expected number of corresponding minor, medium, and major hazard events in 2020. The cut-off points for minor, medium and major are set at 20% and 95% for property damage of 15,000 and 6 million respectively, i.e., property damage below 15,000 is considered minor, between 15,000 and 6 million is considered medium, and above 6 million is considered major. This ensures efficient use of the data and meets the size criteria for hazards. The number of hazard events per year can be aggregated from the historical data provided for each quarter of Storslysia, and both sets of data can be fitted to the ARIMA model, with the better-fitting set being used to predict the 2020 data. The quarterly and annual time series plots are shown in *Figure B-1*, respectively.

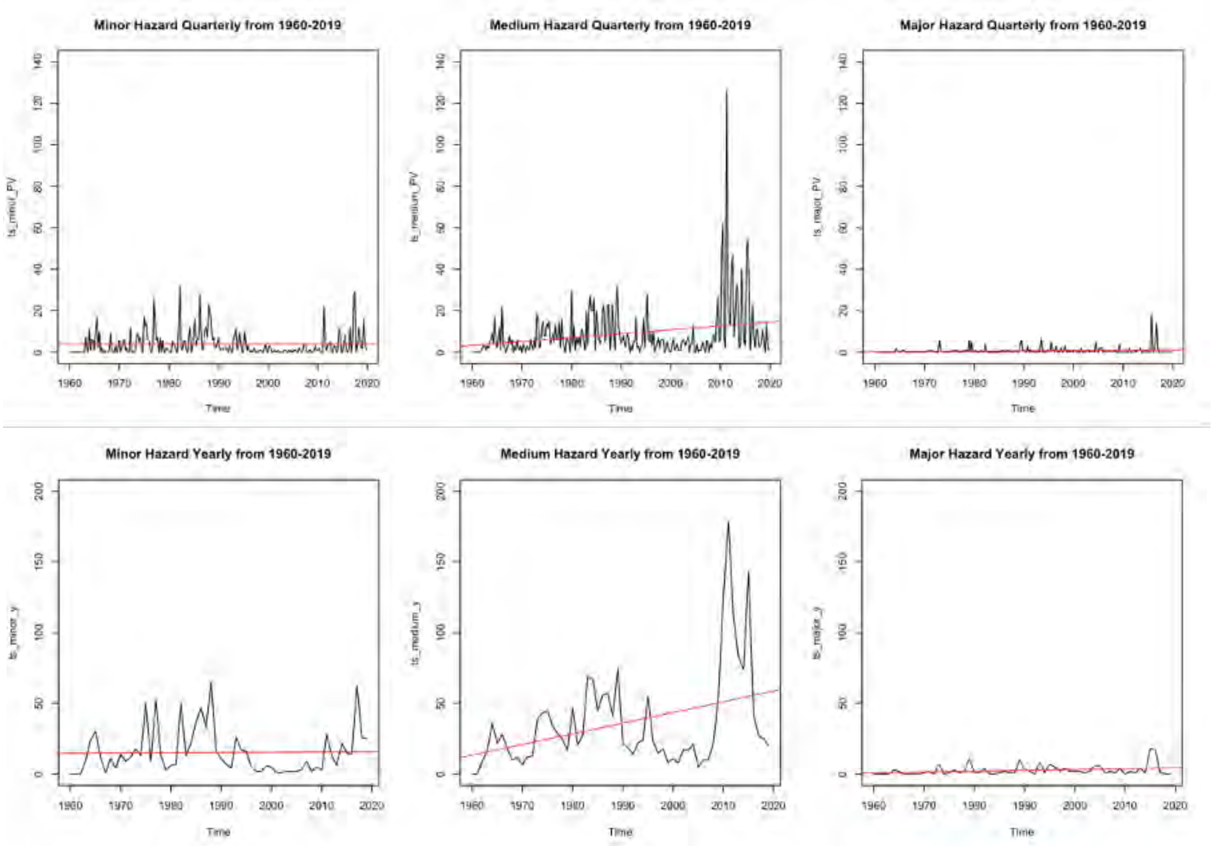


Figure B-1: Quarterly and annual time series plots

As shown in the graph, the number of disasters changes very volatile each quarter, with minor disasters fluctuating the most and major disasters fluctuating the least. The red line represents the overall trend of this time series, and it can be observed that minor hazards show a slow downward trend, medium-sized hazards show a slow upward trend, and major hazards show no obvious trend. When translated into the total number of disasters per year, the trend fluctuations are more moderate, but the overall trend remains basically the same.

To determine the values of the parameters in the ARIMA model, the autoarima function can derive the parameters that may be appropriate based on the data itself. the results are shown in *Table B-2*.

Table B-2: Autoarima Results

Basis	Minor	Medium	Major
Quarterly	ARIMA(1,0,4)	ARIMA(2,1,3)	ARIMA(0,1,1)
Yearly	ARIMA(2,0,0)	ARIMA(0,1,0)	ARIMA(0,0,1)

Then plot the autocorrelation function (ACF) and partial autocorrelation function (PACF) for each interval, observe the number of autoregressive terms (p) and the number of lagged prediction errors(q) in the prediction equation, and then combine the results given by the autoarima function to fit in ARIMA. The ACF and PACF for the yearly and quarterly time series are plotted in *Figure B-3* below.

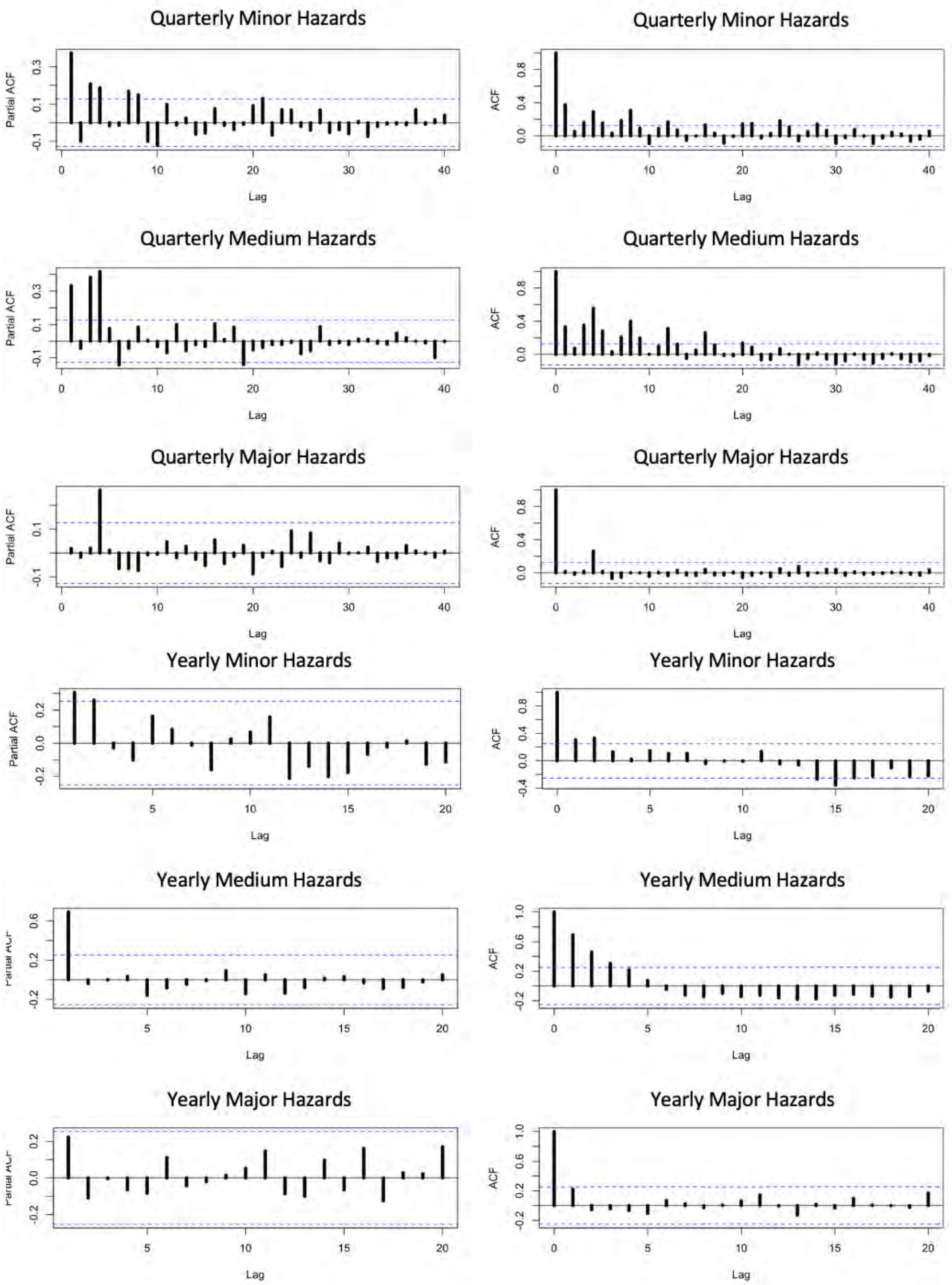


Figure B-3: ACF and PACF for yearly and quarterly time series

The value of d, i.e., the number of non-seasonal differences, can be determined to be stationary by using the Augmented Dickey-Fuller test. Based on the results of the p-values, it can be concluded that the time series of major and medium are non-stationary and the time series of major are stationary on yearly basis, and they are all stationary on quarterly basis. The results are shown in *Table B-4* below.

Table B-4: Augmented Dickey-Fuller test results

Basis	Sample	p-value	Stationarity
Quarterly	Minor	0.02452	Stationary
	Medium	0.04676	Stationary
	Major	0.01	Stationary
Yearly	Minor	0.1717	Non-stationary
	Medium	0.3362	Non-stationary
	Major	0.01	Stationary

Combining the autoarima results with the ACF and PACF plots, all possible combinations of parameters were substituted into the ARIMA model. To assess the goodness of fit of the different model combinations, the AIC and log-likelihood can be evaluated. A lower AIC indicates a higher quality of the model, while a higher log-likelihood, the better the model fits the data set. As yearly ARIMA model yielded better results, we concluded to use the yearly model for the 2020 forecast. The results of AIC and Log-likelihood for different parameters are shown in *Table B-5* below.

Table B-5: AIC and Log-likelihood estimates of fitted models

Basis	Sample	ARIMA	AIC	Log-likelihood
Quarterly	Minor	1,1,1	1486.78	-740.39
		4,1,1	1475.59	-731.8
		1,1,4	1480.96	-734.48
		4,1,4	1459.36	-720.68
		1,0,1	1490.48	-741.24
		4,0,1	1479.26	-732.63
		1,0,4	1480.75	-733.37
		4,0,4	1466.25	-723.12
	Medium	1,1,1	1862.07	-928.04
		1,1,3	1839.64	-914.82
		2,1,1	1820.64	-906.32
		2,1,3	1799.29	-893.65
		4,1,1	1806.23	-897.11
		4,1,3	1803.21	-893.6
	Major	0,0,1	930.64	-462.32
		0,0,4	964.33	-476.16
		4,0,1	967.82	-476.91
		4,0,4	970.57	-475.28
		0,1,1	975.66	-485.83
		0,1,4	981.5	-485.75
		4,1,1	967.37	-477.68

		4,1,4	971.42	-476.71
Yearly	Minor	2,1,0	498.58	-246.29
		2,0,0	500.02	-246.01
	Medium	0,1,0	557.62	-277.81
		1,1,0	558.7	-277.35
	Major	0,0,1	330.11	-162.05
		0,0,2	332.02	-162.01

By comparing the AIC and Log-likelihood estimates of the quarterly and annual models in Table B-5, we can find that the annual model has lower AIC values and higher log-likelihood, indicating that the annual model is better fitted to our data. Therefore, in the next step, we choose the annual ARIMA model for forecasting.

Section B-2: Prediction of number of hazards in 2020

The ARIMA forecasting method was then applied to each model, forecasting 1 period forward until 2020. The forecasting results and the visual comparison with actual data are provided in *Figure B-6* below.

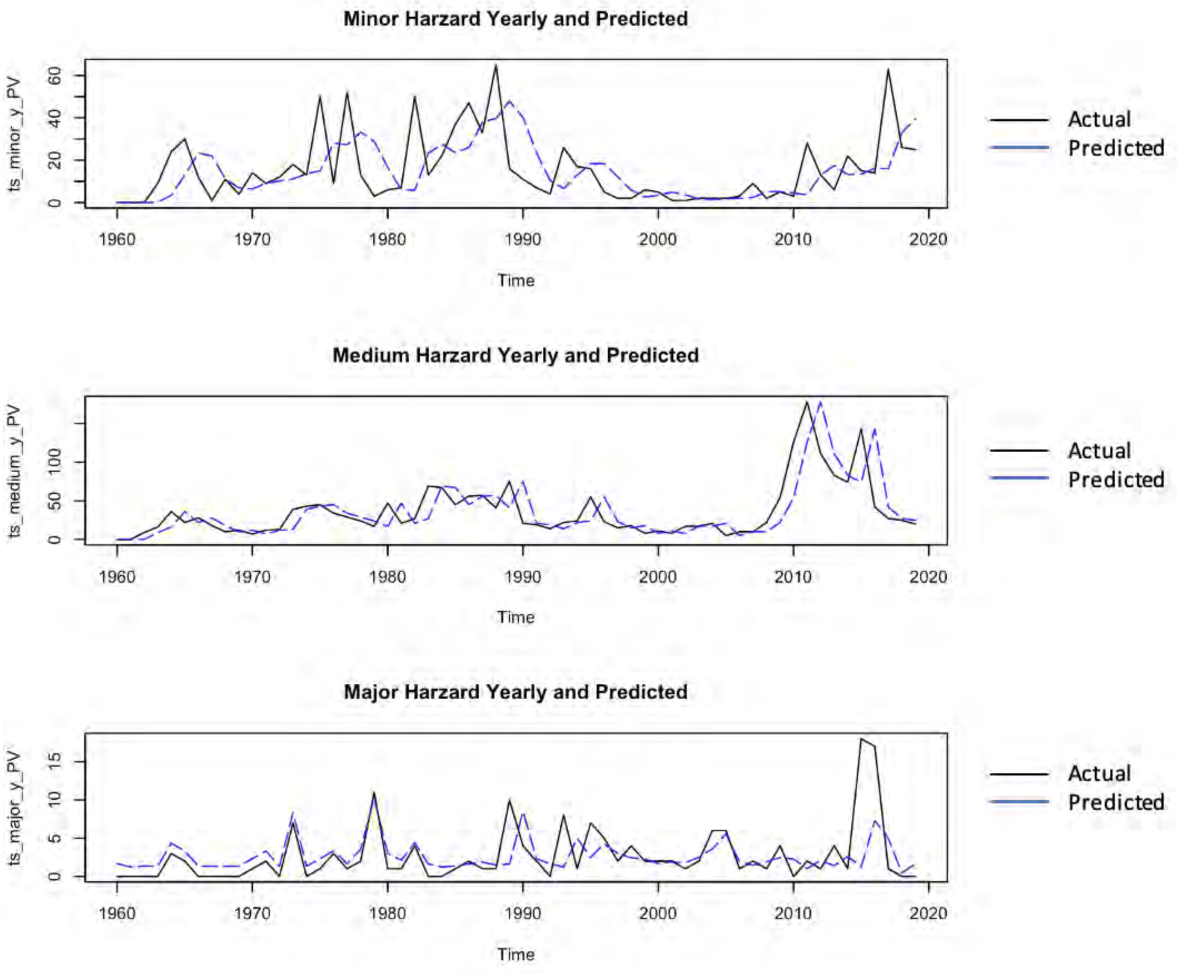


Figure B-6: forecasting results of yearly ARIMA model

Table B-7: Projected results of expected number of hazards in 2020

Basis	Minor		Medium		Major	
Yearly	Actual	Predicted	Actual	Predicted	Actual	Predicted
2020	57	32.705	20	20	2	1.236992

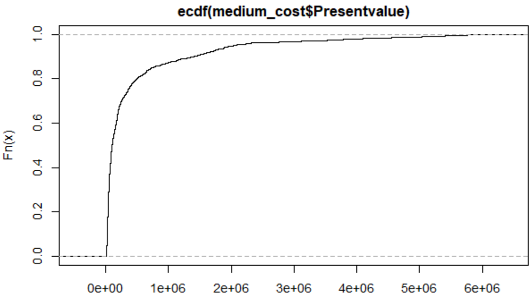
This prediction is then passed onto the model in the excel sheet provided by SSP5. The expected events for the future years will be predicted through the SSP model for each decade, and the years between the decades will be calculated geometrically.

Appendix C – Fitting Distributions

To estimate the cost of each medium and major claim, various potential distributions are fitted against the data and was tested.

Section C-1: Medium Data

Looking at the inflation adjusted data from 15,000 to 6,000,000, we considered a few potential candidates based on the shape of its empirical CDF. We considered the following:



- Log-normal distribution
- Pareto distribution
- Gamma distribution
- Inverse Gaussian distribution

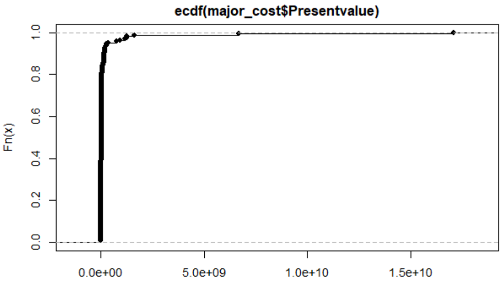
These 4 distributions were fit using the package “univariateML”. After fitting the distributions, Anderson-Darling Test and Cramer-Von Mises Test from the package “goftest” was used to evaluate the goodness-of-fit of each of the distributions.

	p-values	
	Anderson-Darling Test	Cramer-Von Mises Test
Log-normal	2.749e-07	8.271e-10
Pareto	2.749e-07	<2.2e-16
Gamma	2.749e-07	<2.2e-16
Inverse Gaussian	1.884e-05	0.002977

Overall, Inverse Gaussian appear to be the best fitting distribution for medium sized disaster claims.

Section C-2: Major Data

The inflation adjusted data over 6 million have a couple of very high outliers. As it is the top 5 percentile of the data, a number of heavy tailed distributions were considered for fitting the major data:



- Weibull distribution
- Pareto distribution
- Log-gamma distribution

These 3 distributions were, again, fit using the package “univariateML” and evaluated using “goftest”.

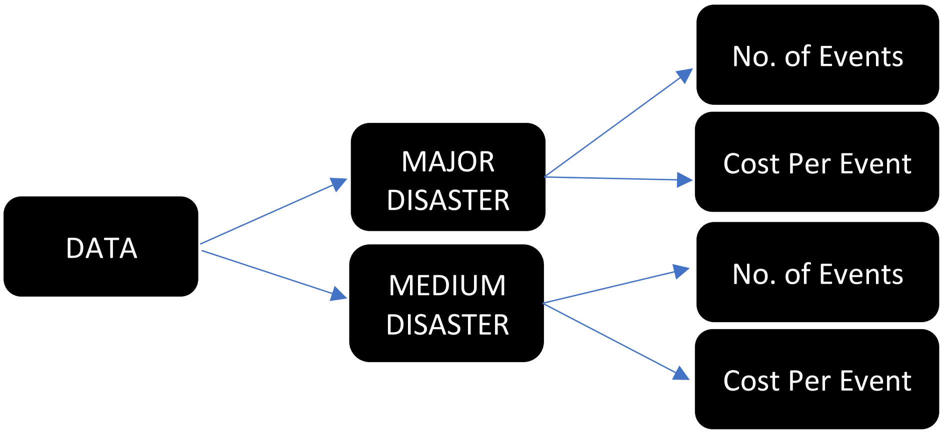
	p-values	
	Anderson-Darling Test	Cramer-Von Mises Test
Weibull	3.681e-06	5.977e-09
Pareto	3.681e-06	<2.2e-16
Log-gamma	1.161e-05	2.64e-05

Overall Log-gamma appeared to be the best fitting distribution for major sized disaster claims.

These distributions will be used to simulate the losses for medium and major disasters when they occur. The cost of medium disaster will be 1.25 times the value simulated by the Inverse Gaussian distribution.

The median price of a property in Storslysia is about Ᵽ 200,000 and this will be divided by the cost of major disaster simulated by the Log-gamma model to simulate the number of households displaced. Each household will have on average 2.5 people, and temporarily housing each person for 12 months will cost 12 x Ᵽ 1857.91. Therefore, the cost of major disaster will be $(2.25 + \frac{2.5\times 1857.91\times 12}{200{,}000})$ times the value simulated by the Log-gamma simulation.

APPENDIX D – Compound Poisson Model and Ruin Simulation



Section D.1 Compound Poisson Model

As per Appendix A and Appendix B, we have split the data provided into number of events and cost per event for both major and medium disasters. Using those data, we have managed to make predictions for both the number of events and the cost per event.

Using the predictions, we can then simulate the costs of future disasters using a Compound Poisson Model:

$$C_t = \sum_{T<t}^{N_{medium,t}} S_{medium,T} + \sum_{T<t}^{N_{major,t}} S_{major,T}$$

where:

$$C_t \textit{ is the simulated cost at time } t$$

$$N_{medium,t} \sim Poi(\lambda_{medium,t}) \textit{ and } N_{major,t} \sim Poi(\lambda_{major,t}) \textit{ are Poisson distributions}$$

$$\lambda_{medium,t} \text{ and } \lambda_{major,t} \text{ are the expected number of the disaster type in each year}$$

$$S_{medium,T} \text{ and } S_{major,T} \text{ are the loss values simulated from Appendix C}$$

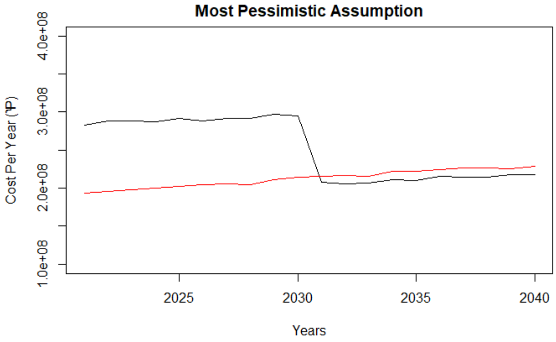
Section D.2 Ruin Simulation

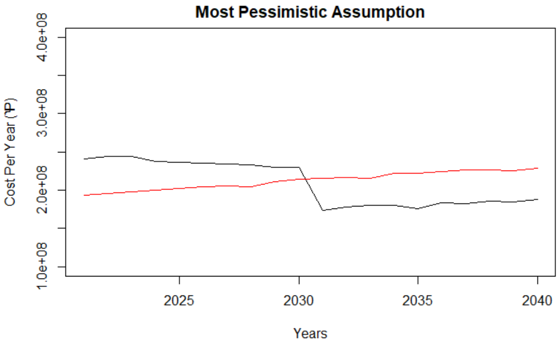
For simplicity, our model will charge the citizens of Storslysia a total of 1.1 times the expected disaster cost for the year to build up reserves. We will have an initial loading of c_0 and premium collected continuously throughout the year at the rate of π_t per year.

Then the reserve at time t is:

$$R_t = c_0 + 1.1\pi_t - C_t$$

APPENDIX E – Relocation Under SSP1





Expect Payback Time Under SSP1 with Different Assumptions	
Assumptions	Expected Year to Break Even
Optimistic B, C	2038
Optimistic B, Moderate C	2042
Moderate B, Optimistic C	2046
Optimistic B, Pessimistic C	2052
Moderate B, C	2055
Pessimistic B, Optimistic C	2058
Pessimistic B, C	2101

Due to SSP1 assumes less disasters in the future when compared with SSP5, the amount saved from the relocation efforts is reduced. However, the increase in years to break even is not significantly higher, generally just 3 to 4 years more than that of SSP5. The same conclusion can be reached as that of SSP5. SSP2 and SSP3 will be expected to have values somewhere between SSP5 and SSP1.

APPENDIX F – Flood and storm resist houses

Flood-resist houses:

The design and material used for construction should be flood resistant. Storslysia may choose to follow similar flood-resist housing scheme in Queensland, Australia as sampled below [reference 10].

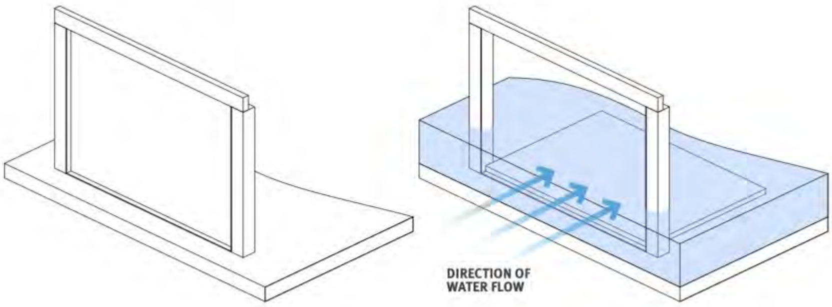
CODE	DESCRIPTION	DIAGRAM	IMAGE
A - THE YARD			
A1.1	**Reduce surface areas which don't allow water to soak into the ground.** • Don't use impervious pavement materials. • Reduce length/width of driveways and other paved areas.		
A1.2	**Create a bioswale and/or rain garden system.** Bioswale Bioswales are a simple landscaping and garden feature used to slow, collect and filter overland flow, allowing for the redirection of flood water away from the house. NOTE: Prior to implementing this strategy consult Brisbane City Council for approvals. Rain garden Rain gardens similarly collect water and are vegetated with water plants. NOTE: Prior to implementing this strategy consult Brisbane City Council for approvals.	Bioswale Rain garden	
A1.3	**Relocate any yard-based structures that are in the path of overland flow.**		
A1.4	**Create fencing which allows overland flow flood waters through.** Flood damage to fences can be avoided by ensuring the fence is water permeable and made of a resilient material.		
A1.5	**Install a submersible pump and sump.**		

Please refer to reference 10 for advice on external services, structure, exterior and interiors.

Storm-resist constructions [Reference 11]:

The houses in Storslysia may choose to have breakaway walls. Which are designed to fail when impacted by fast flowing water during a storm surge. The connection point between the Breakaway Walls must be the weak point so that they break away cleanly on all sides without damaging the rest of the home. They are suitable to enclose garages, storage or work areas under high-set houses, or as non-load bearing walls in the lower level of two storey homes. Some examples of Breakaway Walls include lattice, flyscreen or light-weight framed walls with weak connections to the stumps. Breakaway Walls should not have any wiring or plumbing attached to them that could anchor the walls to the house or ground and prevent them from breaking away cleanly.

Examples of Breakaway Walls



Footings and stumps such as piles, piers and columns need to be protected from the effects of scour and erosion by storm tide currents and waves. The depth of erosion and scour will vary depending on the soil type and foundations as follows:

- depth of scour around stumps could reach twice the diameter of the stumps • depth of scour beside walls or concrete slabs could be 0.15 times the length of the wall or slab. Scour protection can be achieved by:

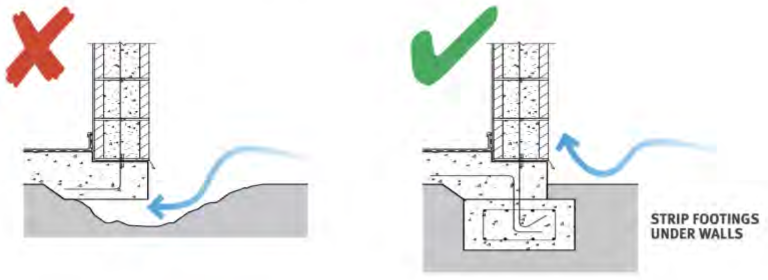
- increasing the embedment depth of stumps and piles.

Note: increasing the diameter of stumps will not provide protection from scour or erosion

- burying strip footings under walls

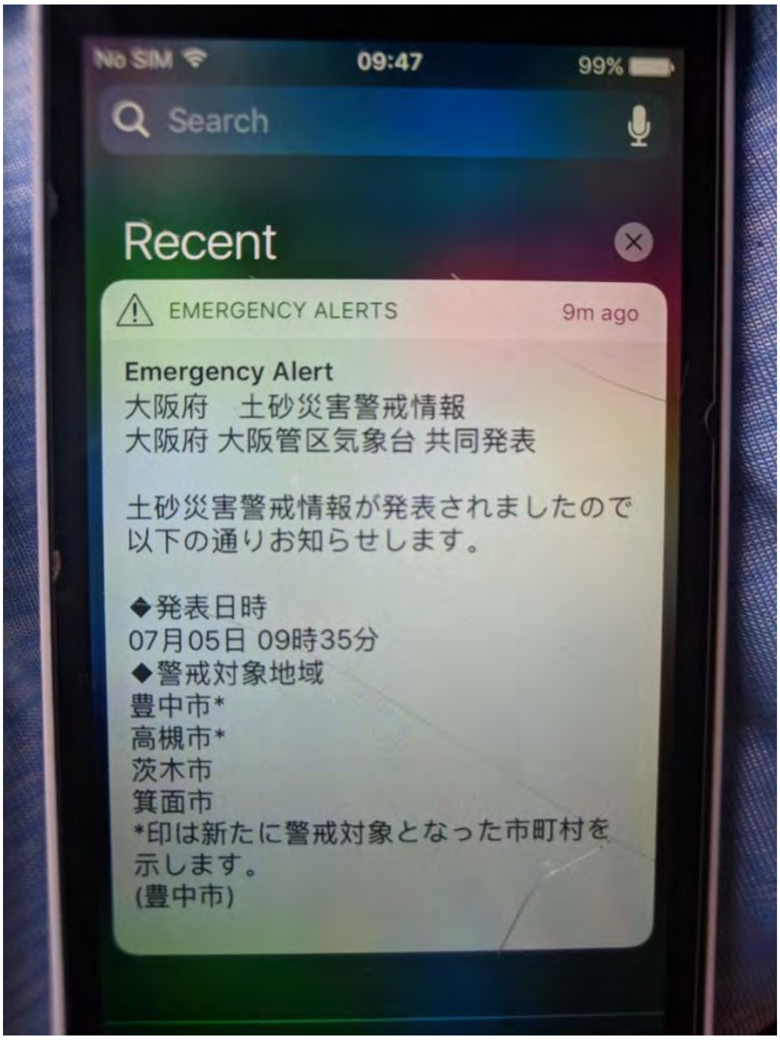
- providing protection around the edges of concrete slabs with a wall below the level of the slab that is at least 600 mm deep. Properly designed and constructed footings can withstand limited scour and erosion impacts during a storm tide.

Protection of concrete slab edges against scour.



APPENDIX G - Hazard warning notification

Japan has its own emergency alert system that provides warnings which used by the Meteorological Agency to transmit information about an earthquake, a tsunami, a volcano eruption, and any other natural disaster. And it can be easily set up on mobile devices for prompt notifications. Civilians' injuries and fatalities may be reduced upon successful implementation of this system.



Emergency Alert
大阪府　土砂災害警戒情報
大阪府 大阪管区気象台 共同発表

土砂災害警戒情報が発表されましたので以下の通りお知らせします。

◆発表日時
07月05日 09時35分
◆警戒対象地域
豊中市*
高槻市*
茨木市
箕面市
*印は新たに警戒対象となった市町村を示します。
(豊中市)

Source Code Documentation

The source code for this project can be found at: https://github.com/Izumi004/ACTL5100

Reference

[1] Raschky, P. A., & Weck-Hannemann, H. (2007). Charity hazard—A real hazard to natural disaster insurance?. Environmental Hazards, 7(4), 321-329.
[2] King, D., Bird, D., Haynes, K., Boon, H., Cottrell, A., Millar, J., ... & Thomas, M. (2014). Voluntary relocation as an adaptation strategy to extreme weather events. International journal of disaster risk reduction, 8, 83-90.
[3] Nguyen, C. N. (2020). Homeowners' choice when the government proposes a managed retreat. *International journal of disaster risk reduction*, *47*, 101543.
[4] Iuchi, K., & Mutter, J. (2020). Governing community relocation after major disasters: An analysis of three different approaches and its outcomes in Asia. Progress in Disaster Science, 6, 100071.
[5] Neumann B, Vafeidis AT, Zimmermann J, Nicholls RJ. Future coastal population growth and exposure to sea-level rise and coastal flooding--a global assessment. PLoS One. 2015 Mar
[6] Boston, J., Panda, A., & Surminski, S. (2021). Designing a funding framework for the impacts of slow-onset climate change—insights from recent experiences with planned relocation. Current Opinion in Environmental Sustainability, 50, 159-168.
[7] Bier, V. M., Zhou, Y., & Du, H. (2020). Game-theoretic modeling of pre-disaster relocation. The Engineering Economist, 65(2), 89-113.
[8] Pralle, S. (2019). Drawing lines: FEMA and the politics of mapping flood zones. Climatic Change, 152(2), 227-237.
[9] Mach K, Kraan C, Hino M, Siders AR, Johnston E, Field C: Managed retreat through voluntary buyouts of flood-prone properties. Sci Adv 2019, 5
[10] Brisbane Sustainability Agency (2022). Flood Resilient Homes Program Flood-Resilience Strategies
[11] Chief Executive Officer of Queensland Reconstruction Authority (2019). Storm Tide Resilient Building Guidance for Queensland Homes