SIMPLIFIED MODEL TO ESTIMATE IMPACT ON COASTAL WATER RESOURCES AND LOSS OF SHORE LINE LAND DUE TO CLIMATE CHANGE AND SEA LEVEL RISE

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ABSTRACT

This paper presents a review of past to current observations in the study of climate change and sea-level rise. It appraised the relationship between climate change and sea-level rise, and other drivers on the climate system and factors contributing to sea-level rise. It also highlighting various impacts of climate change and sea-level rise and suggesting short to long term strategies for effective coastal management. A model was developed to provide an estimation of present sea-level rise invariably indicating how much land is lost and how much effect it will have on the water table and rivers especially in coastal areas where there is no data available. To obtain these estimates, numerical modelling was carried out using parameters selected during the study. These parameters with the help of a conversion table produced initial data which were then applied to available Wellington region data for scenarios of 0.5m, 1.0m and 1.5m sea-level rise. Model testing was carried out to measure loss of land and effect of on water table, and satisfactory results were obtained **and presented here in. T**his model hopes to aid in the decision making process of what adaptation methods to employ or implement in certain coastal areas.

Key Words: Climate change, sea level rise, land loss

1   INTRODUCTION

It is evident that climate change and sea level change is occurring globally (Bell et al 2001 & Chen et.al 2012) and that this threatens coastal habitats round the world. While in some instances resources such as finance, knowledge, data and skill is available, in most instances we lack one or many of these elements a vital criterion for accurate forecast and prediction of sea level change and its impact on water resources as well as land surface. The situation at Wellington was analysed and its impact assessed (Tonkin and Taylor, 2013). However as there are many instances and locations where either data, software or skill is unavailable and in such instances as it is yet required to simulate, forecast and predict in order mitigate and manage coastal zones subject to sea level change impacts a simplified composite model is needed.

It must be noted here that as mentioned in the title this is a simplified model and hence a simple, easy to use and understand model to estimate some values in instances where there is no data and no scientific skills and technology to use.

Research Gap being addressed

Currently unless there is sufficient data for a given location it is not possible to arrive at even an estimated value for loss of land / shore line due to climate change. The simplified model developed in this project will provide information on loss of land, effect on water table and rivers especially where data is scarce or unavailable. Its development adopts two approaches, one being a conceptual approach while the other is a mathematical approach. This paper presents the conceptual approach.

The conceptual approach consists of parameters chosen at random to create a hierarchy of events within the climate system. It will provide estimates of how much land will be lost and how much effect climate change and sea-level rise will have on the water table using scenarios of 0.5m, 1.0m, and 1.5m sea level rise. The model achieved satisfactory results in comparison tests carried out, although it is based on only a few parameters and some assumptions, it hopes to shed some more light into the climate change phenomenon and help in the decision making process of choosing well suited adaptation methods even in situations when data is sparse. (Robert J 2011)

The mathematical approach method proposed to estimate the changes occurring in these areas, initially sea level changes using linear regression method. Changes to land and water table in Wellington New Zealand were simulated, modelled and a simple model was developed thereafter using this data to estimate changes. The model was validated using a different data set series. This model could now be used to easily estimate the

changes to ground water and land loss in other coastal zones, particularly where data is sparse and technical knowhow on modelling is limited, which is generally the case in most areas.

2   THE CONCEPTUAL APPROACH MODEL DESIGN

For the purpose of this work, some climate change elements have been highlighted for consideration and Fig 1 provides a visual of these components. (Church et. Al 2001, and Shindell 2007)
Changes in these elements or parameters have an important part to play in the cycle of events resulting in sea-level rise and the apparent loss of land.

Variations in these parameters will determine the effect of climate change and sea-level rise on the water table, rivers, land and ultimately describe the relationship between climate change and sea-level rise for a particular area.

The pyramid in figure also shows the series of events that occur with climate change residing at the top. As described in literature, climate change results in temperature increase while also increasing oceanic temperature causing thermal expansion and altering rainfall patterns to bring about sea-level rise. The pyramid has been derived upon considering all variables that come into play in the climate change scenario. The numbers chosen were derived giving equal weightage across all variables in the horizontal plane.

Sea-level rise on the other hand affected by local parameters such as local topography, hydrological patterns, storm patterns, localized global average temperature effects and tectonic movements or subsidence will result in effect on water table, loss of land and effect on rivers.

2.1   Effect on water table

Sea-level rise will affect the local water table by increasing its height, by causing an intrusion of salt water into groundwater and the intensity of these effect will depend on factors such as the nature of the coastal bedrock material, seasonal dryness and tidal changes, hydrological and soil characteristics, and as shown in Fig 2., numbers have been assigned to these factors from 1 to 5 based on respective impacts. (Claire, 2030)

2.2   Effect on Loss of land

Sea-level rise will result in loss of land and amount of land lost will also depend on local parameters such as local topography, hydrological patterns and storm patterns with loss of land in relation to the pyramid in Fig 1 and 2, ultimately caused by secondary factors such as flooding, shoreline retreat, increase in tide levels, inundation of low and wetlands, and effect on land drainage. Numbers have also been assigned to these factors in figure, from 1 to 5 based on respective impacts, (Small C, 2003).

2.3   Effect on rivers

Sea-level rise affects rivers by causing an intrusion of salt water into river networks disrupting river ecosystems and flow patterns. (Dragoni et. Al. 2008) As shown in Fig 1, this is also as a result of secondary factors such as flooding, shoreline retreat, inundation of low and wetlands, and effect on land drainage. Numbers have also been assigned to these factors in Fig 2, from 1 to 5 based on respective impacts.

2.4   Parameterization of Conceptual model

One of the objectives of this project is to obtain an estimate of the effect of sea level rise on land and water resources. For the purpose of this model, the following assumptions have been made:

- 90% conversion for all parameters.
- Values are assigned to parameters from a rating scale of 0 -100 or 0-1000 as listed in Table 1.

As shown in Table 1, each parameter has been assigned a level relative to their position in the pyramid earlier described in figure. As the cycle of events occurs down the pyramid from one level to the other, there is a conversion rate of 90% and in levels where there are two or more parameters such as in levels 3 and 4, the conversion factor is split evenly among the residing parameters.

2.5   Conversion table

Numerical estimates of resulting effects have been obtained using a conversion table which provides equivalents for each parameter and their respective units of measure. Fig. 2 provides a side-by-side view of the pyramid and a sample conversion table showing relevant parameters.
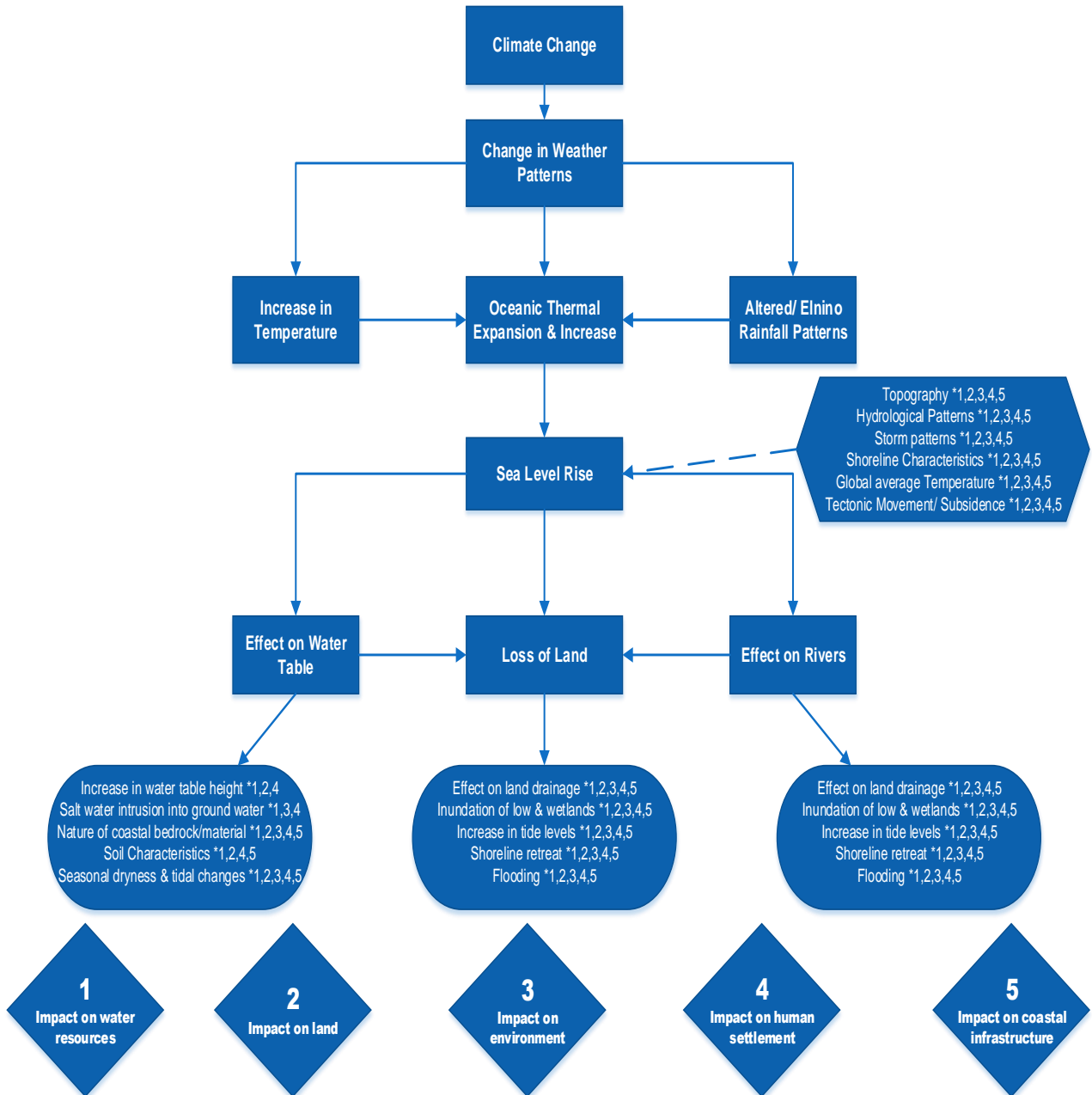
Figure 1   Simplified model showing some components of climate change and sea level rise

Table 1 Parameters rating scale

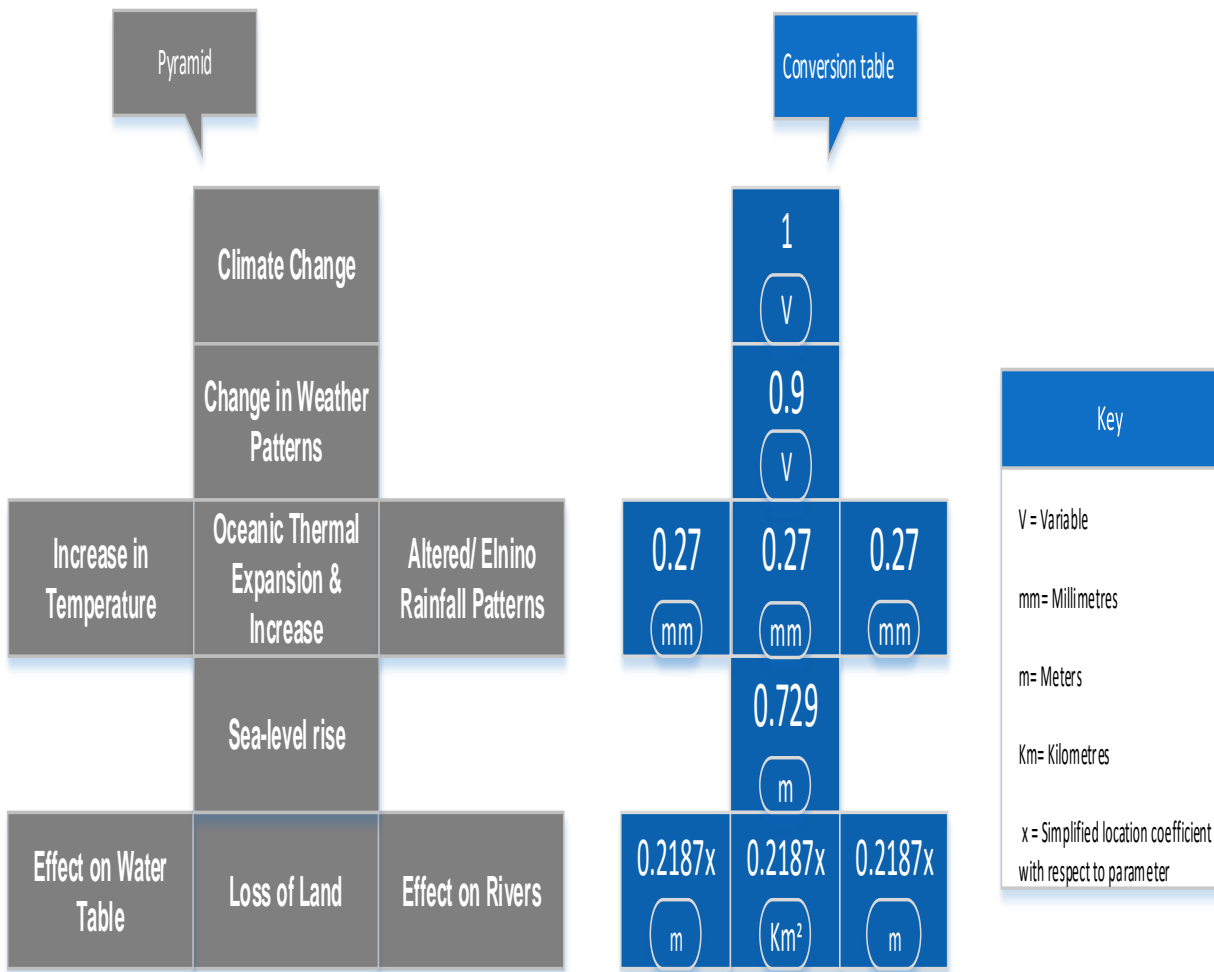| Level	Parameter	Rating
1	Climate Change	0-100
2	Change in Weather Patterns	0-100
3	Increase in Temperature	0-100
3	Oceanic thermal expansion & increase	0-100
3	Altered/Elnino Rainfall Patterns	0-100
4	Sea Level Rise	0-1000
5	Effect on water table	0-1000
5	Loss of land	0-1000
5	Effect on Rivers	0-1000

Figure 2   Climate change pyramid and sample conversion table showing relevant parameters

From the conversion table, Fig 3, a climate change effect rating of 1 (one) on a scale of 1-100 will result in an equivalent land loss of approximately 200cm. At level 1, climate change will produce a 'change in weather patterns' effect of 0.9 at level 2 which also then converts at 90% to 0.81 split equally among the level 3 parameters (Increase in temperature, oceanic thermal expansion & increase, and altered/el-nino rainfall patterns) at 0.27 each.
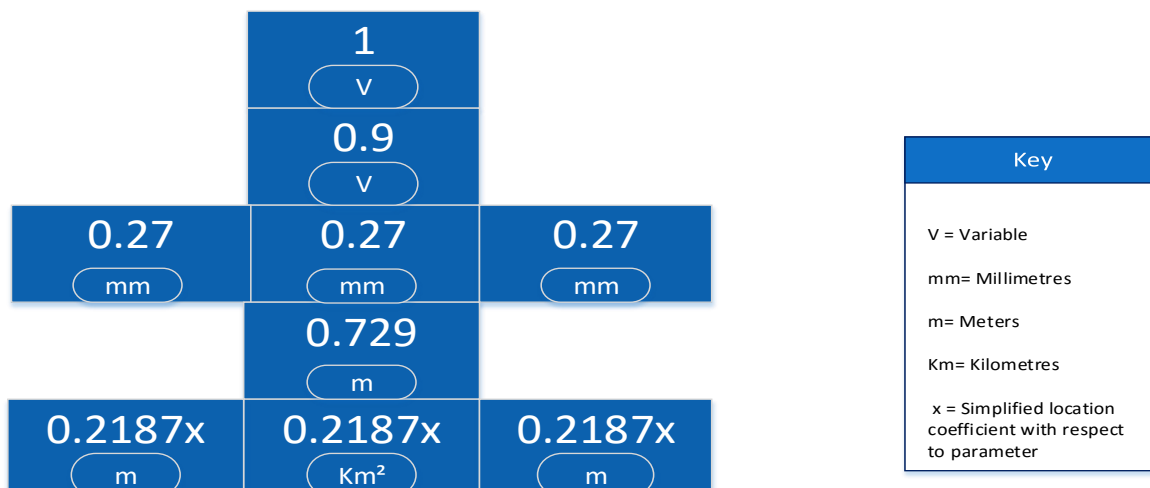

Figure 3   **Figure 3**   A conversion table showing values obtained from a climate change effect rating of 1.

The sum of estimates obtained for level 3 parameters (0.81) is then converted at 90% to produce a sea-level rise of 0.729 which also converts at 90% to cause the effects at level 5.   The intensity or scale of the parameters at level 5 (effect on water table, loss of land & effect on rivers) will be subsequently determined by a multiple of x, which is the location coefficient with respect to the parameter.
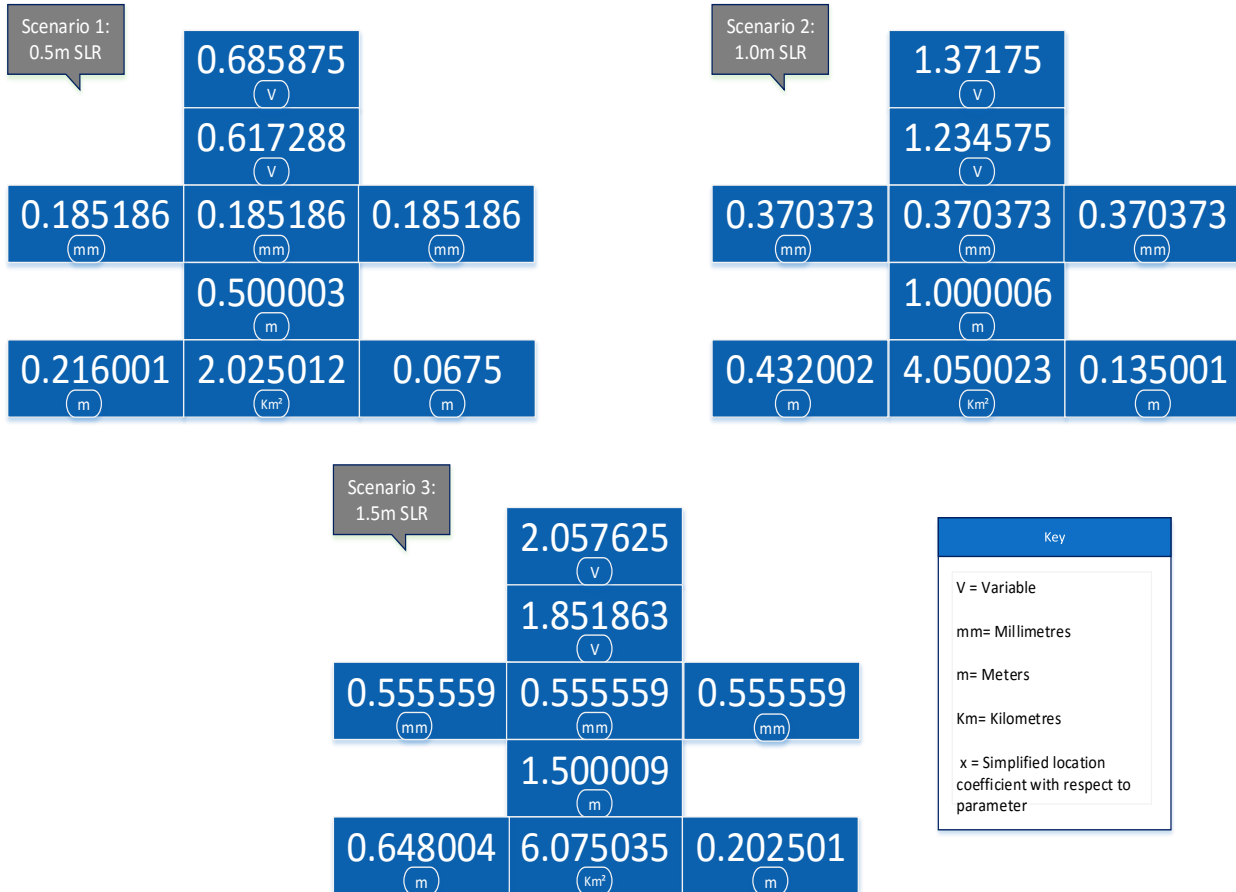

Figure 4   Conversion tables with results obtained from scenarios 1, 2 & 3 of 0.5m, 1.0m, & 1.5m SLR.

2.6   Model testing & Results

Using data from Wellington & considering scenarios 1, 2 & 3 of 0.5m, 1.0m & 1.5m sea-level rise with no storm effects, land loss in Km² was calculated for all 3 (three) scenarios as shown in Fig 4.

Considering scenario 1 of 0.5m sea-level rise, climate change occurred at a rate of 0.68 on a scale of 0-100, resulting in an equivalent land loss of 2.02km². Scenario 2 of 1.0m sea-level rise resulted from climate change at a rate of 1.37 on a scale of 0-100, affecting 4.05km² of land while scenario 3 of 1.5m sea-level rise occurred due to climate change at a rate of 2.05 on a scale of 0-100 thereby causing a land loss of 6.07km².

Table 2   Comparison of Wellington & Model data

Scenario	SLR (m)		Wellington	Model
1	0.5	Loss of	1.14	2.02
2	1.0	land	4.18	4.05
3	1.5	(Km²)	6.95	6.07
1	0.5	Effect on	0.00 - 0.17	0.21
2	1.0	water	0.39 - 0.61	0.43
3	1.5	table	0.76 - 0.98	0.65

The summary statistics used were comparative data from forecast in Wellington. Table 2, provides shows a comparison chart for values obtained from Wellington and those obtained from the model. With a close look at the values for loss of land, we can tell that model values seem within reasonable tolerance of the estimated values for Wellington. Although model estimate (loss of land) for scenario 1 (2.02Km²) is somewhat higher than its equivalent Wellington value (1.14Km²), adaptation measures provided against the model value will definitely address both estimates but maybe at a slightly higher cost.

Effect on water table (in meters) was also calculated using Wellington values for scenarios 1, 2 & 3 of 0.5m, 1.0m & 1.5m sea-level rise and the results (see table) also show model values to be within reasonable tolerance of the estimated values for Wellington. Model values obtained for scenarios 1, 2 & 3 of 0.5m, 1.0m & 1.5m sea-level rise were: 0.21m, 0.43m and 0.65m respectively.

2.7   Discussion

The simplified model designed, described the theory of climate change resulting in an increase in global temperature thereby giving rise to an increase in sea level. It also shows how sea-level rise coupled with a few other parameters cause loss of land in coastal areas as well as effect on rivers and water table.

A conversion table was also developed to calculate the how much land is lost due to climate change and sea-level rise. The model was tested with values obtained from the Wellington region for scenarios 1, 2 and 3 of 0.5m, 1.0m and 1.5m sea-level rise and these provided satisfactory results in comparison with the Wellington data.

Estimates were obtained for loss of land but a few key points of note during model development were the assumptions made such as conversion at 90%, and the assignment of units to parameters. These may in some way affect the reliability or integrity of the model as there were also limitations with regards to parameters, especially when only a few were considered. As stated by Nicholls (2011), thermal expansion accounted for about 25% of the observed SLR since 1960 and about 50% from 1993 to 2003. However, with this model, thermal expansion was a major player accounting for sea-level rise to a large extent. Other dynamic factors or changing coastal processes like changes in inundation area and duration were also not taken into account.

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Predicting sea-level rise impacts as a result of climate change is complex, and simple models are mostly of limited use. However, the simplified conceptual model designed in this project produced satisfactory results in comparison with available data and will help in the decision making process of what adaptation methods to employ or implement in certain coastal areas. Although models like these are based on assumptions of the impact of climate change and a few parameters, they shed some light into the climate change phenomenon, bringing it to the forefront and encouraging coastal authorities to take necessary action.

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