Abstract

Buller River Topographic, Rainfall, and Flow Stream Analysis in correlation to Westport Flood Risk Management

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Floods frequently damage New Zealand settlements, and recently, one of the most significant flood events in the country destroyed a town known as Westport. While previous studies have examined multiple factors in Westport floodings, this research would traverse more. This paper analyzed Westport flooding cases connected to its topography, rainfall, and Buller River's flow stream at Te Kuha. The research aims to characterize elements of flash flood hazards at Westport. The data is retrieved from New Zealand's National Institute of Water and Atmospheric Research (NIWA) website and processed to produce daily mean flow, stage-discharge curve, and flood return period graphs. The graphs created in this research concluded that the 2021 Westport flooding was a 50-year extreme event, meaning Westport should expect a similar flood event to hit the city in 2070s, as it hit them previously in the 1970s. Finally, this research confirms that the Buller River's flow stream at Te Kuha significantly affects flood events at Westport, and future flood management should consider climate change's impact on flood risk at Westport.

Keywords: topographic; rainfall; river flow; flash floods; flood management; flood risk; Westport New Zealand.

1. Introduction

Floods are New Zealand's most common and expensive natural disasters, with over 80 damaging floods reported between 1968 and 2017 (McSaveney, 2017). In July 2021, Buller River floodings damaged over 400 homes and incurred up to $56 Million in insurance costs at Westport (Ministry of the Environment, 2022). At the same flood event, the Buller River at Te Kuha recorded the most significant flow and water level in almost 100 years in New Zealand, with the flow peak amounting to 7640 m^3 per second and the water level peak to 12.8 m (Naish, 2023). According to Keenan & Oldfield (2012), Westport is vulnerable to flooding because of its location on the flood plain between the Buller River and the Orowaiti Estuary, an old channel of the Buller River. "The main source of floods are the tributaries immediately upstream of Te Kuha that drain the rugged Paparoa and McWilliams Ranges as they intercept moisture-laden winds crossing the Tasman Sea.", elaborated by Keenan & Oldfield (2012). Past research by Benn (1990) also described that "the high topographic relief and short step rivers often leads to rapid flooding of low-lying land on the West Coast.". Thus, multiple scientific research studies have concluded that Westport is at a high risk of flash flooding, and further analysis is essential to minimize risks and damages to the town. Regarding the risks above, this paper will cover a few analyses of the river's flow, rate, catchment risks, and current flood management in the city.

2. Study Site

The study site data are retrieved from the the National Institute of Water and Atmospheric Research (NIWA) Website, covered an area of 6350 km² in the Buller District of the West Coast Region, located 16 km from the mouth at grid reference K29:020295, and controlled by natural riffle/gorge (NIWA, 2023). Buller River, as the main object of the research, covers Westport as the second biggest town in the West Coast region. Moreover, based on 1981-2010 data by NIWA, Westport has an average monthly precipitation of ~ 176.78 mm and has the highest mean monthly precipitation of 212.5 mm in June. Figures 1 to 4 below, retrieved from the Te Tai o Poutini Plan (TTPP) (2023), described the Natural Hazards around Westport and its' surrounding area.

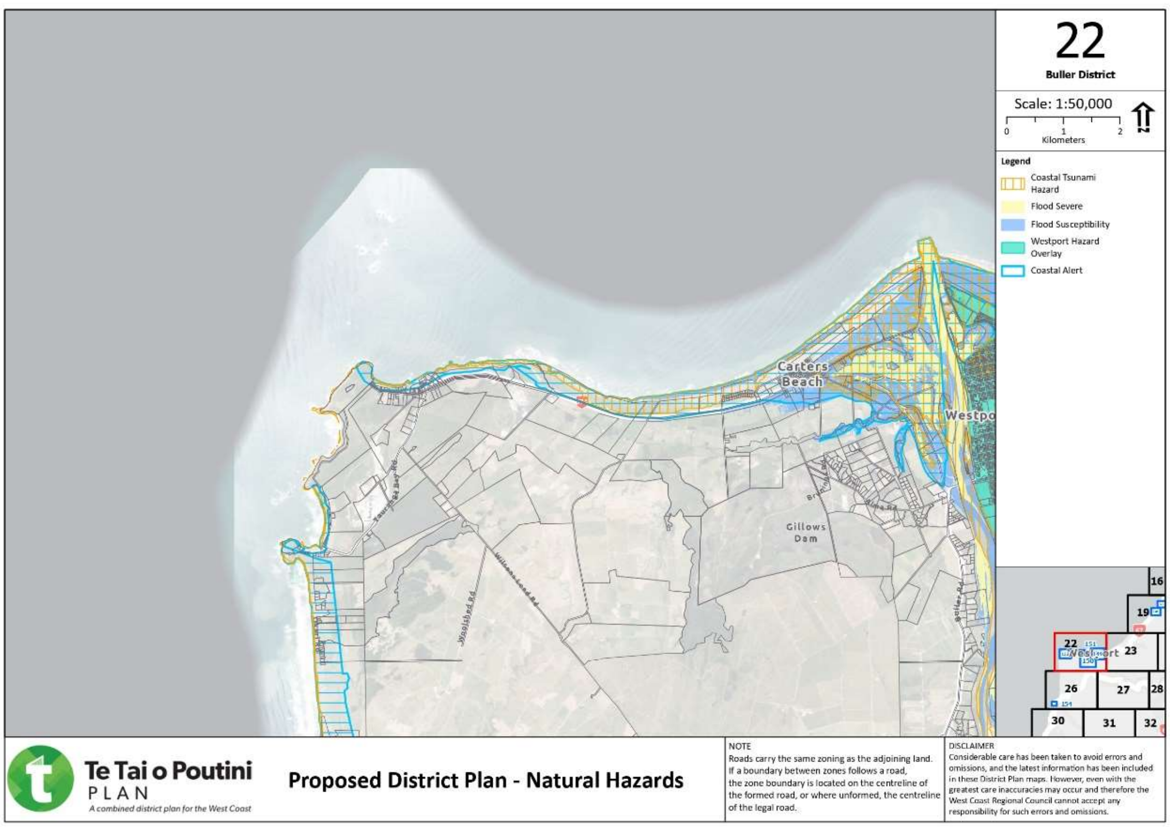

Figure 1: Natural Hazard Mapbook of Westport and other areas in Buller District, retrieved from Te Tai o Poutini Plan Website. The map described that multiple points at Westport are susceptible to natural hazards with various risks and severance.

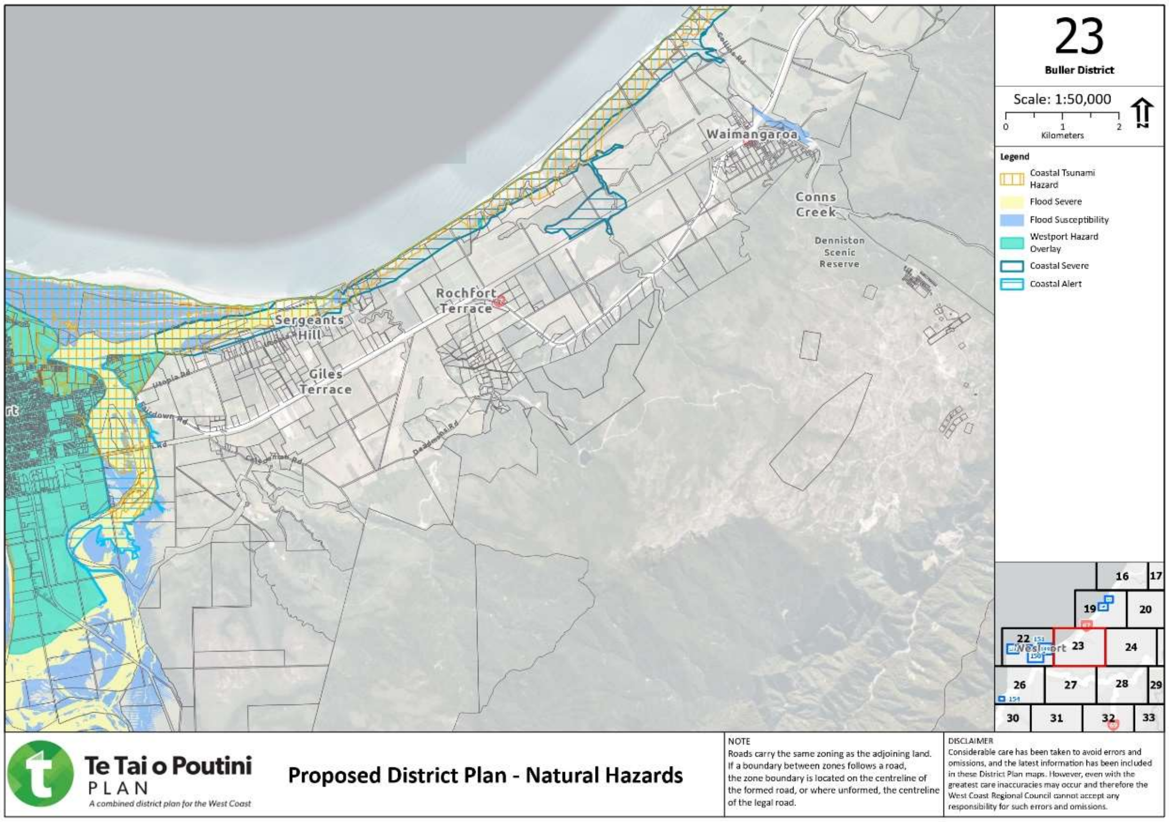

Figure 2: Natural Hazard Mapbook of Westport and other areas in Buller District, retrieved from Te Tai o Poutini Plan Website. The map described that some areas at Westport are susceptible to flood and natural hazard overlay.

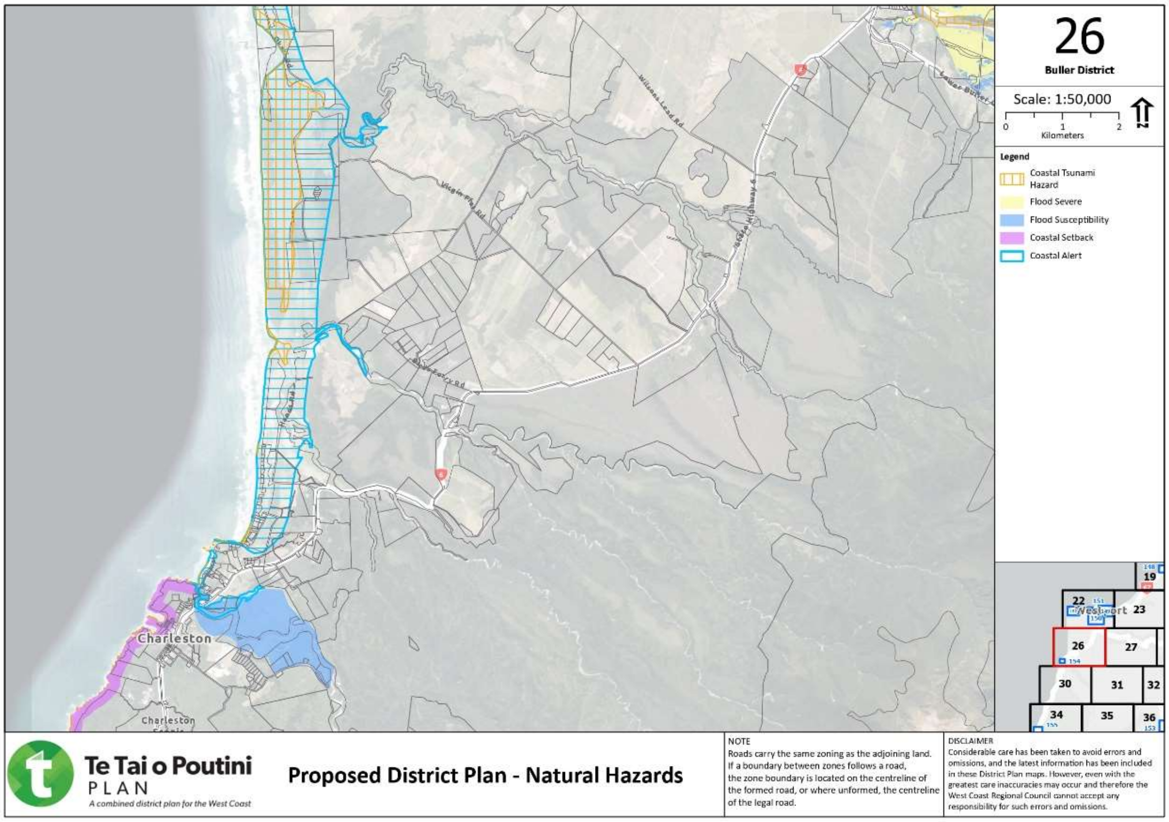

Figure 3: Natural Hazard Mapbook of Westport and other areas in Buller District, retrieved from Te Tai o Poutini Plan Website. The map described Westport areas that are susceptible to flood.

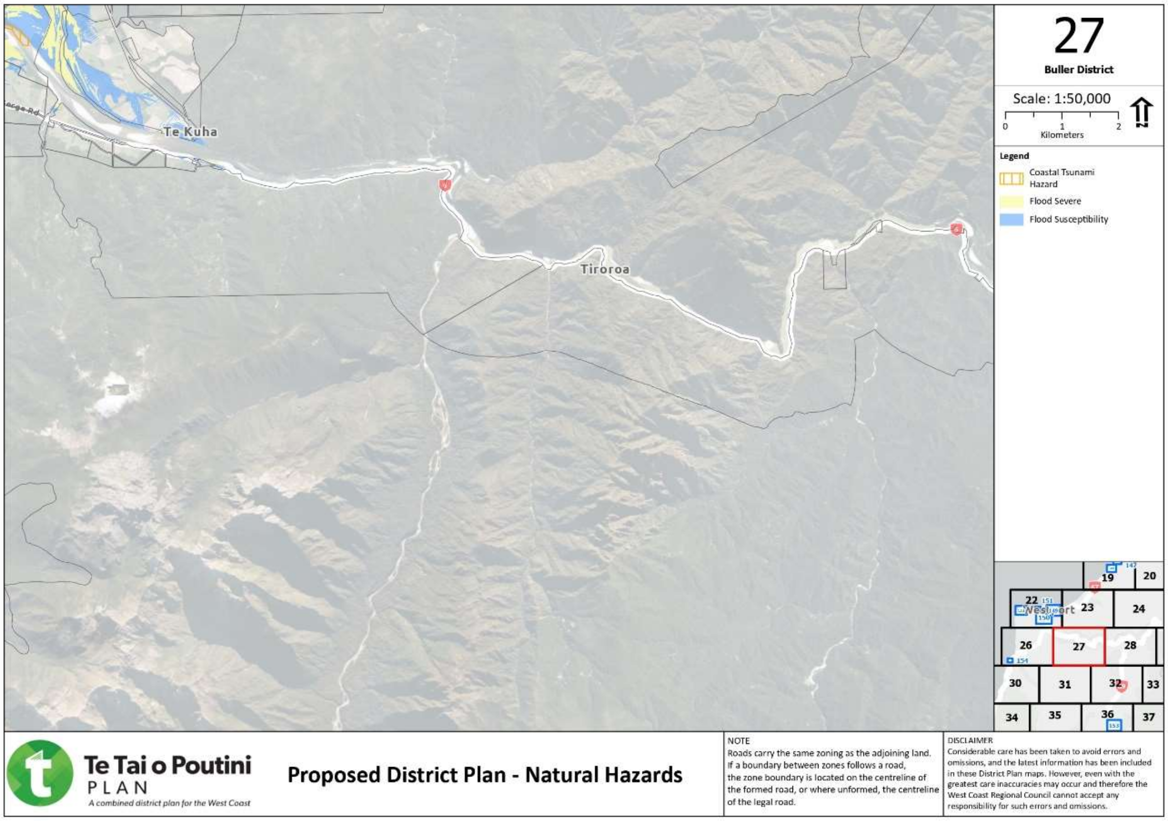

Figure 4: Natural Hazard Mapbook of Westport and other areas in Buller District, retrieved from Te Tai o Poutini Plan Website. The map described Westport areas that are susceptible to flood.

3. Methods

The data sets in this research are retrieved from the NIWA and processed with Excel software to produce daily mean flow, stage-discharge curve, and flood return period graphs. First, daily mean flow graphs the average daily flow against the recorded date. The datasets for the daily mean flow and its date are according to the discharge parameters in a Discharge.Master@91401 dataset with data range that covers the entire period of record, recorded on a daily interval, and flow rate converted in a format of average in cubic meters per second.

Next, the stage-discharge curve plots the annual maximum Stage against the flow rate with a data range that covers the entire period of record, recorded on an hourly interval, and converted in a format of a maximum of cubic meters per second. The annual maximum Stage retrieved the data from the Stage.Master@91401 dataset, while the annual maximum flow retrieved the data from Discharge.Master@91401 dataset.

Finally, the return period graph calculated the future flood events' return period with its flow rate. The calculation in the return period graph would calculate future flood events according to the 1963-2023 records, while the fitted return period extended the maximum flow rate calculation to a 500-year extreme event. The flood return period is calculated under the Weibull formula, while the fitted return period utilizes the Gamma distribution function.

4. Result

The daily mean flow graph, described in Figure 5, shows the average daily discharge of Buller River at Te Kuha from 1963 to 2023. Throughout the years, the daily mean flow at Buller River at Te Kuha peaks at 7898.25 m³/s, a minimum of 57.84 m³/s, and an average of 428.3713 m³/s. Finally, Buller River at Te Kuha has 1,699 events with a daily mean flow greater than or equal to 1000 m³/s and two extreme events with a daily mean flow greater than or equal to 7000 m³/s, which was in the years 1970 and 2021.

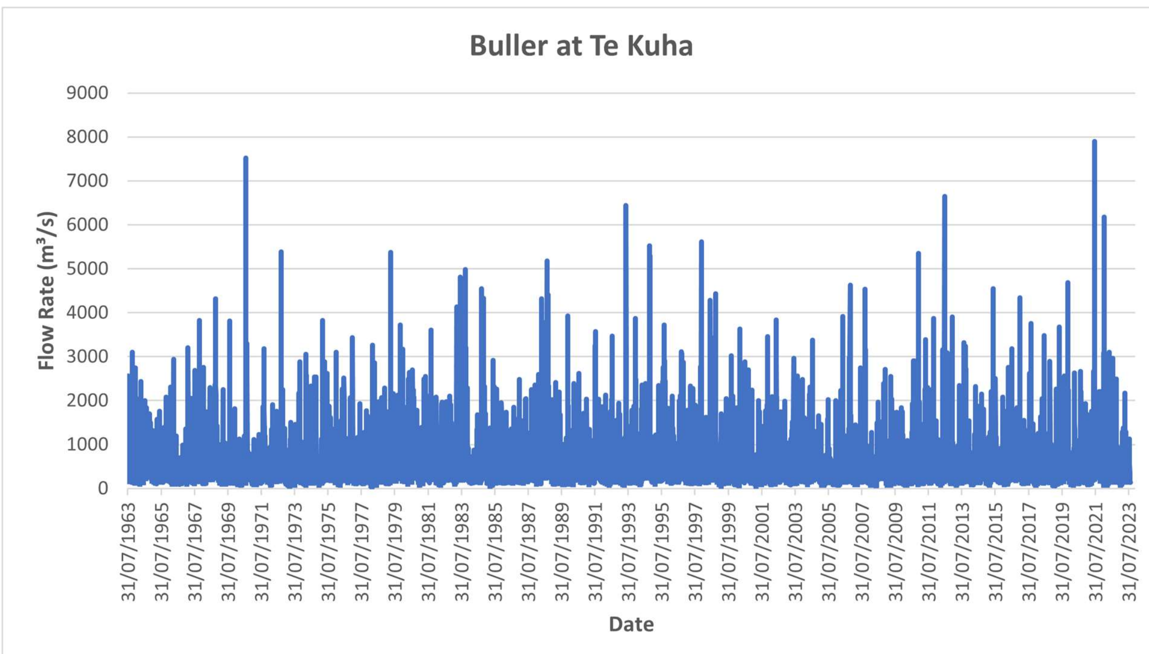

Figure 5: Daily Mean Flow of Buller River at Te Kuha from 1963-2023, described in a line graph with the date on the x-axis vs. the mean daily flow on the y-axis.

Next, Figure 6 describes the stage-discharge curve of Buller River at Te Kuha for 1963-2023. According to the datasets, Buller River at Te Kuha recorded the highest annual maximum flow of 8857.55 m³/s and an annual maximum stage of 12.79 m in 2021. The second highest record was in 1970, with a flow rate of 8194.51 m³/s and stage discharge of 11.89 m.

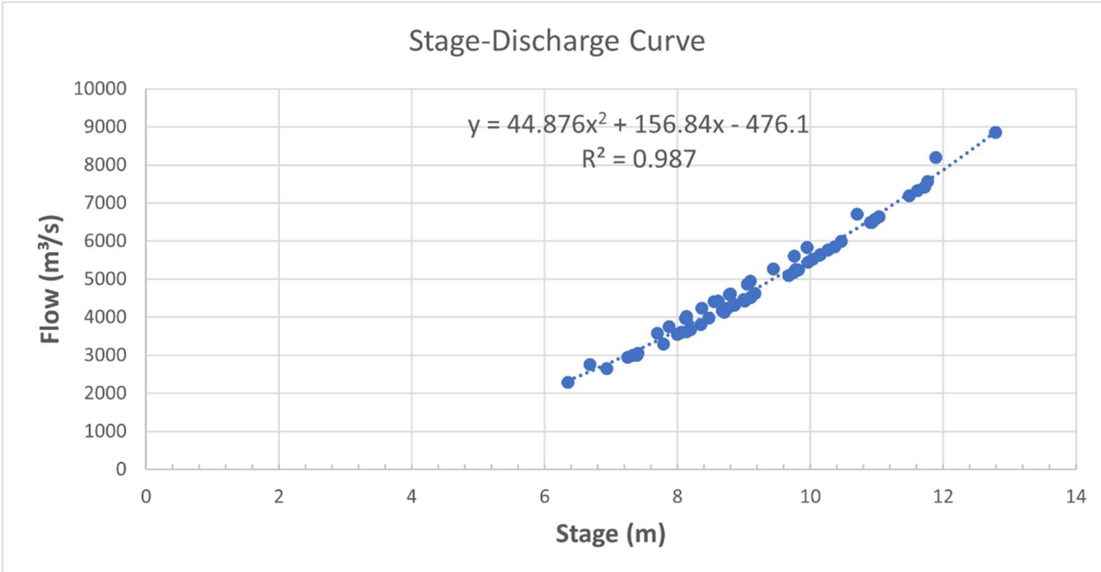

Figure 6: Stage-discharge curve of Buller River at Te Kuha, described in a scatter plot with a second-order polynomial trendline. The plot measures the annual maximum stage in m on the x-axis vs. the annual maximum flow in m^3/s on the y-axis.

Lastly, Figure 7 describes the flood return period of the Buller River at Te Kuha. The calculation shows a 62-year return period would have a flood event with a flow rate greater than 8000 m^3/s. Moreover, the fitted return period calculated that a 500-year flood event would have a flow rate greater than 17000 m^3/s.

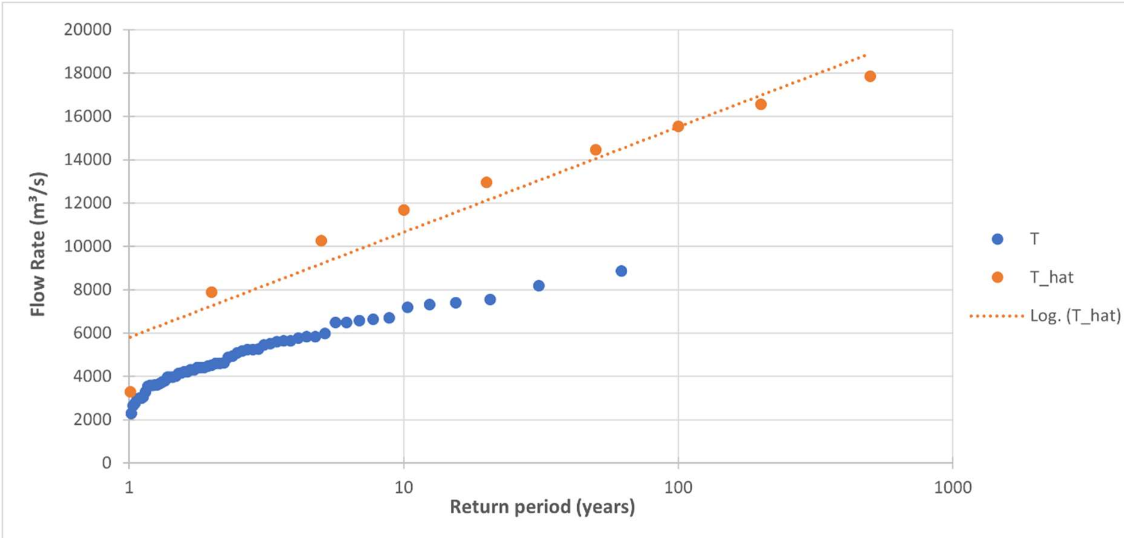

Figure 7: The flood return period for Bulle River at Te Kuha with the return period and fitted return period in years on the x-axis vs. annual maximum flow in m^3/s on the y-axis.

5. Discussions

The graphs and news findings emphasized that a 50-year extreme flood event happened at Buller River at Te Kuha between 1970 and 2021, severely damaging the town of Westport due to flooding. As Benn (1990) described Westport flooding as rapid or flash flooding, Gray (2023) elaborated that a significant factor for flash floods is rain that falls faster than the soil can absorb and rolls over the same areas for hours. In addition, Gray et al. (2005) assessed that every increase in the annual mean temperature for every degree Celsius would raise the expected rainfall under a 50-year return period by 5.2%-8.0%.

Next, the following discussions will analyse how significant rain intensity affects the Buller River flow rate according to the 1968-1970 event. For instance, a rainfall of 71 mm on 9 April 1968, 80 mm on 31 August 1970, and 66 mm on 17 September 1970 fell upon Westport (Benn, 1990). Subsequently, Buller River at Te Kuha recorded a maximum flow rate of 2997.71 m^3/s on 9 April 1968, 8194.51 m^3/s on 31 August 1970, and 6179.14 m^3/s on 17 September 1970. Despite having immense rainfall on 9 April 1968, 17 September 1970 flood event had a higher river flow rate. The author concluded that consecutive rain events significantly impact the river flow rate, especially when the river has not fully discharged its flow. Even so, rainfall still portrays a significant factor for flash flooding in Westport. All in all, flood risks at Westport most likely will worsen in the future as climate change rises.

As sudden and erratic rainfall significantly influences flood events in Westport, Buller District Council (2022) developed a concept of Protect, Avoid, Retreat, and Accommodate (PARA) as a flood management procedure in Westport. Firstly, Protect emphasizes building structural protection against coastal and flooding hazards. Secondly, Avoid aligns the Building Code at Westport with sensible flood resilience within the TTPP district map. Thirdly, Retreat focuses on developing a plan to sustain growth in a low-risk area. Finally, Accommodate proposes to monitor wave sea level rise more accurately, better provision for stormwater infrastructure, and identify pathways regarding insurance. Regarding current flood management, the author agreed that the plan is appropriate and applicable as it covers extensive socioeconomic and topographic factors and deals with current and future risks at Westport.

6. Conclusion

Westport, located on a flood plain, has immense records of flash flooding as rainfall falls. Also, canother 50-year extreme flood event, with a river flow rate greater than 8000 m^3/s and water level up to 12 m, is most likely to happen in the future. Thus, regarding flood management, Buller District Council has approached the risks correctly with the PARA procedure. Finally, climate change may worsen future environmental hazards at Westport, and current flood protection plan should mind climate change's impact on sea level and rainfall.