# NZ Engineering Science Competition Judges Report 2021

The thirteenth annual "NZ Engineering Science Competition" was held from 10am to 6pm on Saturday 7 August 2021. We had 202 teams take part with entries from 61 schools across New Zealand, including our first ever entry from an online high school.

## Competition Question

"How many 1 in 100 year extreme weather events can NZ expect to experience over the course of the next decade?"

With extreme weather events and associated natural disasters appearing regularly in news headlines across the world this year, and with the 2021 United Nations Climate Change Conference (COP26) being held this year, this question was intended to be highly relevant to current affairs.

The question was deliberately open-ended, with no single "correct" answer, and allowed for a wide variety of approaches to answering it. Teams were expected to research and understand the topic, devise a mathematical modelling approach to answering the question, and then write a clear and concise report to present their findings. All of this within just an eight hour period! Overall, the judges were very impressed with the quality of work submitted and range of modelling approaches taken, and had a difficult task to decide on the finalists and competition winner.

## Judging Process

Judging was done over three rounds by members of the Department of Engineering Science and the Auckland Bioengineering Institute. Rounds one and two narrowed the 202 entires down to a shortlist of 11 to enter the third and final round. A panel of four expert judges, with extensive experience in mathematical modelling and data analysis, then reached a consensus on the winning team and the two runner up teams. All judging was completed blind, with team identities only revealed after all judging was completed.

## Judge's Comments

Each team needed to first research the topic and write the introduction for their report. Fortunately, extreme weather events and the impacts of climate change on the severity and frequency of these events is currently a popular topic, both in scientific research and mainstream media reporting. Teams therefore had a wealth of information to consult in researching the topic. It was encouraging to see many teams reference reports from New Zealand institutions, such as MetService, Te Ratonga Tirorangi, and NIWA, Taihoro Nukurangi, which provide a local context to the issue. Overall, the judges were impressed by the quality of the research undertaken by the teams.

As part of determining their approach to answering the question, teams needed to carefully consider the wording of the question. The concept of a "1 in 100 year event" is fairly well defined in scientific literature. It is generally considered to be an event with a 100 year return period i.e. it has a 1% probability of occurring in any given year. This doesn't necessarily mean that such an event will occur only once every 100 years. Unfortunately, the term is often misused in the public domain, commonly in reference to extreme events and natural disasters as a means of reinforcing the severity of an event, rather than as an accurate representation of its return period. The judges noted that quite a few teams ended up with a modelling approach that doesn't fit the scientific definition of a 1 in 100 year event.

It is less clear in scientific literature what exactly constitutes an “extreme weather event”. Although New Zealand has a fairly temperate climate, it does experience extremes of weather, including heavy precipitation (e.g. rain, snow, hail), flooding, strong winds, tornadoes, and marine heatwaves. These events can cause extensive economic and environmental damage, as well as loss of human life. Teams therefore needed to decide on specific types of weather event to consider in the modelling approach. The judges noted a wide variety of event types considered by teams, with heavy rainfall and strong winds featuring commonly. There were a few problematic inclusions, such as non-weather related events like earthquakes and volcanic eruptions. Whilst these are certainly natural disasters that can seriously impact New Zealand, they don’t have a clear connection with weather.

Another potentially important factor in answering this question is that of climate change. The current scientific consensus is that climate change will increase the frequency and severity of extreme weather events in some regions of the world. This corresponds to a decrease in the return period of an event i.e. what was previously considered a “1 in 100 year” event may in the future have greater than 1% probability of occurring each year. Quantifying the impact of climate change on return periods for different types of weather event was a challenging task for the teams that attempted to incorporate this into their modelling. The judges noted a common approach was to model trends using existing studies, using data provided in pre-existing studies. This was done to varying levels of sophistication and success.

There is also the issue of regional differences in climate across New Zealand. What constitutes a 1 in 100 year event will vary across the country. For example, a 2016 NIWA climate report estimated that Mt Cook Village requires a 24 hour total rainfall of approximately 486 mm to be defined as a 1 in 50 year event, compared with only 125 mm in Christchurch. Both locations are in Canterbury, not far apart geographically, but experience very different weather conditions due to differences in elevation and proximity to the Southern Alps. The judges noted that this issue was not specifically addressed by many teams, and for those that did a common approach was to attempt to choose a single location that is broadly representative of all of New Zealand. This was done with varying levels of success.

As part of modelling the problem, each team needed to find data on past extreme weather events in New Zealand. While there is a lot of publicly available data on past weather and extreme events in New Zealand, it can be difficult to find data in a suitable form e.g. in terms of a 100 year return period. Part of the issue here is that there are few locations in New Zealand for which weather measurements have been made uninterrupted for 100 or more years. Modelling tools are therefore widely used in both industry and scientific research to estimate weather conditions with different return periods. For example, the publicly available High Intensity Rainfall Design System (HIRDS), produced by NIWA, can provide an estimate of rainfall intensity with a 100 year return period at many locations across New Zealand. As expected, the judges noted that teams used a wide variety of different data in their modelling. NIWA’s “Historic Weather Events Catalogue” was one of the most commonly referenced sources of data. However, this catalogue is focused on weather events that caused significant damage or casualties, and is not particularly well suited to understanding what events have a 100 year return period. Selecting appropriate data is an important step in any good modelling approach.

The next challenge faced by teams was to come up with their modelling approach. The judges noted that the modelling approach was at least partly dependent on the underlying definitions, assumptions and data chosen by that team. For example, a team attempting to consider the impact of climate change might first attempt to model how they expected the 100 year return period of a

weather event to vary over the next decade. A team that assumed a threshold for an extreme weather event (e.g. daily rainfall exceeding the threshold), were more likely to use a Poisson regression or similar method to estimate the count of events over the next decade. The judges noted that a few teams attempted a modelling approach that was very sophisticated for a high school level of education. However, with this attempted sophistication came minor and/or major issues with the implementation. It is often said in data analysis that it is best practice to use the simplest model possible that does a good job of fitting the data (or even better compare the results of several different simple models).

Although not necessary to be considered a top entry, an increasing number of teams in recent years have been writing computer code to support their mathematical modelling. Similar to previous years, the choice of programming languages is fairly reflective of that used in the scientific community. Popular languages used included Python, Java, C++ and MATLAB. Some online tools were also used extensively, such as NZGrapher. A few teams attempted to use the increasingly topical approach of machine learning to perform model fitting and prediction, though the judges noted issues with their suitability and/or implementation. Computer code written by students was used for a range of purposes, including database querying, data preparation and analysis, simulations for event prediction, and regression to identify relationships between variables. It is important to note that any computer code written must add value to the mathematical modelling, rather than just being included to try and impress the judges.

Once a team had found their answer to the question, they then needed to complete their report. A well written report is essential for doing well in this competition. The report should begin with a short summary/abstract that summarises the findings and includes the answer to the question (counter-intuitively, this is often written last). The report should then continue with an introduction, with information that outlines relevant background information and prior research on the topic.

Many teams tend to then write out separate sections for their definitions and modelling assumptions. While this is not an issue per say, the more common approach in scientific research is to write a dedicated section that describes the modelling approach, which will include the assumptions made and any relevant definitions. This section was the weakest part of most team reports. The judges found that it was difficult to easily understand or follow the modelling approach taken by many teams. It is important to define any equations or modelling techniques used, preferably with relevant references to other research. This should be written in a way that is clear and easy to follow by an audience with a similar level of knowledge.

The next section should detail the modelling results. Relevant figures and tables can be extremely helpful for assisting readers with visualising the understanding your results. The top teams all made effective use of visual tools for presenting their results. Finally, the report should present your conclusions based on the modelling results.

A key part of the modelling process is reflecting on whether the results obtained make sense, when compared with reality. Some teams did this very well and also pinpointed areas where their model could be improved to better reflect reality. Other teams obtained highly implausible results from their model and didn't stop to question them.

Overall, the judges were very impressed at the overall quality of the team reports.

## How to do better

For those students who will be competing again in the future here are a few tips on how to improve your chances of winning

- Ensure you begin your report with a summary/abstract that briefly describes your approach AND the solution you obtained.
- Take care to use a model appropriate to the problem and be aware of your model's limitations (some very sophisticated approaches were unfortunately not applicable to the contexts to which they were applied).
- Explain your approach clearly, so that an audience with a similar level of knowledge can follow your modelling and also understand WHY you have used that approach (some equations seemed to appear out of thin air, with no justification of where they came from or what the variables represented).
- Use visual tools such as graphs, images,diagrams, figures and tables, where appropriate, to effectively and efficiently present information.

## Results

**Winners of The Pullan Prize for first place ($6000)**

- Team 1004 from Westlake Boys High School, Auckland (Year 13): Nate Williamson, Adam Bodicoat, Michael Zhou, Taewon Yun

**Runners Up ($2000 for each team)**

- Team 122 from Northcote College, Auckland (Year 12/13): Scott Kwon, Jeremy Ballard, Michael Rubie-Wong, Alex Brown
- Team 1007 From St Peter's School, Cambridge (Year 13): Christopher Graham, Andrew Qiu, Jimmy Gan, Lincoln Hannah

**Highly Commended**

- Team 1015 from Epsom Girls Grammar School, Auckland (Year 13): Prakhya Mathur, Winola Hu, Sophia He, Aldonza Watt
- Team 39 from King's College, Auckland (Year 13): Felix Duan, Alvin Zhu, Thomas Gordon, Reagan Wang
- Team 31 from Kristin School, Auckland (Year 12/13): Lillian Yuan, Jerry Song, Sophia Fang, Selwyn Liu
- Team 105 from Papatoetoe High School, Auckland (Year 12): Vandan Bhatt, Talha Ashraf, Aryan Patel, Fergus Lee
- Team 99 from Rangitoto College, Auckland (Year 12): Sun-woong Kang, Junzhe Li, David Zhu, Zalan Varga
- Team 147 from Sacred Heart College, Auckland (Year 12/13): William Waters, Brandon Toh, John Dominic Alo, Ciaran Baker
- Team 144 from Wellington College, Wellington (Year 11/12/13): Haveesha Perera, Chinmay Madhusudhan, Benjamin Hong, Abhishek Balram
- Team 1014 from Whanganui High School, Whanganui (Year 12/13): Akshima Marwah, Blair Gowan, Troy Brennan, Calum Sinclair

## Participation

We had 202 teams from 61 schools participate this year.

We had many "Action shot" photos submitted during the course of the day. These photos were uploaded to our department facebook page and can be viewed at: www.facebook.com/engsci

ACG Parnell College and Epsom Girls Grammar School had the most entries from individual schools, each with 13 teams competing. See below for a complete list of schools and how many teams they entered.

| | | | |
|---|---|---|---|
| ACG Parnell College | 13 | Pakuranga College | 4 |
| ACG Strathallan College | 4 | Palmerston North Girls' High School | 3 |
| ACG Sunderland | 1 | Papatoetoe High School | 3 |
| Albany Senior High School | 2 | Pinehurst School | 2 |
| Auckland Grammar School | 4 | Rangitoto College | 8 |
| Auckland International College | 2 | Rosehill College | 2 |
| Avondale College | 10 | Rosmini College | 2 |
| Botany Downs Secondary College | 6 | Rutherford College | 3 |
| Burnside High School | 3 | Sacred Heart College | 1 |
| Crimson Global Academy | 1 | Saint Kentigern College | 3 |
| Dunstan High School | 3 | Samuel Marsden Collegiate School | 3 |
| Epsom Girls Grammar School | 13 | Selwyn College | 4 |
| Fraser High School | 3 | St Cuthbert's College | 3 |
| Freyberg High School | 2 | St Dominic's Catholic College | 2 |
| Hamilton Boys' High School | 1 | St Paul's Collegiate (Hamilton) | 3 |
| Hamilton Girls' High School | 1 | St Peter's School Cambridge | 4 |
| Hastings Boys' High School | 2 | Takapuna Grammar School | 5 |
| Hutt International Boys' School | 1 | Tauranga Boys' College | 1 |
| John McGlashan College | 5 | Tauranga Girls' College | 2 |
| Kaitaia College | 1 | Waimea College | 2 |
| Kāpiti College | 1 | Waitakere College | 1 |
| King's College | 5 | Waitaki Girls' High School | 1 |
| Kristin School | 7 | Waiuku College | 1 |
| Liston College | 2 | Wellington College | 2 |
| Logan Park High School | 2 | Western Springs College | 1 |
| Long Bay College | 1 | Westlake Boys High School | 4 |
| Macleans College | 9 | Westlake Girls High School | 7 |
| Massey High School | 2 | Whanganui High School | 5 |
| Mount Maunganui College | 1 | | |
| Mount Roskill Grammar School | 4 | | |
| New Plymouth Boys' High School | 1 | | |
| Northcote College | 2 | | |
| One Tree Hill College | 5 | | |