SLOW SLIP EVENTS ON THE EAST COAST:
GRAPHING ACTIVITY

EAST COAST LAB
LIFE AT THE BOUNDARY

In this activity, students explore tectonic movements called slow slip earthquakes. They will then plot and interpret a graph using data from actual seismic (earthquake) events in New Zealand.

Key Competencies:	Thinking; Using language, symbols, and texts.
Unit/Topic:	**Primary focus:** Mathematics and Statistics **Secondary:** Science
Level/s:	**4 and 5**
Statistics strand:	**Statistical investigation:** • Gathering, sorting and displaying multivariate category, measurement and time-series data to detect patterns, variations, relationships and trends. • Comparing distributions visually • Communicating findings, using appropriate displays
Science Strand:	**Nature of Science** • Communicating in Science **Planet Earth and Beyond** • Earth systems **Physical World** • Physical inquiry and physics concepts
Lesson Objectives:	**By the end of this activity, students will be able to:** • Understand the difference between fast earthquakes and slow slip earthquakes • Plot and interpret data on a line graph • Describe trends and compare multivariate data from two different locations

Contents

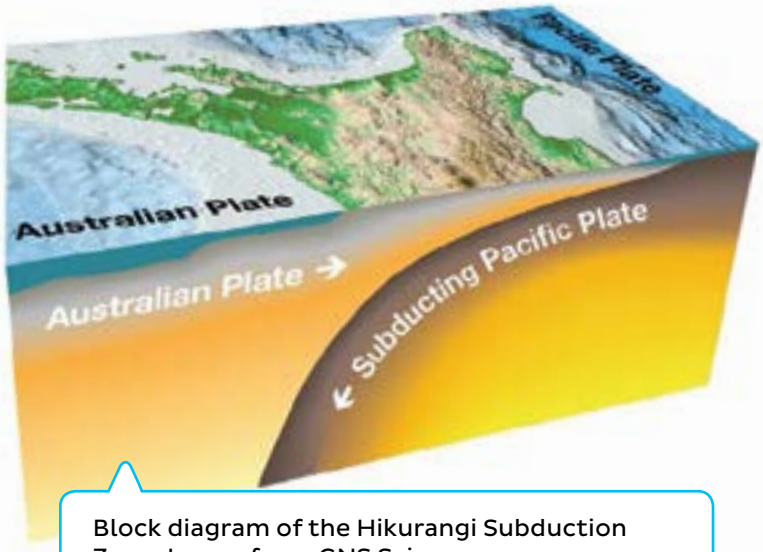
This activity was written in 2018 by staff at GNS and Outer Reaches, in collaboration with East Coast LAB.

EAST COAST LAB
LIFE AT THE BOUNDARY

Information Sheet: Life at the Boundary

New Zealand is a country on the move.

New Zealand experiences many earthquakes because it is positioned on a boundary between two tectonic plates, where the Pacific plate dives beneath the Australian plate through a process called subduction.



Block diagram of the Hikurangi Subduction Zone. Image from GNS Science.

The long subduction zone that is formed off the east coast of the North island is called the Hikurangi Subduction Zone.

The Hikurangi Subduction Zone is potentially the largest source of earthquake and tsunami hazard in New Zealand. If the subduction zone ruptured (broke) it could cause a large earthquake, similar to the magnitude 9.0 Tōhuku 2011 subduction earthquake in Japan.

Not all earthquakes happen the same way or result in significant ground shaking. About fifteen years ago scientists discovered a new type of earthquake happening on the northern part of the Hikurangi Subduction Zone, near Gisborne. This type is different from the usual fast earthquake we can feel.

Slow slip events are also referred to as "slow earthquakes" or "silent earthquakes".

What are slow slip events?

Slow slip events (SSEs) are where movement between the tectonic plates occurs slowly across the subduction zone, over a period of weeks to months, rather than suddenly in a large earthquake. Because of the slow energy release, we cannot feel them. They occur below the Earth's surface over a large area and can involve many centimetres of movement between the tectonic plates.

Since measuring began, dozens of slow slip events have been recorded in New Zealand between 2002 and 2018.

How do we know when they are happening?

Scientists have only been able to detect slow lip events (SSEs) recently due to the installation of permanent global positioning system (GPS) equipment which can detect millimeter changes in land movements. As part of the GeoNet project in New Zealand, continuously operating GPS recorders have been installed throughout the country. Since measuring began in 2002, dozens of slow slip events have been recorded in New Zealand

The GeoNet continuous GPS data shows that these silent earthquakes occurring under New Zealand are changing the shape of parts of the North Island over time periods of weeks to years.

Information Sheet: Life at the Boundary

West vs. East

The outer skin of the Earth, called the crust, is divided into tectonic plates, and these are continuously moving and adjusting.

The Pacific plate is descending **westward** beneath the eastern North Island. For much of the time, the dipping Pacific plate and the over-riding North Island become stuck together at the boundary between the plates, which causes large parts of the eastern North Island to be pushed to the west by the subducting Pacific Plate.

However, during slow slip events, large areas of land move **eastward and sometimes upward** by up to 30mm over days, weeks or months. Watch the Science Learning Hub's animation to find out more about how they behave.

What is the relationship between slow slip events and other earthquakes?

These silent earthquakes are a sign that tectonic stress is being relieved by 'slow slip' occurring on parts of the plate boundary at 5 – 50 km depth beneath the North Island. The slow slip events in the lower North Island tend to occur just below the area of the plate interface that is 'stuck' and building up stress to be relieved in future earthquakes.

There is evidence of earthquake swarms accompanying some slow slip events, suggesting a slow slip event may increase stress in surrounding areas and could push an already stressed fault closer to rupture (and cause an earthquake). However, in other cases, slow slip events can relieve stress on a fault, and this might postpone an earthquake. Earth scientists are working hard to understand the difference.

Interestingly, the Kaikōura earthquake in late 2016 also appeared to trigger a period of slow slip on much of the Hikurangi subduction zone, up to 500km north of the earthquake epicentre. This is the first time scientists have observed such widespread, large-scale triggering of slow slip by a regional earthquake.

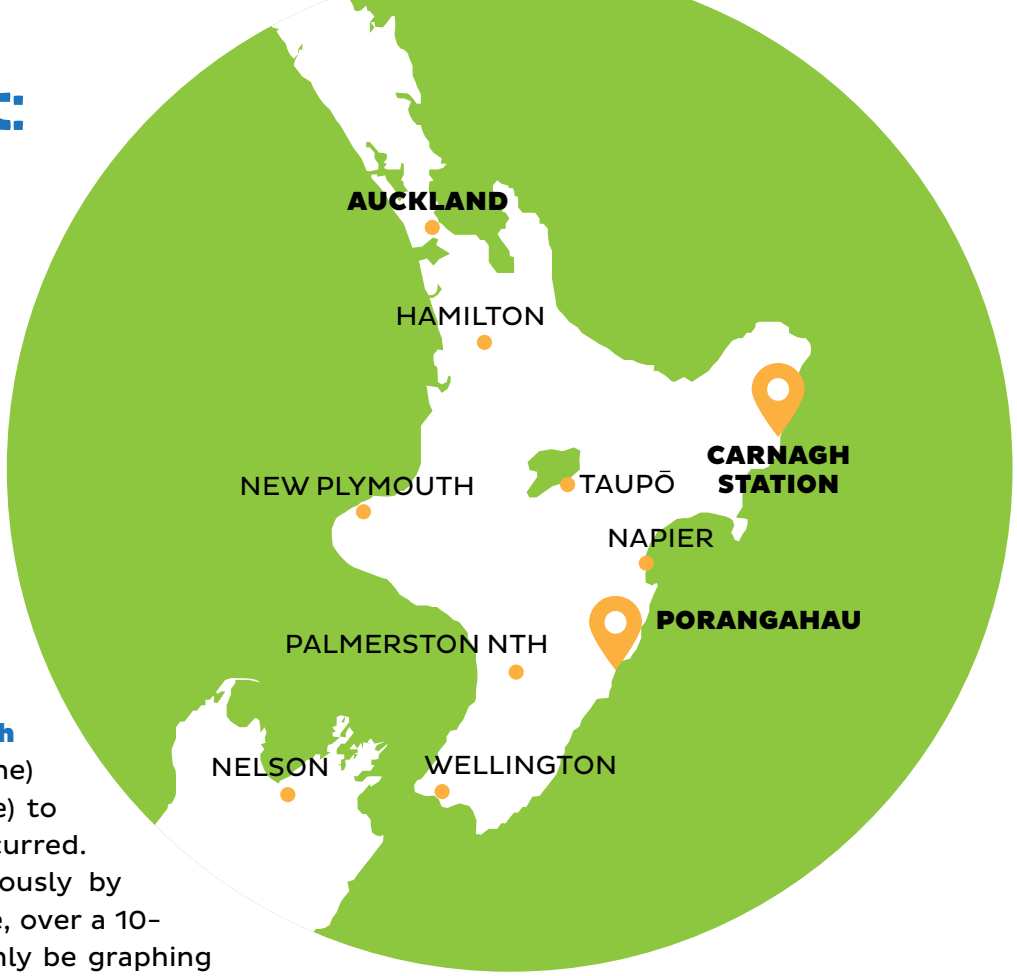
The plate interface (also called the plate boundary) is where the Pacific plate meets the Australian plate.

Communities which are prepared for hazards cope better when they happen.

Hope for the future

Understanding the relationship between slow slip events and earthquakes and the collation of slow slip data will enable better earthquake forecast modelling. More detailed forecasts lead to increased civil defence preparedness.

Student Handout:
A slow slip near Gisborne



Over the last ten years, a GPS site on the northern part of east coast of the North Island, near Gisborne, has been recording regular slow slip events, but another GPS site 244km lower down the east coast has been recording fewer of these events.

You are going to compare data from two GPS sites: **Carnagh Station** (just north east of Gisborne) and **Porangahau** (near Dannevirke) to find when slow slip events occurred. The data was collected continuously by the GPS stations positioned there, over a 10-year period. However, you will only be graphing **one piece of data from 1 January each year**, which is enough to show overall patterns.

Activity 1: Graphing GPS data

GPS movement on 1 January each year at Carnagh Station (CNST) vs Porangahau (PORA) between 2008-2018.

This table shows land surface movement over time.

Positive values (above 0) indicate the GPS has measured the land is moving to the east, and negative values indicate the GPS is measuring the land moving to the west.

Date	Movement (mm) – Carnagh Station site on 1st January	Movement (mm) – Porangahau site on 1st January
2008	4	70
2009	4	49
2010	-12	36
2011	4	15
2012	12	6
2013	-4	-13
2014	-2	-29
2015	5	-48
2016	-9	-61
2017	10	-47
2018	8	-67

Student Handout: A slow slip near Gisborne

Instructions:

1. Plot the Carnagh Station data on the graph below, and join the points with lines.
2. Now plot the Porangahau data on the same graph. Be sure to use a different symbol or colour for the data from the two sites so you can tell them apart.
3. Give the graph a title and a key (legend).

70											
60											
50											
40											
30											
20											
10											
0											
-10											
-20											
-30											
-40											
-50											
-60											
-70											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

Activity 2: Evaluating data and making interpretations

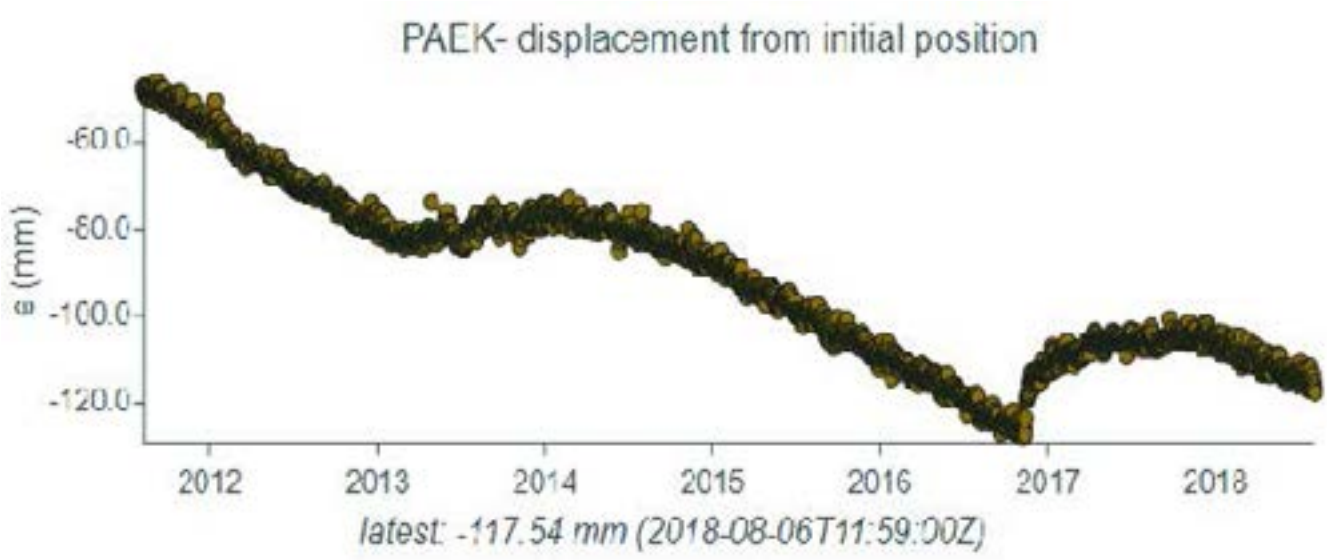
Time Series of GPS data from Paekākāriki (near Wellington), and Carnagh Station north of Gisborne.

Just offshore of the Gisborne and Hawke's Bay regions, slow slip events occur at a very shallow level on the plate boundary (<15 km depth) and occur over a period of around two weeks approximately every two years. In contrast, slow slip events beneath the Kāpiti Coast area and Manawatū region have a very different type of behaviour from the east coast slow slip events.

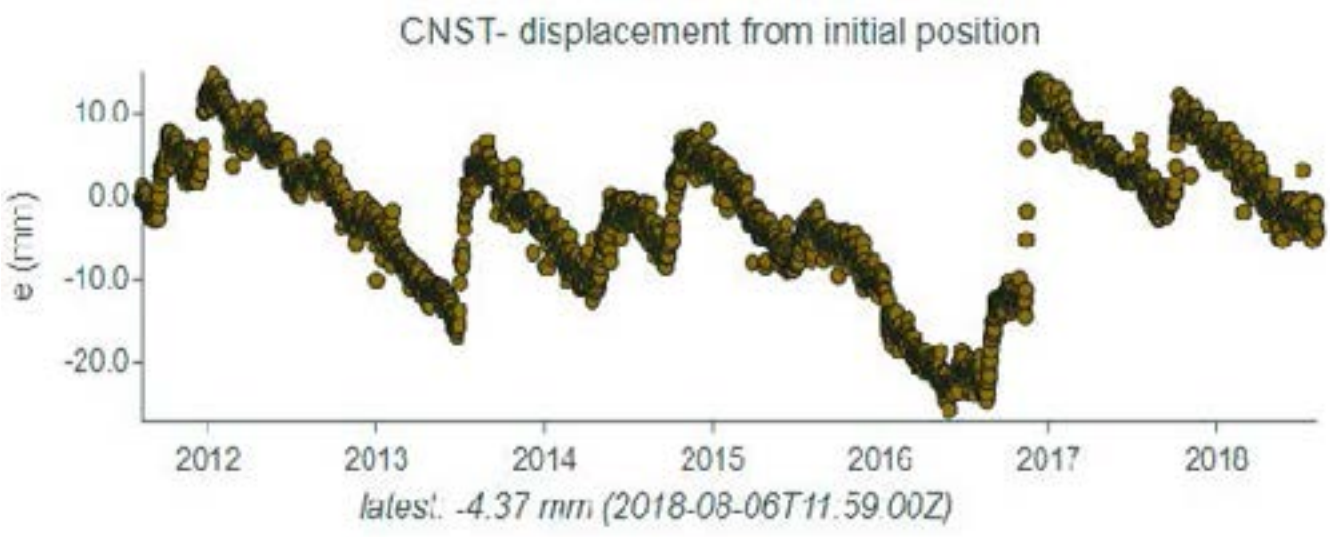
In this next activity, students will compare graphs from Paekākāriki (PAEK) on the Kāpiti Coast, to data from Carnagh Station (CNST) north east of Gisborne.

Students can study the two graphs below from GeoNet **www.geonet.org.nz/data/gnss/map** and then answer the following interpretation questions.

Graph 1: Slow slip data recorded at Paekākāriki (on the Kāpiti coast) from 2012 to mid-2018.



Graph 2: Slow slip data recorded at Carnagh Station (on the east coast near Gisborne) from 2012 to mid-2018.



Activity 2: Evaluating data and making interpretations

- Looking at the graphs, each distinctive trend **upward** indicates the GPS has measured some **eastward** movement **and this happens during a slow slip event.**
- Downward (negative) movement indicates the GPS is moving **west** as parts of the North Island get dragged westward by the subducting Pacific plate.

1. How many slow slip events have been recorded in Paekākāriki between 2012 and 2018?

2. How many slow slip events have been recorded at Carnagh Station on the East Coast between 2012 and 2018?

3. What is the average rate of slow slip events in Paekākāriki between 2012 and 2018? To find the average rate divide the number of events by the number of years.

4. What is the average rate of slow slip events in Carnagh Station between 2012 and 2018?

5. Describe the trends in each graph:

6. Compare the two locations. Which location has the **most** slow slip events?

7. Which has the **longest** slow slip events?

Teacher notes:

Extension

1. Ask the students to locate the most dramatic (largest and fastest) slow slip event recorded at **Carnagh Station** between 2012–2018, and then think about what could have triggered it.

ANSWER: The largest and fastest one was in late 2016. The Kaikōura earthquake in November 2016 triggered distant slow slip in this area **www.stuff.co.nz/national/96738432/kaikura-an-example-of-how-large-quakes-trigger-slowslip-events-at-a-distance**

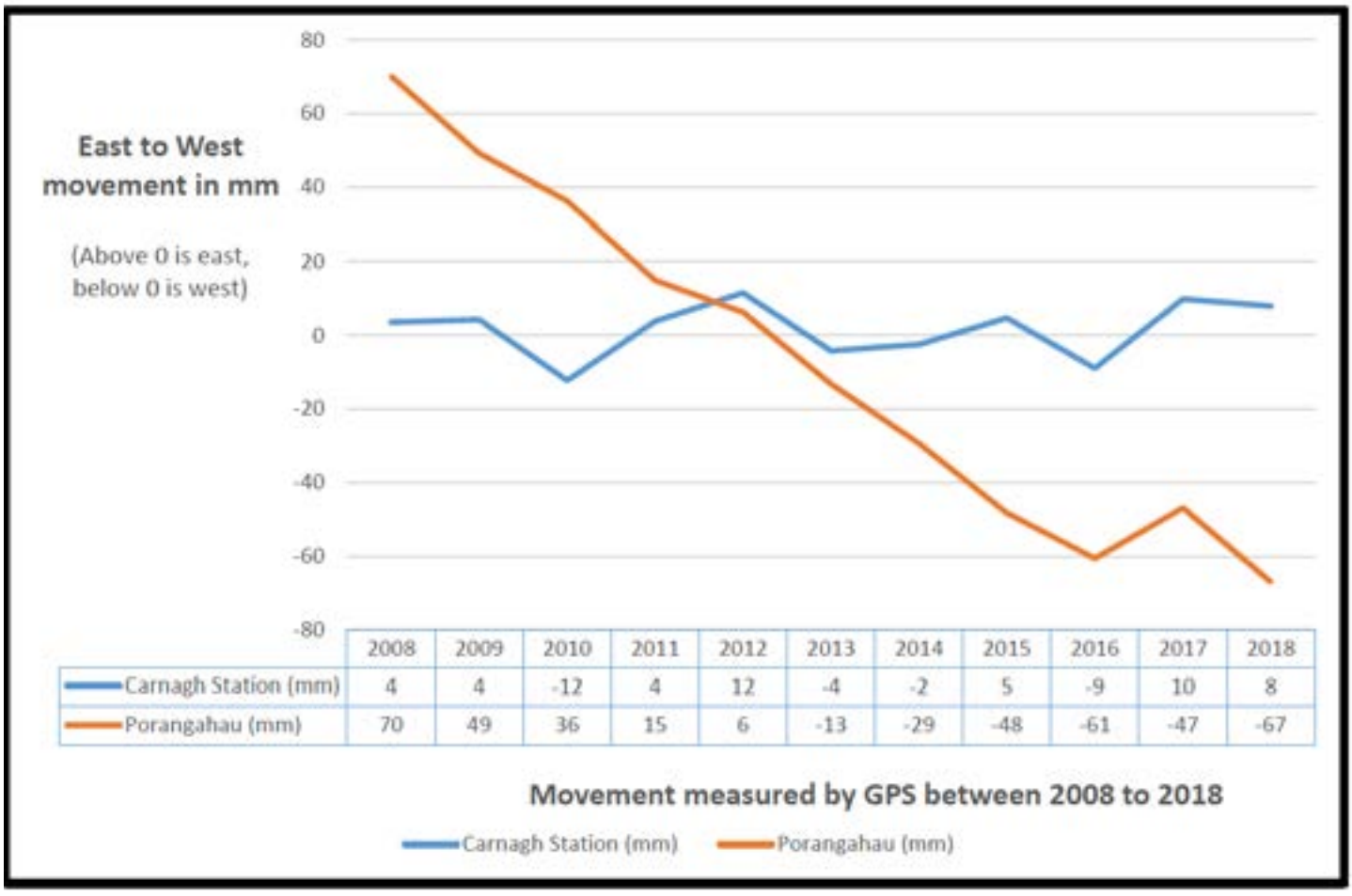
2. Look at this GeoNet site **www.geonet.org.nz/earthquake/sse/hikurangi**. Compare Hikurangi (East Coast) data to Manawatū. What are the differences in the behaviour and location of slow slip earthquakes (SSE) between the two regions?

ANSWER: The data shows that in Manawatū the SSE happen slowly, over a long period of time and very deep. But on the East Coast they occur more often, are shorter in duration, and are shallower.

Activity 1: Answers

The plotted graph should look something like this:

Title: GPS data at Carnagh Station and Porangahau between 2008 to 2018

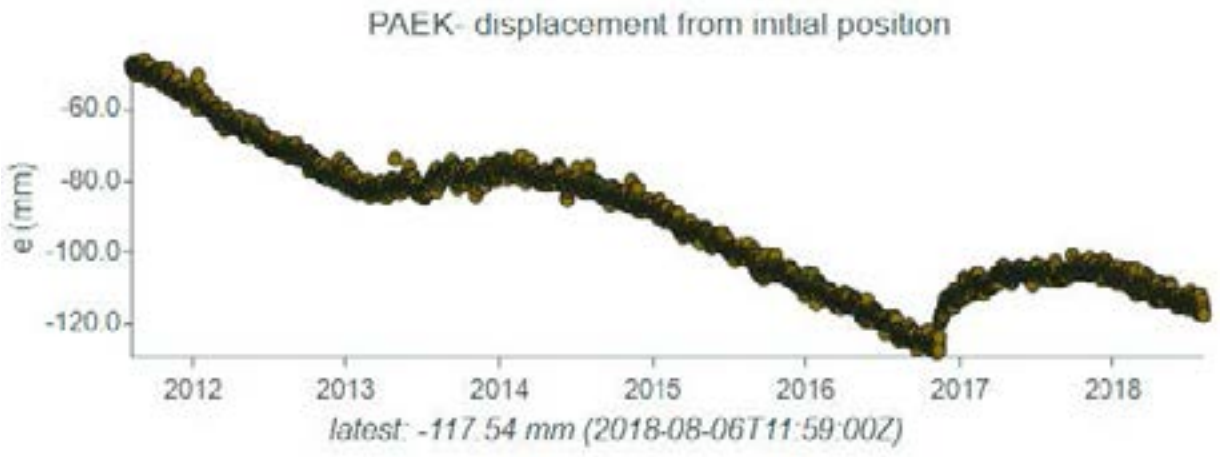


	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Carnagh Station (mm)	4	4	-12	4	12	-4	-2	5	-9	10	8
Porangahau (mm)	70	49	36	15	6	-13	-29	-48	-61	-47	-67

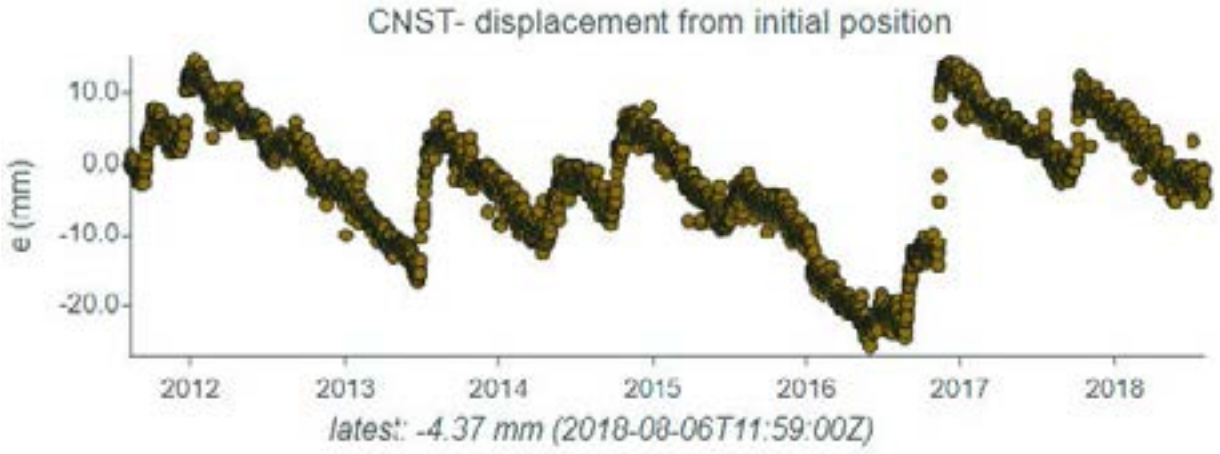
Teacher notes:

Activity 2: Answers

Graph 1: Slow slip data recorded at Paekākāriki (on the Kāpiti coast) from 2012 to mid-2018.



Graph 2: Slow slip data recorded at Carnagh Station (on the east coast near Gisborne) from 2012 to mid-2018.



1. How many slow slip events have been recorded in Paekākāriki between 2012 and 2018?
   Answer = 2.
2. How many slow slip events have been recorded in Carnagh Station on the East Coast between 2012 and 2018?
   Answer = 8 (if the smallest ones are counted the student will get an answer of 10).
3. What is the average rate of slow slip events in Paekākāriki between 2012 and 2018?
   Answer = Number of events/Number of years = 2/6 = 1 every 3 years.
4. What is the average rate of slow slip events in Carnagh Station between 2012 and 2018?
   Answer = Number of events/Number of years = 8/6 = 1.3 every year.
5. Describe the trends in each graph:
   Answer = Paekākāriki is trending downwards so it is going steadily westwards, with two movements to the east. Carnagh station is fluctuating west then east very regularly.
6. Compare the two locations. Which location has the most slow slip events? Which has the longest slow slip events?
   Answer = Carnagh Station has the most slow slip events, they happen often and don't last too long. Paekākāriki on the other hand has less frequent events but they last longer.