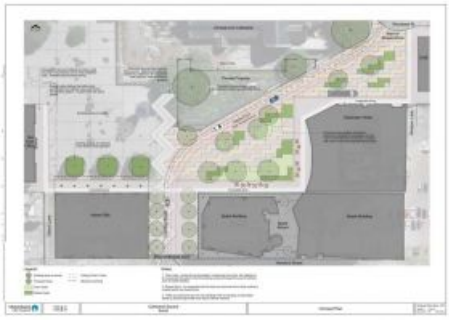
Rebuild ready: 3D mapping of a quake-damaged cathedral



After the cathedral of Christchurch, New Zealand, was hit by an earthquake, drones and advanced photogrammetry software supported the rebuilding work.

Surveying a damaged building can be dangerous. Mapping, using drones, reduces risk to staff and costs to the community. This case study of the iconic cathedral of Christchurch, severely hit by an earthquake, demonstrates how drones and advanced photogrammetry software delivered the orthomosaic map, enabling the accurate spatial planning needed to rebuild the cathedral.

In February 2011, New Zealand's second most populous city was rocked by an earthquake. The iconic Christchurch Cathedral was shattered in the shake, and the clean-up is still ongoing. Christchurch's central city and eastern suburbs were badly affected.

Before the cathedral could be rebuilt and the 'red zone' surrounding it rejuvenated, a full survey was required. Christchurch City Council's surveyor Jed Clement, licensed cadastral surveyor, stepped up to the task with the help of drones and Pix4Dmapper.

Locals describe Cathedral Square as "the heart of the city" and as being "key to Christchurch". It sits in the centre of Christchurch, both metaphorically and literally. The garden city, with its large urban parks bisected by the sleepy ÅŒtÄkaro Avon river, is known for agriculture, for being the gateway to Antarctica and, more recently, for earthquakes.

2D orthomosaic of the Christchurch Cathedral in Pix4Dmapper.

New Zealand is stretched across a fault line and earthquakes are common, although seldom as severe as the 2011 quake. By August 2012, the area had experienced more than 11,000 aftershocks of magnitude two or higher. Aftershocks were felt up to 300 kilometres away from the epicentre.

Strict building standards no doubt saved many lives. Scientists estimate that the shake that damaged the cathedral would have "totally flattened" most cities around the globe. The timber-framed homes favoured in New Zealand are relatively resistant to earthquakes, and most damage was sustained in poorly-designed buildings, or stone structures like the Christchurch Cathedral.

Prior to the 2011 earthquake, the cathedral had been damaged by earthquakes in 1881, 1888, 1901, 1922 and 2010. However, the greatest damage occurred in 2011. The first shake destroyed the spire and part of the tower, and left the rest of the building severely damaged. Aftershocks collapsed the west wall of the cathedral, and what was left of the tower had to be demolished in

2012.

The drone flight captured the damaged Cathedral.

Rebuilding after the earthquake

As the city and the nation debated whether the Cathedral should be rebuilt at all, worshippers gathered in a temporary 'Cardboard Cathedral' made out of comfortingly earthquake-resistant materials – including cardboard. But now the cathedral is being rebuilt and commercial development in Cathedral Square and the surrounding area encouraged. Access to the area has been limited due to quake damage, and it's hoped the development will revitalize the area.

To assist with the rebuild, the Christchurch City Council team launched a drone flight to capture ground levels and provide an up-to-date orthomosaic drone map of Cathedral Square to allow for accurate spatial planning.

The benefits of drones in dangerous situations

Much of Cathedral Square is open, but there were areas of the Square that were impossible to access due to the risks relating to construction as well as the damaged buildings, including the cathedral. Aerial photogrammetry was therefore the best choice for capturing data in these areas.

The drone could fly inside the restricted perimeter fences without risk to the operator. Just as importantly, Pix4D's algorithms allowed for the optimal capture of imagery to render a high-quality 3D model that the surveyors could use to take precise measurements – all without entering the site.

Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

Mapping an inaccessible area with drones

The flight team met in Cathedral Square at 8am on a Sunday morning. The early start meant fewer people around the square and fewer vehicles on the road. While this caused less disruption to the public, it also had advantages for the team. Moving objects (like cars and people) may appear in the orthomosaic as transparent artefacts. While it is possible to remove these 'ghosts' and improve the appearance of the orthomosaic, the early start allowed the team to avoid capturing them in the first place.

The Christchurch City Council survey team's drone pilots licence is pending, and they currently operate under New Zealand's CAA Part 101 operating rules, which also regulate balloons and kites. The aerial mapping flight was approved by the city's Roading Authority and the cathedral trust.

The team hoped for overcast weather, and got it. "We were concerned about the surface being quite reflective, which would mean losing detail in the final outputs," says Clement. "But the morning of the flight could not have been better, being overcast and with no wind." A total of four flights were completed: two oblique and two grid nadir to capture as much information as possible.

A 3D model of Cathedral Square and the Christchurch Cathedral in Pix4Dmapper.

"Unfortunately, we had an issue with the connection to the drone on one of the flights," says Clement. "That meant we were missing one set of oblique images over most of the square, which resulted in missed detail on the cathedral and surrounding buildings."

Despite this issue, the team was able to reconstruct the 3D drone model in less than 23 hours in Pix4Dmapper aerial photogrammetry software.

Before take-off, eight ground control points (GCPs) were levelled to a 5mm accuracy. A further 12 checkpoints were added during processing, giving the mapping project an average ground sampling distance (GSD) of 1.38cm. "Quality ground surfaces and reporting – plus ease of use – is why we chose Pix4D," added Clement.

Modelling a moment in history

The model gave the team the certainty they needed to begin the detailed design phase of the southern portion of the Cathedral Square rebuild. This part of the rebuild is to coincide with the commercial development that is underway on the southern perimeter of the square, and is due to begin opening in late 2019.

Regenerate Christchurch notes that: "Redevelopment will acknowledge the past and the events that have shaped the city, while reflecting the best of the new… This is an opportunity to breathe life back into Cathedral Square and re-establish it as the heart of the city."

The model of the square and broken cathedral is not only a useful tool, but the aerial photography is a snapshot of a moment in the city's history.

A plan to rejuvenate Cathedral Square, developed by the Christchurch City Council.