Williamson, B.E. (2010) Shake proves precautions at chemistry faculty. Flashpoint, (Spring), 4-7.

Shake proves precautions at chemistry faculty

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Due to its location at the boundary of the Pacific and Australian tectonic plates, New Zealand is regularly jolted by earthquakes. The strongest since scientific records began was in the Wairarapa region in 1855, and is estimated to have been of a magnitude between 8.1 and 8.3 on the Richter (M_W) scale. Every one to three years there is a quake of magnitude greater than 7, but generally these have caused little in the way of damage to society or loss of life,[*] due largely to the happenstance of epicentre locations and (more recently) informed and conscientiously implemented design and construction standards.

New Zealanders live with prospect of “The Big One,” a once-every-few-hundred-years $M_W > 8$ rupture of the major fault line that is associated with the plate boundary and which runs along the western edge of South Island and through the southern part of the North Island. The closest approach of this fault to Christchurch is about 130 km, so Christchurch is not regarded as being particular earthquake prone. Indeed, GNS data confirm that its locale is seismically rather quiescent in comparison with other parts of the New Zealand.

When the population of Christchurch and surrounding districts was awoken by violent shaking at 4.35 am on the morning of Saturday 4 September, thoughts naturally turned to The Big One and, “if it’s this bad here, it must be devastating at the epicentre.” We soon learnt that it was “only” a magnitude-7.1 event. But it was shallow (focal depth 10 km) and close, involving a previously undetected fault with an epicentre just 40 km to the west of the city. Remarkably, and perhaps uniquely for such a strong shock in a moderately populated area, there were no deaths and only a couple of major injuries – again a testament to a combination of good luck (regarding the time of the quake) and excellent building standards.

Since that day, there have been a vast number of aftershocks, many of them of a magnitude 5 or greater. Throughout this period, the city has largely managed to function very adequately, despite the focus of the news media on toppled older buildings and the liquefaction of land near estuaries and rivers. This is absolutely not to disparage the trauma that many residents have suffered through loss of homes and occupations, but we can be genuinely thankful that our situation is vastly better than those resulting from events of similar magnitude in other parts of the world.

After the initial quake, and having established that my family and neighbours were “shaken” but unhurt, my thoughts turned to the University of Canterbury and my workplace in the

[*] The only real exception was the 1931 magnitude-7.8 Napier earthquake, which caused 256 deaths and thousands of injuries.

Department of Chemistry. Although it didn't occur to me till later, this is certainly the first time that a New Zealand university has been subjected to anywhere near the shaking that Canterbury and Lincoln universities experienced that morning. In retrospect we have learnt many lessons, and it is the objective of this article to share some of those lessons with a wider community.

With electricity and water off, and electronic security systems defeated, the University of Canterbury campus was almost immediately closed down and the emergency management plan was activated. The university's Emergency Response Team was on site and functioning within 90 minutes of the event and, as qualified staff arrived on campus, an initial assessment of the situation was undertaken and response priorities were identified. By early the next day, engineers had verified the structural soundness of chemistry building and the Head of Department, Professor Alison Downard, accompanied by Associate Professor Emily Parker, Professor Peter Harland and two members of the University Facilities Management Unit, inspected the department. Their assessment was that there were no particular chemical, biological, fire, explosion or flooding hazards; and their recommendation to the Emergency Response Team was that the department should implement its recovery process. The first step in that process was to ensure that critical equipment (mostly refrigerators and freezers) was connected and switched on to protect valuable samples and minimise hazards when the power was returned to the building. All non-critical equipment was disconnected until electrical testing could be conducted.

On the Monday, senior technician Wayne Mackay and I were given the tasks of performing a more detailed assessment and formulating a recovery plan. From the fifth floor down (mostly administration and the teaching laboratories) damage was negligible; but it was significant and progressively worse on the three higher floors. Books, computer monitors, pot plants and filing cabinets were strewn around offices. Damage in the research labs was widespread but apparently superficial, principally involving broken glassware, toppled bench-top instruments and silicone-oil spills. Chemical containment vessels and cabinets appeared to have stood up well, though some had migrated by as much few metres across laboratory floors. From a cursory external inspection, there was no glaring evidence of damage to major instruments, although subsequent testing was to reveal significant and irreparable internal damage to a new mass spectrometer and lesser damage to several other instruments.

The major part of the recovery process was implemented over the next four days as follows:

Tuesday 7 September: Seven staff members (Wayne Mackay, Laurie Anderson, Alistair Duff, Matt Polson, Rob Stainthorpe, Nick Oliver and I), with skills in areas ranging from photography to hazard management, worked to identify, document and undertake first-order mitigation of hazards. Our principal aim was to make the department safe for other workers to start their clean-up procedures. Secondary aims were to generate records for insurance purposes (and posterity) and to establish priorities for action over the following days. Most of the work involved photography, picking up equipment and containers, sweeping up broken glassware, and initial efforts at cleaning up oil and chemical spillages. Freezers and refrigerators were sealed, to be dealt with by a more specialised group on the next day.

Wednesday 8 September: In the morning, appropriately skilled technical and academic staff made initial assessments of the condition of major equipment (X-ray diffractometer, NMR and mass spectrometers) prior to contacting manufacturers and service companies. At the same time, a subgroup of the departmental Safety Committee collated and examined inventories of refrigerator, freezer and cold-room contents, to identify toxic or particularly reactive substances. During the afternoon this latter group unsealed and inspected most of the refrigerators and freezers, leaving a couple of especially hazardous substance to be dealt with later when breathing apparatus were available. In the event, those materials had been very securely protected and isolated, and presented no actual hazard.

Thursday 9 September: Academic and technical staff were invited in to tidy their offices and workshops, and to inspect their laboratories. A small group of PC-trained research students assisted with the assessment and tidying of the department's PC2 lab and technical staff started the testing and safety certification of electrical equipment. General clean-up procedures continued and by the end of the day the laboratory floors were completely cleared of oil.

Friday 13 September: All staff and research students were permitted back into the department to proceed with cleaning up and damage amelioration, with the proviso that no research was to be undertaken until laboratories had been certified safe by the department's safety officer, Professor Ian Shaw.

By the end of that week, the department was well down the track to recovery. With the assistance of Facilities Management personnel, most of the infrastructure had been restored. Fume hoods were still switched off awaiting confirmation that ducting was intact, and the restarting of major instruments was stalled while advice was sought from manufacturers and service companies. We could have resumed undergraduate teaching in the following week, but other sections of the university (particularly the libraries) were taking longer to recover. With the added stress of the ongoing aftershocks, it was determined that undergraduates would not be permitted back on to campus till the following Wednesday, with teaching starting on 20 September.

So what did we learn from this event?

Firstly, due to numerous incremental earthquake mitigation modifications prior to the event, we were actually very well prepared. Perspex guards mounted around chemical shelving and laboratory bench dividers were extremely effective at preventing chemical containers from spilling on to the floor or bench tops. Storage-shelf lips of a little as 2-cm height seem to have entirely prevented equipment falls, whereas books and papers stored on office shelves with no lips were liberally scattered around offices. Evidently, items on flat surfaces had mostly shuffled laterally during the shake rather than bouncing. Substances in refrigerators and freezers had been well contained in plastic trays and sealed plastic containers proved to be particularly safe for holding hazardous materials

A few things didn't fare so well. Chains used to fix light fittings to the ceiling and (in a couple of instances) gas cylinders to walls had been shaken off open-loop hooks. Items left on un-lipped bench tops fell to the floor resulting in a lot of broken glassware. The latter problem was exacerbated by the fairly extensive spillage of silicone oil (used as an inert heating-bath medium). The mixed glass and oil was both the greatest hazard and the most difficult thing to clean up.

Our response plan and actions went well, without resulting in any harm to personnel or additional damage to the building or its contents. The photographs of the affected rooms prior to, and during, cleanup provided comprehensive records for insurance claims and also an opportunity for a post-clean-up departmental slide-show. The stepped progression of activities meant that we could exercise control over access, particularly at the time when some potential hazards had not been specifically identified and aftershocks were at their most numerous. Staff and students were generally very patient about being excluded in the early stages. Perhaps the only real flaw in our arrangements was the difficulty of obtaining a list of contact phone numbers. We had such a list on a university server, but infrastructural disruptions meant that we could not access that list for the first few of days after the quake, the period when we trying to check on people's welfare as well as form task teams and gather information about stored materials.

In light of our experience, what would be our recommendations to other similar departments? Here is a list of things that come to mind.

1. For items (such as gas cylinders) secured by chains, closed-loop chain-hooks should be used with attachment by way karabiner-like shackles. Open-loop hooks permit the risk that the chain will jump free during shaking.

2. Guards (for example Perspex or wire) should be affixed to any shelves or sills where loose items (sample vials, chemical jars, desiccators etc.) are likely to be stored This includes the tops of cabinets, refrigerators, ovens and any other places that are likely to provide tempting storage spots.

3. Low lips should be considered for the edges of research-laboratory benches to limit the possibility of items rolling off the bench on to the floor. Bench-top instruments (chromatographs, ovens, spectrometers etc.) should be fixed to the bench and stacks of such items should be strapped down.

4. Spilt silicone oil is very problematic. Where appropriate, alternatives to oil-bath heating should be used. If oil-bath heaters are required, splash-proof baths should be employed (we need a design) and the oil should be returned to a sealed container when not in use.

5. Items and substances stored in freezers, refrigerators and cold rooms should be contained in (preferably sealed) plastic boxes or trays. Refrigerators and freezers should carry physical identification information that clearly specifies any hazardous substances they contain and the person who should be contacted in case of an adverse event.

6. Wheeled storage cabinets had migrated by as much as a few metres. We wonder whether such cabinets should be fitted with wheel locks. However, it is possible the motion of the cabinet as a whole dampens the risk of items toppling within the cabinet. This is a question that could do with investigation.

7. Half-sized filing cabinets should not be stacked on top of each other. Filing-cabinet drawers should be closed with the key in the locked position to prevent drawers from shaking open and overbalancing the cabinet.

8. Several specified members of staff should carry a full list of contact phone numbers in a cell phone directory. All staff in the department should know who carries those directories and how to contact them.

9. The department should have a generic emergency response plan that can be readily adapted to any adverse event. It should be known which teams of which people should be assigned to tackle each type of predictable task.

10. In case of a power outage, an accessible list should be available as to which instruments should remain switched off or be urgently restarted when power is returned.

Our department has weathered the earthquake very well due to a combination of good luck, good planning and dedicated effort. We owe a great deal to university Emergency Response Team and Facilities Management Personnel. The overall emergency preparedness of the university was tested to a degree far beyond anything else in its history and shown to be well up to scratch. A strong cooperative relationship between the pan-campus controlling body and the departmental response teams greatly facilitated our efforts. Information and assistance was provided promptly, as and when we needed it without unnecessary bureaucratic overheads. At the departmental level we are indebted to the technical staff who implemented the invaluable pre-quake mitigation measures and carried the majority of the post-quake clean-up workload. These people put aside their personal concerns and anxieties at a time when magnitude-5 aftershocks were still a regular occurrence.

Wheeled storage cabinets in research laboratories had migrated by as much as several metres. All of the cabinets in this photo had originally been under fumehoods or benches

Unsecured stacks of bench-top equipment are prone to toppling.

Sub-optimal storage of silicone-oil baths (top) and desiccators on unguarded sills. Fortunately, these items had not fallen, but silicone oil had splashed down the wall on to the floor.

A consequence of stacked filing cabinets. Toppled cabinets would have presented a significant threat to personnel if offices had been occupied during the earthquake.

Spilt silicone oil presented a major slip hazard and was very difficult to clean up.

Superficial mess in an upper-floor office.