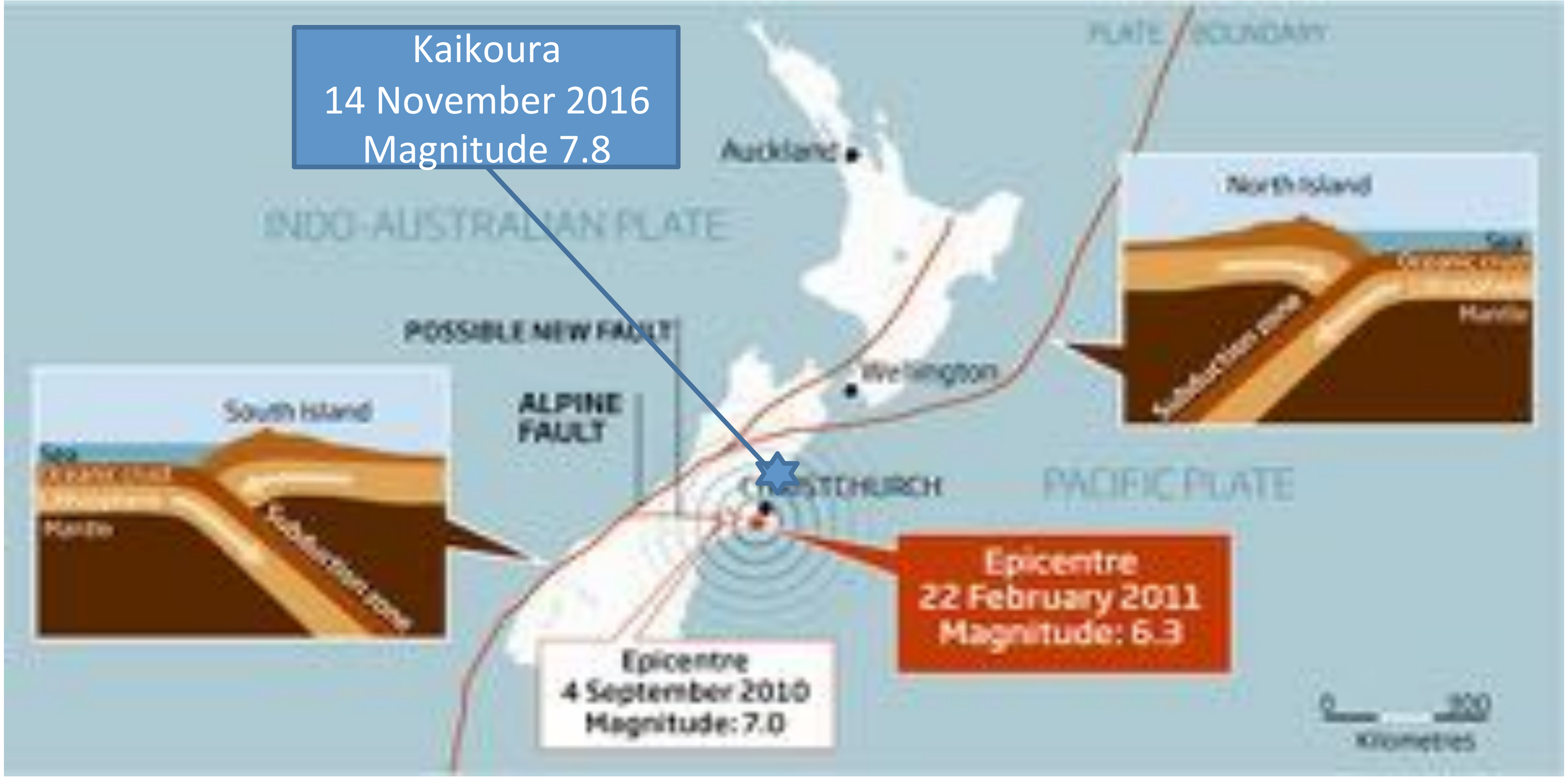
Development and Construction Planning
Lessons Learned from the Earthquake(s)

Mark Allan NZIS President

Learned Response

- Christchurch Earthquake Sequence
- Kaikoura Earthquake Sequence
- Alliance Models SCIRT NCTIR
- Christchurch Property Boundaries and Related Matters Act
- Geotechnical Engineering
- Civil Engineering



Kaikoura
14 November 2016
Magnitude 7.8
PLATE BOUNDARY
Auckland
INDO-AUSTRALIAN PLATE
North Island
Sea
Mantle
Subduction zone
POSSIBLE NEW FAULT
Wellington
South Island
ALPINE
FAULT
Sea
Mantle
Subduction zone
CHRISTCHURCH
PACIFIC PLATE
Epicentre
22 February 2011
Magnitude: 6.3
Epicentre
4 September 2010
Magnitude: 7.0
0
300
Kilometres

Canterbury Earthquake Sequence

September 4th 2010 – Magnitude 7.1
February 22nd 2011 – Magnitude 6.3
June 13th 2011 – Magnitude 6.0
December 23rd 2011 – Magnitude 6.0
More than 18,000 aftershocks

Kaikoura Earthquake Sequence
November 14th 2016 – Magnitude 7.8
More than 18,000 aftershocks

Alliance Models

- SCIRT - Stronger Christchurch Infrastructure Rebuild Team
- NCTIR - North Canterbury Transport Infrastucture Recovery
- Alliances formed between Owner Participants, Non Owner Participants and Sub-Contractors

Eliot Sinclair & Partners Ltd | Andersen & Associates Ltd | Aurecon | Bond Construction Management | Cardno | Chorus | Churchill LDS | City Care | Civil Solutionz | Clark

SCIRT
Rebuilding Infrastructure

Christchurch City Council

CERA
Canterbury Earthquake Recovery Authority
Te Mana Haumanu ki Waitaha

NZ TRANSPORT AGENCY
WAKA KOTAHI

city care
Our people. Making it work.

McCONNELL DOWELL
CREATIVE CONSTRUCTION™

Downer

Fletcher

Fulton Hogan

Aurecon | Eliot Sinclair & Partners Ltd | Bond Construction Management | Chorus | Churchill LDS | City Care | Civil Solutionz | CPG New Zealand Ltd | Eliot Sinclair & Partners

About SCIRT

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) was created in 2011 by the Canterbury Earthquake Recovery Authority to rebuild Christchurch’s earthquake damaged horizontal infrastructure.

SCIRT’s job was to provide a cost-effective and efficient vehicle to quickly get the city's civil infrastructure back on its feet.

SCIRT is an alliance partnership between:

Owner Participants - Christchurch City Council (CCC), Canterbury Earthquake Recovery Authority (CERA), New Zealand Transport Agency (NZTA) and Non Owner Participants – contractors; City Care, McConnell Dowell, Downer, Fletcher, Fulton Hogan.

About SCIRT

SCIRT was defined very early as a 5 year programme, transitioning from emergency recovery to a more business as usual approach as works progressed.

SCIRT was based on an alliance agreement between national and local government and five civil engineering contractors, but was not a conventional alliance.

The contractor delivery teams competed for construction work, which was allocated according to performance in both cost and non-cost Key Result Areas (KRAs). Strong drivers were created for both competition and collaboration.

About SCIRT

"Those companies who performed better were allocated more work," said SCIRT Executive General Manager Ian Campbell. "Delivery teams were paid a fee based on the target cost of work done. Poor performance therefore meant less fee earned; good performance increased the fee."

The difference between target cost (budget) and actual cost for each project was added to a gain share/pain share pot, a share of which (nominally 50% but variable depending on non-cost performance) was paid to (or paid by) the contractors at the end of the programme according to the amount of work each had done.

This encouraged collaboration because all contractors needed to perform to ensure an overall "gain" rather than "pain" result.

About SCIRT

All contractors started out being allocated an equal amount of work; however, each company's share altered over the course of the programme.

Because all the contractors shared pain or gain, it was in all their interests to help each other deliver the best possible outcome.

About SCIRT

SCIRT’s $2.2 billion, five-and-a-half year programme was funded by the New Zealand Government and Christchurch City Council.

It involved more than 700 individual projects across the city repairing and rebuilding underground sewage, storm water and fresh water pipes, rebuilding wastewater pump stations as well as roads, bridges and retaining walls.

Multiple contractors collaborated with government agencies for the greater good of an earthquake-battered community.

About NCTIR

The North Canterbury Transport Infrastructure Recovery (NCTIR) has been set-up by the government under the Hurunui/Kaikoura Earthquakes Recovery Act 2016 to repair and get the road and rail networks re-opened by the end of 2017.

The North Canterbury Transport Infrastructure Recovery is an alliance representing the NZ Transport Agency and KiwiRail on behalf of government, to repair by the end of 2017, the road and rail networks between Picton and Christchurch following the November 2016 Kaikoura earthquake.

NCTIR is an alliance partnership between:

Owner Participants the NZ Transport Agency and KiwiRail and Non Owner Participants – contractors; Fulton Hogan, Downer, HEB Construction and Higgins.

About NCTIR

NCTIR was setup as an emergency response alliance with an expected lifetime of 8 months to reinstate a level of service due to the impact of the main trunk railway line being out of service.

NCTIR has just recently had an improvements package added on to it's scope of work resulting in likely addition of 2 years.

The NCTIR alliance is set up differently to the SCIRT alliance in that the non-owner participants are not competing against each other for work.

Downer

HEB Construction

Fulton Hogan

HIGGINS

North Canterbury Transport Infrastructure Recovery

Move mountains to Reconnect Communities

1. Keep the Lewis Pass and Inland Road roads open
2. Re open the Main North Line
3. Re open State Highway 1 North and South
4. Open the Kaikoura Harbour

The Challenge


Primary 1
NCTIR

The Scale of the Damage

NCTIR
RECONNECTING COMMUNITIES

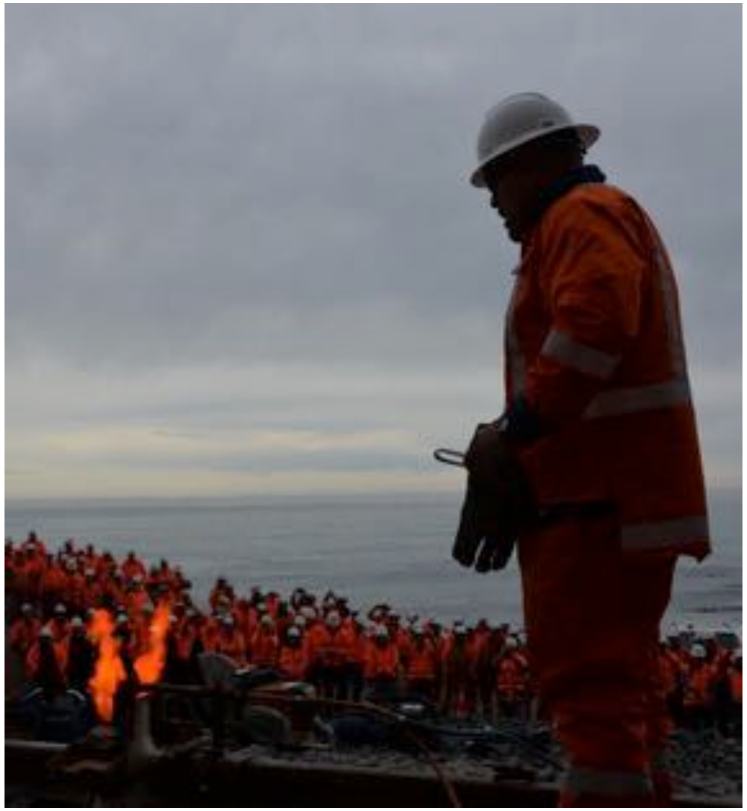

12,000m²
of rockfall
mesh ordered
85
landslides
12 major

7000+ blocks needed

to build the seawalls north of Kaikoura

Each block weighs 5 tonne

Seawall heights range from 5m - 10m+




20
rail tunnels damaged
300m
with major
damage
50 rail bridges need repairs
6 major damage
3 full
190km
rail affected
50,000m3
of ballast produced
to repair
rail corridor


Coastguard ramp is now fully operational
Improving rescue response time by 7 to 15 minutes
$5.7m funding to restore the harbour to full functionality

1500 damaged **sites**

194 km of road affected between Leithfield and Blenheim

69 damaged road bridges


SAFETY


$60mil
to improve
route
4000
vehicles IN TOTAL
through Murchison
each day
2000
Pre earthquake
24/7
crew
keeping the alternate
route safe and
serviceable

The phases

1. Clean the tops of the slips
2. Clear away the slip with machinery
3. Keep the slips from blocking the road and or rail
4. Build the rail and road
5. Make the road and rail resilient

Moving mountains to reconnect communities

NZ TRANSPORT AGENCY

KiwiRail

North Canterbury Transport Infrastructure Recovery

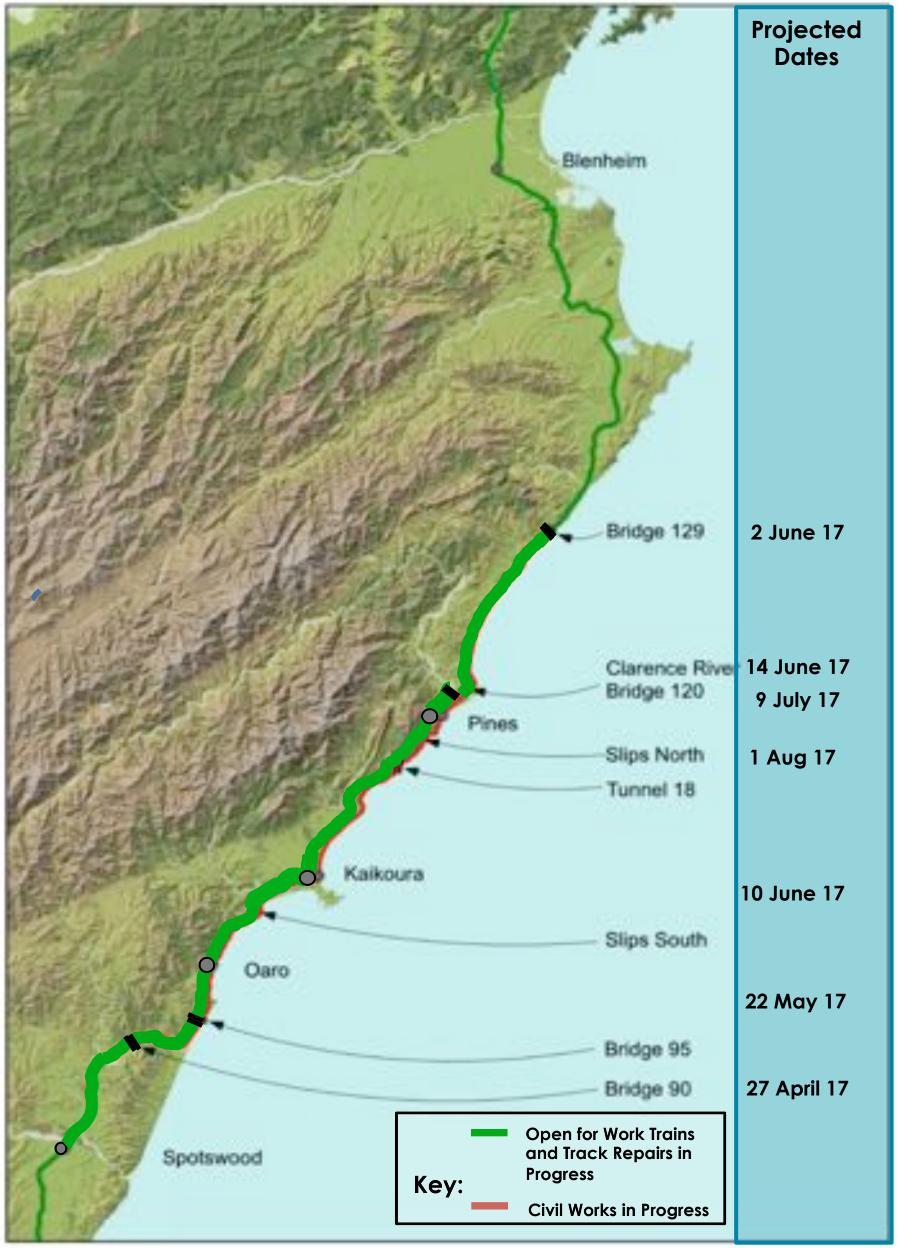
New Zealand Government

NCTIR

RECONNECTING COMMUNITIES

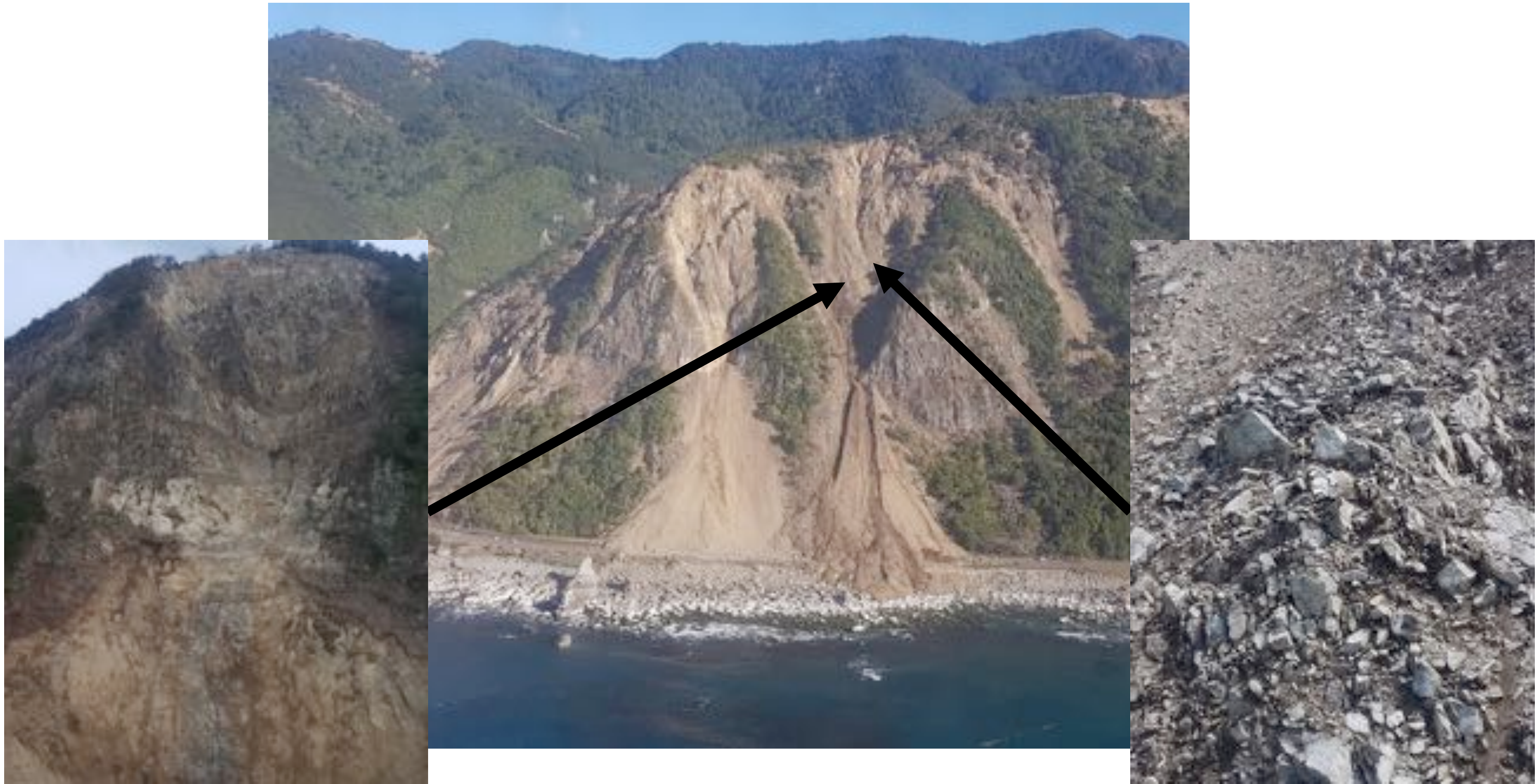
Engineering Resilience

Progress Report



NCTIR
RECONNECTING COMMUNITIES

Stabilising Slip Faces



After Sluicing and Scaling

Before Sluicing and Scaling

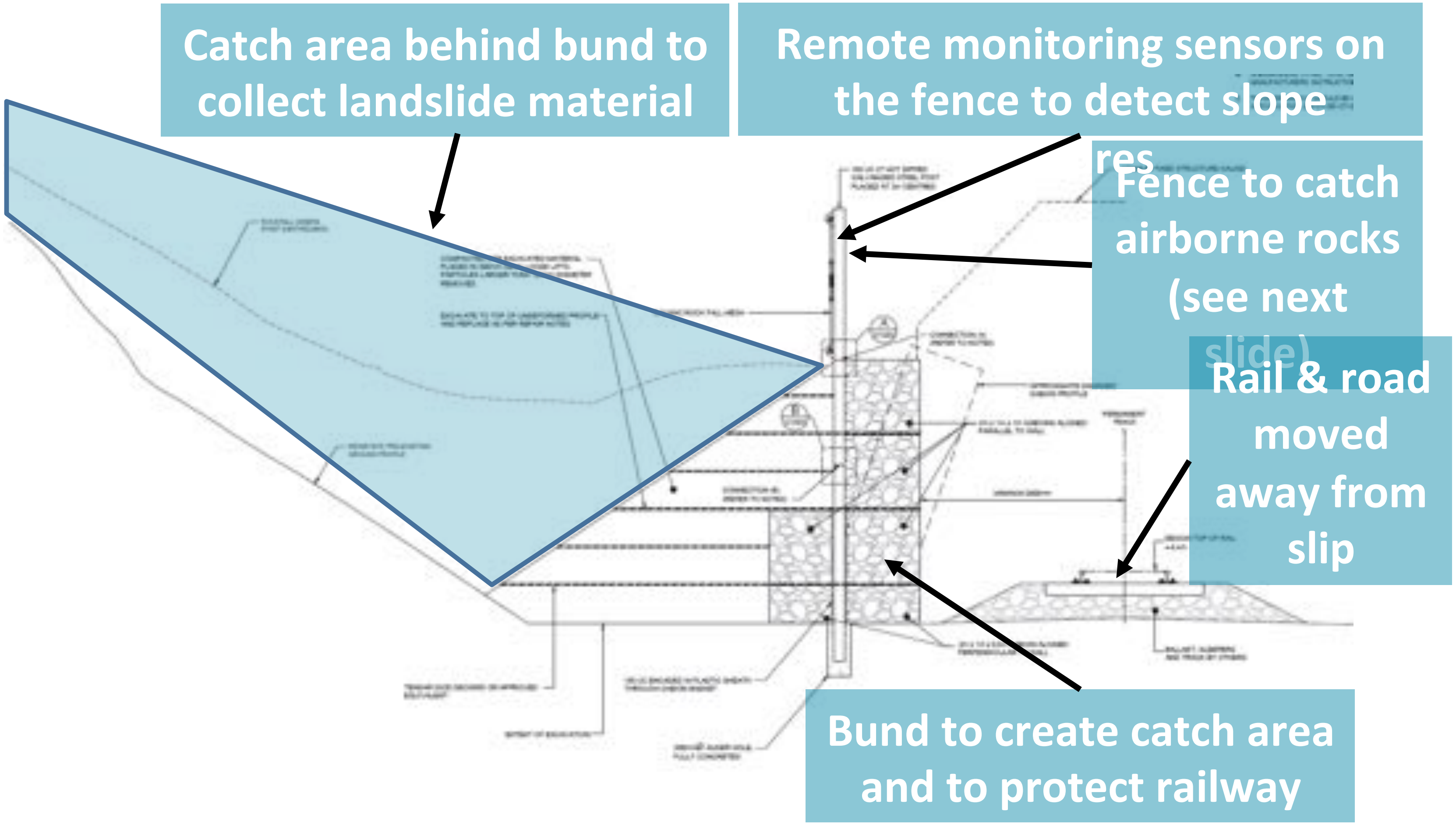
Benches

Slip material lands and accumulates on the engineered bench rather than the transport corridor

Relocate Road and Rail

Stabilising Slip Faces Using Mesh

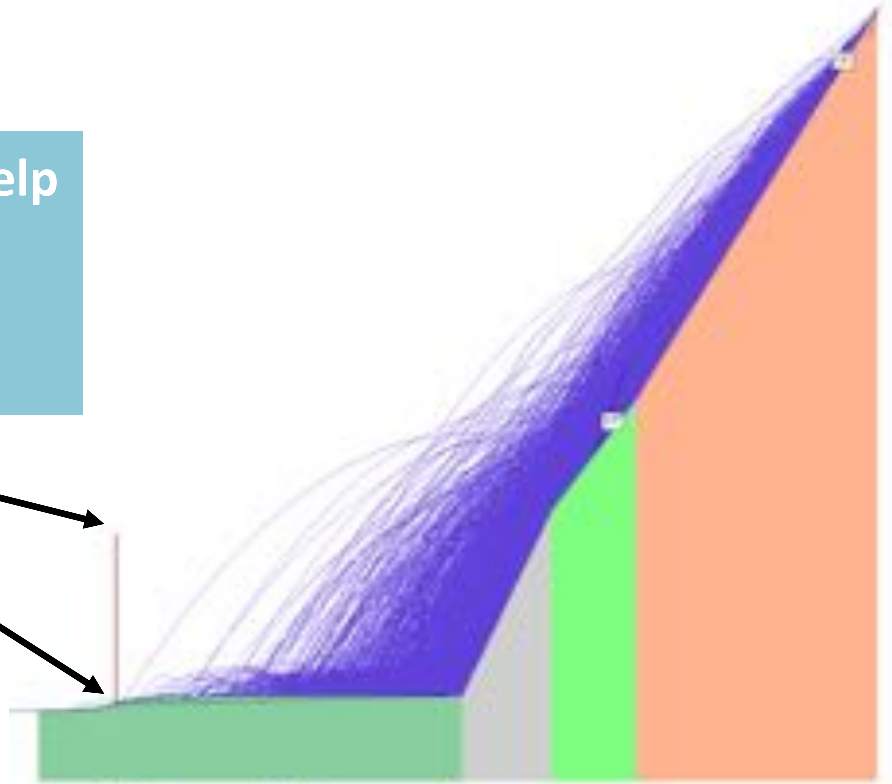
Catch Bunds and Fences



Rockfall Trajectory Analysis

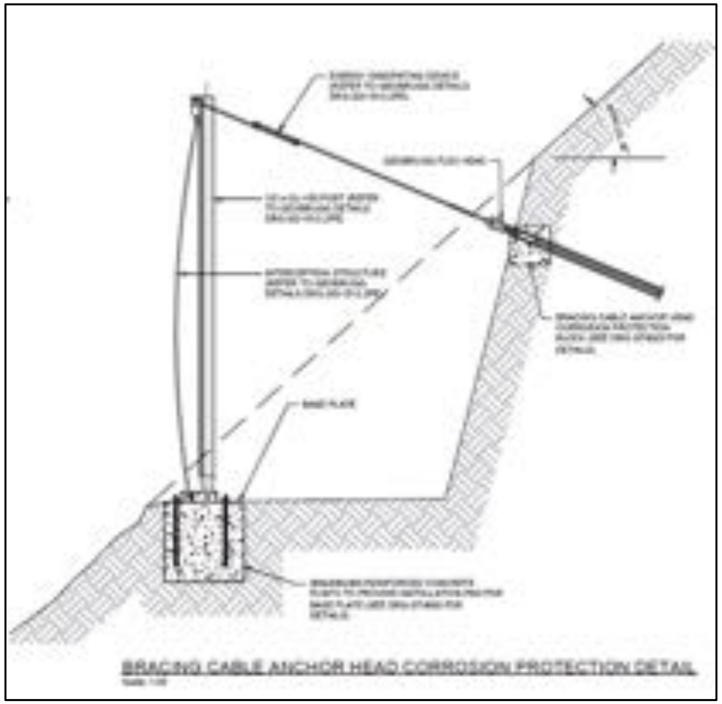
NCTIR
RECONNECTING COMMUNITIES

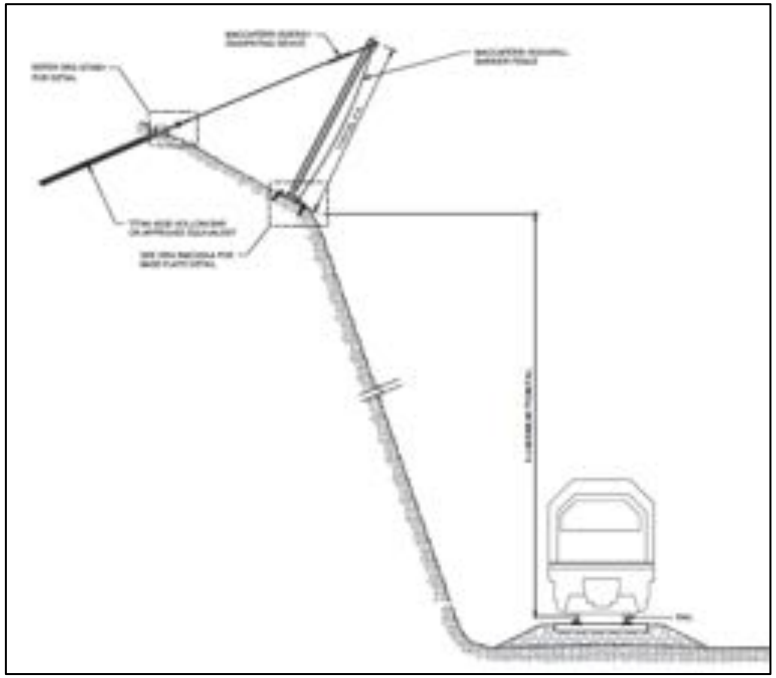
Rockfall trajectory analysis to help design the:
- Height of the fences
- Strength of the fences



Remote Monitoring Systems

Rockfall Fences





Rockfall Fences

August 2017 – slip material barriers near site 27

Rock Fall Shelters

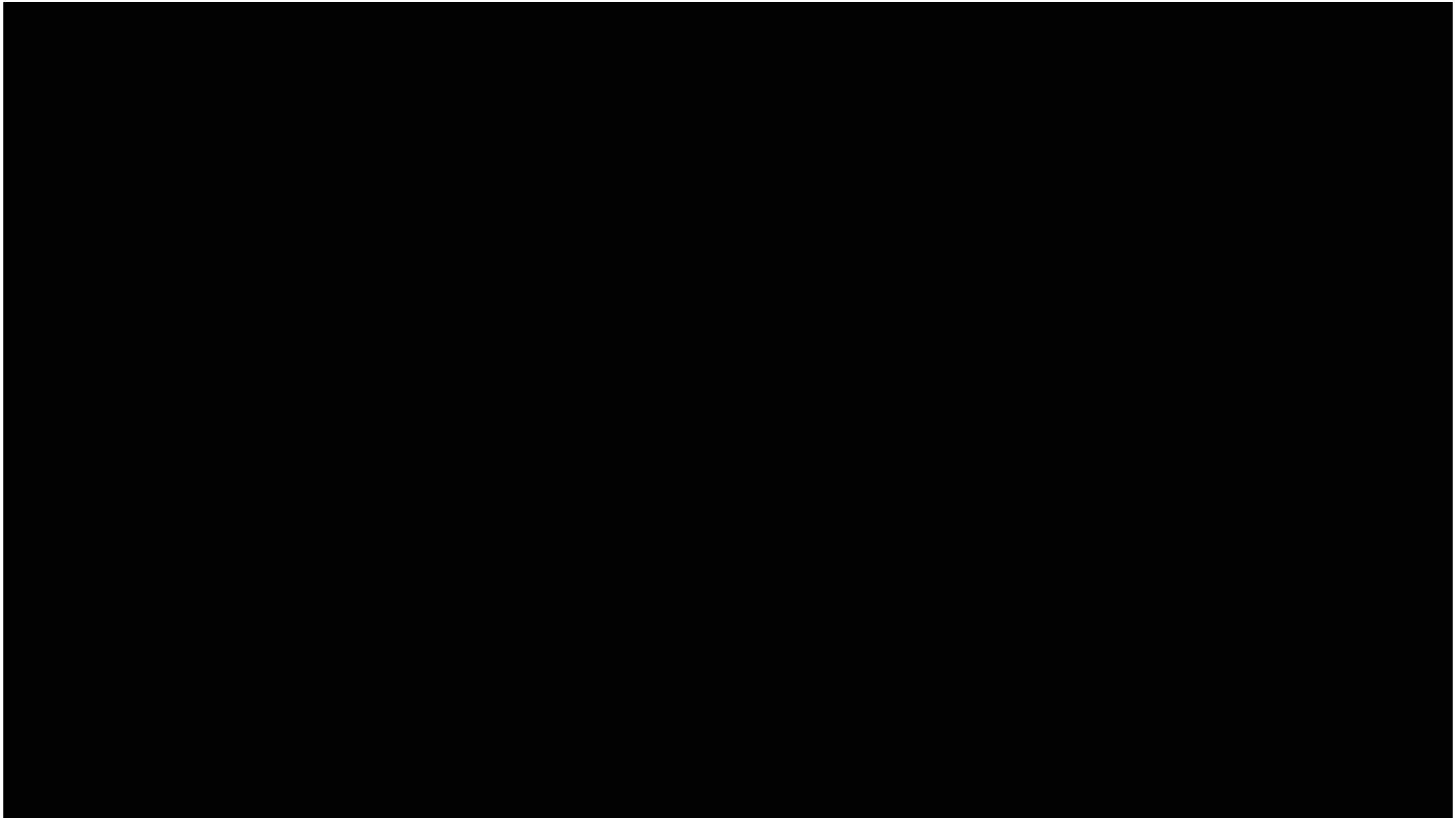
NCTIR
RECONNECTING COMMUNITIES

Containers – Temporary Bunding

Main North Line Rail Network

August 2017 – Final rail weld at site 4. MNL reconnected nine months after quake


Expect trains
Work trains are now running day and night between Blenheim and Christchurch



Data Capture

Ground topo, scanner, mobile scanner, UAV,
Point Clouds, Big Data, GIS

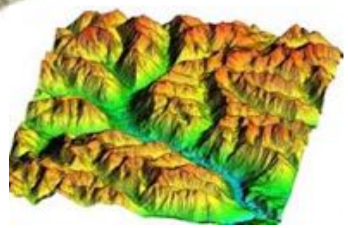
Where to Start?

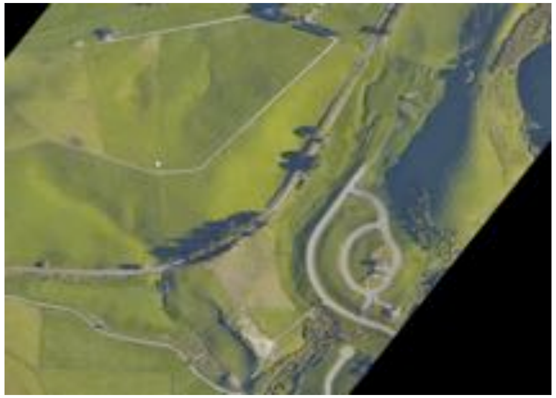
Programme funded by

NCTIR
RECONNECTING COMMUNITIES

LiDAR and Aerial Photography

- **Concept design able to start quickly**
- **Allows large surfaces to be modelled quickly**
- **Images allow comparison between Pre and Post Quake**





Detailed Design = Detailed Survey

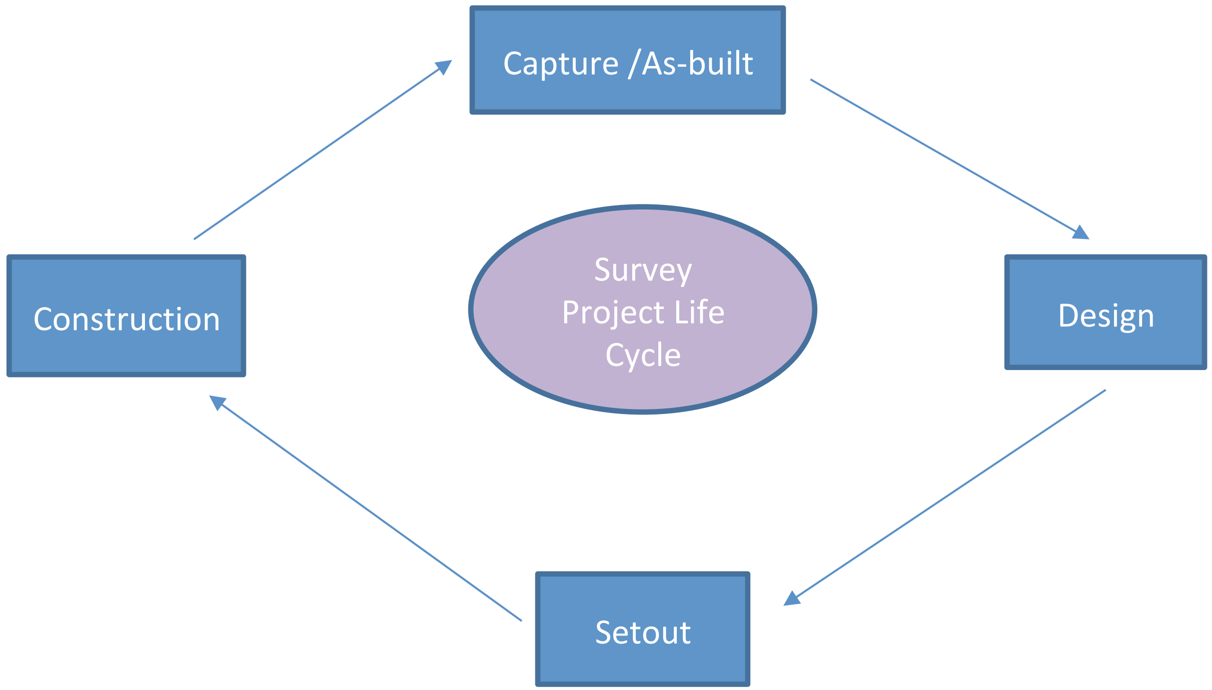
Accuracy?

Datums?

Methods of Capture?

Deliverables Required?

End User?



Quality of Design, Setout and Construction are a direct result of the quality of the original survey

NCTIR Control Network Installed

- Framework that the entire project is based on
- All control marks in terms of each other
- Marks in terms of project datum
- Allows surveys to be started confidently

NCTIR Survey Specification Created

- All consultants able to provide consistent deliverables
- 7 Consultants being used
- Accuracies specified
- Data capture methodology specified
- System setup for easy flow of data through data system (delivery and QA)

Surveying - Equipment

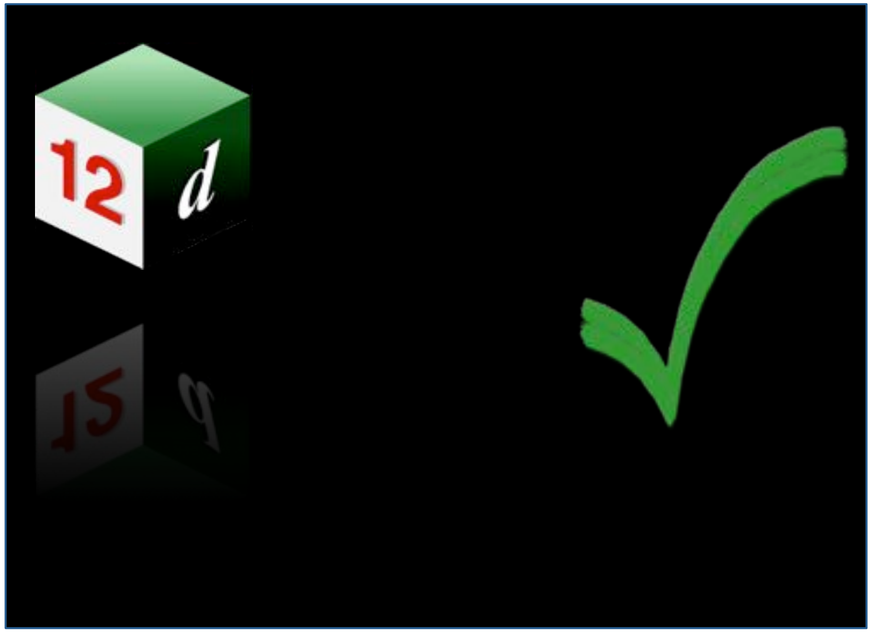
GPS

Scanning

Total Station

Data Management -12d

- 12d Model and 12d Synergy Utilized
  - 12d Synergy – Data management with traceability
  - 12d Model – Civil Engineering and Survey Software
- Allows the maintenance of a live database
  - Model sharing
  - 120+ Designers
- New Surveys and data added everyday
  - Design jobs refresh to show new data captured

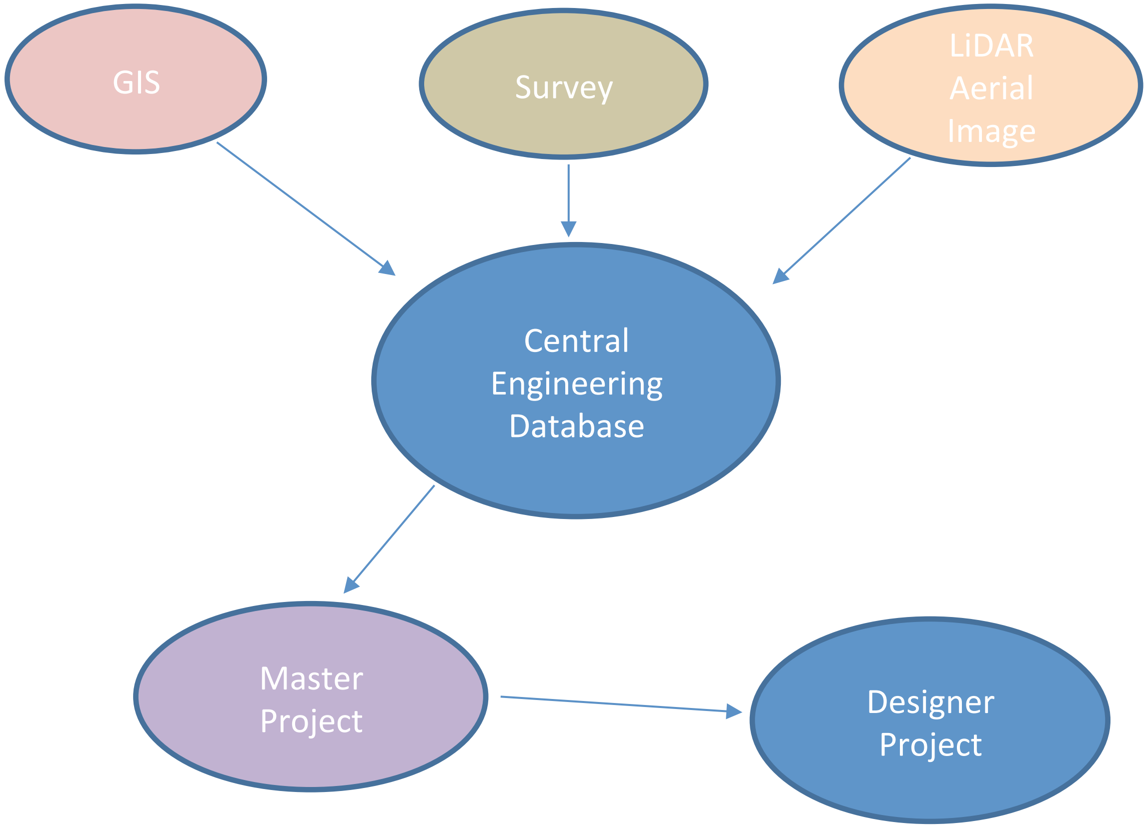


Surveying - Technology

Unmanned Aerial Vehicle (UAV) - Drone

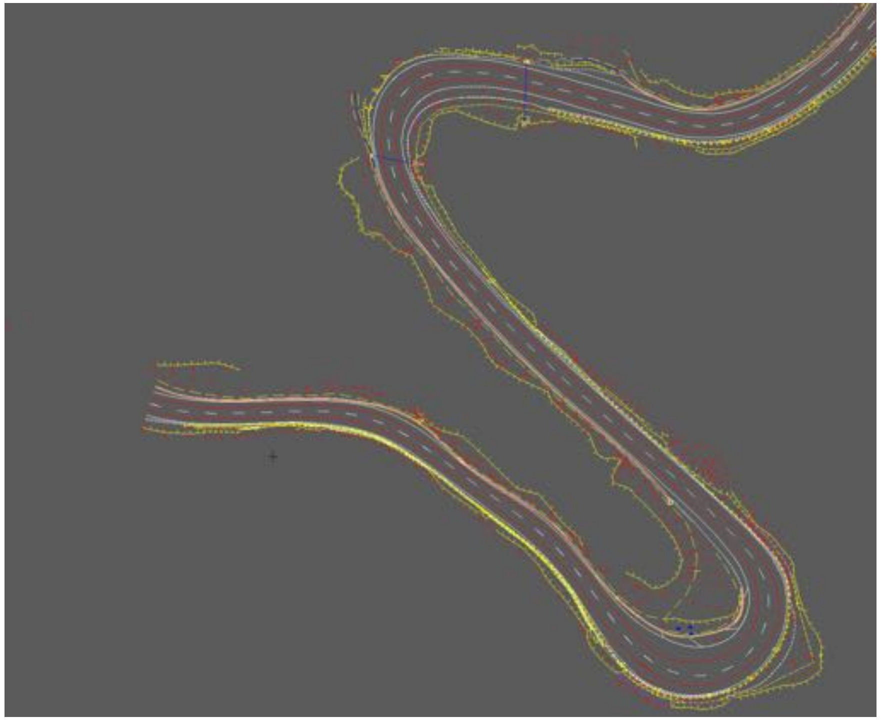
- Gather Data Quickly
- Creates Both Surface models and Aerial Image
- Survey Dangerous Locations
- Integration with other survey methods

Programme funded by


GIS
Survey
LiDAR
Aerial
Image
Central
Engineering
Database
Master
Project
Designer
Project

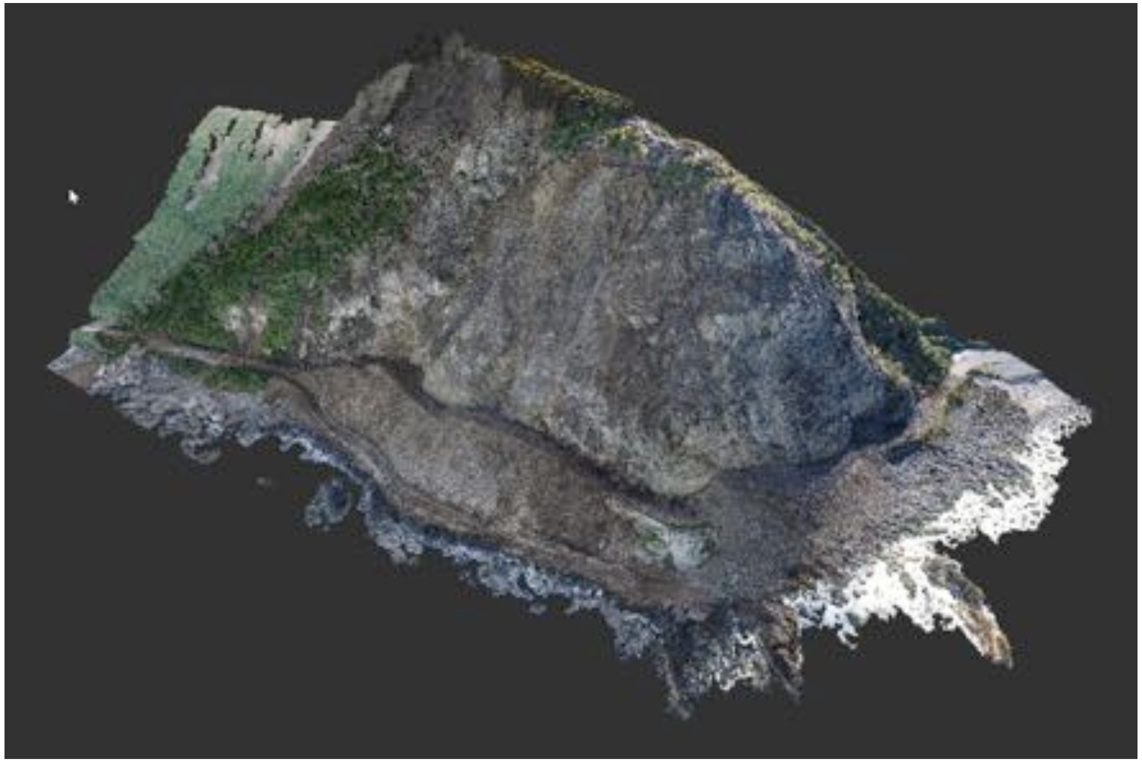
Primary Data Delivery;

- 12d
  - 3D Surface
  - Attributed line strings
- Local Control Tied into NCTIR Control Network

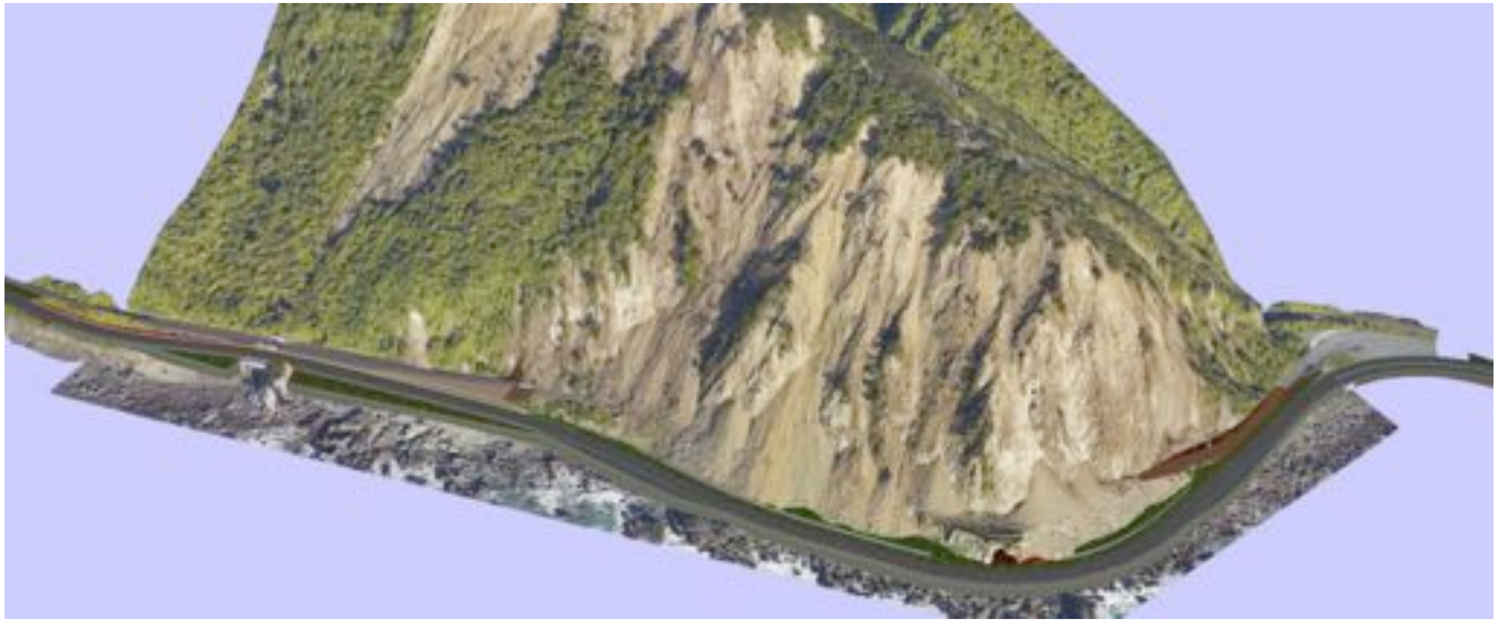


Viewers
Sketch Fab - Geotechs

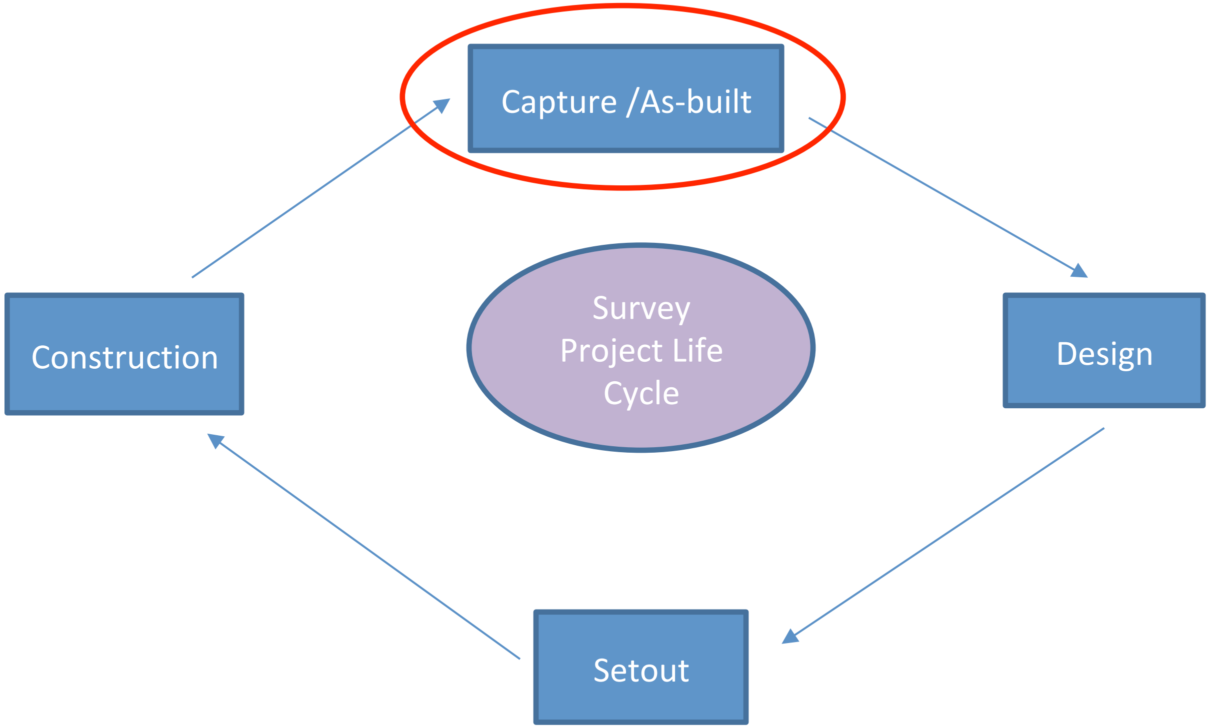
Recap - Designers



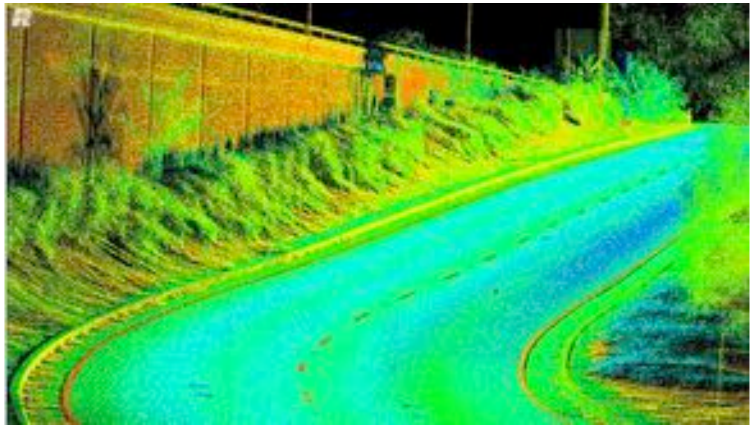
Integrated Design and Survey



Programme funded by


Capture /As-built
Construction
Survey
Project Life
Cycle
Design
Setout

Mobile Laser Scanning for Improvements Package



- GPS for Location
- Internal IMU for accurate solution
- 10mm Accuracy
- Large areas Surveyed Quickly
- Digital String Extraction
- Essential in large improvement package
- Continuous Site not isolated locations

Christchurch Property Boundaries and Related Matters Act 29 August 2016

Note: The provisions of this act do not apply to the Kaikoura Earthquake Sequence.

Surveyors need to take into account earthquake-related land movement when locating property boundaries in Christchurch.

The Act

The Canterbury Property Boundaries and Related Matters Act came into force on 29 August 2016.

The purpose of the act is to provide certainty to surveying and titles in greater Christchurch following the Canterbury earthquakes, to support recovery and the rebuild and to maintain public confidence in the cadastre.

"Greater Christchurch" is defined as the districts of the Christchurch City Council, the Selwyn District Council, and the Waimakariri District Council, and includes the coastal marine area adjacent to those districts.

The "Canterbury earthquakes" are defined as any earthquake in Canterbury between 4 September 2010 and 13 February 2022 and including any aftershock in that period.

The Act

The legislation takes a pragmatic view by saying boundaries have moved with the land.

In most instances, this means that boundaries will be where property owners expect them to be, as marked by features like fences. This legislation will reduce the potential for future boundary disputes and conflicts.

The Surveyor General will consult with surveyors on proposed rules to implement the new legislation.

There is a possibility that there will be boundary conflicts as a result of earlier approved surveys that did not take land movement into account.

The Act

Coverage and impact of the legislation

Sections 7 and 8 of the new Act set rules applying to all boundaries that determine the spatial extent of land.

Section 7(2) says the boundaries are deemed to have moved or to move with the movement of land caused by the Canterbury earthquakes (whether the movement was horizontal or vertical, or both), unless the movement was a landslip.

This does not affect the validity of an estate or interest in land, "and the land (as moved) continues to be the same land, and affected by the same interests, as before the movement".

It also does not affect the boundaries within greater Christchurch defined before 29 August 2016.

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The Act

Section 8 states that a cadastral survey will continue to determine the boundaries of any land surveyed within greater Christchurch if it was done in good faith and without negligence between 4 September 2010 and 29 August 2016, and its cadastral survey dataset was determined to comply with section 9(a) of the Cadastral Survey Act 2002 in that period.

Section 10 removes liability for cadastral surveys or boundary determinations between 4 September 2010 and 29 August 2016 if the liability would not have arisen if the survey or determination had been done on the opposite basis to that used - ie, that the boundaries did or did not move with the movement of land caused by the earthquakes.

Sector Leaders Group

		Scenario 1: Status quo	Scenario 2: Boundaries moved with the land	Scenario 3: Boundaries did not move
Description		No change to common law, with all surveys in earthquake affected areas expected to apply the standard approach. *Case law will emerge over time to establish whether boundaries did, or did not, move with the land.*	Legislation is introduced to state that legal boundaries in Canterbury move where there is shallow ground movement over a large area. This will include a clear definition of when and where this applies to avoid unintended contradiction of existing common law or subsequent application in inappropriate situations. *This is how most surveys have been conducted since 2010, and accords with what landowners would generally expect BUT is likely to be inconsistent with current common law.*	Accept (legislate if required) that legal boundaries do not move where there is shallow surface movement over a large area. *This approach is likely to be consistent with the current common law BUT is a change to survey practice in Christchurch and will mean most surveys completed (and approved) since 2010 will be "wrong" and is likely to trigger a large number of boundary adjustments.*
Implications	Landowners	Uncertainty and cost for landowners which will adversely affect rebuild activity.	Legal boundary will generally align with occupation so property and infrastructure owners will retain ownership of and access to their physical assets. Completed rebuilds will generally be within legal boundaries. The survey plan supporting the legal title may not reflect the current legal boundary. This may mean a resurvey is required for any property-related transactions and improvements and/or investment by the Crown to reduce uncertainty.	Legal title will sometimes not align with occupation causing problems with access, safety, usability, insurance, and maintenance where physical assets sit across legal boundaries. Some assets will need to be relocated. Rebuilds completed since 2010 may be misaligned with the legal boundary. Many landowners are likely to seek boundary adjustments to realign legal title with occupation.
	Surveyors	Significant requirement for surveyors to apply judgements that lead to inconsistent or conflicting boundary determinations. Surveyors will face a higher risk of potential liability, which increases cost to landowners. Some will not be prepared to survey worst-affected areas.	There is scope for surveyor judgement and interpretation of evidence that may lead to inconsistent or conflicting boundary determinations, which increases cost to landowners.	There is less scope for surveyor judgement meaning risks and potential liability to surveyors might be reduced and surveys less costly to complete.
	LINZ	Until case law emerges, it will be unclear whether the cadastre is an accurate representation of legal title. The reputation of LINZ is likely to be adversely affected.	The spatial representation of boundaries in the cadastre will not align with the position of legal boundaries, and will not match other spatial datasets (such as aerial photography). The full benefits of Landonline in supporting efficient property-related transactions and improvements will not be realised for some time.	The digital cadastre will accurately reflect legal title, but will differ from occupation.
	Others	There will be a significant degree of uncertainty in the cadastre and title system, which will be difficult to address – even through an increased level of survey activity to support property-related transactions and improvements.	An increased level of survey activity to support property-related transactions and improvements may be required to satisfy regulators, banks and insurers.	Boundary adjustments, or asset relocation, will be needed to finance and insure assets that fall outside the legal boundary. Council may need to seek retrospective consent for structures that no longer fit within planning controls.
Solutions		Surveyor-General rescinds all existing guidance with surveyors required to <u>interpret and apply evidence in line with existing common law</u>.	Surveyor-General issues new cadastral Principles and Rules for locating new position of earthquake-affected boundaries that includes relying on pegs and marks that have shifted due to earthquake land movement and places reliance on <u>physical monuments and evidence of occupation</u>.	Surveyor-General issues new cadastral rules for locating new position of earthquake-affected boundaries that includes <u>geospatial coordinates in the hierarchy of evidence</u>.
			Legislative change to common law so that title boundaries generally correspond with occupation (as per agreed survey principles).	Voluntary and cost effective / streamlined process established to enable neighbouring landowners to realign legal title with realities of on the ground occupation.
			Surveyor-General provides a clear definition of when survey marks are 'disturbed'.	
			Provide surveyors with additional data on nature and direction of movement across Christchurch to inform survey work.	
			Workshops jointly hosted with survey profession on how to apply rules, the hierarchy of evidence and updated definitions in affected areas.	
			Process established to redo / adjust surveys done on a different basis since September 2010.	
			A streamlined and low-cost notification and boundary dispute resolution process.	
			District Plan and/or legislative exemptions to ensure existing consents remain valid, and any boundary adjustments do not constitute a subdivision under the Resource Management Act to avoid triggering consultation processes.	
			Realigning survey plans with legal boundaries could be implemented over time (ie when surveys are conducted and plans deposited) with residual uncertainty remaining over a long period. Alternatively, to reduce uncertainty about legal title, and cost to landowners, LINZ could: • implement a 'block shift' of the digital cadastre to improve alignment between the cadastre and legal boundaries; and / or • commission framework surveys over specified areas; or • resurvey each parcel and issue a new title over specified areas. Further work is needed to determine whether this would generate material benefits beyond those achieved through adjusting the digital cadastre and clarifying the legal position.	Legislative provision that ensures utilities (eg water, electricity and telecommunications) are legal and have an easement over privately owned land.

Sector Leaders Group

Definitions

There are 3 inter-related concepts relating to boundaries. The alignment between each is different under each option.

- **Cadastre**
  The repository of all accepted Cadastral Survey Data sets held by LINZ
- **Legal boundary**
  The boundary that applies to a specified parcel of land as described in the survey plan supporting the legal title.
- **Physical boundary**
  The boundary as represented by the landowner's occupation of the land. Generally represented by structures and fences.

Measuring performance of the options

The following objectives have been established to assess the options, and identify where trade-offs arise.

- **Landowner rights**
  Are the rights of landowners to undisturbed possession maintained? Are additional costs and delays in property transactions minimised?
- **Certainty**
  Do landowners have a clear understanding of their legal boundary? Are the rules, practices and legal position associated with surveying areas subject to shallow surface movement clear and without unintended consequences?
- **Accuracy of the cadastre**
  Does the cadastre provide an accurate presentation of legal title to support efficient property transactions and improvements?
- **Timeliness**
  Can the solution be implemented quickly?
- **Support rebuild activity**
  Does the solution provides confidence to all parties that survey practices, and any associated legal and planning processes, to continue rebuild activities?

Analysis of the options

In deciding between these options, trade-offs emerge between continuing to realise the benefits of an accurate digital cadastre, certainty about the location of the legal boundary, and minimising disruption and cost to landowners.

Status quo

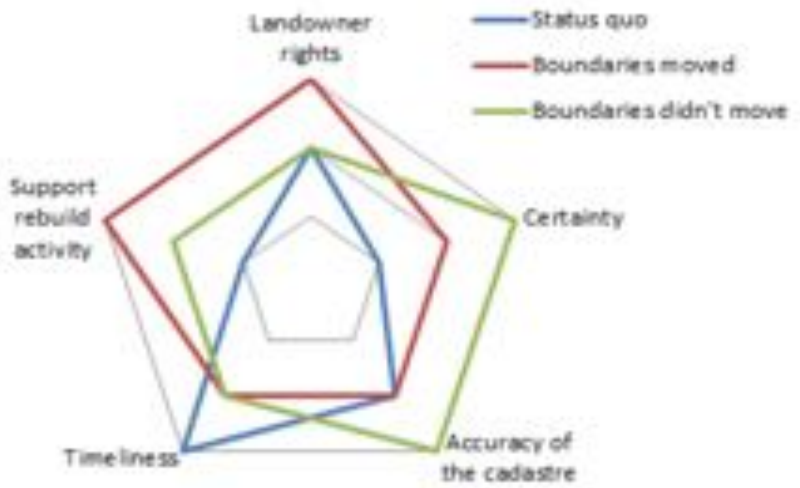
- Essentially a 'wait and see' approach that embeds current uncertainty for all parties until a legal precedent is established.
- Possible that emerging legal precedent is unpalatable, requiring subsequent policy and legal intervention anyway.

Boundaries moved with the land

- Provides the most intuitively correct outcome for landowners, and other parties, and is how most (but not all) surveys have been undertaken since 2010.
- Means that legal boundary as defined in a survey plan may not be an accurate representation of the current legal boundary. This could add costs to property transactions and reduce the value of affected land if LINZ does not intervene.
- Outstanding policy question about the area over which this should be implemented.

Boundaries didn't move with the land

- Provides a simple approach to surveying, with limited scope for judgement and dispute.
- Cadastre is accurate and legal boundaries are appropriately defined in the survey plan.
- Counter-intuitive outcome will create a bow wave of boundary adjustments to realign with occupation. These costs will need to fall somewhere.



Geotechnical Engineering

Canterbury and Kaikoura earthquake sequences resulted in intense ground shaking

Large areas of saturated alluvial soils across the eastern parts of Christchurch liquified resulting in significant damage to land, buildings and services

Many areas were affected by lateral spread

Significant cliff collapse and rockfall in the Port Hills and Banks Peninsula surrounding Christchurch

Christchurch Sumner Road Rockfall

Christchurch – Whitewash Head

Christchurch – Deans Head

Christchurch - Redcliffs

Geotechnical Engineering

Geotechnical Engineering

Since the Canterbury earthquakes, it is now recognised that specialists in geotechnical engineering is needed to assess the ground conditions at a site.

Geotechnical engineers need to work closely at an early stage with the surveyors, civil and structural engineers, architects, planners, Local Authorities and the owner/developers to determine the site constraints, understand geotechnical risks, and to identify design solutions.

Geotechnical Engineering

The Ministry for Building, Innovation and Employment have produced a number of guidance documents that outline various geotechnical and foundation options that can be considered for residential development and are considered to be an acceptable solution.

Foundation options will vary and are typically controlled by the liquefaction hazard, risk of lateral spreading, and the bearing capacity of the insitu ground conditions.

Guidance is now available on assessing and mitigating the risk of rockfall.

Geotechnical Engineering

'The New Zealand Geotechnical Database' has been established to provide a valuable resource for geotechnical engineers to review existing geotechnical data of an area and review the earthquake performance of land.

The database also contains records of surveys, peak ground accelerations in the various earthquakes, groundwater models, flood hazard modelling, geological mapping, active fault mapping, aerial photography taken after each of the significant earthquakes, and more.

Geotechnical Engineering

Methods of deep ground investigation include deep boreholes with SPT testing, DMT, MASW, ground radar, and CPT testing.

There are also specialist deep ground improvement contractors operating in the City that can provide bespoke ground improvement/densification solutions to mitigate the presence of soft or liquefiable ground conditions.

Civil Engineering

We have seen many changes to Civil Engineering design specifications and construction standards

Most are directly related to the geotechnical classification of the land TC1, TC2 and TC3 or equivalent and the designed resilience of the structures in a specified SLS (Static Limit State) and ULS (Ultimate Limit State) event.

Civil Engineering

Examples

Drainage - use of tractive force sewer design using minimum grades and flow rates to provide for more shallow sewers < 2.5m

Use collector sewers and lift stations to compensate for maximum depth specification for sewers and pump stations

Construction of wrapped gravel rafts to support infrastructure including pipelines and manhole structures

Wrapping of pipe joints

Provision of yield joint connections to solid infrastructure, interruption of concrete haunched yield joints and corbels with soft joint

Use of short pipes and long sockets as yield joints

Use of pressure sewers in soft ground

Use of PE pipe - more resilient than uPVC

Civil Engineering

<u>Examples</u>

Roading

Increased pavement depths

Reinforced metalcourse construction - geogrid

Flexible pavements – polymer asphalt solutions

Earthworks TC2 – TC3

Ground improvement - deep compaction - impact rolling

Ground densification – stone piling – grouting and cement stabilisation

Building Foundations TC2 – TC3

Ribraft

Piling – timber, concete, screw piles

Footings backfilled with hardfill

Cost

All measures are adding significantly to the cost

NZIS

Thank you

Questions?