Wairau Road 220kV/33kV Grid Exit Point

The Challenges of Building a new urban Substation

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1 BACKGROUND

The Electricity Commission (EC) approved the North Auckland and Northland (NAaN) Grid Upgrade Project in May 2009. The NAaN project would reinforce Transpower's transmission network through Auckland and into North Auckland by installing a new 220 kV cable circuit from Pakuranga to Albany through a series of existing and new substations.

As part of the NAaN project, a new 220 kV Grid Exit Point (GXP) at Vector's Wairau Rd substation would be constructed, and supplied by cable sections running towards both the Albany Substation and the yet to be constructed 220 kV GXP at Vector's Hobson St substation.

The objective of the GXP at Wairau Road (WRD) is to increase security of supply and capacity for Vector's North Shore network.

The scope of the project was:

- Construction of a 220 kV switch-room and relay room building accommodating a 220 kV three section selectable bus GIS, station ancillaries, control and protection systems.
- Installation and connection of a 120 MVA 220/33 kV YNd3 transformer with provision for a second supply when required.
- Installation of a 33 kV cable connection to Vector's switch board.
- Connection of incoming and outgoing 220 kV cable circuits to the new 220 kV GIS switchgear.
- Associated civil, storm water, water treatment facilities, fencing, access road, lighting and security system.

2 DESIGN CHALLENGES

The design and construction of the substation involved investigating and overcoming a number of challenging issues. The main challenges faced can be summarised as follows;

- Programme Constraints to meet the required May 2013 commissioning date.
- Site Layout and locality constraint difficulties due to the compact nature of the site, while coordinating with the existing live Vector substation and the surrounding urban environment.
- Geotechnical challenges.
- Flooding potential of the site.

2.1 Programme

The substation provides an additional 120 MVA supply into Vector's existing 110 kV / 33 kV Wairau Substation on the same site. The agreed programme required the new supply to be available to Vector on 31 May 2013.

The Detailed Design Tender was awarded to AECOM NZ Ltd at the beginning of 2011. In order to meet the May 2013 commissioning date, it was necessary for the design to be completed as quickly as possible such that construction could begin in late 2011. This would allow approximately eighteen months of site construction works.

Key interfaces into the design programme included;

- 220 kV GIS Switchgear and 220 kV / 33 kV Transformer manufacturers drawings
- Council Urban Design consultation and input
- Resource Consenting
- Building Consenting
- GIS Building secondary response spectra and coordination with the GIS Supplier.
- Coordination with other projects and effected parties including:
  Transpower NZ Limited
  Vector Limited
  Vector's Wairau Rd Substation Maintenance Contractor - Electrix
  Vector's Wairau Rd Substation 33 kV outdoor to indoor conversion project
  NAaN 220 kV Cable project.

2.1.1 Main Plant Inputs

In the 12 months prior to the detailed design award, AECOM, Transpower and Vector undertook an extensive conceptual design study into the new Wairau Rd Substation 220 kV / 33 kV Grid Exit Point. This study established the layout and components of the new substation. The physical size of the GIS was critical, as this set the foot print of the GIS Building on a very constrained site. At the time of detailed design award, the 220 kV GIS switchgear and 220 kV / 33 kV transformer procurement contracts were being finalised and manufacturer's drawings were some months off.

2.1.2 Auckland Council Urban Design Panel

A Council requirement for the development of the Wairau Road site was that the installation and buildings be reviewed and approved by the Council Urban Design team. This would ensure that the development of the site was in keeping with the local urban area and landscape.

The 220 kV substation site is highly visible to the public from the Motorway, Wairau Road, the North Shore Golf Course, and from the North Shore Events Centre.

After some option development between the design team, Transpower, Vector, and the Urban Design Team it was agreed that rather than attempt to "architecturally treat" the entire GIS Building, the approach would be that the GIS Building would stand as a separate dominant solid concrete mass with semi translucent wings either end formed by the transformer enclosures clad with the vertical louvres.

Figure 1 - Architect's Perspective Image

2.1.3 Resource Consent

Transpower submitted the Resource Consent application in early 2011, taking into consideration issues such as the scope and mass of the development, the environmental effects and other local impacts. Resource Consent was granted in April 2011, and thereby set the parameters for a number of detailed design inputs. Any significant changes to the building during the detailed design, such as the height, would now not be possible without applying for an amendment to the Resource Consent.

Figure 2 - Site before Construction

2.1.4 Building Consent

Planning for the construction programme acknowledged that the Building Consent process could cause a significant delay, particularly as the Council approval would coincide with Christmas 2011. So to expedite the process, it was agreed that the Building Consent application would be split to enable the building piling to start early. In late 2011, Building Consent was granted for the building piles, and work was able to start. The remaining GIS Building Consent application was submitted late 2011, and granted early 2012.

2.1.5 GIS Building Secondary Response Spectra

The response of the GIS building to dynamic loads was a critical input into the design of the GIS plant support structure. Likewise, the static and dynamic loads of the GIS plant were a critical input into the design of the GIS building. The result was a series of investigations, modelling, negotiations, delays and modifications between the GIS manufacturers, the building designers, and Transpower.

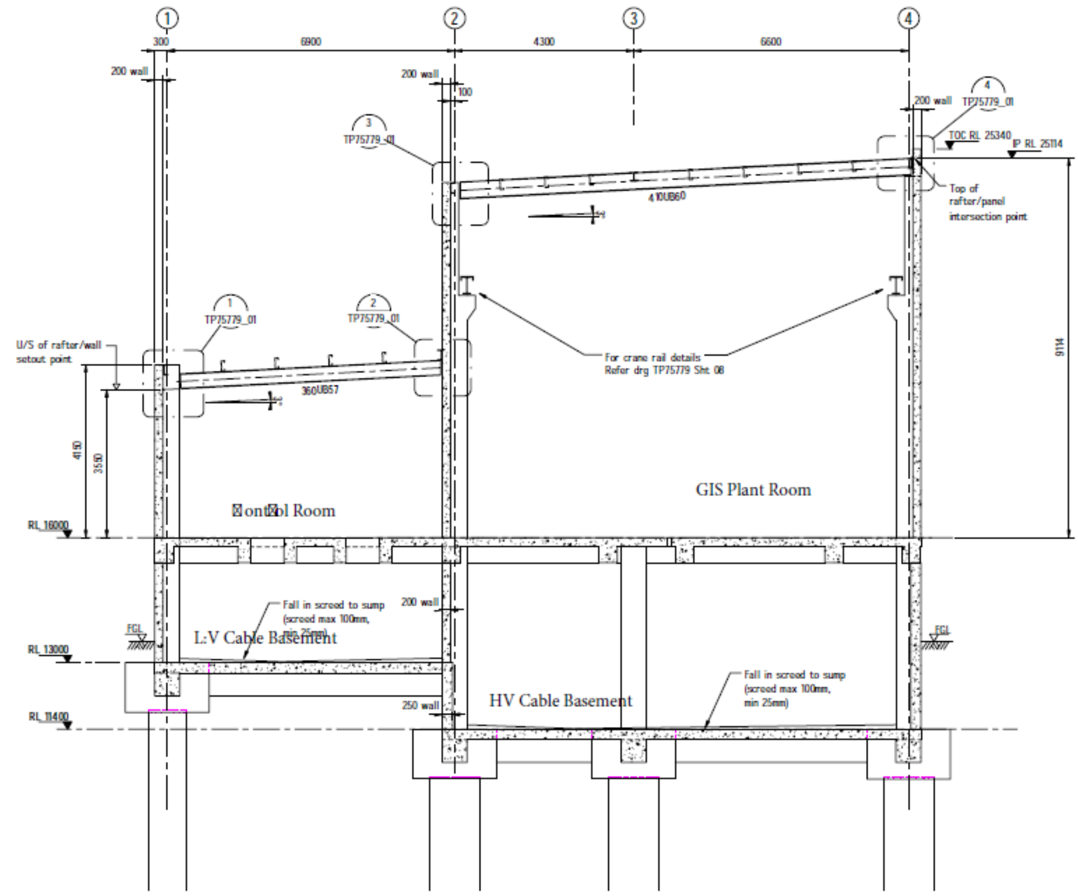

Figure 3 - Section though GIS Building showing the basement and main floor

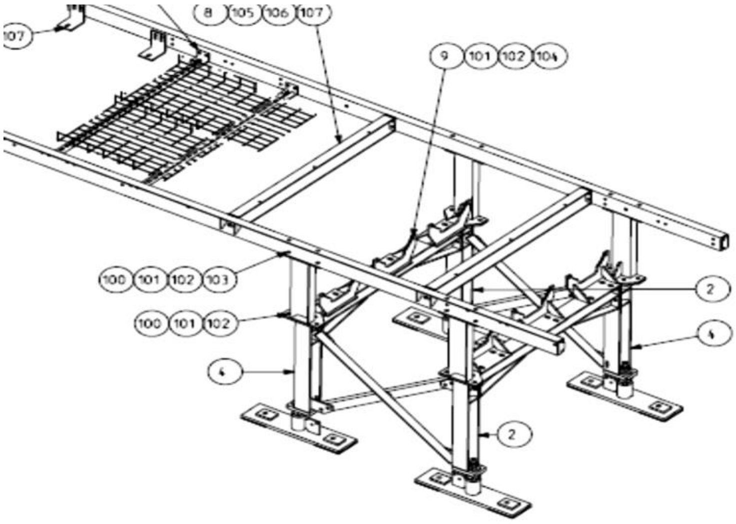

Figure 4 - GIS Circuit Breaker support frame

The secondary response study methodology was to build a 3D model of the building structure and piles, and then introduce scaled earthquake records from at least 3 earthquakes to the model and run an analysis program. The response spectrum was then supplied to Areva for input into the GIS support frames.

The resultant GIS building plant room is a substantial structure consisting of 16 metre piles, a 4 metre high cable basement, and a 200 mm thick cast in-situ concrete floor on 600 mm deep concrete beams. This building is NOT going anywhere!

2.1.6 Design Coordination with Others

The detailed design required coordination with a number of other projects, and affected parties, including;

a. Transpower NZ Limited
b. Vector Limited
c. Vector’s Wairau Rd Substation Maintenance Contractor - Electrix
d. Vectors Wairau Rd Substation 33 kV outdoor to indoor conversion project
e. NAaN 220 kV Cable project.

The management of these interfaces needed careful planning, control and meetings to ensure that the designs meshed as required.

Prior to the 220 kV GIS substation construction, Vector were required to clear the site of three existing 110 kV overhead lines. In parallel with the 220 kV substation construction, Vector had to build and commission a new 33 kV indoor switchboard building on the same site, and re-cable all their existing 33 kV outdoor feeders to the new switchboard. These new cables would run down beside the new 220 kV building, and across the only access bridge to the site.

In addition to the Vector works, the NAaN 220 kV Cable project needed to run the new 220 kV cables into the site, under the new 220 kV / 33 kV transformer, and into the 220 kV building basement.

2.2 Site Layout and Locality Constraint Constraints

The development faced a number of challenges as a result of the site and location.

The land available for the new substation was a small, narrow parcel of land owned by Vector beside their existing 110 kV / 33kV Wairau road substation currently crossed by 110 kV overhead lines and poles. Access to the site was via an existing small single lane bridge existing onto busy Wairau road.

The detailed design went through a number of iterations in order to optimise the size of the Transpower 220 kV substation, while maintaining access to the Vector facilities. The entire project was modelled in 3D in order to achieve a high degree of accuracy, coordination and visualisation of the development.

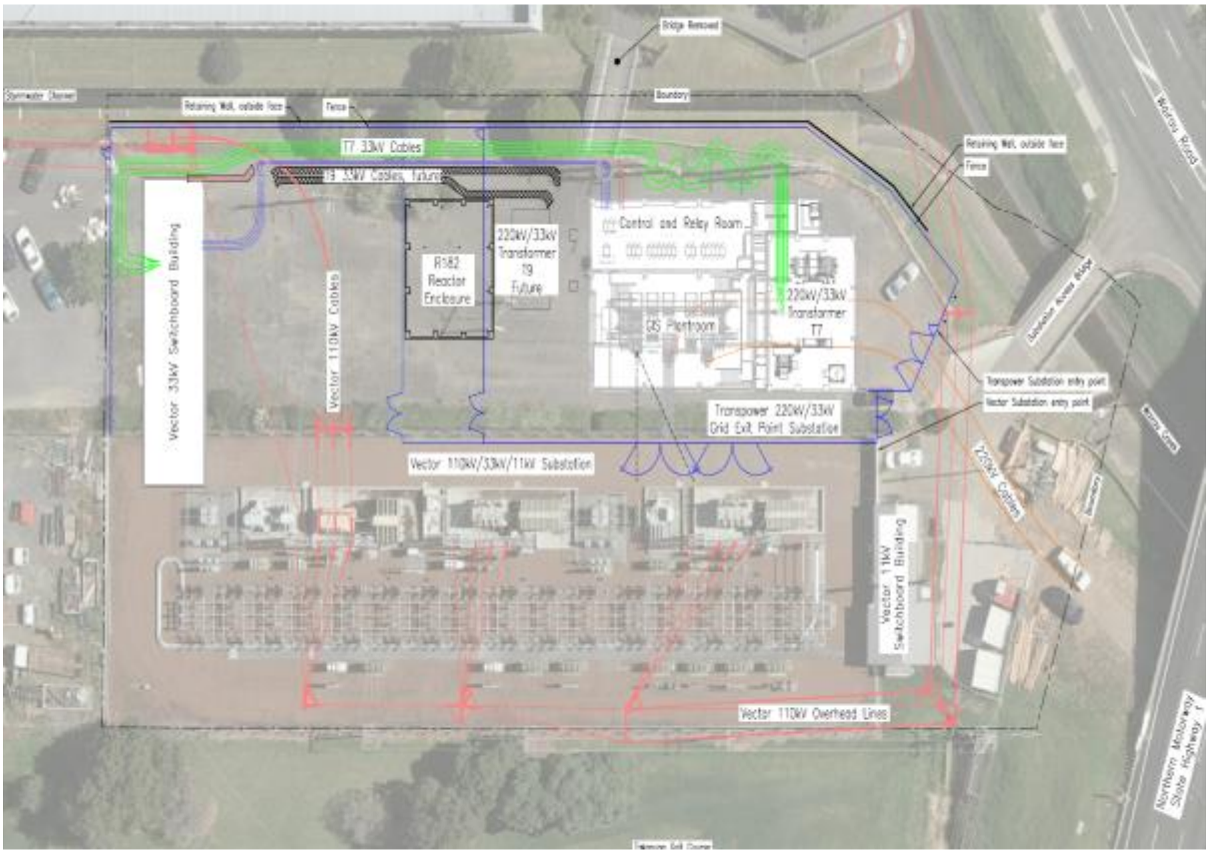

Figure 5 – Areal view of proposed development

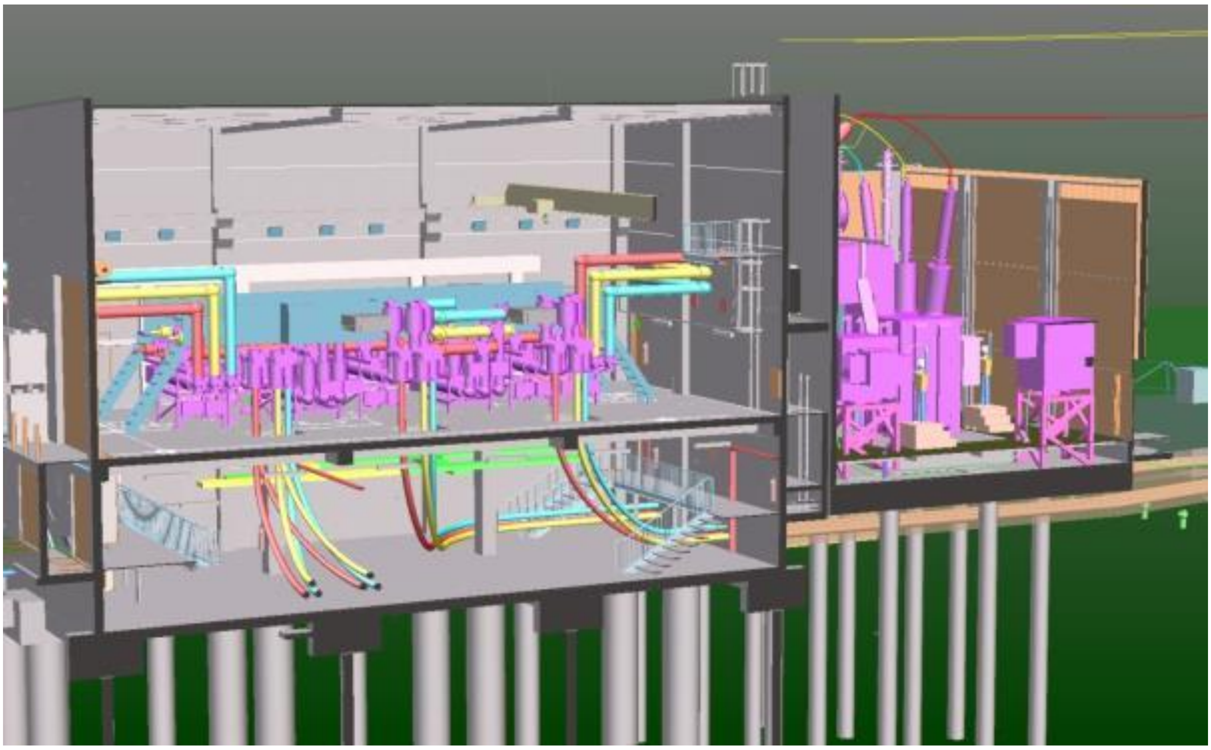

Figure 6 – 3D Model of GIS floor, HV Cable Basement and Transformer enclosure

2.3 Site Geotechnical Challenges

The Wairau Road site geotechnical conditions comprise layers of fill, peat, lake sediments, and basalt lava flows; all overlaying East Coast Bays formation (ECBF) sandstone at a depth of 16 metres. The site overlaps the edge of a basalt flow resulting in highly variable geology in terms of depth to competent rock, rock thickness and rock quality.

The GIS building required a highly stable structure. This necessitated piled foundations, founded on a reliable support base. Due to the variability of the basalt conditions there was a high degree of uncertainty at each pile location as to whether the basalt was suitable for supporting pile loads.

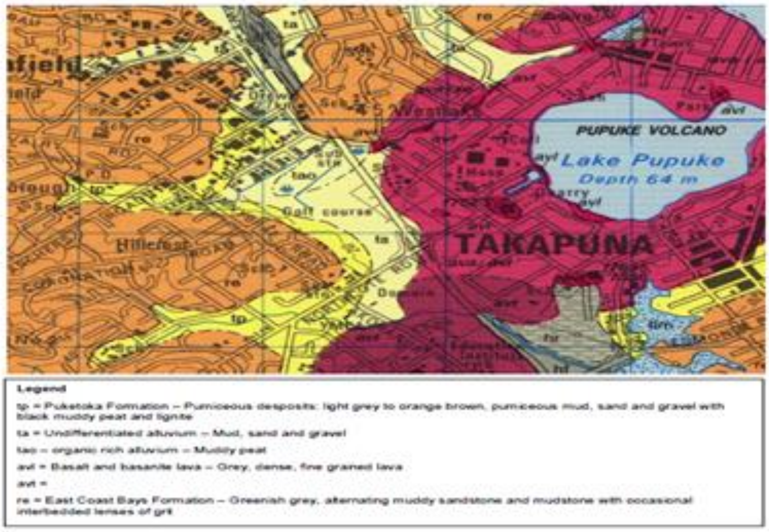

Figure 7 - Geotechnical profile of area

Extensive geotechnical site investigations were required at each pile location to confirm basalt conditions and depth of pile. Most piles were able to found in basalt, but where the basalt was thin or poor quality, the pile had to extend through to found in ECBF rock at 16 metres depth. Pile drilling through the basalt was extremely slow and tough on equipment.

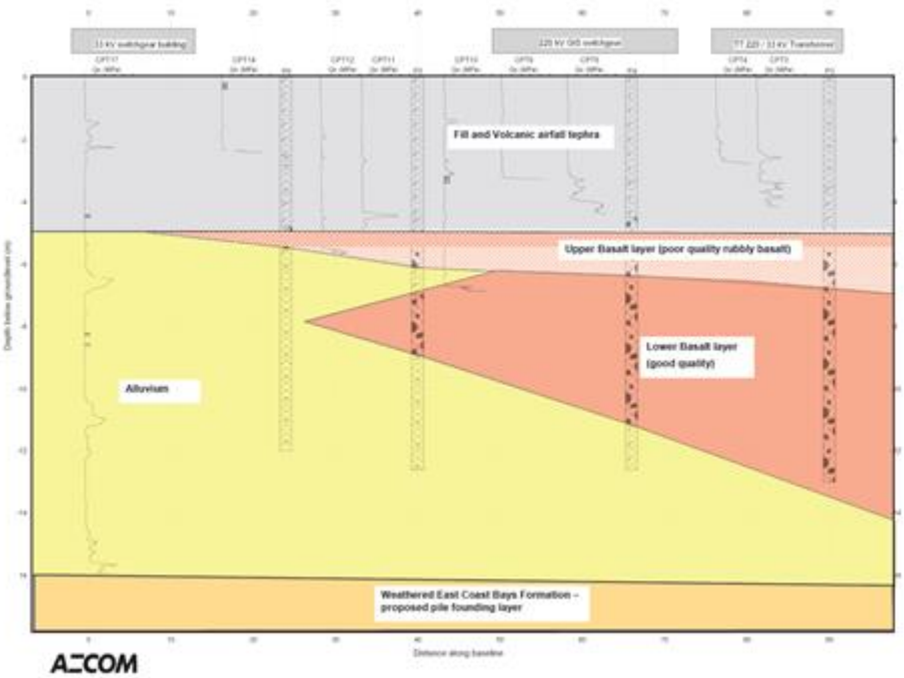

Figure 8 – Geotechnical profile of site

2.4 Flood Prone Site

A flood model and assessment of the site was carried to determine whether or not the site would flood during a major storm event.

The site is located at around 13.5 metres above sea level, and is bordered by the Wairau Creek and a tributary stormwater channel. The North Shore Golf Course lies to the east of the substation; and prior to development of the North Shore, the Golf Course area was part of a low lying swamp. The Auckland City Council advised that they had extensively studied the Wairau Creek and stated that this is their most flood-prone catchment. It wasn't looking good!

The flood assessment determined flood levels on the site for 2, 10, 100, 250, and 450 year average recurrence interval (ARI) storms. Results showed the following flood levels on the site:

ARI (years)	Average depth of flood waters on site (Metres)
2 yrs	0.5 metres
10 yrs.	1.0 metres
100 yrs	1.5 metres
250 yrs	2.0 metres
450 yrs	2.5 metres

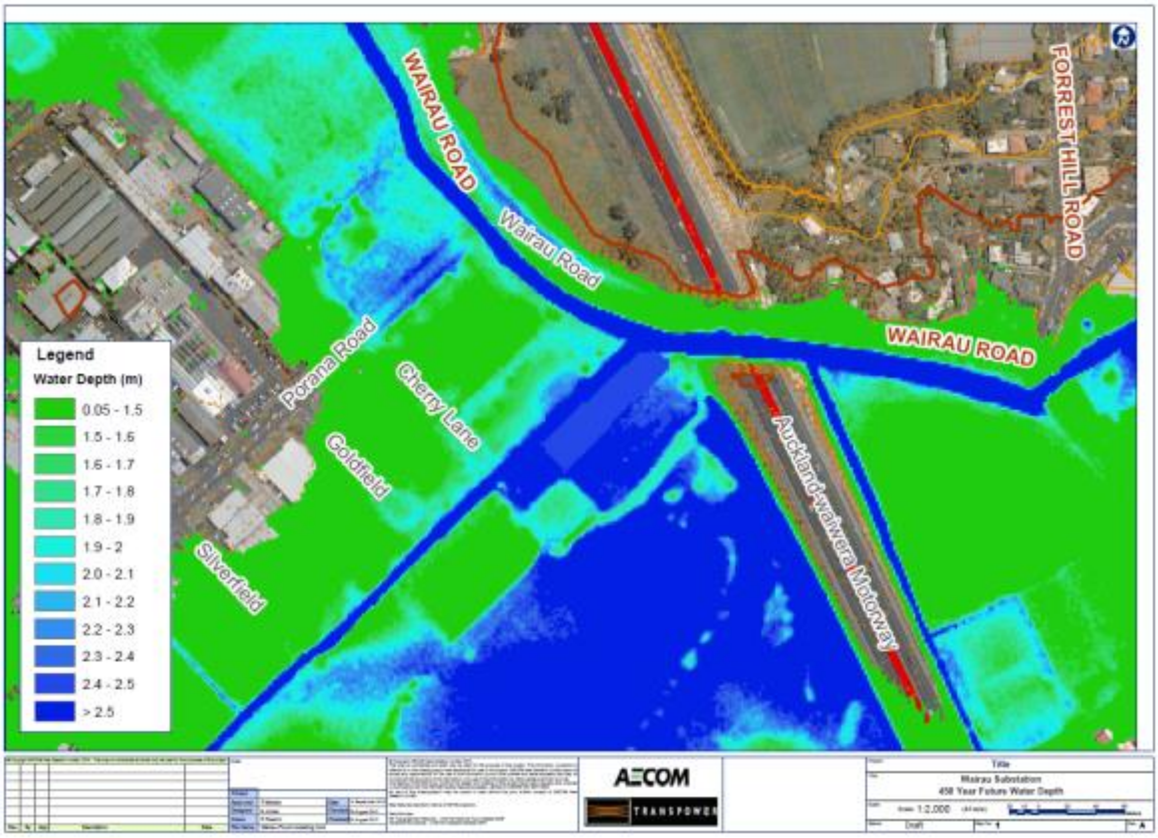

Figure 9 – 450 year flooding profile

As a result of the high probability of flooding on the substation site, all doors to the GIS Building below the 450 year flood level are surrounded by a 2 metre high wall, or bund. Openings through this bund wall are sealed by heavy flood barrier walls. All cable penetrations and plumbing systems entering the building are sealed, and designed to prevent backflow of water into the building.

Figure 10 - Flood Barrier

3 EARLY CONTRACTOR INVOLVEMENT

3.1 Key project risks

The key project risks were time (project programme) and safety. With significant risks also apparent around constructability, access and site logistics. These are all risks traditionally owned by the contractor, as they are the best party to manage them. Given the risks identified it was agreed that an Early Contractor Involvement (ECI) contracting model would be beneficial for the project, as through proactive risk mitigation it could increase time float, provide innovation and quality, and ensure a safe constructible design.

This strategy had its own risk, namely the potential for cost inflation in the contract value. However, it was agreed if the approach was managed appropriately with sufficient resources for cost control, independent verification and benchmarking the contract should represent market value. The majority of the contract value would be competitively priced and directly procured by the contractor, with a requirement for multiple sub-contract prices. These prices along with any work to be completed internally by the lead contractor would be bench marked against market rates by a Quantity Surveyor.

3.2 Constructability

Hawkins Construction Ltd was appointed ECI for the civil, structural, enabling works and the building works, while Electrix was appointed for electrical safety oversight of the construction works contractor and won the contract for installing the 220 kV GIS, transformer & 33 kV cable connections and the protection & control systems.

The ECI process for the electrical contractor provided similar benefits to those for the civil contractor. While having them available for end-to-end site management of electrical risks provided the benefit of their experience on both Transpower and Vector's assets. To that end, Vector and Transpower appointed a site coordinator for the start-up phase of the works to assist the identification of cross-company issues on a small site. In addition to this, a single site village was set up with common facilities to encourage dialogue between the on-site parties at all levels.

While the ECI process generated some initial innovation and good ideas, with time and the iterative nature of the seismic design process it seemed to lack momentum. The concept is good, but requires commitment from all parties to truly realise the benefits.

3.3 Programme/construction sequence

The basic plan for building the substation followed the traditional approach, starting with demolition of existing unwanted services and site features, then piling, foundations floors, walls and roof, then finally the installation of services. Towards the latter part of the construction contract some of these trades were pushed to run in parallel instead of the normal sequential way originally planned. This did cause some rework, especially for the services within the GIS plant room.

3.4 Precast slabs

The precast tilt-slab design pushed the fabricators to the limit and there were a number of setbacks, with several of the slabs cracking before leaving the factory and one had to be removed from site after cracking and moving once it had been put in place.

The design was complicated due to the architectural requirements on the building exterior. The contractor engaged indicated the design could work and ultimately this proved to be correct but there were some points of learning along the way for the tilt-slab fabricator.

The use of precast concrete slabs was recommended for both the walls and floor on the first floor during the ECI process. The floor slabs had to remain cast in-situ to meet seismic requirements, while the walls were changed to precast tilt slab.

3.5 GIS assembly

The Areva GIS was a new model with only a limited number of installations globally. This caused significant risk. The recent GIS installation for the Otahuhu Diversity Project was a mega sized 'Lego' set. The new Areva model installed at Wairau Road substation was significantly changed; with the basic bay and local control cubicle (LCC) factory assembled and shipped in one piece. The bus work and other items however still required thousands of hours of assembly and were packed in over 135 different boxes.

Transpower is a small player on the international scheme even though two GIS boards were being purchased, one for Wairau Road and the other for the Hobson Street Project.

Language, time zone and cultural differences between Transpower and the French manufacturer were significant enough to place additional difficulty in an already technically complex contract.

During contract negotiations for the GIS a point of contention was the hours needed to install it. The manufacturer's estimates at one end of the scale (4000 hours) and the contractor's estimates based on previous work on a different type of switchboard at the other (16,000 hours). A final pricing solution was to agree on a fixed price for a minimum number of hours with those in excess paid at a reduced rate.

4 CONSTRUCTION CHALLANGES

4.1 Health and safety

All the usual construction-related safety issues raised their heads, including working at heights, deep excavations, noise, confined spaces, fumes, asphyxiating gases, concrete splashes, steel ends, lifting large lumps of concrete high in the air and drilling holes deep in the ground.

The close proximity to the 110 kV Vector circuits meant that every lift or delivery had to be planned and managed.

Transpower upped the ante on this project with all participants on site needing a minimum of a Site Safe Civil Passport and a drugs and alcohol test before commencing work. During the course of the project a number of random drug and alcohol test on the entire site were also conducted.

To continue to incentivise behaviour through the project, a number of barbeques were held to congratulate the teams on site for good performance and recognise one or two people that had put in the extra yard in the H&S area. The project celebrated a good safety record, with no serious injuries.

4.2 Coordination of different projects and contracts

At all stages co-ordination meetings were held. These included monthly project-wide meetings with all parties; weekly site meetings for the site contractors and finally daily site meetings for everyone on site to ensure that there were no glitches with the daily activities.

On site activities outside the project's direct control included:

- Vector building a new 33 kV substation and installing cable ducts.
- 220 kV Cables project ducting and running cables into the site.
- Vector maintaining access to their existing substation,

Shutting down the normal site access for some 20 days while the 220 kV cable ducts and trenches along with the Vector cable 33 & 11 kV cable ducts were all installed proved that planning was critical. Preplanning had this coinciding with a lot of steel fabrication and the pouring of only minor items. This did not prove to be the case in practice unfortunately.

One of the most critical roles within the project life was that of the project co-ordinator with a time critical project and the interfaces required between the different parties all needing access to site to complete their part of the work. There being generally no contractual basis for making any of the parties play well together, this was done in a collaborative monthly coordination meeting.

4.3 Flooding

Right from project design the stream and flooding was a known risk. However it is still a bit of a shock when the local small stream decides to overflow your site and car park after a couple of hours of heavy rain.

On 3 July 2012 the site was inundated. Probably not more than 400 mm at the deepest point but the open excavations were completely filled with water. The HV cable basement acted like a swimming pool and was filled to over 2 metres of water.

Figure 11 – LV Cable Basement after the Flood

4.4 Site access issues

The site was like a castle with a drawbridge (small access bridge) and moat around it (Wairau creek). The bridge access to the site was subject to a review to ascertain if it could carry all of the construction traffic and in particular the heavier loads of the transformer, cranes and piling rigs.

The site access bridge had a design loading of 70 tonnes, some of the construction plant loads were in excess of 100 tonnes. New bridge abutments were built so that a temporary bridge could be installed over the top of the existing bridge when the heavy loads were delivered.

The busy Wairau Rd meant that traffic could enter the site from one way only and with no reversing out into the traffic. The access bridge was only wide enough for one way traffic and this created much tricky backing and manoeuvring on the site.

4.5 Environmental

The high water table, during the excavation of the basement and oil containment tank, required constant pumping. With no room to have the normal sediment control ponds, a series of 25,000 litre tanks were used to remove the sediment before the water was discharged into the Wairau creek.

As a result of the flooding studies, to minimise the run off should a flood occur, there was a Consent requirement that no stockpiles of spoil were allowed to be kept on site overnight.

4.6 Gas Insulated Switchgear

GIS installation appears to be a black art with a demand for a dust-free environment and other environmental controls. To that end the plant room has to be swept clean and then all surfaces vacuumed to remove as much dust as possible. The concern is that the fine tolerances within the switchgear, combined with dust or worse – metal particles, will cause a ‘flash over’ either during testing or once the equipment is in service.

To meet programme, the GIS installation had to commence before the building was completely fitted out. In addition the 220 kV cables had to be pulled into the GIS plant room in parallel with the GIS installation.

Figure 12 - GIS Plant room

Figure 13- GIS Plant room

5 SUMMARY

In summary this project was successful because of the cooperation and coordination between all stakeholders, consultants and contractors. Some significant challenges were overcome with input from many parties over the course of the project. The parties and individuals involved worked cooperatively together to achieve an excellent result. The project has been delivered on time and under budget and to appropriate quality.

Figure 14 - Wairau Road Grid Exit Point - The finished product