BERWICK – HALFWAY BUSH 33kV O/H LINE REBUILD

FROM 50m POLE SPACING's TO 130m SPACING's

1

THE PROJECT

- THREE LEGACY LINES FROM WAIPORI HYDRO POWER STATION TO HALFWAY BUSH GXP, ORIGINALLY SUPPLYING ALL OF DUNEDIN.
- BUILT ACROSS THE TAIERI PLAIN AND UP THREE MILE HILL AT 50m SPACINGS.
- SUPPLYING FOUR AURORA ZONE SUBS, BERWICK, OUTRAM, MOSGIEL, TAIERI EAST
- LINES FROM WAIPORI TO BERWICK OWNED AND MAINTAINED BY TRUSTPOWER.
- REPLACE THREE 33kV LINES WITH TWO 33kV LINES.

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BERWICK ZONE SUBSTATION TO OUTRAM ZONE SUBSTATION 12km entire route 32km

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Design Criteria

Known as the "A", "B", and "C" lines.

"A" and "B" line strung with twin twist 3/12Cu, the newer "C" line strung with 19/.101Cu.

"A" and "B" line to be rebuilt, "C" line removed, 30MVA summer noon capacity required.

Ability to underbuild 11kV on new "B" line and retrofit "A" line with 33kV flat underbuild.

Fibre communications between zone subs with ADSS, changed to OPGW for EPR mitigation.

New poles to be taller to maximise spans, reduce Aurora pole inventory, improve road safety for "Car V Pole".

Aurora initially called for a "Solution Studies Report"

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Solution Studies Report outcome

1. The Taieri Plain is well known for flooding and being very low lying (Outram ZS is at 8m ASL).
2. A Geotechnical study would be required to confirm ground conditions for pole foundations along the entire route.
3. A earthing study would be required to confirm EPR mitigation and fault clearance abilities.
4. A structural engineering review would be required to establish engineering parameters based on the results of the geotechnical study and pole strengths.
5. 30MVA summer noon would require 2x Nitrogen AAAC circuits
6. The pole loadings of Nitrogen above Nitrogen and OPGW would preclude the use of wooden or concrete poles at spans greater than those already existing. 45kN inline and 75kN strain/deviation pole strengths were required.
7. The only option was steel poles with the intention for them to be ground planted.

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Outcome of the reports
TerraMDC Geotechnical report

1 / 106 50%

Preliminary Geotechnical Assessment Report: Halfway Bush to Berwick – 33kV Transmission Lines, Connetics Limited

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Terra & CONSTRUCTION MANAGED DESIGN

July 2019

2.9 Alluvial Fan Hazard

Alluvial fans are formed from the eroded soils and rock off steep hill country deposited by the rivers and streams running down onto the lower gently sloped terrain. These alluvial deposits typically accumulate at the mouth or opening of steeper hill valleys and off surrounding hill slopes where the watercourse gradient decreases and channel width increases causing the slowing of water velocity and subsequent sediment deposition and fan formation. Any infrastructure or property formed on alluvial fans can be at greater risk of damage caused by flooding due the steeper gradient compared to the surrounding flood plains. This increases the risk of fast flowing water with entrained debris and sedimentation during flooding events.

Figure 6 maps the alluvial fan hazard zones [7] along the existing power lines route. There are several alluvial fans along the route where it follows the toe slopes of the North Taieri hills and the Maungatua Ranges. The section along Milners Road to Wairongoa Road is within an active floodwater dominant zone. Along the Wairongoa Road and Tirohanga Road it is predominately within an inactive floodwater dominant zone and partially an inactive composite alluvial fan zone. The route along Maungatua Road encounters both active and inactive floodwater dominant zones with the active zones associated with the existing water courses.

Figure 6: Alluvial Fan Hazards along the Taieri Plains along the HWB - BWK Powerlines Route.

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Figure 7 shows the various flooding zones from the base of Three Mile Hill Road and along the northern edges of the Taieri Plains, crossing the Taieri River and running out to the end of Maunagatua Road at the Berwick sub-station. The ORC reports[8] for each flooding zone should be consulted separately to ascertain the potential flood risk to each section of the powerlines route within these individual areas.

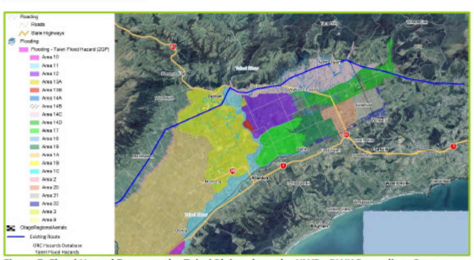
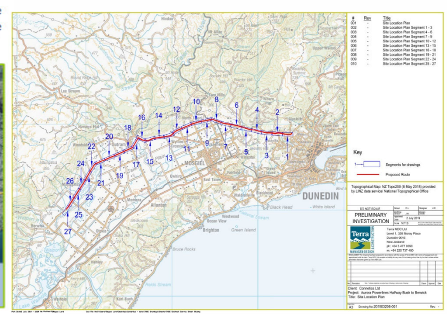


Figure 7: Flood Hazard Zones on the Taieri Plains along the HWB - BWK Powerlines Route.



There are eight geological regions noted in the Table 1 below which lie along the route, with colour coding per the GNS mapping;

Geological Region	Key	Soil / Bedrock Description
1. Dunedin Volcanics 2nd phase extrusives		Loess overlying Basalt, phonolite & dolerite
2. Dunedin Volcanics 3rd phase extrusives		Loess overlying Basalt & interbedded tuffs
3. Dunedin Volcanic Group extrusives		Loess overlying tuff & pyroclastic's
4. Holocene Deposits - Q1 alluvium		Silt, sand and gravels,
5. Late Pleistocene deposits - Q2 alluvium		Silt, sand and gravels
6. Middle Pleistocene deposits Q6 Alluvium		Loess, silt, sand, gravel
7. Undifferentiated Caples Terrane TZIII schist		Loess, weathered Schist over fresh Schist
8. Rakaia Terrane Permian - Triassic TZIV schist		Loess, Weathered Schist over fresh Schist

Table 1: Geological Regions of HWB - BWK Powerlines Route

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3.3 Soil Chemical Testing

Eight bulk soil samples were taken from different test pit locations to obtain a variety of soil samples. The samples were all checked for pH levels and three samples (TP04, TP14, TP19) were selected for a full suite of chemical testing. Full test results are presented in Appendix B.

Table 4 below displays the description of the sample and the tested pH level.

Test Pit	Depth	Sample	pH level
TP04	3.2m – 3.5m	Weathered tuff and dolerite	6.1
TP06	2.0m – 2.5m	Fine to coarse gravely cobbles	6.7
TP09	2.5m – 4.3m	Silty alluvium	6.8
TP13	2.9m – 3.6m	Silty sandy fine to coarse gravel	5.8
TP14	3.9m – 4.2m	Silty alluvium	6.3
TP19	3.0m – 3.6m	Fine to coarse sand	5.7
TP26	3.0m – 3.6m	Silty alluvium	6.0
TP27	3.5m – 4.0m	Silty sandy fine to coarse gravel	5.7

Table 4: Summary of Samples Tested for pH.

A full suite of tests was undertaken on three of the samples, these are summarised below in Table 5. The Water-Soluble Sulphate test were carried out but did not obtain any significant results. TP14 was noted to have a moderate reaction to the hydrogen peroxide test. TP04 and TP19 were noted to have a very vigorous reaction to the hydrogen peroxide test.

Tests	TP04	TP14	TP19
Organic matter (g/100g)	9.3	1.55	2.1
pH Peroxide Test (pH Units)	5.4	5.1	3.2
Carbonate (g/100g as CO_2)	<5.0	<5.0	<5.0
Soluble salts (g/100g)	<0.05	<0.05	<0.05
Ash (g/100g)	91	98	98
Chloride (mg/kg)	75	7	<3
Acid Soluble Chloride (mg/kg)	70	10	<10
Sulphate (mg/kg)	106	9	33

Table 5: summary of Laboratory Chemical Testing.

1 / 4 71%

Hill Laboratories
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R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis Page 1 of 2

Client:	Fulton Hogan Limited	**Lab No:**	2175441 SPv2
Contact:	Sean Connaughton C/- Fulton Hogan Limited Private Bag 1962 Dunedin 9054	**Date Received:**	14-May-2019
		Date Reported:	07-Jun-2019
		Quote No:	98564
		Order No:	52L264
		Client Reference:	
		Submitted By:	Sean Connaughton

Sample Type: Soil

Sample Name:		T.P. 4 07-May-2019	T.P. 14 07-May-2019	T.P. 19 07-May-2019	T.P. 6 07-May-2019	T.P. 9 07-May-2019
Lab Number:		2175441.1	2175441.2	2175441.3	2175441.4	2175441.5
Individual Tests						
Organic Matter	g/100g dry wt	9.3	1.55	2.1	-	-
pH Peroxide Test	pH Units	5.4	5.1	3.2	-	-
Carbonate	g/100g as CO_2	< 5.0	< 5.0	< 5.0	-	-
Soluble Salts	g/100g dry wt	< 0.05	< 0.05	< 0.05	-	-
Ash	g/100g dry wt	91	98	98	-	-
Chloride	mg/kg dry wt	75	7	< 3	-	-
Acid Soluble Chloride	mg/kg as rcvd	70	10	< 10	-	-
pH	pH Units	6.1	6.3	5.7	6.7	6.8
Sulphate	mg/kg dry wt	106	9	33	-	-
Water Soluble Sulphate as SO4 and SO3						
Water Soluble Sulphate	g/100g dry wt	< 0.010	< 0.010	< 0.010	-	-
Water Soluble Sulphate as SO3	g/100g dry wt	< 0.010	< 0.010	< 0.010	-	-
Water Soluble Sulphate as SO4	g/L in extract	< 0.10	< 0.10	< 0.10	-	-
Water Soluble Sulphate as SO3	g/L in extract	< 0.10	< 0.10	< 0.10	-	-

Sample Name:		T.P. 13 07-May-2019	T.P. 26 07-May-2019	T.P. 27 07-May-2019		
Lab Number:		2175441.6	2175441.7	2175441.8		
Individual Tests						
pH	pH Units	5.8	6.0	5.7	-	-

Analyst's Comments

Appendix No.1 - pHfox method report

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-8
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-3
Organic Matter	Calculation: 100 - Ash (dry wt).	0.04 g/100g dry wt	1-3
Soil Prep Dry & Sieve for Agriculture	Air dried at 35°C and sieved, <2mm fraction.	-	1-8
Water Soluble Sulphate as SO4 and SO3		-	1-3

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Soil or Rock Types	Description	Geotechnical Parameters	Potential Hazard Vulnerability for Review in Detailed Design
Recent riverbed sediments: Fine silty clay soils or silty sands and gravels (Alluvium)	Very soft to firm cohesive soils, or unconsolidated weak and loose fine non-cohesive soils ***Ignore the top 1.5m of soil for design:***	Undrained condition S_u = 35 to 50 kN/m² Drained condition Phi (Ø') = 26° C' = 0 kN/m² Young's Elastic Mod $_{soil}$ = 3MPa Bulk Density = 1.6 t/m³	'Domain C' Moderate to High Potential of Liquefaction. Full depth cyclical softening of foundation soils under repeated loading. Unstable soils in deep excavations High groundwater table. Surface flooding likely.
Older Colluvium & Fan debris deposits: Clayey silts or silty Sands and Gravels (Colluvium)	Soft to firm cohesive soils or medium dense fine non-cohesive soils. ***Ignore the top 0.8m of soil for design:***	Undrained condition S_u = 50 to 80kN/m² Drained condition Phi (Ø') = 28° C' = 5 kN/m² Young's Elastic Mod $_{soil}$ = 10MPa Bulk Density = 1.8 t/m³	'Domain B' Low to Moderate Potential of Liquefaction. Near surface (<2.0m depth) cyclical softening of foundation soils under repeated loading. Possible creep ground movement near steep (>22 degrees) slopes. Fan hazards and localised surface flooding with entrained alluvium.
Loess overlying Volcanic inter-bedded basalts & tuffs	firm to stiff (<1.0m) cohesive soils overlying completely weathered volcanic bedrock **Ignore the top 0.5m of soil for design (topsoil):**	Undrained condition Loess: S_u = 80 kN/m² Drained condition Phi (Ø') = 32° C' = 10 kN/m² Young's Elastic Mod $_{rock}$ = 70MPa Bulk Density = 1.9 t/m³	'Domain A' Nil to Low Potential of Liquefaction. Potential for land slippage on slopes >20degrees. Possible creep ground movement near steep (>28 degrees) slopes. Shallow hard bedrock or boulders possible in foundations.
Loess overlying weathered to fresh Schist	Firm to stiff (<1.0m) cohesive soils overlying completely weathered schist bedrock **Ignore the top 0.5m of soil for design (topsoil):**	Undrained condition Loess: S_u = 80kN/m² Drained condition Phi (Ø') = 32° C' = 5 kN/m² Young's Elastic Mod $_{rock}$ = 100MPa Bulk Density = 2.0 t/m³	'Domain A' Nil to Low Potential of Liquefaction Potential for land slippage on slopes >25degrees Shallow hard bedrock possible in foundations

Table 6: Summary of Geological Units, Geotechnical Design Parameters and Hazard Vulnerabilities

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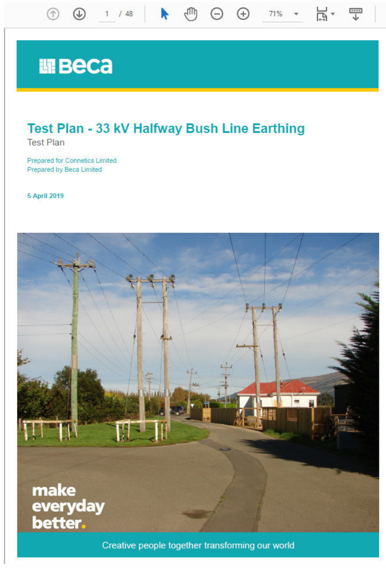
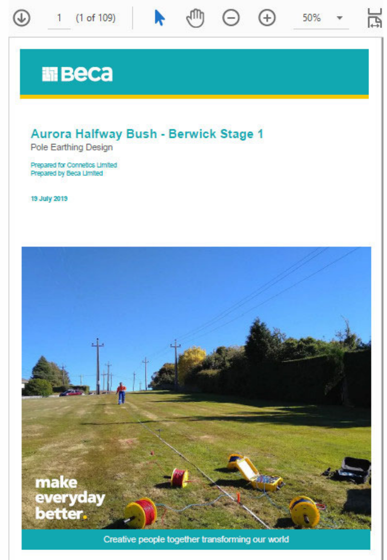
Beca Earthing report





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2 Scope of Design

The project scope of works documented in this report comprises the testing, analysis and hazard mitigation design for steel poles along the proposed line route. This report documents the input data collation, soil resistivity testing and concept pole earthing design for the new 33 kV lines.

The earthing system modelling contained within this report has been carried out in CDEGS version 16.

The concept pole earthing design complies with the standards, guidelines and industry practices identified in Table 1.

Table 1: Standards and guidelines referenced in the concept pole earthing design

Reference	Revision	Title
ESR	2010	New Zealand Electricity Safety Regulations
Aurora NS 2.1	2019	Network Earthing
AS/NZS 7000	2016	Overhead Line Design
IEC 60479.1	2005	Effects of Current on Human Beings and Livestock, Part1: General Aspects
AS/NZS 3000	2018	Wiring Rules
AS/NZS 1768	2007	Lightning Protection
AS/NZS 3835.1	2006	Earth Potential Rise – Part 1: Code of Practice
AS/NZS 4853	2012	Electrical Hazards on Metallic Pipelines
NZECP 34	2001	New Zealand Electrical Code of Practice for Electrical Safe Distances
NZCCPTS	2014	Power Co-ordination Overview Guide
EEA	2006	Guide to Risk Based Earthing System Design
EEA	2009	Guide to Power System Earthing Practice
IEEE 80	2013	Guide for Safety in AC Substation Grounding
IEEE 81	2012	Guide for Measuring Earth Resistivity, Ground Impedance and Surface Potentials of a Ground system

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5.1 Pole Footing Resistance

The pole earth resistance values were calculated using CDEGS for three different foundation sizes: 3 m length (minimum size), 4.2 m length (nominal size) and 5.5 m length (maximum size). The calculated earth resistance values are plotted in Figure 2 below and are also summarised in Appendix B.

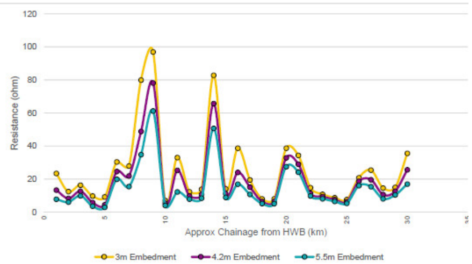

Figure 2: Calculated pole earth resistances for three different foundation types along the proposed line route

3.2 Soil Resistivity

Beca measured soil resistivity along the proposed line route at nominal 1 km spacings. The soil testing was carried out between the 8th and 12th April 2019. Soil conditions were generally damp as the testing was carried out following an extended period of rain.

The measured soil resistivity data was processed in the RESAP module of CDEGS and an equivalent soil resistivity model was developed for use in the CDEGS calculations. The RESAP output plots are included in Appendix A. The derived soil resistivity profiles along the line route are summarised in Table 4.

Table 4: Derived soil resistivity profiles along the concept line route

Location	Soil Layer	Resistivity (Ω-m)	Thickness (m)
HBB01: Under 33kV lines near Balmain Street	Top	532	1.15
	Middle	202	2.95
	Bottom	66	∞
HBB02: Under 33kV lines near Ashmore Street	Top	592	2.21
	Bottom	59	∞
HBB03: Flagstaff-Whare Flat Road	Top	406	1.05
	Middle	121	10.00
	Bottom	83	∞
HBB04: Halfway Bush Road	Top	1512	0.70
	Middle	85	3.46
	Bottom	28	∞
HBB05: Near Transpower Three Mile Hill Substation Switchyard	Top	836	0.61
	Middle	90	3.04
	Bottom	24	∞

Beca

Aurora Halfway Bush - Berwick Stage 1 | 2426439 | NZ1-16294910-4 0.4 | 19 July 2019 | 8

3.5 Special Locations

The new lines will be routed behind Halfway Bush School, Halfway Bush pre-school and residential properties along Balmain Street. They will also be routed adjacent to the Outram Rugby ground along Huntly Road between Bell Street and Formby Street.

The EEA "Guide to Power System Earthing Practice: June 2009" (EEA guide) defines a "Special Location" as any urban or rural area where a significant gathering of people may occur, particularly situations where people may not be wearing footwear. "Special Locations" could be found in areas such as within a school's grounds, children's playground, public swimming pool area, popularly used beach or water recreation area or in a public thoroughfare.

A transferred voltage from a steel pole to the school property fence, playground equipment of drinking fountains, etc, will create a potentially hazardous touch voltage involving children.

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MC MEYER CRUDEN ENGINEERING LTD

Producer Statement 1

Project: 2019060B - Berwick Halfway Bush Overhead Line: Outram Substation to SH87 Section Review

Prepared for: Aurora Energy Ltd

MEYER CRUDEN ENGINEERING LTD

Meyer Cruden Engineering Ltd. 2019060-B 1 of 76

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Outcome of design partner studies

- Geotechnical report showed top 1.5m of soil on Taieri Plain unable to provide any foundation support.
- For this reason flange mounted poles were designed instead of ground planted. Only two poles would be required, 45kN and 75kN. The foundations would be changed to suit, 3.0m deep to 5.5m deep.
- Soil conditions such that corrosion between foundation steel, concrete and pole would not be of concern.
- Publically available literature showed a very diverse set of ground conditions, flood zones, alluvial fans, faultlines.

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Beca earthing report revealed

- In agreeance with geotechnical report, very varied ground conditions were identified. A one solution fits all earthing design would be more than required (i.e. very expensive) . A 20m deep drive earth at each pole.
- A shallow low impedance ground cover was above a high impedance layer resulting in very problematic earthing with regard to EPR concerns. This resulted in the minimum foundation depth increasing to 3.5m and the ADSS changing to OPGW
- Three “Special Locations” were identified, a sportsground, a primary school and preschool.

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Final design parameters

- 14.3m ground flange mount, two piece, slip joint steel poles, 45 & 75kN tip load, pre-drilled and fitted with attachment brackets
- Two foundation bolt cages, 1.5m long 12 or 18 x 30mm bolts.
- Rebar spiral and vertical foundations 3.5m – 5.5m encasing the bolt cages.
- OPGW and OHEW providing EPR mitigation along with driven earths at each pole (location dependent)
- All LV O/H removed and undergrounded. No poles at intersections for road and pole security with 11kV tee off's undergrounded around corners.
- 5.0m deep mass concrete ground stays utilising 20mm Reid Bar, "Banana" turnbuckles and three 105kN stay wires.

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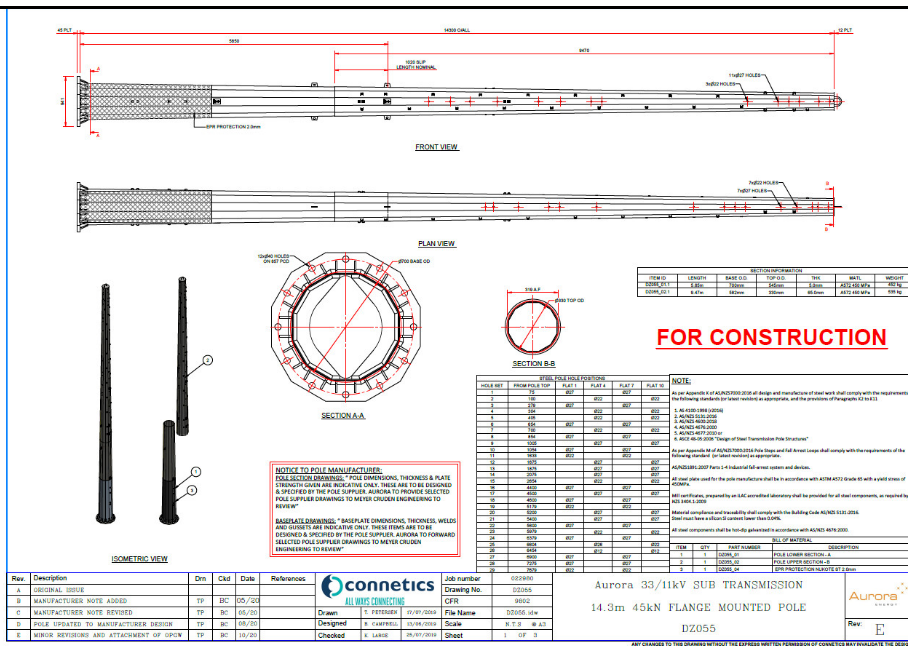

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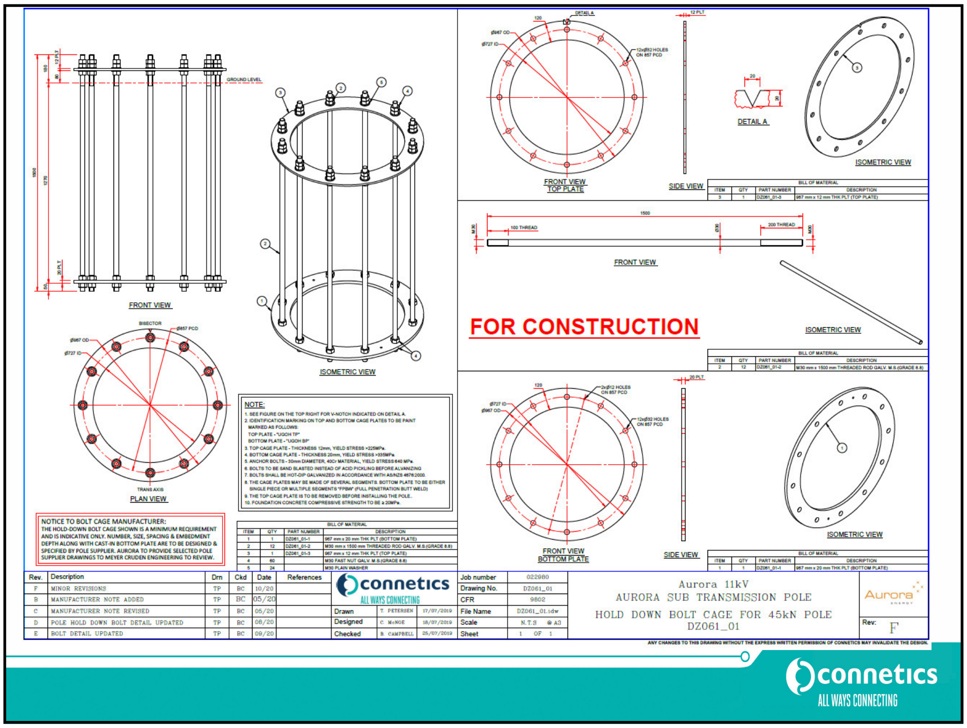
FRONT VIEW
ISOMETRIC VIEW
PLAN VIEW
FRONT VIEW TOP PLATE
SIDE VIEW
DETAIL A
FOR CONSTRUCTION
FRONT VIEW BOTTOM PLATE
NOTICE TO BOLT CAGE MANUFACTURER:
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Aurora 11kV
AURORA SUB TRANSMISSION POLE
HOLD DOWN BOLT CAGE FOR 45kN POLE
DZ061_01
Aurora

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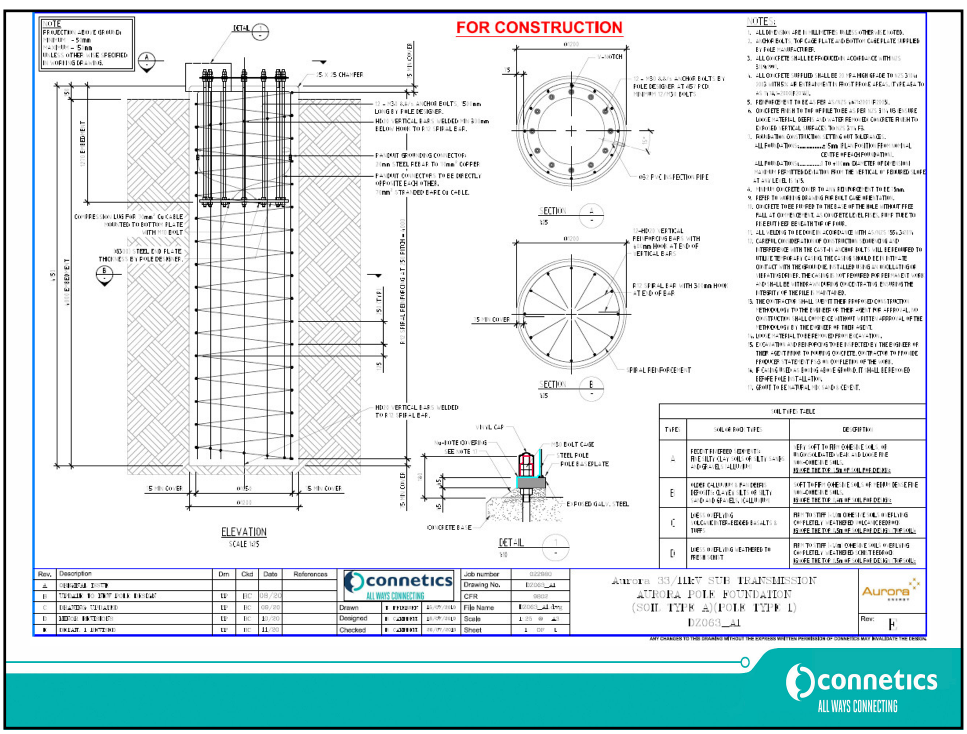
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Aurora 33/11kV SUB TRANSMISSION
AURORA POLE FOUNDATION
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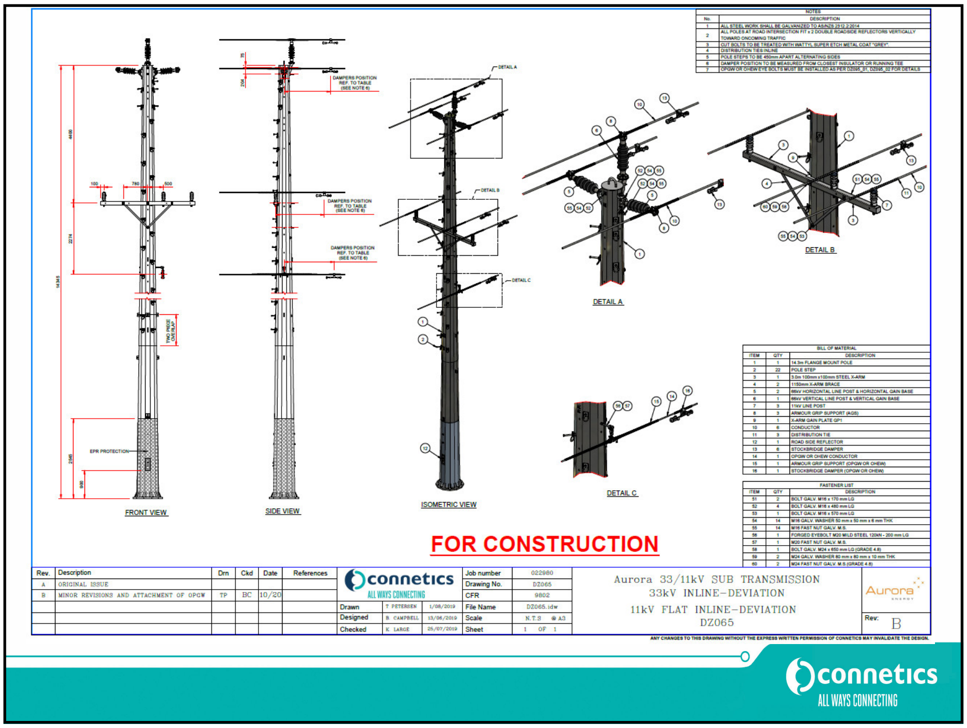
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FRONT VIEW
SIDE VIEW
ISOMETRIC VIEW
DETAIL A
DETAIL B
DETAIL C
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Aurora 33/11kV SUB TRANSMISSION
33kV INLINE-DEVIATION
11kV FLAT INLINE-DEVIATION
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ANY CHANGES TO THIS DRAWING WITHOUT THE EXPRESS WRITTEN PERMISSION OF CONNETICS MAY INVALIDATE THE DESIGN.

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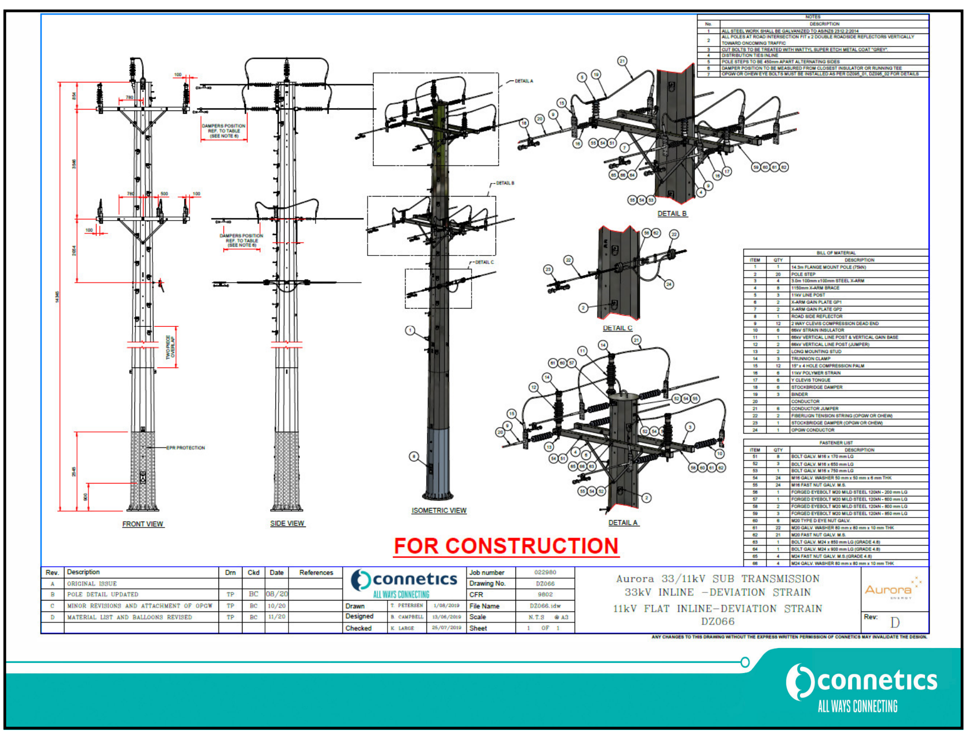
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FRONT VIEW
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Aurora 33/11kV SUB TRANSMISSION
33kV INLINE -DEVIATION STRAIN
11kV FLAT INLINE-DEVIATION STRAIN
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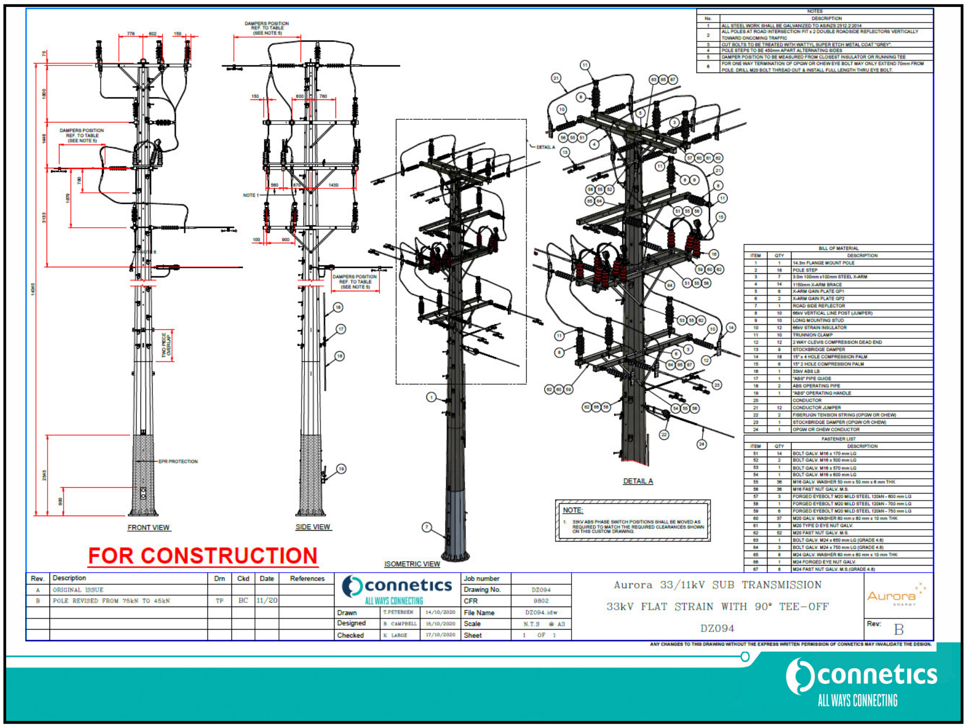

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The Build by Delta Utility Services

- Delta won the build contract and had from January 2021 until April 2021 to remove 270 old wooden and concrete poles, install 92 foundations. Assemble and install 92 steel poles, carry out enabling work at all the intersections and customer connections, carry out an underground conversion of Huntly Road in Outram for 400m, all while rebuilding Outram Z.S.
- Trustpower would only have the “A” & “C” lines to export their hydro generation from Waipori.

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