



TRANSPOWER

NORTH ISLAND GRID UPGRADE PROJECT

AMENDED PROPOSAL

ATTACHMENT G

HIGH TEMPERATURE CONDUCTOR

**Technical Analysis of using High Temperature
Conductor for Duplexing OTA-WKM A&B &
Up-rating OTA-WKM C lines**

October 2006

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Executive Summary

High Temperature conductors (HTC) enable a higher power transfer as the materials they are constructed from do not increase in length as much as conventional conductors when heated. As a consequence, these conductors do not sag as much as conventional conductors and hence a HTC can run in excess of 200C without infringing ground clearances.

An option for the duplexing of the OTA-WKM A&B lines is to use high temperature conductor. For the purposes of investigating this option, conductor data from a number of suppliers, including 3M, was studied.

High Temperature Conductors identified allowed a capacity of approximately 1000MVA per circuit compared with 600MVA per circuit if conventional conductors are used. The physical works, the property and environmental issues are all likely to be similar to those encountered with the duplexing of the OTA-WKM A&B line with conventional Goat conductor.

The differences between the duplexing with conventional Goat and a representative HTC are:-

- the cost of the conductor is much higher, though for a bulk order it has been assumed that the price might reduce substantially.
- the higher capacity requires installation of similar conductor on the OTA-WKM C (HLY-OTA) line to avoid this overloading
- Series compensation will be required on the line
- Losses will be significantly higher than with duplex conductor
- The total reactive power requirement will be approximately 2800 MVar at the Otahuhu end, compared to the duplex option or 220 kV or 400 kV new line options the reactive power requirement represent an increase of approximately 1600 MVar. Out of this incremental reactive support, approximately 620 MVar need to be supplied from dynamic sources.
- An extra cable is required over that required for the duplexing option

The total cost of this option across the same time window as all other options is \$2184m (in 2006 \$) for the lowest of the High Temperature Conductor prices we have. To test sensitivity to bulk order, it has been assumed the conductor price could be reduced by up to 50% for a bulk order, resulting in the final price for this option reducing to \$1975m.

1 Introduction

One of the options that has been evaluated as part of the amended proposal is duplexing of the OTA-WKM A and B lines and then constructing a new 220 kV line at a later date. This has been studied and reported in Attachment I to the amended proposal.

As a variant, the existing “Goat” conductor could be replaced with duplex high temperature conductor (HTC) which is physically similar to the Goat conductor but has a winter rating of 1000 MVA compared to 600MVA for Goat.

Duplexing involves the installation of a second conductor beside the existing conductors.

Investigations have identified that it would be very difficult and expensive to duplex the last section of the line through the urban areas in South Auckland. In addition to provide diversity of supply, if the lines were duplexed, the lines would need to be diverted from Otahuhu substation to Pakuranga substation, and the last section of the line would be cabled. Hence duplexing from Whakamaru to a site South of Auckland then cabling to Pakuranga substation has been studied

In general the works now proposed for duplexing using HTC are :-

- Duplex the Otahuhu – Whakamaru A & B single circuit lines by replacing the existing single ACSR Goat conductor with a duplex HTC arrangement (1000 MVA winter) from Whakamaru to the vicinity of South Auckland;
- Construct a cable termination station under the existing line and terminate the duplex conductors at this station;
- Connect from this termination station to Pakuranga by 220 kV cables;
- The line section from Otahuhu to transition station will not be duplexed and will be disconnected.

A full report on duplexing the OTA-WKM A&B line using “Goat” conductor is included as Appendix I of the amended proposal. This report looks at the duplexing of the OTA-WKM A&B lines, with High Temperature conductor and the other works necessary to meet Upper North Island Load growth and security.

2 Development Plan

To utilise HTC conductor for the duplexing of the OTA-WKM A&B lines a series of projects are required to provide thermal capacity and further investments are need to provide reactive support.

The projects to provide thermal capacity are described in Table 2.1 below and those required to provide reactive capacity in Table 2.2.

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Year	Augmentation
2010	Install BOB 220/110 kV interconnector
2011	Thermally upgrade the 220 kV HAM-HLY-1, HLE-WKM and HAM-WKM-1 circuits (HLE-HAM-WKM section of the OTA-WKM C double circuit line) to 2xGoat 80°C
	Drury Substation
	Drury Substation – Lines
2012	Build new 220kV substation at PAK.
	Install three new 120MVA supply transformers at PAK
	Increase operating voltage of OTA-PAK 1and 2 circuits (OTA-PAK A transmission line) to 220kV
	Partially shift Pakuranga load 110kV 220kV
	Install 1 st PAK-PEN cable
2013	Re-conductor OTA-WKM 1 & 2 circuits (OTA-WKM A and B lines) with HTC Duplex and re-terminate them (via underground cables) on to the PAK 220 kV bus.
	Install two new 220 kV cables from OTA-WKM 1 & 2 circuits deviation point to Pakuranga
2015	Install 2 nd PAK-PEN cable
2016	Reconductor ARI-HAM 1 & 2 circuits to Nitrogen at 75 deg C
2017	Install 40% series compensation on the OTA-WKM 1 & 2 circuits (OTA-WKM A and B lines)
2019	Install OTA-WIR 110 kV cable
	Build switching station at WIR
2019	Reconnect the two disconnected lines from SAK to OTA (existing overhead section) as a bonded pair
	Build new switching station at SAK
2023	Re-conductor 220 kV OTA-WKM C line with Duplex HTC (all sections except HLE to HAM section)
	Install 25% series compensation on OTA-HLE-1 and 2 circuits, and HLE-WKM-1 circuits (OTA-HLE and HLE-WKM sections of OTA-WKM C line)
	Install 30% series compensation on 220 kV HAM-WKM-1 circuit (HAM-WKM section of OTA-WKM C line)
	Reduce series compensation on OTA_WKM 1 and 2 circuits to 25%
	Buss OTA-WKM 1 & 2 circuits (OTA-WKM A and B lines) at HLE
	Install 1 st Cable from OTA to PEN
2024	Install 2 nd ROS 220/110 kV interconnecting transformer
	Reconductor 110 kV BOB-HAM circuits with Nitrogen conductor
2025	Install one 75 MVA Phase Shifting Transformer on the 110 kV ARI-BOB-1 circuit
2027	Install 2 nd PEN-ROS Cable

2028	Decommission the 110 kV ARI-PAK line and shift remaining PAK 110kV load to 220k
	Install 1 Ohm series reactor on OTA-SAK bonded pair
2029	Build new 220 kV double circuit line (twin Chukar at 75 deg) from WKM to ORM
	Install two new 220 kV cables from ORM to PAK
2030	Install 2 nd Cable from OTA to PEN
2032	Build Switching Station at ORM
	Install new 220 kV cable from ORM to OTA
	Install 3 rd ROS 220/110 kV interconnecting transformer
2037	Install new OTA 220/110kV interconnecting transformer (similar to T5)
2039	Install 2 nd cable from ORM to OTA
2040	Install 30% series compensation on ORM-WKM circuits
	Install 3 rd Cable from PAK to PEN

Table 2.1. Thermal Plan for Duplexing OTA_WKM A&B with High Temperature Conductor.

Year	Location	Quantity (MVAR)	Static/Dynamic
2008	OTA	250	S
2009	OTA	100	D
2011	OTA	150	S
2016	HLY	100	S
2019	OTA	150	S
2021	HLY	200	S
2022	OTA	350	S
2023	HLY	200	S
2027	OTA	250	S
2027	HLY	200	S
2035	OTA	150	S
2039	OTA	450	S
2039	OTA	150	D
2041	OTA	250	D
2041	OTA	500	S
	Total	3450	

Table 2.2 Reactive Plan for Duplexing OTA_WKM A&B with High Temperature Conductor.

3 Duplexing the OTA-WKM A&B with HTC

High temperature conductors enable higher power flow due to the nature of the material used in their construction, which have lower thermal elongation, and can carry higher power for the same sag as a normal conductor.

Explaining this in more detail, as power is transferred through electrical conductors the conductor temperature increases. This increase in temperature leads to the conductors extending in length which in turn leads to greater sags. At the design power flow the conductor reaches its maximum sag, and at that point, the conductor must meet the minimum ground clearance criteria. The material of high temperature conductors have a lower thermal elongation, so when heated they extend less. This enables higher power transfer; before the conductor sags to the extent that minimum ground clearances are reached.

There are many high temperature conductor options, but for the purposes of this report, a 3M HTC is studied as 3M have made a submission to the Commission proposing duplexing of the OTA-WKM line with 3M HTC and also replacing the existing duplex Goat on the OTA-WKM C line.

3.1 OTA-WKM A&B Duplex Implementation

The majority of issues associated with installing high temperature conductors are the same as those considered for duplexing with a normal conductor. This is reported on in Attachment I to the Transpower Amended proposal, but the issues are summarised here:-

- Foundations on the OTA-WKM A&B line are of an old design and will require strengthening to carry the increased loads.
- Tower strengths need to be increased to cater for the increased loads, this can often be achieved by installing strengthening to the existing towers.
- Tower replacement may be needed where strengthening of towers cannot provide sufficient capacity.
- Conductor clearances to ground must be maintained at the required minimum, but for many reasons explained in more detail in the duplexing report, there are occasions when the installation of duplex conductor requires work to meet the required ground clearance.
- The OTA-WKM A&B lines have long sections with no strain towers (up to 56km). It is now international and Transpower practise to ensure that the failure of any one tower does not cause a cascade failure of many towers. This is met by ensuring a good distribution of strong towers or strain towers along the line. To meet this requirement, some new strain towers are proposed to break up the long sections of line.
- The duplexing work itself involves removing the existing conductor and using it to pull through two new conductors.

Table 1 in Attachment I to Transpower's Amended proposal shows the work required for duplexing using twin Goat conductor. The works for installing twin HTC conductor are extremely similar, with only a potential increase in the amount of work to ensure ground clearances for HTC, with Goat conductor about 18% of spans on the lines will require some work but 26% of spans will require work for duplex HTC conductor. This is due to the different sag characteristics of HTC. The estimated work, based on desktop studies only, is summarised in Table 3-1.

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Work needed	Details	A Line	B Line
Foundation strengthening	Foundation strengthening is needed on 75% of towers with grillage foundations and strengthening is need on all piled foundations. This is usually achieved by the pouring of concrete around the tower legs, generally underground.	360 grillages	346 grillages
		15 Piles	14 piles
Tower strengthening	Strengthening needed on towers where loads are presently between 90% and 100% of specification loads. High level analysis only has been completed, but it is TP experience that towers loaded to 90-100% generally need minor strengthening (2-3 pieces in the tower bridge).	104	108
	Between 100% and 110% of specification loads.	131	127
	Between 110% and 115% of specification loads.	41	52
Tower replacements for overload	>115 overloaded	46	47
Tower replacements for ground clearance	The OTA-WKM A&B thermal upgrade project is removing existing ground clearance issues. The solutions used are appropriate for simplex conductor but not for duplex conductor. For instance, one of the solutions removes conductor from existing spans but leaves a residual longitudinal load on the tower. This is acceptable for one conductor but when doubled by duplexing, will overload the tower. As a result, some of the towers need to be replaced. Other solutions to gain extra ground clearance are; to install towers on piled foundations, convert towers to “floating strains” or undertake earthworks. At this stage Transpower can only estimate the likely distribution of solutions. The estimates here are based on the Goat conductor (18% of spans requiring work) and the type and mix of solutions required for HTC is not yet known as 26% of spans are assessed to require ground clearance work.	5	5
Towers raised on piles		5	5
Conversion to floating strains		10	8
Earthworks		30	25
Tower replacements to provide extra strain towers for anti cascade design	There are long sections of the line with no strain towers which can potentially lead to a cascade collapse of many towers. For the proposed increase of capacity afforded by duplexing, it is prudent and consistent with best practise to install extra strain structures.	5	5
Duplexing	Install protection for underling services (roads, power lines).Remove the existing “Goat” ACSR Aluminium conductor, generally using it to pull through two HTC replacement conductors. Clamp conductors at each suspension tower, and strain tower. Reinsulate where the increased conductor weight or tension exceeds existing insulation strength. Install spacers in the spans.		

Table 3-1. Summary of estimated work needed to duplex the OTA-WKM A&B lines with HTC

3.2 Environmental – OTA-WKM A&B Specific

A detailed description of the applicable environmental legislation and how it applies to duplexing is provided in Attachment I to the Amended Proposal. The issues specific to the duplexing of the OTA-WKM A&B line are detailed here.

The OTA-WKM A&B lines traverse seven local authority boundaries, and two Regional Council boundaries. The works must comply with all the rules, restrictions and resource consent requirements in each of these separate plans.

In the absence of a specific rule that permits the works associated with duplexing throughout each of the Councils, Transpower has the option of either seeking resource consents for the works, or designating the OTA-WKM-A and B lines under the RMA.

In summary the provisions of each Council differ in respect of these works, and just as for duplexing with normal Goat conductor, consents may only be required from one or two Councils. It is considered that Resource Consent / Certificate of Compliance is the appropriate tool to secure the necessary approvals.

On this basis, a project programme of 15 months (21 months including Environment Court) for consenting the OTA-WKM-A and B lines in accordance with the statutory requirements of the RMA is appropriate.

Table 4, extracted from Attachment I to the Amended Proposal, summarises the environmental issues associated with the Scope of Works necessary to duplex the OTA-WKM A&B lines with either Goat or HTC conductor.

Duplex Goat and Duplex HTC meet the electric and magnetic field limits as shown in Figures 3-1 and 3-2¹.

The electric field is similar for both duplex HTC and duplex Goat conductor, but the magnetic field for HTC is 60% higher than Goat conductor but still well below internationally recognised limits.

¹ Note that these EMF curves are for the worst combination of conditions, maximum power transfer, maximum sag, which requires a still hot sunny day, and at a location directly under the lowest point of the span. The data is provisional at present, and is being verified.

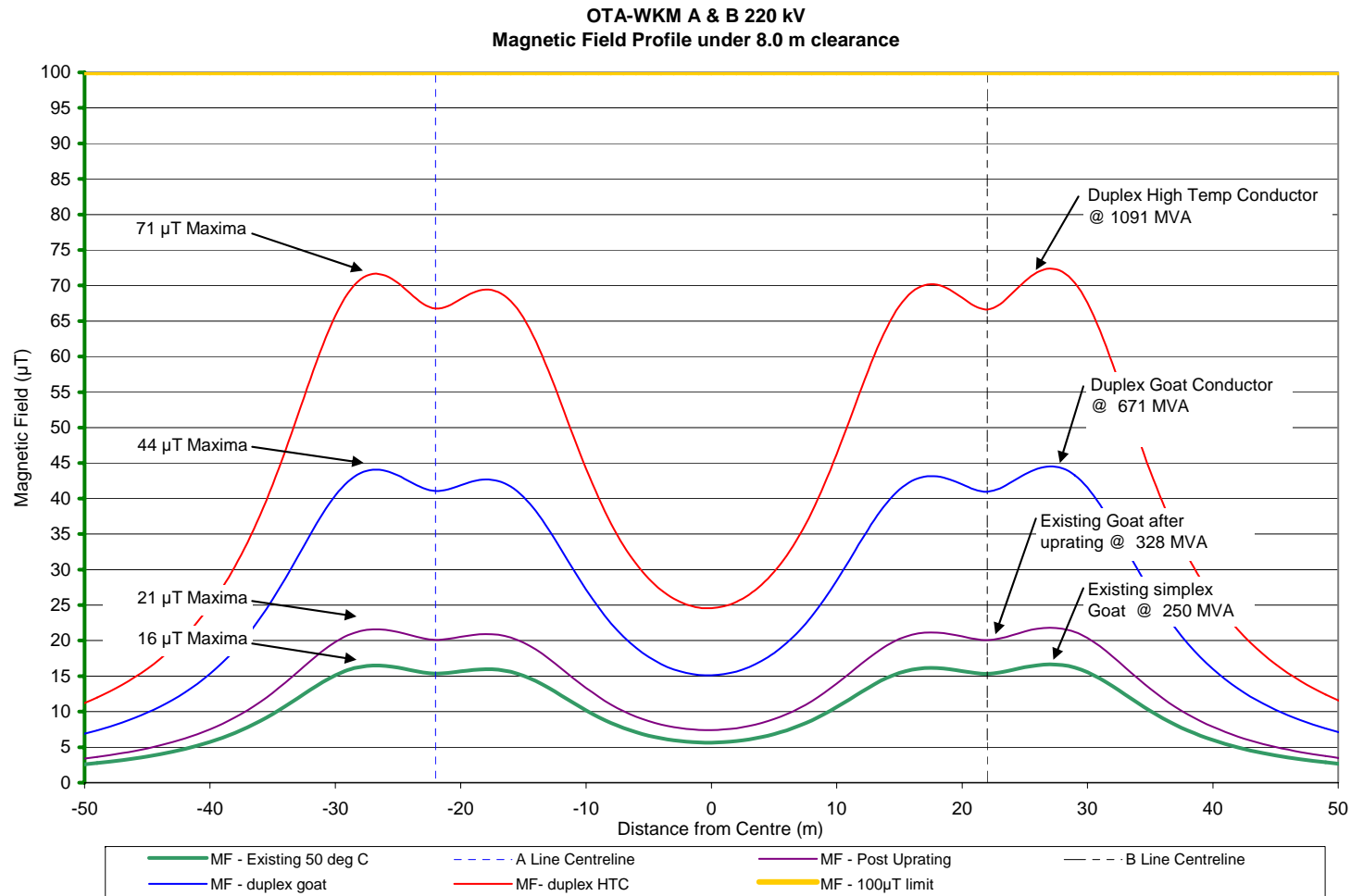


Figure 3-1. Magnetic fields under OTA – WKM A&B lines

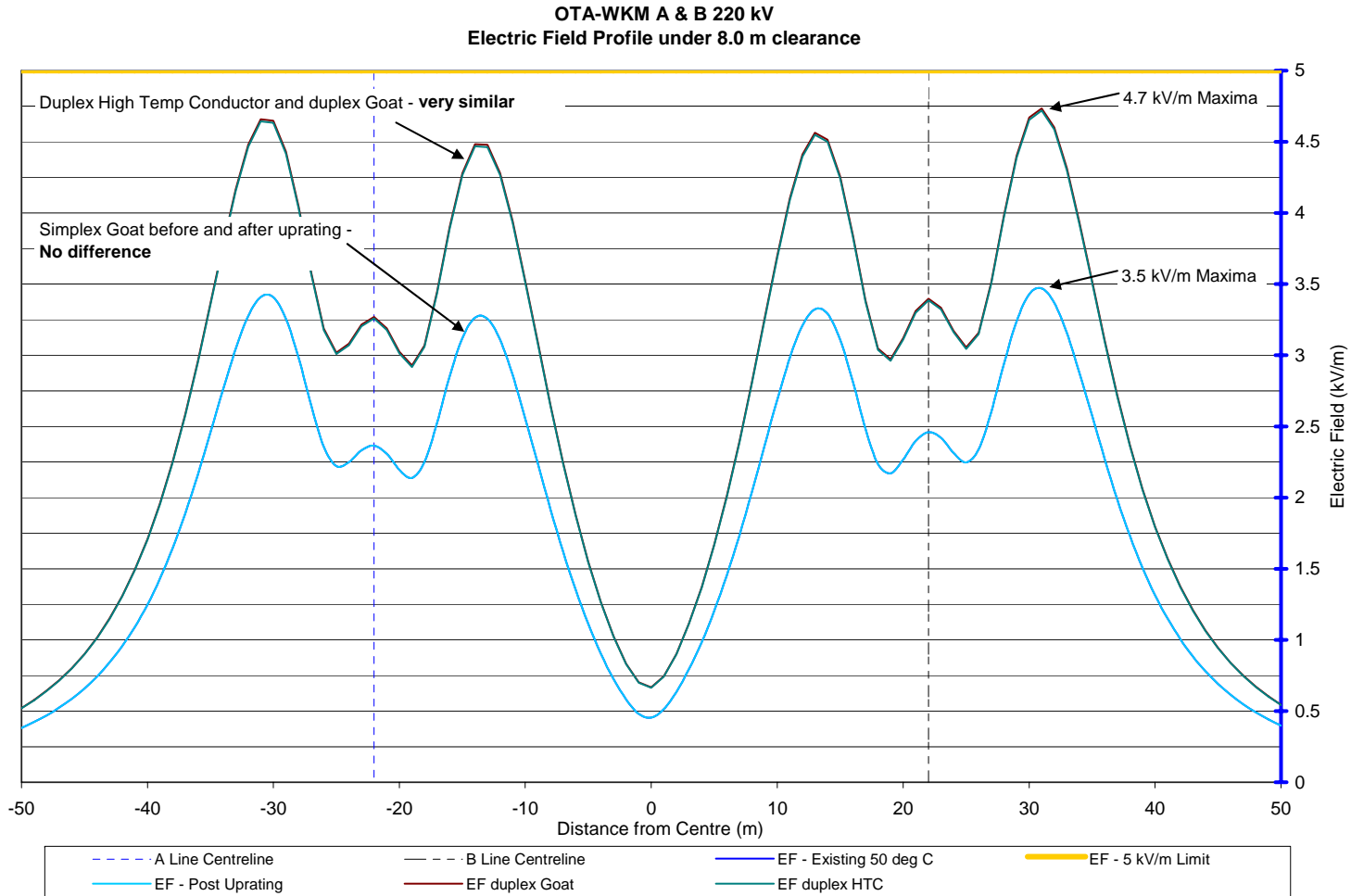


Figure 3-2. Electric fields under OTA – WKM A&B lines

3.3 OTA-WKM A&B Property

A detailed description of the general issues associated with obtaining property rights for upgrading and new transmission lines is provided in Attachment I to the Amended Proposal. These are all relevant to the duplexing of the line whether it be with HTC or normal Goat conductor.

The specific issues associated with this project are described here.

It is Transpower's view that the works required to the lines to duplex with Goat or HTC will cause injurious affection to land in parts of the OTA-WKM route(s). This is largely dependent on the intensity of the use of the land traversed by the lines.

Residential, rural-residential or lifestyle, and high value specialised land uses will in general be injuriously affected by the required works. Some properties, particularly residential and rural residential where the dwellings are within the "corridor" created by the two lines, may be affected to an extent that the entire property would be purchased.

The "corridor" effect of having the two transmission lines relatively close together may also extend the injurious affection into less intensive land uses where dwellings in particular are in close proximity

To assess the extent of the likely property costs for the works for duplex Goat, two independent valuer's opinions have been obtained concerning the ability of the work to be carried out in accordance with Section 23(3)(b) of the Electricity Act. Both valuer's have determined that given the location of the works, in a number of instances, there is a high probability that the works will cause an "injurious affect" to the adjoining land and hence will require a property right to be obtained to allow the works to proceed. This information has then been used to establish the cost estimate to enable the required property rights to be obtained.

This work has not been repeated for HTC but the conclusions are applicable as Goat and duplex HTC will require the same easement width and have the same impact.

Table 3-2 summarises the Property issues associated with the duplexing of the OTA-WKM A&B lines.

TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
<i>Physical engineering work</i>	<i>RMA -Authorisations and Risks</i>	<i>Timelines for consents²</i>	<i>Electricity Act Authorisations and Risks</i>	<i>Timelines for property rights</i>
Foundation Strengthening	<p>Activity authorised as a permitted activity in half the plans.</p> <p>However, some plan rules are ambiguous and permitted activity status would need to be confirmed with Council planners.</p> <p>2 Councils will require resource consents – need for public notification unclear and would have to be negotiated and determined with the Councils on an individual basis.</p> <p>Key risks to project: timing and costs.</p>	<p>From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>To date no property rights have been required for foundation strengthening.</p> <p>Transpower believes that the vast majority of all foundation strengthening work can be legitimately be undertaken using the provisions of the Electricity Act (Section 23).</p> <p>The only requirements required to be complied with is issuing notices to the landowner (section 22) of when the actual work is undertaken, when and what access is required.</p> <p>The landowner can deny access due to legitimate farming operations or impose a section 23F claim which must be resolved prior to the work proceeding.</p>	<p>Statutory time frames set by the Act (10 working days) excluding any Section 23F claim</p>

² Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
<i>Physical engineering work</i>	<i>RMA -Authorisations and Risks</i>	<i>Timelines for consents³</i>	<i>Electricity Act Authorisations and Risks</i>	<i>Timelines for property rights</i>
<i>Tower strengthening</i>	<p>Activity authorised as a permitted activity half the plans.</p> <p>However, some plan rules are ambiguous and permitted activity status would need to be confirmed with Council planners.</p> <p>2 Councils will require resource consents – need for public notification unclear and would have to be negotiated and determined with the Councils on an individual basis.</p> <p>Key risks to project: timing and costs.</p>	<p>From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>Minor tower strengthening with no significant visual impact has not required property rights</p> <p>As above, although this largely relies on the extent of the re-strengthening. For example if extensive additional steel tower components are required this will invoke injurious affect. (generally unlikely)</p>	<p>As above</p>

³ Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
<i>Physical engineering work</i>	<i>RMA -Authorisations and Risks</i>	<i>Timelines for consents⁴</i>	<i>Electricity Act Authorisations and Risks</i>	<i>Timelines for property rights</i>
Tower replacements	<p>This activity would be authorised as a permitted activity by some councils provided the tower remained in the same or similar position. In one Council – this condition applies, and the tower would have to be less than 25 metres in total height. Other Council rules are ambiguous and consent status would have to be determined in consultation with the Council. 2 Councils would require resource consents. Applications may be publicly notified or non notified – this would have to be negotiated and agreed with the individual councils.</p> <p>Key risks to project: timing and costs.</p>	<p>From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>When assessing this component of the work, it is largely reliant on the location of the tower to the surrounding landscape and proximity of dwellings to the line. Replacement of towers that are like for like i.e are the same shape, style, height and is effectively the same as what already exists, Transpower believes that it can rely on using the provisions of the Electricity Act (section 23). However the issues are considered to be so risky that Transpower acquires additional property rights to avoid the confusion and possibility of challenge. Some examples where we have been already challenged are when the towers are to be built outside the alignment or are mid span (moved significantly away from the existing tower location or where there is an existing residential dwelling that is in close proximity to the line...</p>	<p>Good faith negotiations can take approximately 6-12 months and where agreement can not be reached Transpower can seek approval from the Minister of Lands to compulsory acquire the relevant interest in the land which will be a registered easement. This process has approximately a 24 month timeframe.</p>

⁴ Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
<i>Physical engineering work</i>	<i>RMA -Authorisations and Risks</i>	<i>Timelines for consents⁵</i>	<i>Electricity Act Authorisations and Risks</i>	<i>Timelines for property rights</i>
<i>Towers raised on piles</i>	<p>This activity would be authorised as a permitted activity by some councils provided the tower remained in the same or similar position. In one Council – this condition applies, and the tower would have to be less than 25 metres in total height. Other Council rules are ambiguous and consent status would have to be determined in consultation with the Council. 2 Councils would require resource consents. Applications may be publicly notified or non notified – this would have to be negotiated and agreed with the individual councils.</p> <p>Key risks to project: timing and costs.</p>	<p>From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>Generally by taking this approach we are increasing the height of the towers and there is new or additional permanent equipment that can now be clearly seen and which may have an impact to the land-value. Initially Transpower believed that this activity could be undertaken under the provisions of the Act, however we have since had to revise this approach as landowners supported by their registered valuers and legally advisors have successfully justified that it does create an injurious affect and additional property rights are required. Property.</p>	<p>Good faith negotiations can take approximately 6-12 months and where agreement can not be reached Transpower can seek approval from the Minister of Lands to compulsory acquire the relevant interest in the land. This process has approximately a 24 month timeframe.</p>

⁵ Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

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TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
Physical engineering work	RMA -Authorisations and Risks	Timelines for consents⁶	Electricity Act Authorisations and Risks	Timelines for property rights
Floating strains	<p>Six Councils would authorise this activity as a permitted activity. One Council would require a resource consent if arguments made to authorise the work under existing use rights were unsuccessful.</p> <p>Key risks to project: timing and costs.</p>	<p>If resource consent required. From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>Transpower believes that the vast majority of this activity can be legitimately be undertaken using the provisions of the Electricity Act (Section 23). The only requirements required to be complied with is issuing notices to the landowner (section 22) of when the actual work is undertaken, when and what access is required. The landowner can deny access due to legitimate farming operations or impose a section 23F claim which must be resolved prior to the work proceeding.</p>	<p>Statutory time frames set by the Act (10 working days) excluding any Section 23F claim</p>
Earthworks	<p>Both Regional and District Councils control earthworks – for different purposes. Authorisations required depend on volume, location, slope, and proximity to water bodies. Expected that majority of Councils will require consents, notification also possible depending on circumstances. No certainty of this until discussed with individual councils.</p>	<p>If resource consent required. From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>Transpower believes that the vast majority of this activity can be legitimately be undertaken using the provisions of the Electricity Act (Section 23).When in doubt an agreement can generally be reached with the landowner to undertake this activity. The only requirements required to be complied with is issuing notices to the landowner (section 22) of when the actual work is undertaken, when and what access is required. The landowner can deny access due to legitimate farming operations or impose a section 23F claim which must be resolved prior to the work proceeding.</p>	<p>Statutory time frames set by the Act (10 working days) excluding any Section 23F claim</p>

⁶ Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

TABLE 3.2 SUMMARY - PROPERTY AND CONSENTING ISSUES ASSOCIATED WITH DUPLEXING THE OTA-WKM A&B with HIGH TEMPERATURE CONDUCTOR (HTC)				
Physical engineering work	RMA -Authorisations and Risks	Timelines for consents⁷	Electricity Act Authorisations and Risks	Timelines for property rights
Duplexing	<p>Potentially 3 Councils would authorise this activity as a permitted activity. Other Councils requirements ambiguous or definitive on requiring a resource consent. Where consents required, public notification probably. Environmental effects that would come under public scrutiny include EMF, EPR, EMI, RFI and visual effects.</p> <p>Key risks to project: timing and costs, relationships and risk of consent refusal.</p>	<p>From point of lodgement with Council - between 3 months (non notified process) and two years (notified and appealed)</p>	<p>The works required to be completed on the transmission lines for duplexing will in many instances cause injurious affection to, Residential, Rural residential, Intensive rural uses such as well developed horse studs, and any land where the line(s) are in close proximity to the dwelling(s). The principal cause of injurious affection is the aesthetic impact, particularly from the “corridor” of effect of the transmission lines as well as the strain towers on a limited number of properties. It is on this basis that Transpower believes that by undertaking this activity Transpower can not solely rely on the statutory provisions of the Electricity Act and must seek additional property rights in certain circumstances.</p>	<p>Good faith negotiations can take approximately 6-12 months and where agreement can not be reached Transpower can seek approval from the Minister of Lands to compulsory acquire the relevant interest in the land which will be a registered easement. This process has approximately a 24 month timeframe.</p>

Table 3-2. Summary of property and consenting issues associated with duplexing OTA-WKM A&B with high temperature conductor (HTC)

⁷ Time line estimates assumes that all consents required lodged with all council simultaneously. Time lines will be sequential if consents lodged independently.

3.4 OTA-WKM A&B Transmission Line Project Costing

Costs for design and construction, property and environmental costs were estimated for the duplexing of the OTA-WKM A&B lines with Goat conductor, and are contained in Attachment I to the Amended Proposal. These are generally applicable, except for the conductor cost.

In summary costs for duplexing the OTA-WKM A&B lines with twin HTC are:-

OTA-WKM A&B Duplex Costs	
Design and Construction & conductor costs	\$259m
Property Costs	\$83m
Environmental Costs	\$4m
Project Management & Contingencies	\$85m
Total	\$436m

Table 3-3. Cost summary for HTC

It is worth noting that data obtained by Aerial Laser Line Survey in 2005 indicates there are at least 203 buildings under the lines between Whakamaru substation and Chapel Road in South Auckland. The property costs include for the purchase of an easement and for the removal of some of these structures, but not all, whereas a new line has no structures within the easement.

4 Cables

The new 220 kV cables that are being proposed for the 400 kV and 220 kV options, including duplexing the OTA-WKM A and B lines with twin Goat conductor, are rated at 668 MVA. There is also the option to install forced cooling on the cables, for use during system contingencies, that will increase the rating to 1115MVA. The duplex Goat option has a rating of approximately 600 MVA so a single cable can be used for each circuit. With the HTC option, the loading on the circuits will exceed the uncooled rating of the cables by a considerable margin precontingency, so an additional cable and bus will be required at the cable transition station.

Costs for cables are in the Development Plan Budget.

5 Upgrading the OTA-WKM C line

The six circuits supplying the Auckland area will naturally share the power flow between them. To fully utilise the thermal capacity of the HTC conductor on the OTA-WKM A and B lines, at least the WKM-HLE-OTA line which runs parallel to the A&B lines need to be reconducted with the HTC and series compensation will have to be installed on the lines. The maximum capacity is utilised when A&B lines with HTC are also bussed at HLE and all line segments with HTC are series compensated to approximately 20%.

Costs for the upgrading of the OTA-WKM A&B line and the series compensation are included in the Development Plan Budget.

6 Reactive Compensation

Transmission lines consume reactive power (vars) when heavily loaded. The reactive consumption is equal to the square of the current flowing through the line multiplied by the reactance of the line. The HTC line will consume over two times the reactive power of the duplex Goat arrangement. The fully loaded circuit with HTC conductor consumes approximately 1125 MVar of reactive power compared to approximately 500 MVar for the duplex goat option (under contingency conditions). If the WKM-OTA- C line was also reconducted with HTC the increase in reactive consumption would be multiplied by three (assuming one line is out of service under contingency).

When a circuit trips the reactive consumption on the remaining lines increases instantaneously and this increase in reactive consumption will have to be predominantly supplied by dynamic reactive support in the form of synchronous condensers or Static Var compensators. The HTC line will be heavily loaded precontingency, and when the load is transferred to the remaining circuits there will be a relatively large increase in reactive consumption.

The total reactive power requirement when all the HTC lines are loaded to full capacity, under N-1 contingency condition will be approximately 2800 MVar at the Otahuhu end. Compared to the duplex option or 220 kV or 400 kV new line options the reactive power requirement represent an increase of approximately 1600 MVar. Out of this incremental reactive support, approximately 620 MVar need to be supplied from dynamic sources.

7 Line Losses

The power loss in a transmission line is equal to the square of the current flowing through the line multiplied by the resistance of the line. The HTC line losses will be approximately 2.3 times that of the Goat arrangement when fully loaded.

The line losses in the Otahuhu-Whakamaru corridor will increase to approximately 310 MW under the normal operating conditions (winter peak) when the lines are fully utilised. This represents an increase of approximately 150 MW compared to the modified 400 kV option, or the 220 kV option or the 220 kV duplexing option.

8 Substation costs

The use of HTC increases the current flow in the 220kV switchyard at Whakamaru. The small costs associated with substation changes are included in the Development Plan budget.

9 Development Plan Cost Summary

The summary in the table below shows the costs of the Thermal and Reactive Development Plan for duplexing of the OTA-WKM A&B line and the other works necessary to ensure this option integrates with the existing system, and allows demand growth and security requirements to be met. The total cost of this option is \$2184m (in 2006 \$s).

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Alternative: HTC duplexing of the A and B lines, followed by the C lines, followed by new twin duplex chukar								
Costs (\$'000)								
Year	Augmentation	Design/ Procure /build	Investigation	Property	Proj Mgmt	Consenting	Contingency	Total
2009	250 MVAR static compensation	6030	0	0	482	0	977	7489
2009	100 MVAR Dynamic compensation	20228	0	0	1618	0	3277	25123
2010	BOB interconnector	7605	0	0	608	20	1232	9465
2011	Drury Substation	13047	0	4750	1044	250	2114	21204
	Drury Substation –Lines	1517			121		406	2045
2011	Thermal Uprating of sections of OTA_WKM C south of HLE with GOAT80	3034	0	500	243	20	813	4610
2011	150 Mvar static compensation	4439	0	0	355	0	719	5513
2012	PAK 220kV substation 3x120MVA supply transformers at PAK	46298	0	0	3704	250	7500	57752
	1st PAK-PEN cable	48447	0	500	3876	400	7848	61071
	Convert existing 110kV OTA_PAK circuits to 220kV operation	506	0	0	40	5	135	687
	OTA Enabling Work	2747	0	0	220	0	445	3412
	OTA Subs Work	3307	0	0	265	0	536	4108

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Year	Augmentation	Costs ('\$000)						
		Design/ Procure /build	Investigation	Property	Proj Mgmt	Consenting	Contingency	Total
2014	OTA_WKM A and B lines- HTC Duplex Disconnect OTA_WKM A and B sections between SAK and OTA OTA_WKM A and B lines redirected from SAK to PAK with 1 cable per line	261948	0	83134	20956	4000	70160	440198
	SAK Cable transition station	1535	0	1100	123	350	249	3357
	2x220 cable SAK-PAK	106351	0	4000	8508	400	17229	136488
2015	Second PAK-PEN cable	48447	0	500	3876	400	7848	61071
2016	PAK Subs Work	5516	0	0	441	0	894	6851
	PEN Subs Work	2674	0	0	214	0	433	3321
	Reconducting ARI_HAM 1 and 2 circuits to Nitrogen at 75Deg C	7585	1000	1065	607	20	2032	12309
	100 MVAR static compensation	3480	0	0	278	0	564	4322
2017	OTA-WKM A and B lines 40% Series Capacitance	37118	0	0	2969	185	6013	46285
2019	110kV cable from OTA to WIR	28319	0	0	2265	0	4588	35172
	Switching station at SAK	10360	0	0	829	0	1678	12867

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Year	Augmentation	Costs (\$'000)						Total
		Design/ Procure /build	Investigation	Property	Proj Mgmt	Consenting	Contingency	
	150 Mvar static compensation	4439	0	0	355	0	719	5513
2021	200 Mvar static compensation	5274	0	0	422	0	854	6551
2022	350 Mvar static compensation	7380	0	0	590	0	1196	9166
2023	200 Mvar static compensation	5274	0	0	422	0	854	6551
	OTA_WKM C - Duplex HTC (all sections but HLE to HAM)	206253	0	500	16500	20	55243	278516
	OTA_WKM C installed with 25% series capacitance on OTA_HLE, and HLE_WKM sections and 30% series capacitance on HAM_WKM section.	65740	0	0	5259	0	10650	81649
	OTA_WKM A and B bussed at HLE	5709	0	3100	457	350	925	10541
	1st Cable from OTA to PEN	48681	0	0	3894	400	7886	60862
	OTA Subs Work	5819	0	0	466	0	943	7228
	PEN Subs Work	2626	0	0	210	0	425	3261
2025	PST on ARI-BOB	7492	0	0	599	0	1214	9305
2027	450 MVAr static compensation	8581	0	0	686	0	1390	10657
2028	Decommission ARI_PAK 110kV line	4046	0	0	324	0	655	5025

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Year	Augmentation	Design/ Procure/ build	Costs (\$'000)					Total
			Investigation	Property	Proj Mgmt	Consenting	Contingency	
	1 Ohm series reactor on OTA_SAK bonded pair	2023	0	0	162	0	328	2512
2029	Construction new 2 duplex Chukar circuits from WKM to ORM	141998	22500	55400	11360	5500	38033	274791
2030	2nd Cable from OTA to PEN	48681	0	0	3894	500	7886	60962
2032	Cable transition Station at ORM	2624	0	7100	210	250	567	10750
	New cable from ORM to OTA	52908	0	2810	4233	400	8571	68922
	OTA Subs Work	5819	0	0	466	0	943	7228
	PEN Subs Work	2626	0	0	210	0	425	3261
2035	150 Mvar static compensation	4439	0	0	355	0	719	5513
2039	2nd cable from ORM to OTA	52908	0	2810	4233	400	8571	68922
	OTA Subs Work	5819	0	0	466	0	943	7228
	450 MVAR static compensation	8581	0	0	686	0	1390	10657
	150 Mvar dynamic compensation	25285	0	0	2023	0	4096	31403
2040	30% series compensation on ORM_WKM circuits	37118	0	0	2969	0	6013	46100
	3rd Cable from PAK to PEN	48447	0	500	3876	400	7848	61071
	PAK Subs Work	5587	0	0	447	0	905	6939

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Year	Augmentation	Costs (\$'000)						
		Design/ Procure/ build	Investigation	Property	Proj Mgmt	Consenting	Contingency	Total
	PEN Subs Work	2659	0	0	213	0	431	3302
2041	250 MVar Dynamic compensation	35398	0	0	2832	0	5735	43965
	500 Mvar static compensation	9102	0	0	728	0	1475	11305