

CHAPTER 5. ENERGY - CONTENTS

Electricity - Description of Service	5.2
Waipori Power - Generation System	
Transpower (NZ) Limited - High Voltage Transmission	
Dunedin Electricity Limited - Distribution	
Map - Electricity Supply (Rural Area)	
Map - Electricity Supply (Urban Area)	
Otago Power Limited - Distribution	
Electricity - Assessment of Vulnerability	5.14
Waipori Power - Generation System	
Transpower (NZ) Limited - High Voltage Transmission	
Dunedin Electricity Limited - Distribution	
Otago Power Limited - Distribution	
Electricity - Mitigation Strategies	5.25
Waipori Power - Generation System	
Transpower (NZ) Limited - High Voltage Transmission	
Dunedin Electricity Limited - Distribution	
Otago Power Limited - Distribution	
Fuels - Description of Service	5.30
Liquid Petroleum Products	
Gas	
Map - Liquid and Gas Fuels	
Solid Fuels	
Fuels - Assessment of Vulnerability	5.34
Liquid Petroleum Products	
Gas	
Solid Fuels	
Fuels - Mitigation Strategies	5.37
Liquid Petroleum Products	
Gas	
Solid Fuels	

ELECTRICITY - DESCRIPTION OF SERVICE

Waipori Power - Generation System

General Description

The Waipori system is a hydro-electric power generating complex located in the Waipori River Valley approximately 55km by road, southwest from Dunedin. Access to the locality is possible by four routes:

- From Berwick directly up the Waipori Gorge Road within the Waipori River Valley.
- From Berwick up Shaws Hill Road on the true right flank above the Waipori Gorge.
- From Lawrence via the Lawrence - Waipori Road to Waipori Falls Road.
- From Outram via State Highway 87 to Traquair or Lee Stream and then via Mahinerangi Road across the Edgar Stark Bridge and causeway to Waipori Falls Road.

The main elements of the scheme with Mahinerangi Dam at the upstream end and No. 4 power station at the downstream end, comprise:

- Mahinerangi Dam which impounds Lake Mahinerangi, the main storage reservoir for the scheme.
- No. 1A Power Station and associated intake and supply tunnel.
- No. 2 Dam and lake.
- No. 2A Power Station and associated supply tunnels and penstocks.
- No. 3 Dam and headpond.
- No. 3 Power Station and associated supply tunnel and penstock.
- No. 4 Dam and lake.
- No. 4 Power Station and associated supply tunnel and penstock.

The scheme utilises the water flow from the Waipori River catchment and the elevation difference of approximately 360m between Lake Mahinerangi and the tailwater (outlet) at No. 4 Power Station. Flow rates through the system vary up to a maximum of about 39 cubic metres per second. The maximum combined generation output of all four power stations is about 80MW. Flood flows in excess of maximum generation flows are able to be by-passed via spilling facilities at the dams, down the natural river channel and downstream storage lakes.

The system is controlled from 2A Power Station. Recent technological changes have been made which now allow the system to be operated automatically on a pre-programmed basis or remotely through a Telecom communication link.

Dams

Mahinerangi Dam

Mahinerangi Dam is a concrete structure consisting of gravity abutments with a central circular gravity arch section between them, giving the dam a total crest length of approximately 166 metres and a maximum height from base to crest of about 38 metres. The dam was constructed in two stages commencing in 1929 and completed in 1946.

The volume of water impounded in Lake Mahinerangi at maximum operating level is approximately 216 million cubic metres. Flood flows are able to be passed from Lake Mahinerangi to downstream of the dam using:

- Spillway floodgate in left abutment of dam (maximum practicable discharge approximately 120 cubic metres per second).
- High level sluice outlet in left abutment of dam (maximum practicable discharge approximately 15 cubic metres per second).
- No. 1A station supply system and by-pass (maximum practicable discharge approximately 40 cubic metres per second).

In extreme flood conditions the dam could be overtopped without risk of structural failure. A 'low level' outlet at the base of the central arch section is currently not operational.

The dam is inspected annually in accordance with SEED (Safety Evaluation of Existing Dams) procedures which includes survey monitoring of:

- Crest movements
- Structural inspection of the condition of the concrete, joints and foundations
- Operational inspection of control gates and sluices
- Frequent monitoring of seepage.

To date these inspections have revealed no major defects which might cause concern about its condition or safety.

Although the dam was designed in the 1920's the structure was re-evaluated in 1995 using modern computer analysis techniques and applying current design criteria. The results of the analysis have indicated that risk of failure by sliding or overturning is low and that stresses due to applied loads including earthquake effects are also low and within acceptable limits.

No. 2 Dam

No. 2 Dam is a concrete gravity arch dam located approximately 1km downstream from Mahinerangi Dam and has a crest length of 55m with a maximum height of 20m from base to crest. The volume of water impounded in No. 2 lake at maximum operating level is approximately 320,000m³.

Flood flows are able to pass freely over the full crest length of the dam and down the original river bed. Up to 40 cubic metres per second may be discharged through the 2A supply tunnels and power station. There are five manually operated sluice outlets through the base of the dam which are only used for draining the lake.

No. 2 Dam like Mahinerangi Dam is also subjected to annual SEED inspections and the results of these inspections together with the information gained from modifications, grouting and concrete repairs have indicated that the dam is structurally sound and functioning normally. Structural analysis of the dam carried out in 1992 indicated that stress levels for both normal and abnormal loading conditions are well within acceptable limits.

No. 3 Dam

No. 3 Dam is a small concrete gravity dam located approximately 220m downstream from No. 2A Power Station has a crest length of 24m and a maximum height of 10m. The volume of water impounded in No. 3 headpond at maximum operating level is approximately 20,000m³.

Flood flows are able to be passed using:

- Spillway floodgate which is capable of passing approximately 150 cubic metres per second when fully open and without the dam being overtopped.
- Low level sluice which is capable of passing approximately 20 cubic metres per second.
- No. 3 supply tunnel and power station, maximum flow approximately 20 cubic metres per second.

The dam, constructed in 1953, is founded partly on schist bedrock and partly on the toe material of an existing debris slide. In 1985 the upper half of the right abutment block was anchor stressed to the bedrock below the dam following dislocation caused by the pressure of the debris slide thrusting against the abutment. In 1986 the rest of the dam was anchor stressed to the underlying bedrock to improve the overall sliding stability of the structure. The anchor stressing has been successful in reducing the rate of dislocation in the right abutment block from about 2mm/year to 0.45mm/year.

The dam is routinely inspected and carefully monitored for movement. Further remedial measures may need to be taken if the movement affects the operation of the dam or the risk of failure increases.

No. 4 Dam

No. 4 Dam, a concrete arch dam located approximately 5km downstream from 2A power station is the last or most downstream dam in the Waipori System. It has a crest length of 76.5m and a maximum height of 17m which impounds approximately 376,000m³ of water.

It incorporates a flood control gate and spillway capable of passing approximately 150 cubic metres per second without overtopping the dam. The dam has a low level sluice outlet capable of passing approximately 20 cubic metres per second and the supply system and power station are also capable of passing up to 20 cubic metres per second.

No. 4 Dam is subjected to annual SEED inspections and to date the results from these have indicated that the dam is structurally sound and functioning normally. A computer analysis of the dam, carried out in 1991, has indicated that stress levels for both normal and abnormal loading conditions are well within acceptable limits.

Relevant File References

Further information and background information on the Waipori dams is held on the following Duffill Watts & King Ltd files:

- Mahinerangi Dam
 - 14/69/18 SEED Inspection Reports and Movement Monitoring Results
 - 14/69/26 Mahinerangi Dam Finite Element Analysis
 - 14/69/2 Lake Retention Levels and Spillway Test
 - 14/78/1 Lake Retention Levels (1979)
 - 14/78/3 Lake Mahinerangi Management Procedure
 - 14/111 Dam Inventory Data
- No. 2 Dam
 - 14/68/1 General Information
 - 14/68/10 Survey Monitoring of Movements
 - 14/68/11 SEED Inspection Reports
 - 14/68/13 No. 2 Dam Finite Element Analysis
- No. 3 Dam
 - 14/74/1/3 Survey Monitoring of Movements
 - 14/74/1/5 Design and Construction of Anchor Stressing 1985/86
- No. 4 Dam
 - 14/74/13 SEED Inspection Reports and Movement Monitoring Results
 - 14/74/17 Finite Element Analysis No. 4 Dam

Intakes/ Supply Tunnels/ Penstocks

1A Station Supply System

The supply system consists of:

- A reinforced concrete intake tower in Lake Mahinerangi.
- A concrete lined horseshoe shaped tunnel linking the intake tower to the turbine at 1A Power Station and also to the by-pass alongside the station.
- Control valves and gates to regulate the water flow from the lake and through the turbine or by-pass.
- A gate in the intake structure, capable of closing under full flow conditions.

The system can pass operational flows up to 37 cubic metres per second and a maximum flow of 42 cubic metres per second at a nominal net head of 27m. The turbine output is approximately 8.9MW under a net head of 27m at a flow of 37 cubic metres per second.

2A Station Supply System

The supply system consists of:

- Two intakes; No.1 intake through No.2 Dam and No.2 intake just upstream of the right hand abutment of No.2 Dam.
- Two parallel near horizontal concrete lined tunnels from the intakes to the base of the surge tank where they join to become the pressure tunnel.
- A single 1.98m diameter steel and concrete lined pressure tunnel from the surge tank to the base of the hillside behind 2A Station.
- Steel penstocks from the downstream end of the pressure tunnel to each of the three turbines in 2A Station.
- A surge tank at the upper end of the pressure tunnel to reduce pressure surges resulting from changes in flow velocities within the system.

The system can pass operational flows up to 36.8 cubic metres per second under a net head at the turbine inlet valves of approximately 178m. The recorded total generation output from 2A Station under maximum operational flow conditions is 57.5MW.

The intake to the No.2 tunnel is fitted with three rectangular cast iron gates and the No.1 tunnel is fitted with a cast iron butterfly valve at its upstream end. The intake gates and butterfly valve are not used to control flows through the system but are primarily used to exclude water from entering the tunnels from No.2 lake during maintenance or inspection work.



Penstock System Waipori 2A Station - Waipori Power Generator Ltd

No.3 Station Supply System

The supply system consists of the following main elements:

- A concrete intake structure set into rock on the left bank of the Waipori River approximately 40m upstream of No.3 Dam. The intake is fan shaped in plan with three 1.83m x 1.22m cast iron gates set at 15° to each other which perform a stoplog function to exclude water entering the tunnel from the adjoining No.3 headpond.
- A 2.4m wide by 2.5m high concrete lined tunnel with semi circular roof, is 1,220m long from the intake to a differential surge chamber at its lower end.
- A 2.28m diameter steel penstock approximately 102m in length from the surge chamber to the No.3 power station.
- A reinforced concrete differential surge chamber with a main tank diameter of 10.67m and height of 13.72m above the tunnel-penstock connection.

The static head at No.3 power station is 50.29m and the current maximum output is 7.6MW at a flow rate of 18.9cubic metres per second.

No.4 Station Supply System

This system is similar to the No.3 Station system except that it operates under a higher head (57.3m) and that it has a steel conduit (penstock) section between the intake and the upstream end of the tunnel.

Specific details of the No.4 supply system are:

- A concrete intake structure incorporated on the upstream side of the right abutment of the No.4 Dam which is of similar size and form to the No.3 intake.
- A steel conduit, 2.28m diameter and approximately 39.6m long, linking the intake to the upstream end of the tunnel.
- A concrete lined tunnel of the same cross section as the No.3 system tunnel and an overall length of approximately 1,100m.
- A 2.28m diameter steel penstock approximately 102m long from the surge chamber to the No.4 Station.
- A differential surge chamber, of similar form and dimensions to the No.3 surge chamber, located above the tunnel-pressure conduit connection.

The current maximum output of No.4 Station is 8.2MW at a flow rate of 17.6cubic metres per second.

Power Stations

A summary of essential structural details of the four power stations in the Waipori complex is:

	1A Station	2A Station	3 Station / 4 Station
Completion of construction	1983	1968	1954
Construction materials: -substructure -superstructure	Reinf. concrete Struct. steel/ Precast concrete	Reinf. concrete Reinf. concrete / Struct. steel	Reinf. concrete Reinf. concrete
Roof Cladding	Galv. steel sheeting	Precast concrete/ Galv. steel sheeting/Butyl rubber	Reinf. concrete Asphaltic membrane
Design Loading	NZS4203:1976	NZSA 1900 Chapt/8:1965	NZS 95 Parts I to IV Clauses 412 and 413 (b)
Overhead cranes (Machine Hall)			
SWL (tonnes)	55.5	52	40
By-pass facility	Tunnel and penstock 2.5m i.d x 59m long	Rect. reinf. concrete channel 5.5m wide x 3.9m high x 247m long	Natural river channel

Mechanical/Electrical Plant

The 1A station is equipped with a single vertical Kaplan turbine-alternator set of nominal 10,000 kW capacity. Under normal operation an external electricity supply is used to start the turbine alternator and run it up to speed. In emergency conditions a large capacity DC battery supply within the station is available to perform a "black start" or "cold start" which can only be done from within the station as it is a fully manual operation.

The hydraulic by-pass system, adjacent to the powerhouse is also able to be operated from the emergency DC power source to provide water downstream for the other power stations, should the generator be unserviceable.

The 2A station is equipped with three virtually identical vertical Francis turbine-alternator sets of nominal 20,000 kw capacity. Like 1A station, the machines require an external source of power for initial starting, following which they change over to their own internal power source. Only under very specific circumstances, not often prevailing, can a "black start" be performed on any of these machines.

No.3 and 4 stations are identical, each having a single vertical Francis turbine-alternator set of nominal 8,000 kW capacity. They both need an external power supply for initial starting before changing over to their internally generated power supply and neither can be "black started".

Station Switchyard

Each of the four stations has an adjacent outdoor switchyard in which is installed the machine transformers and transmission line circuit breakers. Each major item of equipment is fitted with seismic restraints. The construction is unpiled reinforced concrete of a conventional type. Each plant item containing mineral insulating oil is surrounded by an oil retaining bund wall arrangement.

1A station switchyard operates at 33,000 volts, 2A at a combination of 33,000 and 110,000 volts, and both 3 and 4 stations are 110,000 volts.

Station Control Systems

Each machine is fully automatic to the extent that it will respond to a primitive start command; the machine starting, synchronising and waiting for loading commands. Likewise, the machines will respond to a simple stop command following which they will unload, de-synchronize and shut down, eventually coming to rest. These commands can be issued locally at each station or from the centralised control room at 2A station. Furthermore each machine is able to be manually loaded from the control room at 2A or locally in the stations. Interfacing each machine control system is an automatic programme feature, which can accept time/load profiles to start the machine, bring it to a set load figure for each half hour of the day, and shut the machine down. The operative loading profile is modified automatically by the hydraulic supply conditions to the turbine when water levels fall outside preset limits. The automatic programmes are resident at each station and will repeat on a daily basis until modified from a central processor at 2A station or from a remote access terminal at any point in the Telecom network. Each machine is also protected by monitoring systems that will alarm when a dangerous state is approached, and shut the machine down when a dangerous state is reached.

Generation Transmission

Two separate transmission systems are available for export of Waipori generation. No 1A station and up to two machines in 2A station can be connected to the 33,000 volts transmission system of the Dunedin Electricity network while up to two machines together with 3 and 4 stations export into the 110kV national grid at Berwick. For further detail see the Section on High Voltage Transmission.

Transpower (New Zealand) Limited - High Voltage Transmission

General Description

The electrical transmission system comprises a regional supply from the national grid to a local distribution network. The regional supply network is owned by Transpower New Zealand and the distribution networks owned and operated by Dunedin Electricity Limited and Otago Power Limited.

Dunedin Electricity's Dunedin network is supplied with electricity from two Transpower substations, one at Halfway Bush and the other at South Dunedin. Waipori Power Generation Limited also feeds some power into Transpower's network at Berwick Substation and Dunedin Electricity's distribution network from the Waipori 80MW power stations.

Otago Power's rural network is supplied from Transpower substations at Naseby, Balclutha and Palmerston. Otago Power Limited also has a 10MW power station at Paerau which can back feed into the Transpower network.

Transmission Lines

Dunedin and the eastern part of Otago are supplied with electricity from the national electricity grid via a number of transmission lines:

- | | |
|--|---|
| • Roxburgh - Three Mile Hill (A) | 220kV Double circuit on single towers. |
| • Three Mile Hill - Halfway Bush | 220kV Double circuit on single towers. |
| • Roxburgh - Halfway Bush (A) | 110kV Double circuit on single towers. |
| • North Makarewa - Three Mile Hill (A) | 220kV Double circuit on single towers. |
| • Gore-Halfway Bush (A) | 110kV (Passes through Berwick) Single circuit on poles. |
| • Three Mile Hill - South Dunedin | 220kV (Separate circuits on same set of 220kV poles/towers) |
| • Halfway Bush - South Dunedin | |
| • Halfway Bush - Palmerston | |
| | 110kV Two single circuits on single poles with a double circuit on single towers near Dunedin |

The majority of the lines pass over hilly and sometimes rugged terrain as well as flatter plain areas.

There is inherently some redundancy built into the network, should a line go out of service. For example, the loss of Roxburgh - Three Mile Hill would still allow reduced capacity via the remaining Roxburgh - Halfway Bush, North Makarewa - Three Mile Hill, Gore - Halfway Bush lines.

The greatest disruption would occur from loss of the Three Mile Hill - South Dunedin/Halfway Bush - South Dunedin line with both circuits being on the same set of steel poles and towers. Some limited backfeeding could be achieved by Dunedin Electricity. Loss of both circuits between Halfway Bush and Palmerston would result in a complete outage at Palmerston.

Substations

There are four Transpower substations in Dunedin City:

- Halfway Bush
- South Dunedin
- Three Mile Hill
- Berwick

Halfway Bush Substation, Three Mile Hill Switchyard and South Dunedin are all equally important in the supply of electricity to Dunedin. Three Mile Hill and Berwick substations are only switchyards and are therefore unable to reduce the line voltages to the lower voltages supplied to Dunedin Electricity and Otago Power.

The loss of individual substations would effect the network to varying degrees, for example:

- Complete loss of Halfway Bush: There would be a reduced supply to South Dunedin via the single circuit Three Mile Hill - South Dunedin line. The supply to Palmerston would be completely disrupted.
- Complete loss of South Dunedin: Dunedin Electricity Limited could supply 70% of Dunedin via the Halfway Bush Substation.
- Complete loss of Three Mile Hill: Halfway Bush and South Dunedin could be supplied at a reduced capacity via the Gore - Halfway Bush line, Roxburgh - Halfway Bush lines and the Halfway Bush - South Dunedin line.
- Complete loss of Berwick: Reduced capacity with Gore - Halfway Bush line out and disrupted supply from Waipori.

Control System

Halfway Bush Substation is the focal point for the control of Transpower's network in the Otago area and is manned 24 hours a day, 7 days a week. Overall control of the South Island portion of the national grid is carried out at Transpower's South Island Control Centre, at Islington, Christchurch.

Transpower is able to use three independent means of communication to control its network:

- Power Line Carrier
- Telecom telephone network
- Two-way radios/digital microwave radio

The power line carrier system enables the high voltage transmission lines themselves to transmit voice and electronic communication. The two-way radio is an independent Transpower system utilising Transpower's own communication towers, microwave dishes and repeater stations. It is extremely unlikely that all three systems would fail simultaneously and any one of the systems would be sufficient to control and operate the Transpower network.

Dunedin Electricity Limited - Distribution

General Description

The Dunedin Electricity Ltd distribution network delivers approximately 900GWh annually to 50,000 consumers over a 1,100sqkm area. Of this amount, 90GWh are supplied from the 33kV connection to the Waipori Power Generation Ltd complex and the remaining energy is supplied from Transpower's Halfway Bush Substation (500GWh) and South Dunedin Substation(310GWh).

The Dunedin Electricity network comprises a total of some 1,900km of lines and cables of various voltages (33kV, 11kV, 6.6kV and 400V), 18 zone substations (33kV/11kV and 33kV/6.6kV) and 2,240 distribution substations (11kV/400V and 6.6kV/400V).

Transmission Lines

From South Dunedin

Five Dunedin Electricity zone substations are supplied from the Transpower South Dunedin substation via parallel 33,000 volt cable-transformer units. Thus a fault in a single 33,000 volt cable or zone substation transformer will leave the remaining cable-transformer unit able to cope with its design load. The five zone substations and their approximate areas of supply are as follows:

- North City
 - Cumberland Street
 - Connected via 33kV underground cable
 - 2,100 consumers
 - Part central business district, part North Dunedin
- South City
 - Crawford Street
 - Connected via 33kV underground cable
 - 2,700 consumers
 - Part central business district, south city area to Oval, Wharf Street area
- St Kilda
 - Corner Bayview Road/Prince Albert Road
 - Connected via 33kV underground cable
 - 4,200 consumers
 - St Kilda, Tainui, Portsmouth Drive areas
- Corstorphine
 - Corner Stephenson's Road/Corstorphine Road
 - Connected via 33kV underground cable
 - 3,500 consumers
 - Corstorphine, St Clair, Concord
- Andersons Bay
 - Corner Somerville Street/Cranston Street
 - Connected via 33kV underground cable
 - 4,300 consumers
 - Andersons Bay, Waverley, Tomahawk, Highcliff, Macandrew Bay

From Halfway Bush

Nine Dunedin Electricity zone substations are supplied from the Transpower Halfway Bush substation in Wakari Road via parallel 33kV cable/line - transformer units. Thus a fault in a single cable/line or transformer will leave the remaining cable/line - transformer unit able to cope with its design load.

The nine zone substations are:

- Smith Street
 - Smith Street
 - Connected via 33kV underground cable
 - 3,800 consumers
 - Part central business district, Roslyn
- Willowbank
 - Great King Street
 - Connected via 33kV underground cable
 - 2,500 consumers
 - Part North Dunedin, Maori Hill, Gardens area
- Ward Street
 - Ward Street
 - Connected via 33kV underground cable
 - 1,500 consumers
 - Fryatt Street area, Ravensbourne, Logan Park area
- Neville Street
 - Behind Carisbrook
 - Connected via 33kV underground cable
 - 4,000 consumers
 - Part South Dunedin, Caversham, Mornington area
- Halfway Bush
 - Taieri Road
 - Connected via 33kV underground cable
 - 3,700 consumers
 - Halfway Bush, Wakari, Helensburgh
- Kaikorai Valley
 - Stone Street
 - Connected via 33kV underground cable
 - 2,700 consumers
 - Part Mornington, Kaikorai Valley, Brockville

- Green Island
 - Boomer Street
 - Connected via 33kV overhead lines
 - 3,200 consumers
 - Burnside, Green Island, Fairfield, Waldronville
- North East Valley
 - North Road near Watts Road
 - Connected via 33kV overhead lines and underground cable
 - 3,000 consumers
 - Pine Hill, North East Valley and part Opoho
- Port Chalmers
 - Church Street
 - Connected via 33kV overhead lines
 - 2,300 consumers
 - Port Chalmers from St Leonards to Aramoana, Peninsula from Broad Bay to Taiaroa Head

From Halfway Bush-Waipori Overhead Lines

A further four zone substations are teed off the three Dunedin Electricity 33,000 volt overhead lines which run between the Transpower Halfway Bush Substation and Waipori 2A Station. At the corner of Tirohanga Road and Gordon Road, three lateral 33,000 volt overhead lines connect the Waipori-Halfway Bush lines to the Mosgiel zone substation on Gordon Road near the Silverstream.

These substations are:

- Mosgiel
 - Gordon Road
 - Connected via 33kV overhead lines to HWB-Waipori lines
 - 2,200 consumers
 - West Mosgiel, North West Taieri
- East Taieri
 - Quarry Road
 - Connected via 33kV under ground cable to Mosgiel substation
 - 3,900 consumers
 - East Mosgiel, Brighton to Taieri Mouth
- Outram
 - Huntly Road
 - Connected to HWB-Waipori 33kV overhead lines
 - 800 consumers
 - Outram, Allanton, part Taieri area.
- Berwick
 - Outram-Berwick Road
 - Connected to HWB-Waipori 33kV overhead lines
 - 600 consumers
 - Berwick, Henley, part Taieri area

At Berwick, the three 33,000 volt lines continue to Waipori 2A station. These three lines normally operate in parallel and have a firm load capability of 34MW, which equates to approximately the maximum peak load of the four zone substations teed off these lines.

Distribution Lines (11kV and 6.6kV)

At each zone substation, approximately 12 HV (High Voltage) distribution circuits radiate to supply distribution substations. In the urban areas, these circuits intertie with each other so that a normally open meshed network is available to provide limited backup to faulted sections of the HV distribution network. For those HV distribution lines that supply rural loads, there are fewer interties and in some cases extensive lengths of spur lines with no backup may exist.

Supply of Essential Loads

- Dunedin Hospital - supplied via two parallel 6.6kV feeders from North City zone substation
- Wakari Hospital - supplied from consumer substation via a 6.6kV feeder from Halfway Bush zone substation.
- DCC Civic Centre - supplied from a consumer substation located in DCC Library via a 6.6kV feeder from Smith Street substation
- Civil Defence HQ - supplied from a distribution substation in Moray Place via a 6.6kV feeder from Smith Street substation
- Port Otago - supplied via a 11Kv feeder from Port Chalmers zone substation
- Dunedin Airport - supplied via a 11kV feeder from Outram zone substation

More detail on essential loads is given in the section on vulnerability.

System Control

The Dunedin Electricity Limited system control is located on the corner of Jutland and Halsey Streets, Dunedin. The control room is staffed during normal working hours. During the remaining hours, a telephone answering service attends to consumer calls and the SCADA (System Control and Data Acquisition) automatically initiates call-outs directly to the System Controller.

The functions of the control centre include:

- Co-ordination and planning of switching operations to allow maintenance contractors access to clearly defined parts of the electricity network under defined conditions for both planned and unplanned work.
- Co-ordination of fault response by contractors and handling consumer fault calls out of hours.
- Monitoring of system loads and operation of load management equipment.
- Attending to all alarms generated by the SCADA system.

Equipment installed within the control room to aid the controllers in their duties includes:

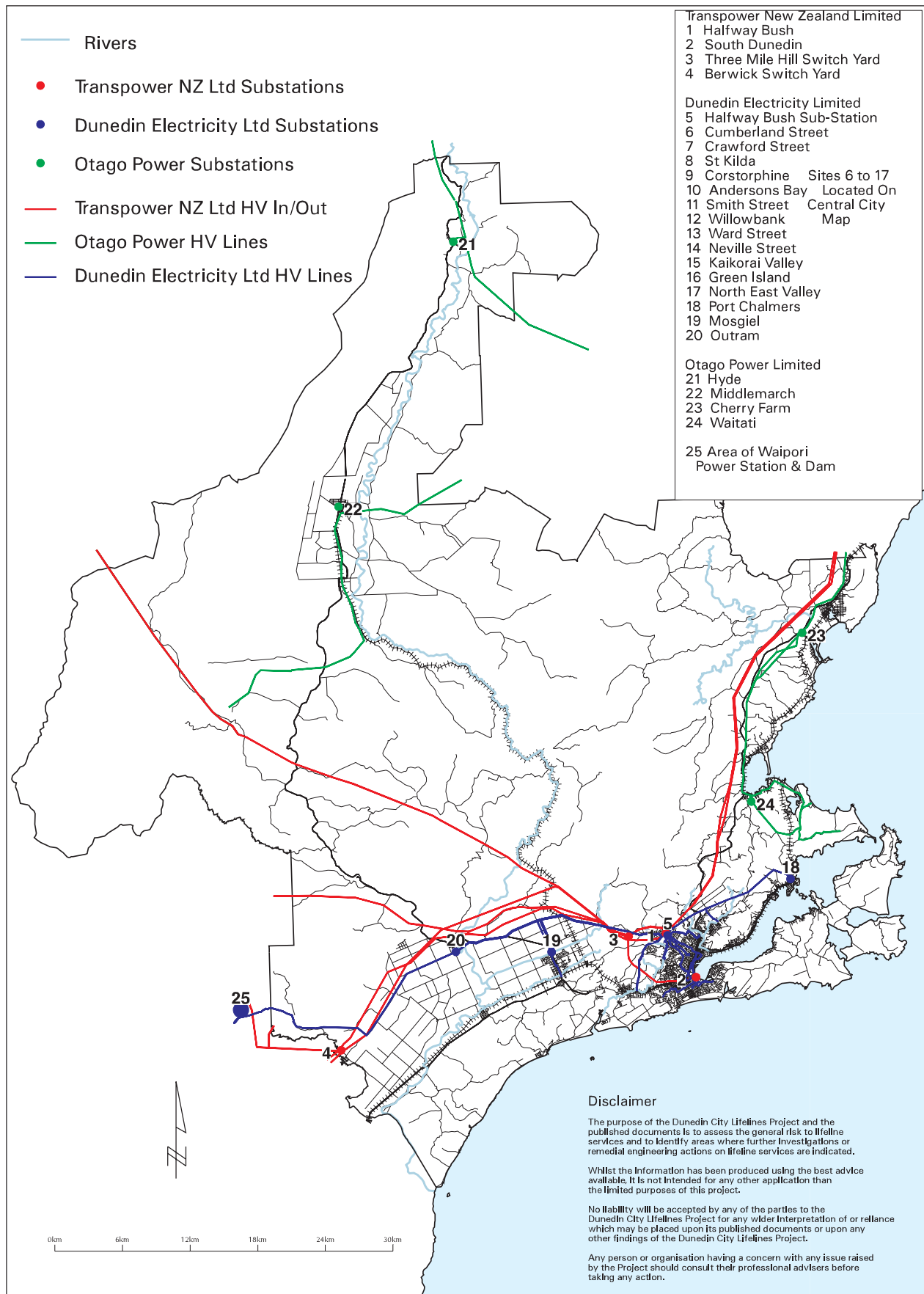
- A SCADA system which allows remote control of the 200 33kV / 11kV / 6.6kV circuit breakers and 36 tapchangers located at the 18 zone substations, plus approximately 1,500 indications, 1,000 alarm points and 300 analogue displays.
- Load management system (ripple control).
- VHF communications using "A" band to Telecom transmitter sites at Signal Hill, Swampy Summit and Saddle Hill for voice communication with contractor's vehicles.
- Plans of all network distribution circuits - both in paper and digital format.
- Office equipment such as facsimile, copier machines, etc.

A small diesel generator located on site produces a 230 volt supply for essential items within the control room.

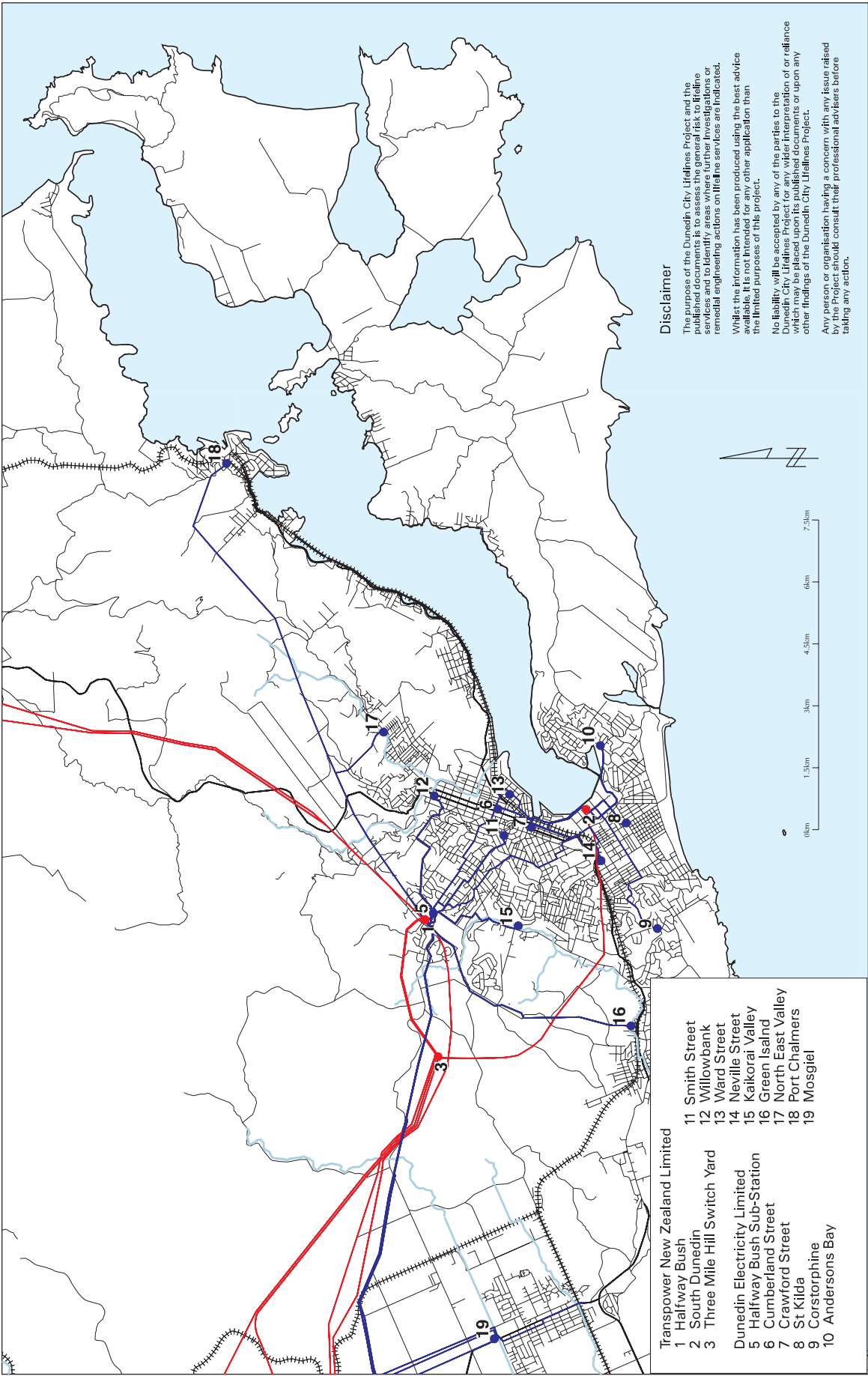


Typical Pole Mounted Transformer - Civil Defence

Electricity Supply (Rural Area)



Electricity Supply (Urban Area)



City Consultants
June 17, 1999

Transpower New Zealand Ltd HV In/Out

Dunedin Electricity Ltd HV Lines

Contains Data Derived from LINZ's DCDB
LINZ DCDB Digital Licence No. DN141117/19
Crown Copyright Reserved

Otago Power Limited - Distribution

General Description

Otago Power has no major point of supply substations in Dunedin City. The northern coastal area, mainly encompassing Waikouaiti and Waitati, is supplied via two 110kV lines from Halfway Bush in Dunedin to Palmerston substation. These lines and substations are owned and operated by Transpower.

Otago Power takes supply at 33kV from Transpower Palmerston, and supplies Waikouaiti and Waitati, plus outlying regions, via a single 33kV line generally following a route close to State Highway 1. Otago Power substations are located at Cherry Farm (at the Karitane turnoff) and Waitati (corner of Killarney and Foyle Streets). These substations supply Waikouaiti and Waitati respectively via local 11kV lines.

The township of Middelmarsh is supplied via a 33kV line from Ranfurly. There are only two sections where the line crosses into Dunedin City, these being a 14km stretch near Hyde and the final 10km into Middelmarsh itself. Substations are located at Middelmarsh and Hyde to supply the townships and surrounding districts via local 11kV lines.

Loss of these facilities could affect the supply to up to 2,000 homes.

Other susceptible elements of the network are:

- The 11kV line from Cherry Farm substation into Waikouaiti township.
- The 11kV line from Waitati substation feeding to Doctors Point, Purakanui, Long Beach and Heyward Point.
- The 11kV lines between Cherry Farm and Waitati substations, via Karitane, Seacliff and Warrington.

Other than these, Otago Power services supply only small localised areas.

ELECTRICITY - ASSESSMENT OF VULNERABILITY

Waipori Power - Generation System

Civil Components

Earthquake

Generally all major structures (dams, tunnels, and power stations) are founded or constructed on or within solid schist. The scheme is located approximately 25km north-west from the Akatore fault, the closest known active fault. Other faults have been identified closer to the scheme (principally McNamara's fault) but these are considered to be less active.

The vulnerability of the various structures has been assessed on whether they are free standing and above ground or whether they are contained within the ground itself. On this basis the dams, power stations, penstocks and surge tanks are regarded as prone to ground shaking without enhancement because of the presence of the rock foundation. The supply tunnels on the other hand are generally located within rock and are unlikely to be affected significantly by any ground shaking. Furthermore none of the tunnels are intersected by any known active faults and hence are unlikely to be damaged by dislocation. Liquefaction is unlikely to be of any concern because the required conditions for this phenomenon are not present at Waipori.

Flooding

Risks due to uncontrolled flooding from the Waipori catchment are significantly reduced by the implementation of the current lake management procedures for Lake Mahinerangi. Flood peaks can normally be absorbed within the operating regime of the lake without the need to spill excess water. The greatest vulnerability to flooding arises from uncontrolled inflows from side catchments below Mahinerangi Dam and No. 2 Dam. Such inflows can normally be catered for by generation control and in extreme events by floodgate control on the dams. In the unlikely event that floodgates are inoperable during a major flood, the lake level may rise to a point where some flooding of the upstream power station will occur. While the risk of structural damage from such an event may be trivial, inundation may affect the ability of the hydraulic control of generation flows to function.

There is an additional risk of flooding at 2A Station from the adjacent Governors Stream. Special measures which have been constructed to cope with deluges from this source since 1981 have significantly reduced the exposure of 2A Station to this risk.

At No. 4 Station the risk of blockage of the adjacent Aggie's Stream could lead to some inundation of the station.

Weather

The risk of damage to the various components by weather conditions is minimal as above-ground structures (dams, intakes, power stations, surge tanks and penstocks) are robust and well able to withstand the effects of wind, snow, ice or hail storms without significant damage and the tunnels, being underground, are unaffected by weather risks.

The only disruption is likely to be to access roads due to weather effects such as washouts and flooding from heavy rain, and blockages by snow drifts in severe snowstorms. The latter is normally only a risk for roads above 2A Station and around Lake Mahinerangi.

Landslide

The hillsides in the vicinity of 2A Station and No. 3 Dam are comprised of clay and weathered schist overlying sound schist angled gently at about 30 degrees towards the valley floor. Precise survey measurements of ground marks within this region since 1983 have indicated a slow but steady downslope creep of the overburden material. This rate varies from about 0.5mm to 3mm per year. Because of the gentle attitude of these slopes, various investigations have indicated that a sudden massive landslide failure of the hillside is unlikely.

The only structures directly affected by the creep movement are the 2A surge tank and No. 3 Dam. Remedial work has been carried out to these structures in the past (1983-85) and regular monitoring of deformation and movement continues to be carried out. To date only minor deformations have occurred with no disruption to the operation of the system.

A minor localised landslip has also been identified in the oversteepened sides of the trench for the No. 3 Station penstock. Further fretting of the slope may occur from time to time but is unlikely to disrupt the operation of the penstock.

Technology

The structures of the Waipori scheme in general are not prone to technological risks. Minor superficial damage such as broken lights, windows and cladding of buildings occurs from time to time but this does not affect the operation of the scheme.

Fragility

While the development of Waipori has spanned from the early 1900's to the 1980's, regular inspections and timely maintenance of the various structures has ensured that risks of damage arising from ageing and general deterioration by wear and tear are much reduced.

All structures are capable of sustaining normal operational loads without damage, but some of the older power station structures, because of the method of detailing, may be less able to resist extreme loadings from a major earthquake without significant damage.

Redundancy

The four power stations making up the scheme are arranged in a cascading series down the Waipori River from Mahinerangi Dam. By suitable operational control and use of by-passes around each station, the failure or non-operation of any one station does not prevent operation of the remaining stations.

Because of the relatively low output from 1A, 3 and 4 stations the impact of outage from any one of these three stations is medium to low. 2A Station on the other hand produces a significant quantity of the power generated from Waipori and hence has a high impact loss if an outage occurs.

Cost

In assessing the cost of reinstatement of damage to the various installations caused by one or more of the identified risks, the following groupings have been used:

Category	Factor	Cost
Low impact	1	<\$100 000
Moderate impact	2	\$100 000 to \$500 000
Major impact	3	\$500 000 to \$1,000,000
Uneconomic/extreme impact	4	>\$1,000,000

Furthermore it has been assumed that damage from any one event or combination of events will not result in the total loss of the facility or facilities.

In general, older structures which have not been designed to current standards will suffer greater damage in extreme events. Conversely, more recent structures will be better able to withstand extreme events.

The following table summarises the assumptions made in deriving the cost impact for the major civil components at Waipori:

Component	Reinstatement (expressed as %age of total value of component)	Factor
Dams:		
Mahinerangi	5%	3
No. 2 Dam	10%	2
No. 3 Dam	20%	2
No. 4 Dam	10%	2
Power Stations:		
1A Station	10%	3
2A Station	10%	3
3 Station	30%	2
4 Station	30%	2
Hydraulic Control:		
1A Supply	10%	2
2A Supply	10%	2
3 Supply	20%	1
4 Supply	20%	1
Hydraulic Supply Systems:		
1A	5%	1
2A	10%	2
3	20%	1
4	20%	1
Access Roads	5%	1

Mechanical/Electrical Plant

Earthquake

In general, the plant and equipment within the power house for the 2A and 1A power stations was specified to meet earthquake conditions corresponding to a horizontal acceleration of 0.75g. It is therefore extremely unlikely that any material damage will occur to the equipment itself as a direct result of the earthquake movements. Some short term disruption may result. Some disturbance to mechanical protection devices may occur as a result of "shaking". Minor damage to the building fabric or fittings may also lead to some

short term disruption. Numbers 3 and 4 stations, built in the early 1950's were designed to a lesser earthquake standard than currently adopted, but it is unlikely that any long or medium term disruption will result from a moderate seismic event.

With respect to outdoor equipment, major items have recently been secured with earthquake mountings and care has been exercised to ensure that the major electrical connections are of a type or design that will accommodate the anticipated differential movement likely to arise from a seismic event.

Flooding

Normal operational procedures, including lake management procedures for Lake Mahinerangi, minimise the risk of flooding from the major catchment area. The greatest risk arises from large inflows to the lower catchment combining with possible jamming of the floodgates at No.3 & 4 dams. In general this will only result in minor flooding to lower levels of the power stations where resultant effects will have minimum impact.

The two areas most at risk are No.2A station with the proximity of the two diversion channels and No.4 station with the proximity of Aggie's Creek.

Weather

The risk of damage to installations from weather effects is limited to the outdoor yards at the power stations or the overhead transmission and communications systems. Any damage is likely to be minimal and able to be rectified within a short period of time. The time taken for the restoration of overhead service will generally be governed by the ability to gain access and by possible landslide blockage.

Landslide

A monitoring programme, conducted since 1983 has confirmed a slow but steady creep in the hillside above 2A Station and No 3 Dam varying from 0.5 to 2mm per year. A geotechnical review of the hillside has concluded that a sudden large landslip is unlikely.

Other minor slip areas have been identified near No.3 surge tank and above the right abutment at No.4 dam but these are unlikely to cause disruption to plant operation.

Technology

Generally plant and equipment are not exposed to any technological risk.

Fragility

- 1A station: all elements meet current standards, first third of economic life.
- 2A station: all elements meet current standards, second third of economic life.
- 3 station: turbine alternator control systems and switchyard meet older standards second third of economic life, remaining items meet current standard second third of economic life.
- 4 station: same as 3 station

The equipment in 3 and 4 stations, because of its age and the standards prevailing at the time of manufacture, may be more susceptible to extreme loadings.



Interior, 2A Station, Waipori - Waipori Power Generation Ltd

Redundancy

The fact that there are four stations in the Waipori scheme, each capable of operating independently, creates some redundancy of generating plant.

With respect to the transmission, there are two separate systems through which the generated output can be delivered. Loss of either system would limit the amount of power output to approximately 50% of the maximum rating.

Time

With the exception of the generating sets and their control and protection equipment, first aid repairs and alternative procedures could return

the identified elements to service within one week. With regard to generating sets and control equipment, it is assessed that the only long term disruption to plant operation would result from a landslide or flood similar to events of 1980. Damage could be rectified or alternatives instituted within a period of three months. Only a major failure of the power station building itself would result in a long term problem. In such an instance, major failure of the station foundations affecting embedded or supported plant could require up to three years for planned replacement.

Transpower (New Zealand) Limited - High Voltage Transmission

System Design

Transpower's transmission lines, sub-station equipment and buildings in Dunedin vary in age from approximately 35 years (Halfway Bush Sub-station) to 20 years (Three Mile Hill Switchyard). Most equipment in switchyards has been sourced from overseas and is designed to withstand a variety of earthquake loadings from 0.25g or less for older equipment to 0.7g or more for new equipment. Some brittle equipment such as the 220kV circuit breakers and bushings, utilising porcelain structurally, has been designed to withstand in excess of 1.5g. This is due to the inability of such equipment to absorb earthquake energy without sudden and unpredictable failure.

As most of Transpower's equipment is more vulnerable to damage from moderate to severe seismic attack than the other hazards such as flooding, windstorm etc, a significant effort has been made in the past to improve the seismic restraint of critical items of equipment, including transformers, circuit breakers and switchyard and substation buildings.

Transmission lines and their supporting towers normally perform well during earthquakes due to their high strength-to-weight ratio. Wind and snow induced loads are the critical load cases for such structures. However, the foundations of transmission towers may be vulnerable to damage from earth movement, such as landslides or slope instability, triggered by a seismic event in combination with high soil moisture content in a few critical areas.

Transmission Lines

Transpower's transmission lines form a network, covering a number of routes over widely varying terrain from coastal plains to inland rolling hill country. Some redundancy is built into the system whereby an outage on any one line (depending upon time of day/time of year) may not affect supply to Dunedin Electricity's or Otago Power's distribution networks. This results in a relatively robust and reliable system with minimal outages under normal circumstances. The lines with the least redundancy are the Three Mile Hill/Halfway Bush to South Dunedin line and the Halfway Bush to Palmerston line. In both cases there are dual circuits either on the same set of poles/towers or dual lines running on a parallel route next to one another.

Most towers and poles supporting transmission lines are well founded to prevent collapse under high wind or ice conditions, and therefore are not highly vulnerable to earthquake induced slope instability. A few tower/pole sites however maybe vulnerable. A special and extensive study would be required to detect specific sites of high risk and could therefore constitute a possible mitigation measure.

Most transmission towers are not highly vulnerable to failure from wind or snow loadings as their design is based on worst case criteria which seldom if ever occur. Also their "as built" strength often significantly exceeds that required to withstand the design loadings. The conductors have a factor of safety in excess of two, based upon design loads and are usually clear of trees etc that may topple in heavy winds. Occasionally flashovers can occur when conductors are blown too close to one another.

During heavy snowstorms, transmission lines are the weak link in the system due to flashovers between phases or circuits. Flashovers can be caused by conductors becoming too close to one another when snow suddenly falls from a lower conductor, allowing it to spring up and hit a conductor above.

Transmission lines are largely unaffected by flooding, even in river beds, due to their relative high strength and small exposed surface area, provided the foundation embedment is sufficient to cover scour.

Substations and Switchyards

Substation equipment and buildings are vulnerable to some damage from a significant seismic event. A survey was carried out at all of Transpower's substations / switchyards in Dunedin:

- Halfway Bush Substation.
- South Dunedin Substation.
- Three Mile Hill Switchyard.
- Berwick Switchyard.

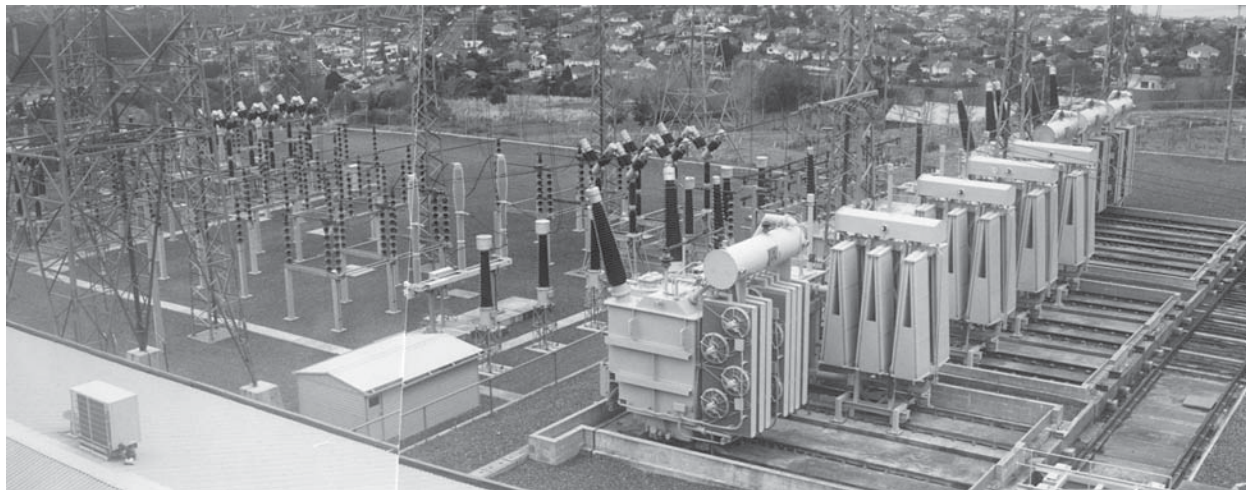
Halfway Bush Substation (220/110/33kV)

Halfway Bush Substation was initially constructed in the 1950's with significant upgrading in the 1960's. It is sited on a hillside of predominantly volcanic rock under varying layers of clays and silts. This area has a moderate risk of seismically induced land slippage.

Although the buildings were constructed prior to the 1974 Loadings Code, the buildings now being used for operating the substation appear in the main to be of robust construction. The majority of the construction consists of reinforced cast in situ concrete walls, floors and columns which are likely to be well tied together. The only area which should be specifically checked is the north wall of the crane building which may be constructed of unreinforced masonry. The older buildings on the site will soon be entirely surplus to requirements and may well be demolished.

The most important elements of the switchyard equipment are the power transformers. All the transformers have been retro-fitted with seismic hold down brackets that will provide a high degree of protection from damage. The most vulnerable items are likely to be the 220kV circuit breakers and other items utilising relatively slender ceramic insulators or bushings.

Although newer items should be able to withstand 1.5g, which equates approximately to a maximum credible seismic event, older items could well fail. Studies of similar substations after major earthquakes, eg in California, tend to confirm this. As part of Transpower's on-going upgrading programme, three more circuit breakers have been upgraded recently.



Transpower Halfway Bush Substation - Transpower Limited

Transpower also has some spare circuit breakers in stock at Halfway Bush, South Dunedin and at its South Island warehouse in Addington, Christchurch.

Other areas that should be investigated further and possibly mitigated at Halfway Bush are:

- Check integrity of the standard Circuit Breaker (CB) frames.
- Check the hold down details of the oil storage tanks.
- Tighten some bolts and replace hold down bracket on TI transformer bank.
- Ensure all spares restrained adequately.
- Restrain all VDUs, faxes, filing cabinets and similar furniture.
- Secure drums and equipment in oil filter building.
- Restrain all loose cabling.
- Restrain hot water cylinder.

South Dunedin Substation (220/33kV)

South Dunedin substation was constructed in the 1970's on reclaimed land at the south end of Otago Harbour. The underlying ground of silty sands and marine mud has settled significantly subsequent to the construction of the substation. Such settlement appears to have been relatively even and has slowed down over time. Well founded (piled) buildings and equipment such as the crane building and power transformer foundations, have remained at their original level resulting in voids under the foundations.

The transformer pads were increased in depth approximately five years ago to minimise the lateral loading on the supporting piles.

All the substation buildings have been constructed in a robust manner, probably in accordance with the provisions of the 1974 Loadings Code. The most vulnerable items of equipment are likely to be the 220kV circuit breakers and similar equipment utilising slender ceramic insulators or bushings. Due to the underlying soils, any given earthquake is likely to be magnified resulting in higher seismic loads than at Halfway Bush, thereby increasing the risk to buildings, contents and equipment. Significant liquefaction may also occur.

South Dunedin has an exposure to damage from significant tsunami or storm surge events.

Areas requiring further investigation and possibly mitigation include:

- Investigate further the potential for the site to be subjected to liquefaction to assist with future strategic planning.
- Check the robustness of the standard CB support frames, and check on the capacity of the circuit breakers themselves.
- Inspect the transformers following significant upgrading work.
- Check the capacity of the standard timber battery racks.
- Check on the continued corrosion damage to many of the concrete poles supporting the bus work in the 220kV area.
- It is noted that the crane building is to be decommissioned.

Three Mile Hill Switchyard

The Three Mile Hill site was constructed in the 1970's and is essentially a switchyard as it does not have the facility to step down voltage to directly supply the distribution authorities. Its main function is to facilitate the control of a number of Transpower circuits:

- Roxburgh - Three Mile Hill.
- Three Mile Hill - Halfway Bush.
- North Makarewa - Three Mile Hill.
- Three Mile Hill - South Dunedin.

The switchyard is sited on the top of a hill on volcanic rock and clays and silts of varying depth. The area has a moderate to low risk of seismically induced landslide, but could be exposed to severe snowstorms. A severe seismic event has the greatest potential to result in damage and significant outages.

The buildings are likely to have been built in accordance with the 1974 Loadings Code and should survive a severe earthquake substantially intact. The most vulnerable equipment will be those items which have slender ceramic insulators for support.

Areas requiring further investigation and possibly mitigation include:

- Check manual CB channel support beam for torsional strength.
- Check on strength of Current Transformer (CT) base bracket.
- Increase strength of hold down detail for emergency generator fuel tank.
- Restrain fax machine, printer and light storage on overhead shelving.
- Check on base restraint of fire fighting water storage reservoirs.
- Change method of pole storage in adjacent yard to not rely on security fence posts for support.

Berwick Switchyard

Berwick switchyard is used to control the feed from the Waipori Power Station into the Gore - Halfway Bush transmission line. The switchyard is relatively small and the control building is a small light timber framed structure. The floor level of the building is raised up approximately one metre on a well braced piled floor. This has resulted in a seismically robust building which should also be above flood level. The equipment, being 110kV, has less slender ceramic supports, and is therefore less at risk from seismic damage.

The site, being on alluvial soils in the Taieri Plain, is exposed to negligible risk of land slippage and only moderate risk of severe winds or snowstorm damage.

Areas requiring further investigation or mitigation include:

- Make good rusting gantry baseplates and replace missing bolt on one leg.
- Check strength of CB baseplate.
- Check strength of CT support frame.
- Straighten communications pole next to building.

Control System

Power Line Carrier

This system enables information to be carried over the main high voltage transmission lines and as such has the same vulnerability to loss of services as the transmission lines.

Two-way Radio / Digital Microwave Radio

This method of system control is an independent Transpower system involving communication towers or poles at substations, supporting transmitting and receiving equipment. Repeater sites are designed to resist most credible earthquakes, windstorms or snowstorms. A slight risk is the possibility of foundation damage due to land slippage at isolated sites. The major concern is the maintaining of the orientation of transmitting / receiving equipment to within the very tight tolerances required, although there would be a very low risk of a seismic event causing a permanent disorientation of such equipment. It would be more likely that a severe windstorm could cause a temporary mis-alignment problem.

Telecom Telephone and Cellular Networks

Refer to the Communications / Broadcasting vulnerability assessments.

Dunedin Electricity Limited - Distribution

General Description

In general, the subtransmission system is provided with sufficient redundancy to ensure supply to zone substations and most HV feeder circuits have sufficient inter-tie connections to provide continuation of supply to major consumers by alternative routing.

However, there are particular areas where, by virtue of location, the risk of hazard damage is higher than normal. One such area is South Dunedin, due to flood potential, earthquake faulting and/or liquefaction. In such locations the potential for serious and prolonged outages may be greater for underground cabling than for overhead reticulation.

A programme to check the seismic response of all zone substation plant commenced in 1996 with early efforts concentrating on the oldest substation.

It has been found necessary to carry out some remedial work by strengthening the hold-down arrangements for the main transformers and additional bracing for some structures. Less remedial work is expected to be needed for those zone substations constructed from 1970 onward and these will be surveyed during 1998/99.

Transmission Lines

From South Dunedin

The five zone substations supplied from the Transpower South Dunedin substation are all supplied via 33kV underground cables and all but one of these lies within the high risk area for damage by earthquake and flooding.

In particular the St Kilda substation is located in virtually the lowest part of Dunedin City and lies across what is inferred to be an active fault, as is the Transpower substation which feeds the five Dunedin Electricity Limited zone substations. St Kilda substation is liable to flooding, earthquake and liquefaction effects and loss of this substation is highly likely in such events.

The Andersons Bay, South City and North City substations are likely to be subject to damage by earthquake as they lie within the potential liquefaction zone and enhanced shaking area. They are however less exposed than the St Kilda substation and we may expect less damage to equipment and buildings and the flood risk is reduced as they are on higher ground. Corstorphine substation is relatively more secure, lying at higher levels and outside the enhanced earthquake shaking area.

All five pairs of 33kV underground cables which supply each zone substation from South Dunedin are particularly liable to be damaged by earthquake. As each pair of cables is laid in the same one metre deep trench, there is a risk that, where the cables cross the fault line, both circuits will be damaged. If this occurred then total loss of supply to the zone substation would occur with restoration time dependent on the number of simultaneous faults. Repair time for each circuit is likely to be several weeks. There is a lower risk due to flooding.

From Halfway Bush

Of the nine zone substations supplied from the Transpower Halfway Bush substation the Neville Street and Ward Street substations lie in the higher risk earthquake zone and are exposed to hazards similar to St Kilda. The exposure of Ward Street to flooding should also be recognised due to the relatively low level of the substation and its proximity to Otago Harbour.

Substations at North East Valley, Willowbank, Kaikorai Valley and Green Island will suffer less extensive damage due to shaking but still lie in enhanced shaking areas. We may expect damage to older buildings and disruption to substation equipment.

The remaining substations at Smith Street and Halfway Bush would appear to be exposed to the least risk and should suffer less damage.

The Neville Street, Ward Street, Willowbank, Halfway Bush, Kaikorai Valley and Smith Street substations are each supplied via a pair of 33kV underground cables generally laid in the same trench. The Ward Street and Neville Street circuits are exposed to the greatest risk since more of their length lies within the enhanced shaking zone. One mitigating factor is that there is a separate 33kV inter-tie cable between Neville Street and Ward Street substations which can be utilised as long as there is supply available to either Ward Street or Neville Street. If damage does occur, repair time is likely to take several weeks.

The Green Island, Port Chalmers and North East Valley substations are each supplied by two parallel overhead circuits on separate pole lines. These circuits are exposed to some shaking and landslip risk, although if damage does occur it is likely that repair will be in the order of days rather than weeks.

From Halfway Bush - Waipori 33kV Subtransmission Lines

The four zone substations serviced by the Halfway Bush - Waipori 33kV lines (Mosgiel, East Taieri, Outram and Berwick) will be subject to damage by earthquake but on a reduced scale. At the same time they may be prone to flooding damage due to their low lying location or proximity to water courses, although recent events such as the 1980 Taieri floods have shown the zone substations not to be affected. The Outram substation adjacent to the Taieri River flood bank and the Mosgiel substation adjacent to the Silverstream are the sites with most exposure.

The three parallel Half Way Bush-Waipori 33kV circuits which supply the zone substations of Mosgiel, East Taieri, Outram and Berwick are prone to extreme wind events where material blows across all three lines causing major interruptions to supply. Full supply to the Taieri area is available if two of the circuits are in service, but if only one circuit is available then supply is limited to 60% of maximum load.

Distribution Circuits (11kV and 6.6kV)

Underground cable circuits are less prone to risk unless they cross an active fault line or a landslip prone area. Ground mounted distribution transformers are exposed to flooding, liquefaction areas and landslip but have a reduced risk due to shaking.

Overhead pole mounted circuits are at risk from earthquake shaking and liquefaction. Particularly at risk are poles with transformers mounted on them which in the Dunedin area accounts for 70% of distribution substations. Many of these pole mounted transformers are small and, in rural areas supply only one or two consumers.

Essential Loads

Dunedin Hospital

Dunedin Hospital is supplied via two parallel 6.6kV feeders from North City substation. Whilst there is redundancy in the 6.6kV cables, this supply relies upon both North City zone substation and the Transpower South Dunedin substation, both of which have a high probability of loss.

Wakari Hospital

Wakari Hospital is supplied by a 6.6kV cable from Halfway Bush zone substation with alternative supplies available from Kaikorai Valley zone substation. The risk of total loss of supply is therefore minimal.

DCC Civic Centre and Civil Defence HQ

Both these sites are supplied from Smith Street zone substation and from Transpower Halfway Bush substation. As Smith Street is exposed to less risk than most zone substations, these supplies are more secure.

Port Otago

Port Otago is supplied by an 11kV feeder from Port Chalmers zone substation. Supply to this site is most at risk due to landslip (11kV cable and 33kV overhead lines) and to shaking.

Dunedin Airport

Dunedin Airport is supplied by an 11kV overhead line from Outram zone substation and there is an alternative supply using the intertie with the overhead lines from Berwick zone substation. The consumer substation as well as the adjacent HV circuits are prone to flooding and pole mounted equipment is also prone to shaking.

System Control

With the System Control Centre being located in a reasonably modern building (upgraded in 1998) the equipment and services are less susceptible to damage than zone substations.

The main equipment in the control room, essential for the co-ordination of restoration of supply following a disaster, consists of the SCADA, load management and communication systems. The SCADA and load management systems have some redundancy and the main risk will be to the associated power supplies and communications systems.

The main HV supply to the System Control Centre is from Ward Street and Halfway Bush substations. A standby diesel generator powers battery charging systems and essential circuits. Checks need to be made on the susceptibility of the generator to shaking and the possible rupture of fuel lines.

Communication circuits which are at risk include Telecom circuits associated with the VHF communications transmitters on Saddle Hill, Signal Hill and Swampy Summit. The communication circuits which link the SCADA system to the zone substations are also at risk especially those which cross the active fault or are in landslip areas. These circuits are owned by either Dunedin Electricity (pilot cables in Dunedin urban areas) or Telecom (mainly Taieri area).

General Vulnerability

The historical design of the distribution system is very similar to other urban distribution systems throughout New Zealand, Australia and Britain. The design of the subtransmission system is mainly based upon coping with single contingency events where random failures of equipment can be expected to occur and hence a single backup alternative circuit will be available.

Natural disaster poses a much greater risk to the system since there is a greater likelihood of multiple events, causing prolonged loss of supply to a significant portion of the network.

Otago Power Limited - Distribution

General Description

The distribution network operated by Otago Power Limited is susceptible to disruption from a variety of hazards because of terrain. Because of the lower density of population served the network does not provide any effective redundancy in a number of supply areas.

The principal hazards to the network are earthquake, flooding and weather and there are some areas where tsunami may be destructive.

Individual service lines of 33kV and 11kV are duplicated where they are critical to the network elements and the service area is significant, but some local damage may occur due to earthquake shaking of pole mounted transformers.

Transmission Lines



Cherery Farm Substation - Civil Defence

Supply From Transpower Palmerston

Supply at 33kV from Palmerston is by a single overhead line direct to a substation at Cherry Farm. There is an 11kV alternative supply line running along a similar route beside S.H.1. The 33kV line is not particularly vulnerable, running over undulating country with reasonable access from S.H.1. The line is reasonably well protected from weather, landslips and the earthquake potential is considered to be in the lower range.

There is some possibility of damage due to flooding or tsunami in the area around Cherry Farm Sub-station, which is located in a flood prone estuary.

Local supply between Palmerston and the Cherry Farm Substation is considered to be at relatively low risk, apart from the low areas from Waikouaiti to Cherry Farm where it is vulnerable to flooding.

From Cherry Farm Substation, the 33kV line has a low exposure to hazard except for the length running alongside Blueskin Bay, particularly the section leading to the Waitati substation where there is the possibility of flooding and tsunami impact. Earthquake effects are likely to be low, but may induce some land slipping, particularly on the 11kV line along Coast Road which services the Warrington and Seacliff areas.

The substation at Waitati is on a flood plain and may be damaged by extreme flood and, although remote, there is a possibility of tsunami effect in Blueskin Bay. The 11kV loop around Doctor's Point is exposed to weather conditions, but generally represents a low risk.

Supply From Ranfurly

The 33kV lines cross undulating country from Ranfurly substation to Waipiata and Hyde then onwards to Middlemarch, Clarks Junction and Hindon.

Because the supply lines are radial and there are no duplicate 33kV or 11kV lines the service is at risk from hazard impact. The substations are at low risk from flood and landslipping, but are exposed to damage from earthquake shaking owing to their proximity to the Hyde fault.

The 33kV line is susceptible to weather influences, particularly in the sections at Hindon and Clarks Junction, but because of the low population served are not a priority risk on the network.

ELECTRICITY - MITIGATION STRATEGIES

Waipori Power - Generation System

Civil Systems

The Waipori scheme has been developed over 95 years of design and construction. By the inherent nature of the terrain and age of the scheme, various elements are vulnerable to earthquake. For the purpose of a continued power supply the generation is shared across four dam/penstock/powerhouse segments and thus a redundancy is available for individual element failures.

The exposure downstream of the scheme from the worst scenario of uncontrolled discharge caused through a penstock or similar failure is an immediate increase in the level of the Waipori River. This discharge is self reducing (by the reducing retained lake level or, in the case of Lake Mahinerangi, controlled by gates), and as a result of both the roughness factor and length of the Waipori Gorge only a gradual overtopping of stop banks at Berwick is expected.

Continual re-examination of such critical elements of the supply system and regular maintenance form a reassuring picture of both dam and penstock reliability.

Overall reassessment by engineering consultants indicates that no meaningful mitigation measures other than regular maintenance are available and any damage from major natural hazard would be dealt with by "response management" at the time of impact.

Mechanical/Electrical Plant

The principal risks to electrical and mechanical plant and machinery arise as a result of the effects of an event causing damage to the civil structures and buildings of the hydro scheme. For this reason, the principal risk management strategies are focussed on the civil works themselves and rely upon duplication of essential electrical and mechanical systems and /or retention of a range of strategic spares.

Plant exposed to risk has been identified as falling into six defined categories.

Turbine Alternator Sets

In 1A and 2A Stations the machine design specification requires the plant to withstand a horizontal acceleration of 0.75g. In 3 and 4 Stations, designed in the early 1950's no criteria was specified.

Little can be done at this stage to modify the plant in any meaningful way to increase the security of the turbine alternator sets against a seismic event. Steps can be taken however to increase the security of auxiliary plant by ensuring mountings meet expected loadings imposed by current design events.

Control and Protection Equipment

Electro-mechanical devices can be subjected to damage from shaking. Mitigation could be effected by total replacement with solid state devices but the cost involved in implementing this strategy is presently prohibitive. An acceptable strategy would be to ensure planned replacements adopt solid state technology. In the interim, the strategy adopted has been to maintain a strategic reserve of replacement devices.

Local Power Supplies

Each local supply facility is backed up from an alternative source. The strategy adopted to mitigate the effects of events involves a shared holding of spare componentry with Dunedin Electricity Limited.

Switchyards

As for local power supplies, redundancy, spares and alternative configurations provide mitigation.

Transmission

Sufficient spares are held to enable the effects of design events to be rectified within acceptable time limits.

Communications

Duplication of communication links along geographically different routes has been adopted to provide security. General area communications have been provided by telephone circuits backed up with VHF radio communication.

Conclusions

Civil Works

The existing mitigation strategy is to closely monitor the key older elements and to compare the performance of these elements against present NZ standards. An example of this is the Mahinerangi Dam, which was structurally analysed in 1993 using new techniques and found to be satisfactory. The process is a continual one which relates to the annual operational strategy of the scheme, involving ongoing monitoring under the SEED process combined with continual maintenance.

Mechanical/Electrical Plant

Probably the most significant risk to plant and equipment arises from the prospect of flooding of the installations. Current strategies to minimise this risk involve adherence to a lake level management plan to minimise the risk of a discharge from the main storage reservoir. This management plan is regularly reviewed in the light of additional hydrological information and the assessment of the risk from an expanded perspective by using alternative review consultants.

The risk of downstream flooding is mitigated by provision of facilities to prevent the ingress of floodwater to the installations and no further work is believed to be of practical advantage.

Recommendations

It is considered that the existing inspection arrangements, coupled with good and regular maintenance afford the best mitigatory strategy in increasing the survivability of civil, mechanical and electrical components of the system.

Transpower (New Zealand) Limited - High Voltage Transmission

General Description

Responsibility for the high voltage electrical transmission network rests with Transpower Limited who have a long standing record of attention to seismic aspects and other hazard mitigation of their facilities. This has included detailed surveys and, where appropriate, strengthening and upgrading of buildings and equipment.

Transpower Limited has a policy with the following objectives:

- To maintain power supplies during and after an Edgecumbe-size earthquake (MM IX).
- To restore power supplies to earthquake damaged areas within a maximum time of three days.
- To ensure the safety of the public and personnel.
- To minimise the resulting cost of repairs.

Involvement in Lifelines Projects such as Dunedin's, along with those of Wellington, Christchurch and Auckland, has provided a broader insight into earthquake and other disaster related issues. This in turn has led to the identification of specific concerns and items requiring attention in order that objectives be met.

Transmission Lines

Transmission lines generally were found to be robust against earthquake loading, with snow and wind storms being the likely causes of temporary outages. When an instantaneous flashover occurs due to conductors becoming too close together, usually during wind conditions that cause the conductors to oscillate, the protection systems will attempt to reinstate the circuit a given number of times before either the service is reinstated or shut down.

Transpower however are concerned about the foundations of some of its towers, particularly in areas of high slope instability potential. This has resulted in the commencement of a geotechnical investigation into some tower foundations in the Dunedin area. The towers to be inspected include a number on the Halfway Bush - South Dunedin and Roxburgh - Three Mile Hill transmission lines. All foundations found to be inadequate will be upgraded as part of an overall programme of increasing reliability.

Substations and Switchyards

Following the inspection of Transpower's four substations or switchyards in the Dunedin area, a number of specific items were identified as requiring either mitigation or further investigation.

All items that required mitigation and no further investigation have been put onto Transpower's routine maintenance schedule and will be attended to as soon as possible, while items that require further and more detailed assessment will be attended to as a separate issue, with the nature and timing of any investigation work being dependent upon the outcome of the assessment.

The availability of spares for damaged equipment is dependent on some held on site and others held at the Transpower South Island warehouse at Addington, Christchurch. It is critical that all spares are stored in such manner that damage to these during a moderate to severe earthquake is highly unlikely. This could be achieved by ensuring that spares are securely held down or stored lying horizontally on the ground to eliminate the chance of tipping over. It is not inconceivable that a major seismic event could hit both Christchurch and Dunedin simultaneously, thereby making help from Christchurch unlikely, so Transpower also holds an inventory of spares in their warehouses at Palmerston North and Otahuhu, (Auckland) which would be available in Dunedin when transport allowed.

All Transpower substations in the Dunedin region have a degree of redundancy and it is considered likely that sufficient equipment would withstand the earthquake to be able to restore some power supplies in a day or two or possibly less.

If a severe earthquake or other disaster was to hit the Transpower South Island Control Centre in Christchurch, Halfway Bush Substation could take over control of the national grid in their area. Supply could be normal in capacity but may be less secure than would usually be the case.

Transpower appreciates that the South Dunedin substation is relatively vulnerable to damage from earthquake, liquefaction, flooding and storm surge. In the longer term, these factors will be taken into account when further upgrading is required.

Transpower continually reviews design standards in line with experience gained from Edgecumbe, Northridge, Kobe, and other similar seismic events. Transpower also continues to develop operational procedures and training to respond to major earthquakes.

Control Systems

Although no specific areas of concern were identified, Transpower continues to review all existing control systems, and upgrade them with the latest technology when appropriate. This is an ongoing exercise due to the general trend of keeping manning levels to a practical minimum.

Transpower has always been aware of the need to build in redundancy to its control systems to ensure they remain operational at all times, including during and following a major disaster such as a severe earthquake.

Conclusions

As a result of continual re-examination of the integrity of their high voltage transmission systems, Transpower Limited have identified and listed on "Record Sheets" a number of relatively minor items for attention and one or two more significant strengthening objectives.

The general overview of the Transpower Limited systems indicates a high level of preparedness and satisfactory hazard resistance built into design.

Recommendations

Continue the present level of maintenance and progressively undertake works described on in house record worksheets.

Dunedin Electricity Limited - Distribution

General Description

As part of its routine operations, Dunedin Electricity is able to respond promptly to a wide range of emergencies. However, widespread damage to the distribution system will place very large demands upon resources and it will be necessary to utilise the resources of neighbouring power companies (where possible) and those from the large nationally based power contracting companies.

In the event of a major emergency, it is also likely that Transpower's supply system will be affected (especially the South Dunedin supply point) plus there will be damage to consumers' premises and thus some of the electrical load requirements will be reduced. This will facilitate the transfer of load from affected zone substations to alternate supporting zone substations.

Exposure to Earthquakes

Exposure to an earthquake is the most widespread risk faced by the network although the risk is greater for those items of plant in the vicinity of the Akatore fault line.

The following mitigation measures have been identified and a work programme is currently in hand (40% complete), with the pre-1965 substations being given top priority. Consultants have been employed to survey and advise remedial measure for each substation.

Zone Substations

Checking of:

- 33kV transformer hold down arrangements.
- 33kV transformer pad strengthened to resist overturning.
- The bracing on radiator banks, conservator tanks and switchgear support frames.
- 11kV switchgear hold-down arrangements.
- Control panel hold-down.
- Battery banks for support and bracing.
- The building (one building has had abutments added to the end walls to assist in carrying lateral loads).

Cable Systems

The 33kV cables could be damaged by excessive differential ground settlement during an earthquake but no 33kV cables were identified as being at risk by being supported on bridge structures. Temporary overhead lines may be erected to expedite the restoration of supply to some underground areas.

Overhead Line Systems

The mounting of transformers on two-pole substations should be checked and upgraded where necessary, although while damage to the overhead system may be widespread it should be repaired without too much difficulty as only standard components are used.

Ground Mounted Distribution Substations

Check the mounting of transformers in consumer substations.

General

For all the above situations, management of the restoration process will be enhanced by:

- Up to date plans and information which are available to as many of the contractors as possible. The establishment of a PC electronic based system with paper back-up will facilitate this.
- All spares are managed within a separate inventory system. Checks are to be made that the appropriate number of essential stocks of each item are held given the improved knowledge about each risk that is now available. In addition, some spares have been identified as being in need of securing against movement and additional bracing of these is under way.
- Ensure emergency stock levels of poles, line hardware and replacement conductor is available.
- Ensure emergency stock levels of distribution transformers are available. A new storage pad is currently being constructed providing for a hold-down arrangement to secure these transformers against movement during an earthquake.

Exposure to Flooding

Generally, the risk of flooding to any zone substation is relatively minor with the following zone substations considered to be most at risk:

- Ward Street
- North City
- St Kilda
- Willowbank
- Neville Street

The distribution network at the 6.6kV / 11kV level is made up of many lines and cables able to provide many options and alternatives for at least a limited power supply.

Specific Flooding Mitigation Measures

- Prepare plans to identify essential services supplied from the above zone substations and keep up to date all plans for the transfer of load (where possible) to adjacent zone substations.
- Ensure sump pumps are in place and well maintained.
- Maintain a supply of sandbags at St Kilda, Ward Street and South City.
- Ensure an alternative emergency control room is available with a secure communications and power supply to the central control equipment. Currently, the back-up emergency control room is located at Smith Street zone substation which has almost nil risk from tsunami or flooding.

Exposure to Tsunami

The risk of tsunami is high for St Kilda zone substation and slightly lower for North City, South City, Andersons Bay and Ward Street zone substations and the control room in the Halsey Street office block.

Specific tsunami mitigation measures

- Prepare plans to identify essential services supplied from the above zone substations and keep up to date all plans for the transfer of load (where possible) to adjacent zone substations.
- Ensure sump pumps are in place and well maintained.
- Maintain a supply of sandbags at St Kilda, Ward Street and South City.
- Ensure an alternative emergency control room is available with a secure communications and power supply to the central control equipment. Currently, the back-up emergency control room is located at Smith Street zone substation which has almost nil risk from tsunami or flooding.

Conclusions

Managing the risks of a natural disaster is an integral part of Dunedin Electricity's Asset Management Plan. This is updated annually and provides detailed information on asset planning for the following 10 year period.

An extensive programme of strengthening work at major substation sites has been under way for two years and is targeted for completion in 2001. Expenditure on bunding around zone substation transformers is complete and has exceeded \$350,000. In addition, the seismic survey programme currently under way for zone substations is expected to cost in excess of \$300,000.

Recommendations

Dunedin Electricity has demonstrated a high commitment to improving the electrical infrastructure assets to minimise the impact of a natural disaster or hazard, and intends to continue with the direct preventative maintenance and upgrading activities already initiated.

Otago Power Limited - Distribution

General Description

The entire distribution reticulation system is subject to a wide range of hazard impact on a random basis. The extensive network traverses areas subject to earthquake shaking, flooding and landslip, and it is largely impossible to predict where such events would affect the supply.

Supply lines are built to normal standards with due regard to topography and receive maintenance associated with low levels of consumer demand.

At the time of examining the system network under the Lifelines Project, work has been undertaken to improve survivability of the substation at Cherry Farm from flooding and earthquake hazards.

In the next 1-2 years, there are plans to alter the supply arrangement to the northern coastal area by providing an alternative to the Cherry Farm and Waitati substations. This will improve the security of supply to both these areas.

Generally speaking, the mitigatory measures envisage carrying on with current levels of maintenance and providing for major hazard damage by rapid repair work following an incident.

Conclusions

It is recognised that there is a widespread potential for damage to the network from hazard events, but it is not possible, on economic grounds, to effect any meaningful mitigation strategy other than to provide for management of repair work following the event.

Recommendations

Continue general maintenance, select and effect securing of transformers and control equipment against earthquake shaking.

Re-examine reticulation routes with reference to stability of terrain at power poles and progressively strengthen under general maintenance programmes.

Review existing repair facilities with respect to skilled labour and quantity of spare components.

FUELS - DESCRIPTION OF SERVICE

Liquid Petroleum Products

General Description

This brief encompasses all bulk liquid petroleum products which are received into Dunedin from tankships discharging at the Fryatt Street Oil Wharf. These products are transferred by pipeline to above ground storage tanks pending distribution to inland markets by road delivery vehicles or to the marine market via pipeline sales. Storage tanks are situated on the premises of BP Oil at Parry Street, Caltex Oil at Fryatt Street, Shell Oil at Wickliffe Street and Fulton Hogan Bitumen Division at Fryatt Street.

Automotive Products

Two grades of petrol are stored and distributed in Dunedin from Caltex Oil and BP Oil Terminals. Unleaded 91 Octane and Unleaded Premium 96 Octane are delivered by road vehicles throughout Otago, primarily to BP, Caltex, Shell and Mobil branded service stations but also to individual farmers and commercial users. Diesel fuel, which can also be known as Gas Oil, AGO (Automotive Gas Oil), ADF (Automotive Diesel Fuel) or LDO (Light Diesel Oil), is stored and distributed from the premises of BP Oil, Shell Oil and Caltex Oil to all the above users and is also used extensively by road transport, rail, mining, manufacturing, contracting and fishing industries.

Aviation Fuels

Only one grade of aviation fuel, Jet A1 (aviation turbine fuel), is stored and distributed from Dunedin. This product is stored at BP Oil and delivered by road delivery vehicle to a small number of BP and Mobil customers. The principal user is the Air BP facility at Momona Airport with minimal amounts being delivered to other multi-user tanks at Wanaka, Queenstown, Te Anau and Taieri airfields.

Fuel Oils & Bitumen Products

Only one grade of fuel oil is stored and distributed from Dunedin. Light Fuel Oil (or LFO 220 Secs) is stored at the Shell Oil Terminal and is delivered by road to commercial and manufacturing users who utilise it as a heating/boiler fuel. Light Fuel Oil is also used extensively as a bunker fuel and pipeline deliveries are made to vessels berthed at the Oil Wharf in Fryatt Street.

Bitumen products, 180/200 and 45/55 Bitumen, are stored at the Fulton Hogan Bitumen Terminal in Fryatt Street and delivered by road vehicles to roading contractors in Otago and Southland.

Berthing Facilities & Connecting Pipelines

All replenishments of liquid petroleum products arrive in Dunedin by tankship which can only be discharged at the berth commonly known as the Oil Wharf at Fryatt Street. This wharf is owned and maintained by Port Otago Limited but tankship discharges are organised/controlled by the oil industry companies and their designated contractors. The oil wharf is the terminal point of the pipeline network which extends to the BP, Caltex, Shell and Fulton Hogan tankage. Connection between the tankship and the appropriate pipeline is made by way of heavy duty flexible cargo hoses. This wharf is also utilised for pipeline bunkers, where diesel or light fuel oil is delivered onto vessels from tankage at BP, Caltex or Shell premises.

In all there are five separate pipelines of 200mm diameter which are dedicated to transfer of product:

- An insulated and electrically trace-heated line to Fulton Hogan tankage in Fryatt Street, used for delivery of bitumen. This line is owned by Shell Oil.
- A Light Fuel Oil (LFO) line which runs along Fryatt Street, through the Caltex Terminal and under Wickliffe Street to a tank in the Shell Terminal, is owned by Shell Oil. This line is also used for the delivery of LFO pipeline bunkers to vessels berthed at the oil wharf.
- A petrol line runs above ground along Fryatt Street and then underground to the BP Terminal in Parry Street with a tee-off in Fryatt Street to the Caltex tankage. Ownership is 100% BP from the tee-off to Parry Street but equal BP, Shell and Caltex ownership from the tee-off back to the wharf.

- A diesel line with the same route and ownership as above extends through the Caltex Terminal, under Wickliffe Street to tankage in the Shell Terminal. This line is also utilised for the discharge of Jet A1 and for the delivery of diesel pipeline bunkers to vessels berthed at the oil wharf.
- A spare line, currently de-commissioned, which runs only to the BP Terminal in Parry Street, is owned by BP Oil.

Bulk Storage

Details of bulk storage tanks (by company with capacities expressed as millions of litres) are:

BP Oil - Parry Street

Tank	Current Product	Capacity
D1	Slops	2.2
D2	Diesel	2.2
D3	Unleaded 96	2.0
D5	Diesel	2.0
D6	Unleaded 96	1.5
D7	Jet A1	1.0
D8	Unleaded 91	6.0

Caltex Oil - Fryatt Street

Tank	Current Product	Capacity
502	Unleaded 91	4.6
503	Diesel	0.5
529	Unleaded 96	4.2
530	Unleaded 91	2.1

Shell Oil - Wickliffe Street

Tank	Current Product	Capacity
4	Diesel	6.8
7	Diesel	4.7
6	Light Fuel Oil	5.0

Fulton Hogan - Fryatt Street

Tank	Current Product	Capacity
1	45/55 Bitumen	1.3
2	180/200 Bitumen	0.5
3	180/200 Bitumen	3.2

It should be noted that facilities to load petroleum products into road delivery vehicles are not available at Shell Oil. The Shell tankage is piped up to the loading gantry at Caltex Oil and Shell vehicles load their product there. Mobil Oil do not have any bulk storage facilities and load their requirements from the BP Terminal at Parry Street.

Special User Bulk Storage

This category of user is now somewhat limited in numbers as the modern trend is for fuel requirements to be uplifted from service stations/truckstops by way of a card system. Police, fire service, government agencies, local authorities, transport and contracting companies all utilise this option for the vast majority of their requirements. The following storage could still be classified as special user:-

Air BP - Momona Airport	150,000 litres above ground tankage - Jet A1
Tranz Rail - Strathallan Street	100,000 litres above ground tankage - Diesel
St. John Ambulance - York Pl.	10,000 litres underground tank - Unleaded 91.

Gas

General Description

The present gas supply in Dunedin by Otago Citigas Limited was first established in 1863 and, though considerably reduced in service area and providing energy from a different source, continues to supply a significant number of customers in parts of the city (see map).

Up until 1986 coal gas was produced at the Andersons Bay Road plant, but from 1986 onwards Liquid Petroleum Gas (LPG) has been used as a feedstock. In 1990 a new plant to produce tempered LPG was

commissioned and in 1995 the Land Fill Gas (LFG) system was added and placed on line to service approximately 500 customers.

Citigas Installations

The current (1997) gas supply system extracts LFG from the Green Island Landfill. The LFG is pressurised, scrubbed and delivered to the tempering plant in Hillside Road, Dunedin via a 100mm diameter pressure main (8 bar). This same area at Hillside Road provides for gas cylinder filling.

City Reticulation

The original (from 1863) city reticulation has been much reduced from a length of about 330 kilometres to a present day length of about 110 kilometres, which is administered from the DELTA Utility Services premises in Halsey Street. The principal service lines run from Hillside Road to consumers along Andersons Bay Road, Hillside Road, Cumberland Street, Princes Street and George Street to Normanby. There are substantial network areas in South Dunedin and Caversham.

Liquigas Plant (Including berth facility).

A substantial storage plant was constructed in 1985 at Fryatt Street, Dunedin. This plant receives LPG by sea tanker which berths alongside the plant area at a privately owned wharf. The entire plant and wharf area are electronically alarmed and protected against malfunction. Bulk LPG is loaded to road tankers and delivered to commercial users and bulk suppliers within the city area.

There are eight bulk storage tanks on the Fryatt Street site, each of 135 cubic metres capacity which in total represents a tanker vessel cargo and will normally sustain the Dunedin area for approximately three months.

Service Station LPG Storage

Throughout the city there are upwards of thirty service station LPG supplies stored in bulk tanks of approximate 5 cubic meters capacity. These tanks are predominantly located at service stations within the area between Mosgiel and the Gardens and are well protected from accidental impact. Gas supplies are delivered by road transport in all cases.

Special User LPG Bulk Storage

There are relatively few LPG bulk storage supplies operating for industrial clients, but isolated supplies are located at the brickworks at Abbotsford and the PPCS meat works on Dukes Road, Mosgiel. Supplies are delivered to these sites by road.

Solid Fuels

General Description

This brief encompasses all commercial and domestic grades of coal received into Dunedin in bag and bulk form. Such products are mainly received by road.

The main coal used in Dunedin is Ohai coal which comes from Solid Energy's Wairaki No. 6 underground mine situated at Ohai in Western Southland.

Other coals sold in Dunedin are Mossbank Ohai, Nightcaps coal by Southern Mining, West Coast coals from Strongman, Island Block Terrace and other private mines, Kai coal from Kaitangata in South Otago and lignite from Newvale Coal in Waiumu mine near Gore.

Domestic grades are stored in warehouses and merchant yards, with commercial grades being stored in individual customer bunkers.

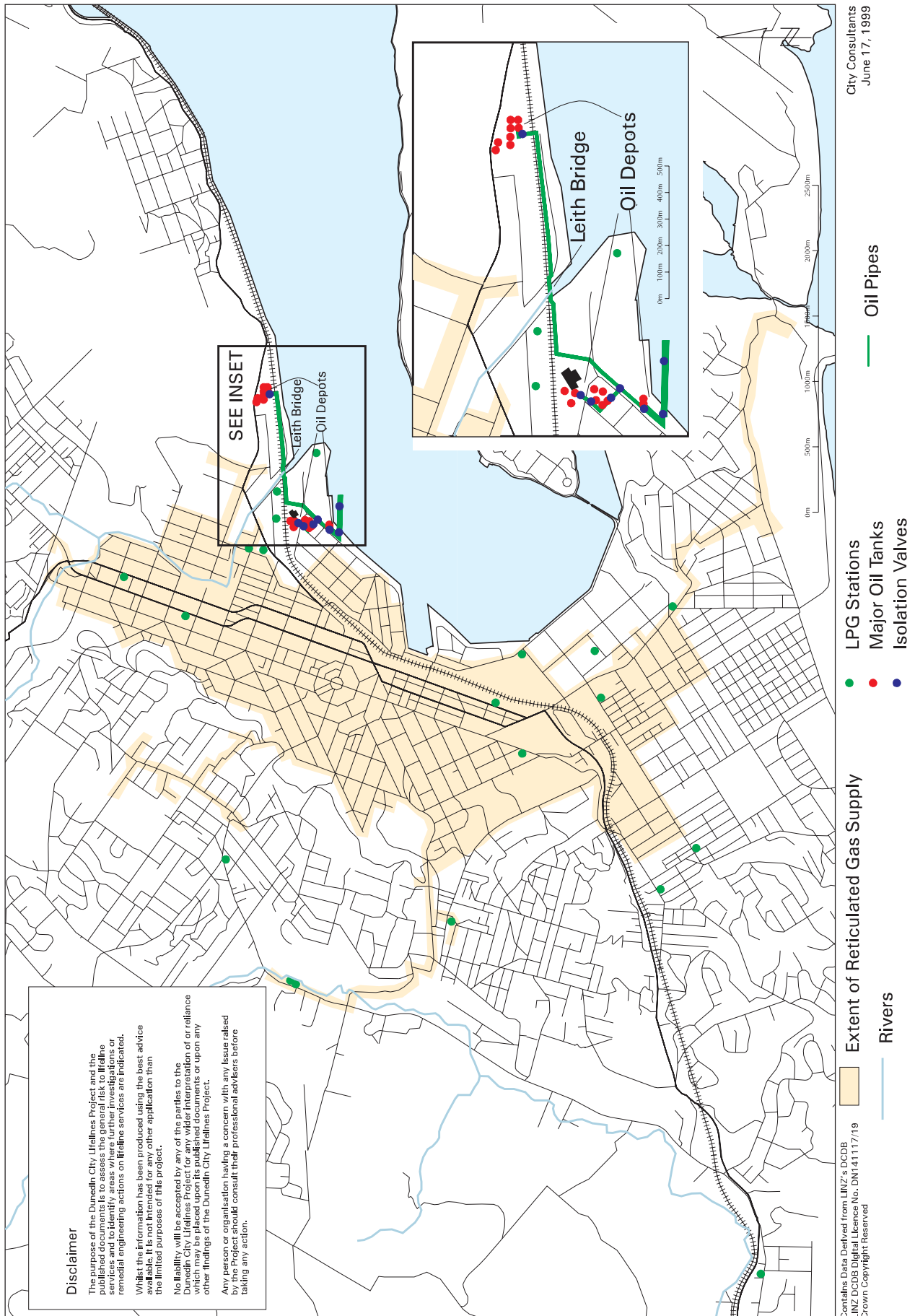
Domestic Products

Domestic grade coals are the larger screening sizes, generally above 18mm diameter which are more suited for use on an open fire or multifuel appliance.

Commercial Grade Coal

Generally commercial grade coals are screening sizes less than 18mm. Ohai coal or Newvale lignite are the two main products supplied to industries in Dunedin.

Liquid and Gas Fuels



Inward and Distribution Transportation

Solid Energy currently bags its domestic products which are then palletised and transported to Dunedin for distribution from its Portsmouth Drive Retail Centre. Other companies sell in bulk to resellers in Dunedin. Commercial coal from Ohai is supplied to individual customer bunkers in truck and trailer loads of 25 tonnes. If customers' bunkering facilities are unable to handle quantities of 25 tonnes then they are supplied via AJ Allen Industrial Coal from their site in Anzac Ave using smaller trucks.

Quantities Stored

Solid Energy stores 1,100 tonnes of bagged coal at Portsmouth Drive. (This falls to less than 100 tonnes by the end of winter). AJ Allen stores 300 tonnes of industrial grade coal in bulk. Coal Packers at Burnside store less than 200 tonnes. There would be less than 60 tonnes stored at smaller merchant yards. Dunedin Public Hospital stores 60-80 tonnes in its bunkering system, which is about 3 days' consumption in winter.

FUELS - ASSESSMENT OF VULNERABILITY

Liquid Petroleum Products

General Description

The susceptibility of bulk fuel supply to natural and other hazards arises from their being only a single harbour side wharf facility and the close proximity of all bulk storage. There is no diversity with respect to importation of bulk fuels which arrive exclusively by sea.

All of the bulk fuel installations lie within an area of enhanced earthquake potential and the order of vulnerability is consistent throughout the supply system network.

Fryatt Street Oil Wharf

This wharf is constructed on timber piling with a moderately heavy concrete deck but, because of its robust design for berthing large vessels, it is likely to sustain only minor damage in the event of a worst case earthquake. It is anticipated that the wharf would not be put out of operation, but that some damage could occur to "on deck" pipelines and manifolds. This would include damage to lines which are installed for purposes of ship bunkering.

Steel Pipelines

Where lines are above ground, we may expect fracturing of support brackets due to the probability of some liquefaction and there is a potential for some leakage at flanges. Underground pipelines offer a better survival potential, due to their construction from continuously welded pipe.

It is not possible to differentiate between individual pipelines, but all are considered susceptible and all will suffer to a greater or lesser degree, dependent upon condition. It is probable that fracturing of lines will represent the greatest inhibition to supply, assuming that bulk supply by sea remains possible.

Leith Rail Bridge Crossing

This crossing represents an area of significant vulnerability to hazard impact, though loss of the bridge crossing will only isolate one storage area. The potential damage may be considerable if the structure of the bridge collapses, but is not likely to be a long term loss as temporary service could be made effective within a reasonable time.

Tank Farm Storage

Tests were initiated by BP Oil NZ Ltd. in 1994 to assess the potential damage to its Dunedin bulk storage installation. The conclusion of this report (which we believe may reasonably be extended to the other adjacent bulk storage facilities), was that there is little likelihood of settlement from liquefaction or extreme damage due to earthquake shaking, having due consideration of return periods and statistical probability of earthquakes producing felt intensities of MM VIII or more.

In considering the probability of faulting extending through the harbour area, it is nevertheless possible that intensities greater than MM VIII may occur, in which event we may anticipate some damage to the compacted clay bunds and banded areas, with possible minor leakage from storage tanks into these areas. It is not anticipated that this event will produce a major derangement of tankage or supply pipelines.

Special User Storage

Above ground bulk user storage tanks at Momona Airport and the Tranz Rail depot in Strathallan Street are both susceptible to earthquake damage, especially from liquefaction settlement. Damage is most likely to result in fracture of supply lines from storage rather than damage to the tanks themselves.

The underground tank at St John Ambulance Station in York Place is expected to survive earthquake damage with minimal leakage.

Gas

General Description

The disasters most likely to cause serious disruption to the Otago Citigas systems are flooding, earthquake and gas fires or explosions.

Flooding

The following may result as a consequence of major flooding:

- Damage to above ground installations.
- Ingress of water into the low pressure system causing local or complete cessation of supply.

Earthquakes

The effects of earthquake will be more apparent on the older lead in jointed systems resulting in loss of supply, major leakage and fires or explosions. In the event of complete cessation of supply the entire system may have to be purged before any supplies can be safely restored.

Fires and Explosions

Under normal circumstances gas is distributed to an appliance, where it is mixed with air and allowed to burn safely. In the event of air entering a gas main in sufficient quantities, an explosive mixture may be created and could explode at any source of ignition. In the event of leakage, explosive concentrations may be found in buildings, underground cavities or any enclosed space which is poorly ventilated. Should leakage occur adjacent to poorly ventilated structures all unauthorised persons will be evacuated to a safe distance and the area will be ventilated.

Land Fill Gas Installation

The recently established Land Fill Gas installation is located in an area vulnerable to tsunamis, but not to general flooding. The plant lies on the boundary of an area subject to "enhanced" earthquake shaking.

The effect of flooding from Kaikorai Stream upon the land fill area is considered to be small, but there is a more serious potential for damage from tsunami if the Kaikorai Stream is in flood. Such flooding would severely damage surface structures, cause settlement and markedly disrupt gas production.

Collector System

Because of the nature of the site fill, damage potential to the vertical "collector pipes" through shaking may be significant, particularly in the upper connections and collection manifolds. The proximity of an active fault line in the area increases the risk to this element of the plant installation.

Damage by vehicular impact or vandalism is considered to be small.

The 110mm diameter PVC pressure main from the LFG installation to the south entrance of the Caversham tunnel is encased within a cast-iron pipe sleeve which will suffer damage due to enhanced shaking during earthquake. The gas line however is "pliable" and though it may receive damage due to impact from the cast iron sleeve, it is not likely to be severely fractured in many places.

Beyond the tunnel's cast iron north portal the line is again sleeved in cast iron pipe to near Carisbrook and thereafter to the Hillside Road plant is bedded in fine material in a trench. This section is likely to suffer displacement from liquefaction and may be severely damaged.

Although critical lengths of the LFG transmission pipe are encased in cast-iron sleeves, flooding may cause local "wash away" with resultant damage which may be accentuated by the light product weight providing no gravity resistance to floatation or sideways thrust when exposed. It is expected that damage will be light, but difficult to repair.

An area where flooding may cause disruption to the supply pipeline is close to the Green Island bridge at the Brighton Road intersection.

Tempering Plant and Storage

The tempering plant at Hillside Road (and other installations at this location which are above ground) are susceptible to enhanced earthquake effect including liquefaction because of the proximity of a fault. This area will likely suffer from derangement and supply may be inhibited for a considerable period. Less likely are effects from flooding and tsunami but, as the area is extremely low lying, they must be considered a risk to the system.

The gasometer at Kensington is founded on good quality rock, but is old and therefore likely to experience structural damage due to shaking or fault movement which could render it inoperable for a substantial period.

City Reticulation

The gas reticulation system is composed of a wide range of pipe diameters of variable quality and age, so any assessment of the vulnerability can only be generalised to give an appreciation of the potential damage. Because of the importance and density of the population area served by gas, further analysis is required.

It is virtually impossible to predict the location of damage to the gas reticulation, but it is expected that there will be many areas where dislocation of pipelines will occur due to ground shaking and many pipe joints and junctions are likely to fracture. This may result in local fire damage and possibly isolated explosion.

Significant areas are liable to liquefaction, tsunami and flooding and serious disruption to service is anticipated.

Little damage is anticipated from escape of gas due to vandalism, leakage or excavation accidents but damage may be considerable when caused by earthquake and followed by explosion or fire.

Service Station LPG Storage and Special User LPG Bulk Storage

The majority of service station bulk storage LPG tanks in Dunedin are within areas subject to enhanced shaking. A similar situation applies to tanks provided for special bulk storage at a number of industrial sites in Dunedin. The form of damage most likely is fracture of underground supply lines to filling points or to manifolds servicing industrial heating plant.

Construction of tankage, support and protection against impact from natural and technological events is already more than adequate with design incorporating protective screening.

Solid Fuels

General Description

As the supply of solid fuels to the city is principally dependent on road transport, disruption of the roading network, particularly towards the south, will have serious consequences. Rail haulage may be an alternative so long as the permanent way is undamaged and tunnel access is clear.

Bulk Storage

Access to, and storage of, bagged domestic coal supplies at Solid Energy Limited Portsmouth Drive are subject to disruption by earthquake, liquefaction, flooding and tsunami.

At lesser risk are A.J. Allen's stockpiles at Anzac Avenue and many other smaller supplier's storage yards. Coalpacker's yard at Burnside is likely to experience shaking but not liquefaction.

Delivery and Distribution

In spite of the exposed nature of stockpiles, earthquake damage is expected to be minimal.

Dunedin Hospital

A particularly dependent user of coal is Dunedin Hospital for its boiler. Relatively small storage capacity and possible loss of road access make this user highly vulnerable to loss of continuous supply.

FUELS - MITIGATION STRATEGIES

Liquid Petroleum Products

General Description

The existing awareness of the importance of fuel supplies to the continued viability of Dunedin City and its hinterland has been reviewed with respect to the impact of hazards causing delay in replenishment of fuel stock due to damage to port and pipelines facilities.

Storage tanks are generally maintained at good levels, with products being substantially duplicated by the three supply companies involved. Each installation is protected against foreseeable hazard damage under rigid design criteria.



Oil Pipelines from Oil Wharf to Storage Tanks Crossing Leith Rail Bridge - BP Oil Limited

Potential damage may occur to pipelines crossing the Leith Bridge which is a common carrier for other service pipelines. Any failure here will almost certainly be fracturing of the pipelines due to bridge displacement rather than to inherent pipeline condition.

Similarly, pipelines upon the oil wharf may suffer damage due to wharf structure displacement and alternative means for handling product to storage will need to be found.

Distribution of product by land transport is dependent on the availability of suitable road access. The number of road tankers available appears adequate if road access is possible.

Conclusions

Analysis of the liquid petroleum products system has identified the oil industry tank farms and the pipeline network linking them to the Fryatt Street Oil Wharf as the areas where supply could possibly be disrupted by earthquake.

The pipelines are primarily underground with above ground sections in Fryatt Street and across the Leith rail bridge. The majority of the underground sections have been replaced in the 1980's and 1990's and the whole system is subject to a comprehensive annual engineering inspection and a remedial works programme is initiated following each inspection. Each product receipt via the pipelines is also preceded by a pre-use pressure test and visual inspection to verify integrity.

Any earthquake damage to an individual pipeline could easily be circumvented by utilisation of the other lines to receive fuels from a tankship. Likewise, it is envisaged that damaged sections of multiple lines (eg. the Leith Bridge crossing) could be by-passed with temporary pipework in cases of extreme need.

All oil industry tankfarms have been extensively upgraded in the 1990's to ensure their bunded areas are capable of retaining significant spillage. Two new tanks have been constructed in this period and a number of others have had major refurbishments to meet current code requirements which encompass seismic considerations. An ongoing programme of works is in place to accommodate inspection and upgrade of the remaining tanks.

Recommendations

Continue with the existing programme for tank refurbishments and pipeline inspections.

Re-examine contingency preparations for delivery of product from the wharf to the tank farm and across the Leith Bridge. Because there is diverse storage of the same fuels by separate companies and an existing policy of maintaining adequate stock levels, and because it is not practical to duplicate facilities at a lower risk locality, no further mitigatory actions are recommended.

Gas

General Description

Citigas installations and the associated reticulation have been reviewed in the vulnerability analysis, and much of the installation shows a relatively high element of risk. This risk is a function of the exposure of the reticulation and treatment plant to enhanced earthquake shaking, coupled with the age of the asset.

It is therefore difficult to present a case for other than replacement of significant lengths of pipeline, particularly as most sections of the principal gas main have no redundancy. It is considered, however, that progressive replacement of the most vulnerable elements may be a more acceptable course of action. Indications are that the 400mm diameter main line from the tempering plant to the Kensington gasometer, and the gasometer itself need priority treatment.



Kensington Gasometer - Citigas Limited

Landfill Gas

Due to the modern design standard adopted for construction of the landfill gas plant and reticulation from Green Island, the risk of damage by earthquake is reduced but there may be damage to the vertical collector pipes and manifolds. Flooding at the landfill is a potential problem which may put the gas production out of action for a period, but is not likely to be long term in effect. Nevertheless the service may be unavailable for some weeks.

The tempering plant at Hillside Road is at risk because of its location. While the plant itself is on a good foundation base, there is a possibility of damage due to shaking and settlement between the plant base and its supply pipelines. This should be further examined for possible mitigatory action by installation of flexible connections.

Liquid Petroleum Gas Plant

This modern and sophisticated plant has effective protection against earthquake and flood. Hazard events have been taken into account in the design and it is considered that no further mitigatory works need to be incorporated.

Service Station LPG Storage and Special User LPG Bulk Storage

These users are supplied by bulk LPG road tankers and are essentially stand-alone tanks with modern sophisticated protection gear installed. The standards of design and maintenance are high and further mitigatory works appear to be unnecessary.

Conclusions

The Lifeline most susceptible to damage by natural hazard is that operated by Citigas Otago Limited. This damage potential is likely to be widespread within the reticulation system due to earthquake ground shaking which may cause random joint separation with attendant loss of gas into ground pockets, with resultant risk of fire or explosion.

As a result of age, the general quality of the reticulation pipework is variable with considerable lengths identified as "at risk" from damage by earthquake. Some risk from flooding is also possible and may cause disruption of service for several days whilst "purging" is taking place.

Recommendations

Any mitigatory work will need to be selective and it is recommended that further examination of the supply reticulation will be needed before commitment of capital to replacement of pipework or incorporation of more protective equipment.

In so far as the present review of the system has been made it is considered that mitigatory work should centre on the 400mm main close to the Kensington gasometer and on the gasometer itself.

Solid Fuels

Conclusions

Solid fuel supplies are considered to be at minimal risk from hazards but are dependant upon roading and availability of adequate stock.

Investigation has further raised awareness of the importance of coal supply to Dunedin Hospital and this would appear to be the most significant dependency on solid fuels.

No meaningful physical mitigatory action to ensure supply is required except to ensure continued diversity of stockpiling, adequate quantity availability (particularly in winter conditions) with normal protection being given to loading equipment and transportation vehicles.

Recommendations

Review adequacy of stockpiling with special reference to the Dunedin Hospital.

Prepare a contingency plan for re-supply of solid fuels from existing sources given loss of road or rail facilities.

CHAPTER 6. TRANSPORTATION - CONTENTS

Roading - Description of Service	6.3
State Highways	
Major City Connector Routes	
Suburban Link Routes	
Service Access Roads	
City Bridges	
Map - Transport and Bridges (Rural Area)	
Map - Transport and Bridges (Urban Area)	
Roading - Assessment of Vulnerability	6.9
State Highways	
Highway Structures	
Major City Connector Routes	
Suburban Link Routes	
Service Access Roads	
City Bridges	
Roading - Mitigation Strategies	6.15
State Highways	
Major City Connector Routes	
Suburban Link Routes	
Service Access Roads	
City Bridges	
Conclusions	
Recommendations	
Harbour - Description of Service	6.18
Sea Channel	
Berthing Facilities	
Cargo Handling	
Buildings	
Transport Links	
Utilities	
Other Facilities	
Harbour - Assessment of Vulnerability	6.23
Sea Channel	
Berthing Facilities	
Cargo Handling	
Buildings and Hardstandings	
Transport Links	
Utilities	
Other Facilities	
Harbour - Mitigation Strategies	6.25
Sea Channel	
Berthing Facilities	
Cargo Handling	
Buildings	
Transport Links	
Utilities	
Other Facilities	
Conclusions	
Recommendations	

Rail Systems - Description of Service	6.27
General Description	
Main Trunk Line - North	
Main Trunk Line - South	
Rail Operations	
Rail Systems - Assessment of Vulnerability	6.29
General Description	
Main Trunk Line - North	
Main Trunk Line - South	
Rail Operations	
Rail Systems - Mitigation Strategies	6.31
General Description	
Main Trunk Line - North	
Main Trunk Line - South	
Rail Operations	
Conclusions	
Recommendations	
Air Transport - Description of Service	6.32
Dunedin Airport	
Other Landing Facilities	
Airways Control System	
Air Transport - Assessment of Vulnerability	6.34
Dunedin Airport	
Other Landing Facilities	
Airways Control System	
Air Transport - Mitigation Strategies	6.36
Dunedin Airport	
Other Landing Facilities	
Airways Control System	
Conclusions	
Recommendations	
Public Transport & Heavy Haulage - Description of Service	6.38
Introduction	
Passenger Services	
Heavy Haulage	
Heavy Vehicle Fleet Maintenance	
Public Transport & Heavy Haulage - Assessment of Vulnerability	6.39
Passenger Services	
Heavy Haulage	
Heavy Vehicle Fleet Maintenance	
Public Transport & Heavy Haulage - Mitigation Strategies	6.40
Passenger Services	
Heavy Haulage	
Heavy Vehicle Fleet Maintenance	
Conclusions	
Recommendations	

ROADING - DESCRIPTION OF SERVICE

State Highways

General Description

Provision and operation of the principal motor transport routes into and around the City of Dunedin is vested in Transit New Zealand, which maintains a regional office and technical staff within the city in Skeggs House, Tennyson Street, Dunedin.

The responsibilities of the regional office are to provide technical and administrative supervision of all new construction and the general maintenance of the existing State Highway network throughout Otago and Southland.

The principal motor transport route is State Highway 1 (SH1) which passes through the city. Details of highways under regional office control both within and outside the city boundary are set out below.

State Highway 1 (North of City)

State Highway 1 is the major transport route serving the Dunedin area. To the north of the city the highway travels over the Northern Motorway to Waitati and then over the Kilmog Hill to Waikouaiti and beyond. At Palmerston there is a highway junction with State Highway 85. Beyond Oamaru the highway crosses the Waitaki River before entering Canterbury.

Major geographical features affecting the highway are the Waitaki, Kakanui, Waianakarua, Waikouaiti and Waitati Rivers as well as the steep hills of the Kilmog and Northern Motorway sections. The steep hills (particularly the northern motorway) are frequently subject to closures during winter due to snow. The major geological feature which affects the highway is the unstable southern yellow-grey earth formations of the Kilmog Hill which have given rise to continual slip and slump maintenance since it was constructed.

The highway carries moderate traffic volumes of 5,500vpd (vehicles per day) at the northern motorway decaying to 4,000vpd north of Palmerston. Heavy traffic makes up 13% of this volume.

State Highway 1 (South of City)

To the south, State Highway 1 is still the major transport route although there are alternatives within the city area. The highway consists of a one-way, 50km/hr pair from the Gardens through to Andersons Bay Road, followed by a short length of single lane each way partially divided carriageway 100km/hr by-pass around Caversham. The highway then climbs to Lookout Point through a three lane, two way (two southbound and one northbound) 50km/hr section before entering the four lane divided, 100km/hr carriageway Green Island Motorway. Following this the highway again reduces speed to 50km/hr through Sunnyvale followed by a short length at 100km/hr before entering the 50km/hr Fairfield straight. Beyond Fairfield the highway continues as 100km/hr apart from speed restrictions through smaller townships. The Mosgiel interchange is the main interchange south of Fairfield and connects SH1 and SH87. Further south the highway crosses the Taieri River, the Waipori River and, at Balclutha, the Clutha River. State Highway 8 joins the highway at Clarksville Junction just south of Milton.

Geographical features of importance include Saddle Hill, the Taieri floodplain and the hills north and south of Balclutha. The Saddle Hill area is occasionally closed due to snow in winter. Geologically the highway traverses relatively stable country to the south of Dunedin with the exception of silty flood plains between the Taieri River and the Waipori River. The section passing through Fairfield is located over disused coal mines.

Traffic volumes through the city are up to 30,000vpd on the one way pair. This decays rapidly beyond the Mosgiel interchange to be around 8,000vpd south of Allanton.

State Highway 87

State Highway 87 is one of three routes to Central Otago. The other two are State Highway 85 and State Highway 8. State Highway 87 runs from the junction with State Highway 1 at the Mosgiel interchange through the town of Mosgiel then along the western side of the Taieri Plain to Outram. From here the highway heads inland into the Taieri hills and west to the Strath-Taieri valley. The highway then goes through the town of Middlemarch and north to the Maniototo area where it joins State Highway 85.

Major geographical features are the Taieri River at Outram and at Kokonga and the Taieri hills. Frequently during winter the highway is closed between Middlemarch and Outram due to snow.

Traffic volumes are heavy at the Mosgiel interchange (12,500vpd) but drop off rapidly after Mosgiel and beyond Outram the volumes are as little as 500vpd. With the recent completion of sealing of this highway it is likely that traffic volumes will increase faster than the regional average traffic growth rate.

State Highway 88

State Highway 88 is the link between the Central Business District and the main port at Port Chalmers and joins the one-way system (State Highway 1) at St. Andrew Street and has a link to Stuart Street (designated as an off-ramp). From here it travels along Anzac Avenue over the Water of Leith and then sidles around the bottom of the West Harbour hills through Ravensbourne, Maia, St. Leonards, Burkes, past Roseneath and Sawyers Bay before entering Port Chalmers via George Street. The highway terminates on Beach Street prior to entering the port log storage area. The highway follows a narrow twisting route, supported in many places by retaining walls of varying conditions of repair. There are several speed zones in the 13km length of the highway.

Major geographical features are the steep slopes over which the highway sidles and the proximity of Otago Harbour. There are no major watercourses along the route. Geologically the main feature is the potentially unstable brown granular clay slopes which could compromise the retaining walls or slip on to the highway.

Traffic volumes are moderate at 9,500vpd on Anzac Avenue and 4,500vpd at Sawyers Bay. The heavy traffic proportion was 8% in 1990 and may have risen since due to the port generated traffic, particularly logging trucks.

State Highway 8

This State Highway which lies outside the Dunedin City area begins north of Timaru and runs west through the Mackenzie Country then south into Central Otago over the Lindis Pass then east through the Cromwell Gorge and Alexandra, alongside the Clutha River and out to State Highway 1 at Clarksville Junction. The route is a preferred one for vehicles from Dunedin into Central Otago and the Queenstown-Lakes area, and is therefore an important linking highway in servicing the city.

The highway has been subject to slips and flooding on a number of occasions in recent years and is also affected by snow and ice during winter. Traffic volumes are 1,700vpd west of Clarksville Junction.

State Highway 85

This State Highway runs from State Highway 1 at Palmerston through the north end of the Maniototo Valley then down the Manuherikia Valley to join State Highway 8 at Alexandra. The highway is affected by snow and ice during winter. Traffic volumes are 950vpd west of Palmerston.

Highway Structures

There is a total of 67 State Highway bridges, large culverts or subways within the Dunedin City area. State Highway 1 has 26 bridges, 6 large culverts and 5 subways, State Highway 87 has 18 bridges and 8 large culverts and State Highway 88 has 3 bridges and 1 large culvert. Most of these structures are made of reinforced concrete and have a modern form of construction, that is, built from 1955 onwards. This means that they have some features, such as linkage rods between spans, to minimise the chance of a superstructure span dropping off the piers during an earthquake. However one older bridge with multiple column piers has only limited ductility and this could lead to failure from a large seismic loading. In several places the highway is supported by retaining walls which may move during an earthquake. Any such failure is likely to affect any one lane and therefore would not entirely cut road access.

Principal structures considered are:

- State Highway 1 (North) Tumai Overpass
Waikouaiti
- State Highway 1 (South) Waipori
Taieri
Allanton
Mosgiel Overpass
- State Highway 87 Taieri Bridge Outram

Major City Connector Routes

Dunedin City has urban arterial routes running both north to south and east to west. The strongest of these routes comprise State Highways 1 and 87 and State Highway 88 to the port facility in Port Chalmers. Urban arterials under the City's control, form strong alternatives within the city boundaries.

The strongest non-State Highway route from the metropolitan area to the west is Three Mile Hill Road. This allows a western access to Mosgiel, the Taieri Plains and Central Otago. It also provides an alternative route to the Dunedin Airport. Three Mile Hill Road also connects to major routes to the south (State Highway 1) and west (State Highway 87).

Three Mile Hill Road starts at the top of Taieri Road and continues onto the eastern section of the Taieri Plains and further access to the west via Dukes Road. The Three Mile Hill Road has recently been resurfaced but is prone to closure in the winter from snow and ice.

Kaikorai Valley Road is an urban arterial that runs from the intersection of Stuart Street and Taieri Road and follows the valley until it intersects with the State Highway 1 on-ramp at Burnside Corner. It gives access, via Townleys Road, to the Southern Water Reservoir. It is wide in formation and has a pavement suitable for high volumes of traffic.

Alternative routes to the south include the Brighton Road route to Taieri Mouth Road which begins at the intersection of Main South Road and State Highway 1, at the southern end of the Green Island township. This route can also access State Highway 1 via the Taieri Mouth - Waihola Road. Brighton Road is a medium width road which is sealed but has surface undulation in many places and a history of pavement failure. This is due mainly to the excessive heavy traffic loadings involved with recent forestry developments and harvesting. At various places along Brighton Road there are alternatives to reach State Highway 1 and the airport. These are mainly unsealed, narrow and winding in nature, but provide an alternative. Brighton Road has numerous culverts and one bridge of importance located just south of the Island Park Golf Course and which straddles the Kaikorai Estuary and is old but appears adequate for its present purpose. Taieri Mouth Road continues to the township at Taieri Mouth which is outside the Dunedin City boundary.

The pavement characteristics of major urban arterials in Dunedin City are of adequate pavement depth with either a two coat chip seal or asphalt surface finish. All urban arterials are regularly maintained to ensure the integrity of the surface.

Major bridge installations serving the City include the Cumberland Street Overbridge, which straddles the rail precinct in the Central Activity Area and links State Highway 1 on Crawford Street. It is accessed through four on/off ramps and a central ramp from Crawford Street. There are also two bridges of major importance on Chain Hill Road over State Highway 1 and at the Mosgiel interchange. At the intersection of Stuart Street and Highgate a bridge on Highgate provides grade separation over Stuart Street. It has two on ramps and one off ramp, recently improved or of new construction.

Suburban Link Routes

Alternative connectors to State Highways are Leith Valley Road to the north and Kaikorai Valley Road to the south. Leith Valley Road is an unsealed winding road that runs adjacent to the northbound State Highway 1 and is accessed from George Street via Malvern Street and connects to SH1 above Waitati.

Routes to the north, other than State Highway 1 include the North Road/Norwood Street route to Mt Cargill Road. This also allows access to the port facility at Port Chalmers via Blueskin Road. The Norwood Street route was previously the main northern route out of Dunedin but is currently a collector road on the Dunedin City road hierarchy and is narrow, winding and sealed with many corners which have to be negotiated at low speeds.

Access from or to the beach fronts at St Clair and St Kilda can be gained by using Queens Drive, King Edward Street and Andersons Bay Road in the north and Forbury Road in the South. Both Forbury Road and Andersons Bay Road are of high quality pavement catering for medium to high traffic volumes and both have sufficient width for two lanes of traffic in each direction if required. Forbury Road, however, has the St Clair cliffs overlooking it. King Edward Street, a collector road in the Dunedin City Council road hierarchy, starts at Victoria Road and continues until it intersects with Princes Street at the southern end of the Central Activity Area.

Routes to and from the Otago Peninsula are based around either Highcliff Road or Portobello Road. Portobello Road is a narrow, winding, sealed road adjacent to the Otago Harbour running from Andersons Bay Inlet to the township of Portobello. From there it continues as Harington Point Road which runs to the lighthouse facility at Taiaroa Head. At points on this road, traffic speed is required to reduce dramatically to negotiate the corners. Highcliff Road is the alternative route to the township of Portobello and the southern side of the Peninsula. It runs along the top of the Peninsula hills is sealed and winding in nature and becomes



Stuart Street Overbridge - Civil Defence

very narrow at the top of its climb to the hills. The pavement and surface are in good condition and adequate for the low to medium traffic volumes it must handle.

Highcliff Road gives access to water reservoirs and radio station transmitter facilities around Camp Road and Sandymount.

Service Access Roads

Some key lifelines sites are at remote locations serviced either by minor roads or specific access roads. These are generally narrow gravel roads which have little or no other purpose for being maintained. Typical of these are roads servicing Swampy Summit and Mount Cargill communication sites, the Mount Grand Water Treatment Station and the

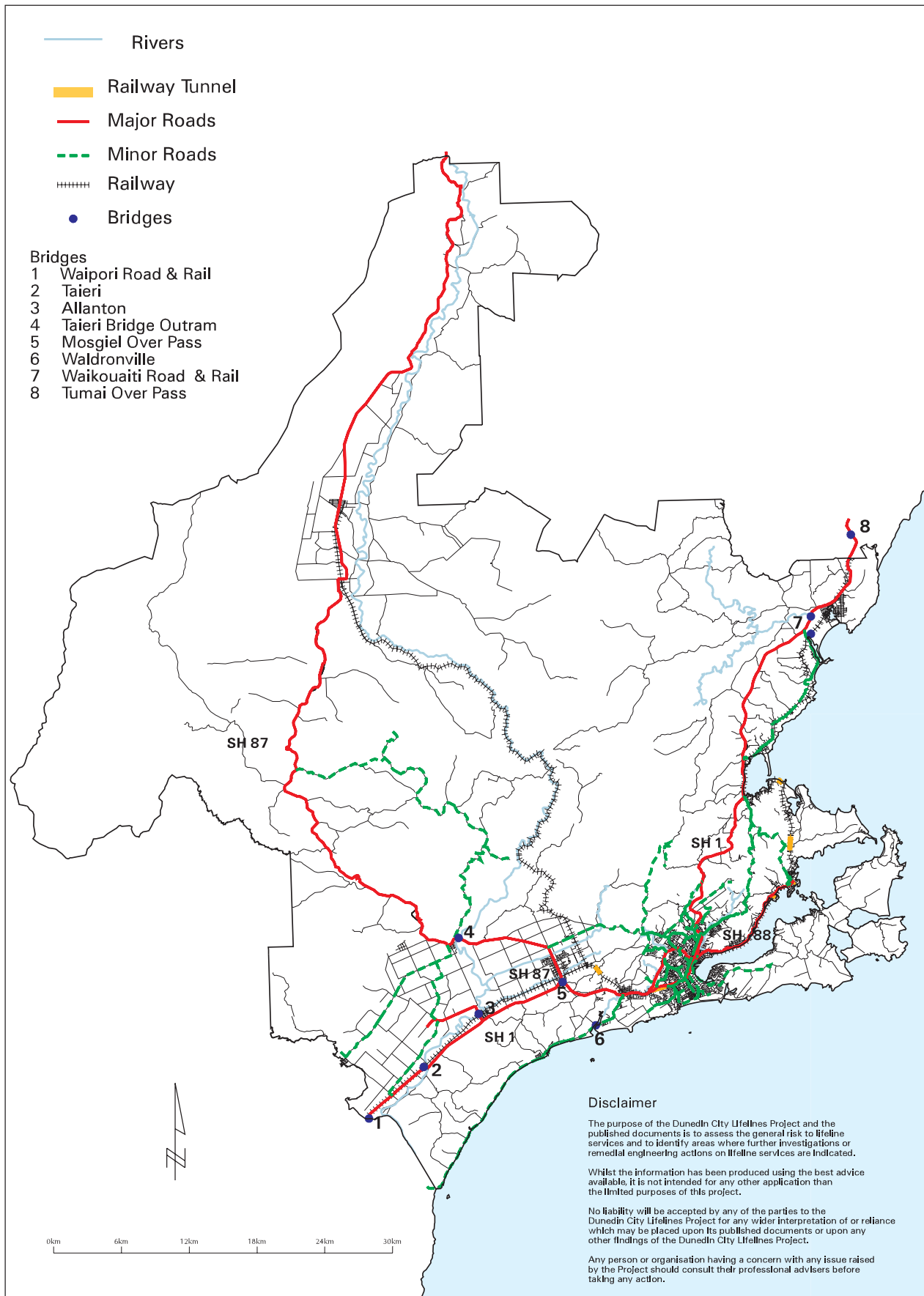
Southern, Ross Creek and Sullivans Dam water reservoirs. Other facilities are generally serviced by normal suburban roads.

City Bridges

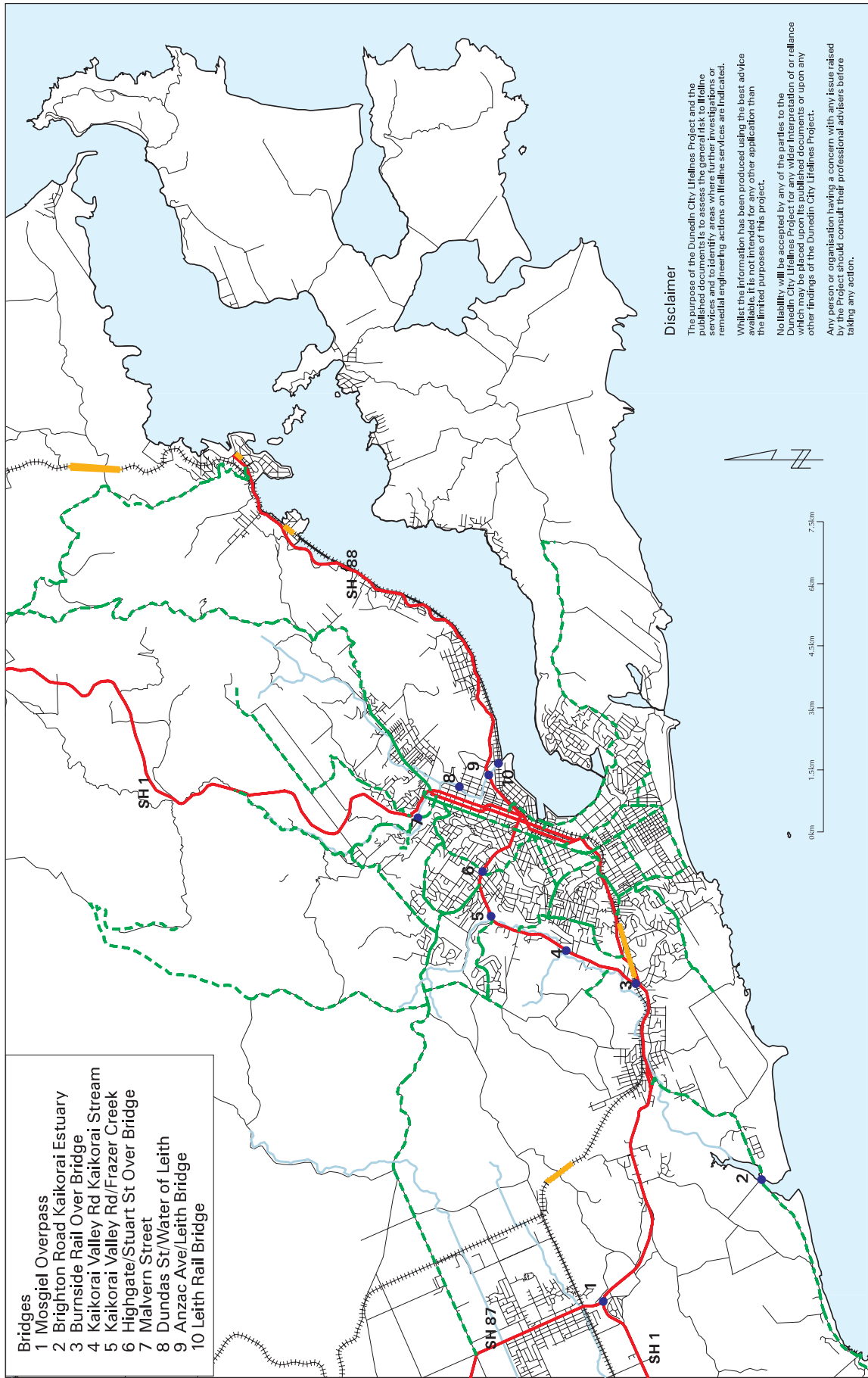
A summary has been made of major bridge structures situated on arterial routes (other than State Highways) which may be at risk in the event of a major natural disaster. Arterial routes considered in this appraisal are:

- Stuart Street - Taieri Road.
- Brighton Road - Green Island to Brighton.
- Kaikorai Valley Road.
- Leith Valley Road.

Transport and Bridges (Rural Area)



Transport and Bridges (Urban Area)



- Bridges**
- 1 Mosgiel Overpass
 - 2 Brighton Road Kaikorai Estuary
 - 3 Burnside Rail Over Bridge
 - 4 Kaikorai Valley Rd Kaikorai Stream
 - 5 Kaikorai Valley Rd/Frazer Creek
 - 6 Highgate/Stuart St Over Bridge
 - 7 Malvern Street
 - 8 Dundas St/Water of Leith
 - 9 Anzac Ave/Leith Bridge
 - 10 Leith Rail Bridge

Contains Data Derived from LINZ's DCDB
LINZ DCDB Digital Licence No. DN154117/19
Crown Copyright Reserved

City Consultants
June 17, 1999

- Major Roads
 - - - Minor Roads
 + + + + + Railway
 ▭ Railway Tunnel
 — Rivers
 ● Bridges

ROADING - ASSESSMENT OF VULNERABILITY

State Highways

Assumptions used

A number of assumptions were made in carrying out the vulnerability analysis described in the section on methodology:

Assessment Item	Assumptions carried to Chart
Technology	Bulk fuel / gas storage sites assessed as posing a direct hazard through explosion damage to the highway structure. The effects of lack of fuel on transport following an event has not been considered.
Fragility	The “standard” to which roads are designed does not include for earthquake or liquefaction movement. Therefore sections prone to these effects have all been assigned 4 points for fragility. The design of bridges does allow for these factors and they are assigned points in accordance with their structural capacity. For flooding and landslides 2 or 3 points have been assigned depending on the perceived resilience to damage of the asset.
Redundancy	Parallel routes have generally not been assumed to provide full redundancy. Widespread events such as earthquakes are likely to affect parallel routes as well as the primary route.
Cost	Due to the expense of roading reinstatement and the funding policy where for any emergency event over \$20,000 funding must come from the Transfund emergency fund we have made the assumption that all costs are “major impacts” where funding is sourced from external sources (i.e. Transfund). It may be argued for the highway that this is moderate impact where costs are funded by reprioritising of programmes.

State Highway 1 (City Area)

The section of SH1 through the city between Caversham and Pine Hill will be affected by:

- Liquefaction during earthquake events.
- Flooding of the Water of Leith.
- Tsunami where the highway is below the 5m contour level.

A prominent fault trace runs through the harbour and SH1 is vulnerable to being blocked by building collapse and landslip. Movement along this fault will invariably cause disruption along a significant length of highway with liquefaction and earthquake damage likely to affect water, gas, sewerage, power, and telephone hardware buried within the road. Effects of service failure are likely to impinge on road reinstatement and in particular washouts and flooding due to burst water pipes, will create serious disruption.

Should SH1 be incapacitated, there are numerous parallel routes through the city. It is likely, however that any event of sufficient size to affect the State Highway will also affect the alternative routes, so the security of this section of the route is very important.

State Highway 1 (North of City)

The Northern Motorway (Pine Hill to Waitati) will be affected by:

- Snow and ice during winter (short term closures only).
- Earthquake and rain generated landslides.

The long term effects of road closures due to snow are minimal but a larger scale event such as an earthquake will have extensive effects. While the Northern Motorway is supported by two alternatives (Mount Cargill

Road and Blueskin Bay Road), it is likely that one or both of these routes will be affected to a similar or worse degree than the State Highway. Bridge structures are also likely to be affected and this is covered separately in a section which follows.

Between Waitati and Waikouaiti, the road will be affected by:

- Tsunami.
- Flooding of the Waitati River.
- Flooding of the Waikouaiti River.
- Instability in the Kilmog area.

North of Evansdale the Coast Road offers an alternative route to Waikouaiti. This road is of low standard but would suffice as temporary access (should it remain usable) for light vehicles while State Highway 1 is being repaired. The Kilmog Hill is susceptible to landsliding and general slope instability. An earthquake, could trigger a major landslide (15m depth x 100-200m in length) over this section. Heavy rainfall or snow will also temporarily close the road on a regular basis.

Flooding of the Waikouaiti River between Merton and Waikouaiti occurs occasionally and a large flood will cause major scouring to the existing road and supporting embankments, with closures of greater than two days anticipated. Alternative routes between Dunedin and Waikouaiti include State Highways 85 and 87, although these involve detours of over 100km.

The section between Waikouaiti and Palmerston is expected to be relatively sound following an earthquake, although some minor slips can be expected. Flooding or tsunami damage to sections of the highway will cause disruption but is likely to be repaired reasonable quickly.

In the case of widespread flooding or snowstorms, equipment and human resources are likely to be stretched. This will have an impact on the time required to recover the serviceability of State Highway 1.

State Highway 1 (South of City)

Between Caversham and Milton, the road will be affected by:

- Liquefaction during earthquake.
- Landslides in the Green Island and Saddle Hill areas.
- Flooding on the Taieri Plains.

The overall vulnerability of this link is identified to be lower than for the section north of Dunedin. Alternative routes between Dunedin and Mosgiel exist, with Three Mile Hill being the most obvious.

The flood free highway between Mosgiel and Waihola has improved the reliability of the route during flooding of the Taieri and an alternative low standard route exists along the coast.

A fault along the eastern side of the Taieri Plain could cause severe disruption to the road should a sizeable earthquake occur, although alternative routes exist along the western side of the plain.

The section through Fairfield is subject to settlement due to the presence of old mining works.

State Highway 87

Between Mosgiel and Middelmarsh the road will be affected by:

- Flooding of the Taieri river near Outram.
- Liquefaction during earthquake.
- Snow and ice closures during winter.

Flooding of the Taieri River at Outram and Kokonga have caused closure of the State Highway in the past with a central section of the Outram bridge being washed away in 1981.

Snow and ice closures occur frequently between Outram and Middelmarsh during the winter months but these are generally short term (1-2 days) and often occur during widespread snowstorms that also affect State Highway 85 and State Highway 1 north of Dunedin.

The State Highway 87 route links Dunedin with Central Otago. Alternative routes consist of State Highway 85 (Pigroot) through Ranfurly and State Highway 8 through Roxburgh. Closure of State Highway 87 would not be considered to cause serious disruption to the central Dunedin city area, although, combined with closure of State Highway 8 and State Highway 85, the effects would be substantially increased.

State Highway 85

State Highway 85 is technically outside the area being investigated by this project but closure of this link to Central Otago will have adverse effects on commercial and tourist activity in Dunedin. The highway is prone to snow closure during winter, generally for periods of less than 2 days and the Deadhorse Pinch landslide will fail in a sizeable earthquake closing the highway, potentially for several days. Alternative routes into Dunedin exist via State Highway 87 and State Highway 8.

State Highway 88

State Highway 88 will be affected by:

- Liquefaction during earthquake
- Tsunami
- Landslides
- Flooding

State Highway 88 is of significant importance as it provides the only means of access for heavy vehicles to Dunedin's main port. Closure of this link essentially cuts road access between the city and the port, although alternative access is available via Blueskin Bay Road. This road is of poor geometric standard and is unsuitable for commercial use and access by emergency vehicles should be possible, assuming the route has not been affected by the event which closes State Highway 88. Harbour transport could be used for emergency access if both routes are lost.

State Highway 88 follows the harbour coastline for the majority of its 13 km length. Steep slopes stand above the highway, many of which are supported by retaining walls in various conditions of repair. Seismic activity in the Dunedin area is likely to cause potentially large landslides to cross the highway. Sections are also retained at various locations below the highway directly adjacent to the harbour edge and failure of retaining walls and causeway support is likely to take several days or weeks to repair.

The potential for economic impact is considered to be high as a substantial amount of Dunedin's trade is routed through Port Chalmers. Loss of commercial access to this facility will undoubtedly affect the city's operation. The entire length of the highway is also within the high tsunami risk zone and effects of a large tsunami would cause similar disruption to a major earthquake.

Highway Structures

To the North of Dunedin

The Waikouaiti River bridge has unrestrained roller bearings at one end of the 3 spans and with a large seismic loading it is likely that one span would drop into the river.

The Waitati River bridge has piers with little ductility which is likely to lead to a pier failure from a large seismic loading. If necessary a temporary ford can be constructed.

The Patmos Avenue underpass has its north abutment founded on a slope which is likely to move with large seismic loading. The original bridge was lengthened to cope with earlier slope movement but further movement could cause the bridge to collapse. Failure of this bridge will only block State Highway 1 until the debris can be cleared.

To the South of Dunedin

The bridge over State Highway 1 at Otokia may be critical. Although it has linkage rods, they may not be strong enough to keep the bridge intact given the long length of the structure (370m) which could expose it to different phases of the earthquake wave. The current detour route via the old Henley bridge is out of service while the bridge is being brought back to a standard suitable for light vehicles and heavier vehicles still may not be able to use this detour in the future.

Deep Stream bridge on State Highway 87 has a masonry pier and approach fill at the southern end which has moved in the past. During a large seismic event either one of these deficiencies is likely to cause damage to the bridge.

The State Highway 1 Abbotts Creek bridge, which can be regarded as a critical bridge, is likely to have slumping of its approach fills during a large earthquake.

The Taieri River Bridge on State Highway 87 which was damaged during the 1980 flood has since been strengthened against both flood and seismic loadings.

Major City Connector Routes

The major arterial routes within Dunedin are under the control of Dunedin City Council and provide intra-linking between state highways and other major connectors.

Three Mile Hill Road is an alternative east-west link from the city to the Taieri and beyond. It is prone to adverse impact due to weather and fault proximity. During winter months the road is exposed to impact from ice and snow, which increases accident potential and reduces access by limiting the alternatives for vehicles travelling east to west. A fault trace crosses Three Mile Hill Road and could cause land movement and direct impact from the fault.

Loss of this link to the west leaves State Highway 1 as the only major route available to cope with larger traffic movements.

Kaikorai Valley Road is the link from Stuart Street to Green Island and hence is a major route from the city to the south and has a pavement structure consistent with its heavy volume of traffic.

The area of Kaikorai Valley Road has been identified as being subject to earthquake amplification and there have, in the past, been isolated incidents of land instability. The impact of earthquake activity is the highest risk, although there is a potential for flooding from the Kaikorai Stream all along the valley, particularly where the stream crosses the road at various points.

Kaikorai Valley Road is a strong link within the city's major connector network, providing access to an industrial area located at the southern end of the road. Loss of this link north of this point limits the access for industrial vehicles and requires use of the suburban hills for through traffic.

The alternate connector route that gives access to the south is Brighton Road / Taieri Mouth Road. Brighton Road is susceptible to amplification of earthquake intensity and to tsunami and flooding from the mouth of the Kaikorai Stream at the estuary. There is a fault trace off-shore from Brighton Road which gives potential for increased earthquake intensity and impact. The road surface itself is subject to pavement failure in places mainly due to heavy logging traffic use. The impact of a tsunami would be severe here as Brighton Road runs along the shoreline at a low contour interval (<20m) and is built on a sandy base which would not withstand the impact. A tsunami would adversely effect the whole area adjacent to the road as well as the road itself. Loss of this link north of Scroggs Hill Road would limit access to properties in Brighton and Ocean View, although alternatives are available through Scroggs Hill Road and McIntosh Road to the north and other links with Taieri Mouth Road to the south. The potential for flooding centres around the Kaikorai Estuary, which is the outlet for the Kaikorai Stream and in extreme flood conditions could undermine the banks and hence the structural integrity of the Brighton Road formation at this point. The bridge structure is also highly susceptible to enhanced shaking and flood damage due to its age and construction.

Taieri Mouth Road is the continuation of Brighton Road past the Brighton township, and is of the same basic pavement structure as Brighton Road with some recent upgrading and enhancements. The potential impact from tsunami and earthquake due to the proximity of a traced fault, are the greatest risks that are apparent. Taieri Mouth Road is located along the shoreline to the Taieri Mouth township from Brighton below a 20m contour level. It is built on a sandy base which would be susceptible to failure when exposed to large quantities of water. If Taieri Mouth Road were to be cut off it would leave the alternatives to the south as State Highway 1 from Mosgiel, and the other minor unsealed east-west links to the State Highway from the coast.

Suburban Link Routes

Suburban links to the north, other than by State Highway are Leith Valley Road from Malvern Street, North Road / Norwood Street to Mt Cargill Road and the Port Chalmers link by Blueskin Road to Waitati.

Leith Valley Road is at risk from proximity to a fault trace to the west, its limited formation depth and strength and to limited impact from surface water in heavy rains and / or storms.

From the Port Chalmers and West Harbour areas an alternative route north is by Blueskin Road from Port Chalmers, given that State Highway 88 is accessible. Blueskin Road climbs to near the top of Mt Cargill and is susceptible to weather extremes such as snow and ice.

Mt Cargill Road is narrow and winding and exposed to weather extremes such as snow and ice and at times may be impassable to traffic.

North Road and Norwood Street lead in to the Mt Cargill route to the north and are at risk from landslide and earthquake amplification due to the nature of the underlying soil types in the area which would place the carriageway formation at risk from subsidence and cracking.

In St Kilda and St Clair, roads that would be lifeline links adequate to carry larger volumes of traffic in an evacuation are King Edward Street, Forbury Road, Andersons Bay Road, Hillside Road and Victoria Road.

King Edward Street is located below the 2 metre contour on soils sensitive to liquefaction. In an earthquake of reasonable magnitude these soils will liquefy and become unstable with a tendency to flow and subside which will undermine the structural integrity of the pavement. A tsunami would have adverse effects on the link to the southern suburbs and limit access to the coast.

Forbury Road is on the boundary of unstable soils in South Dunedin and at the eastern end of the road is in an area of soils prone to liquefaction. It is below the St Clair cliffs and close to an inferred fault trace. Loss of the Forbury Road link would leave other alternatives for access to the east, although these links are prone to the same adverse impact from tsunami and earthquake.

Victoria Road provides a north - south link from King Edward Street / Prince Albert Road to Forbury and basically follows the coastline. It is exposed to the same impacts from tsunami and earthquake due to being below the 2 metre contour and located on soils susceptible to liquefaction and amplification of earthquake intensity. This would lead to a degradation of the subgrade and failure of the road. The loss of this link leaves few north - south alternatives in the area with equal capacity for traffic.

Andersons Bay Road is an important arterial road which runs from St Kilda in the east to connect to the Southern Motorway near the Oval and is exposed to tsunami and increased impact from earthquake. It is also built on sensitive soils and could be prone to amplification of earthquake intensity. Loss of Andersons Bay Road would leave other roads in the area as alternatives but as stated before all the roads in this area of South Dunedin have similar vulnerability characteristics from tsunami, liquefaction of soils and amplification of earthquake intensity. Andersons Bay Road is also built on what was the original coastline before reclamation of the foreshore area.

Hillside Road is a collector link in the road hierarchy and carries moderate levels of traffic with normal peak periods. It links the southern part of South Dunedin with the important arterial links from Forbury Road to King Edward Street. Although more inland than most roads in the area it is still exposed to sensitive soils and possible amplification of earthquake intensity. Tsunami is a real threat at the eastern end of the road. Loss of this link would increase volume on Macandrew Road or other more minor roads but Macandrew Road is exposed to the same extent as other roads in South Dunedin and is susceptible to liquefaction of underlying soils, earthquake amplification and tsunami.

The hill suburbs of Mornington, Maryhill and Maori Hill provide alternative links to major arterials that connect east to west in the city and give access to a large section of the residential housing in Dunedin.

The link from Princes Street to the west is High Street and Mailer Street. High Street is a very steep street but its vulnerability is not as extreme as others in the city. It has some risk from shaking and there are a number of historic buildings on its frontage but it would appear that the underlying strata will withstand reasonable impact. Tsunami is only an issue at the intersection with Princes Street. From the High Street/Mailer Street link is the Elgin Road/Mornington Road link which runs from Mailer Street to the intersection with State Highway 1 at Lookout Point. Both Elgin Road and Mornington Road are susceptible to amplification of earthquake intensity.

An alternate route to the south via Easter Crescent, Middleton Road and Blackhead Road to Brighton Road is sealed and recently upgraded but the route is steep in places and susceptible to landslips. Blackhead Road is in close proximity to an inferred fault trace but no other evidence of hazard amplification is apparent. The route is not at risk from tsunami as it follows the coastline at a sufficient height above sea level, and earthquake hazards are the same as most areas in Dunedin.

Two main routes to the western area of the city are State Highway 87 and George King Memorial Drive. George King Memorial Drive starts near Outram and intersects the State Highway half way to Middlesmarch. At the southern end of the Drive some amplification of earthquake magnitude could occur.

Service Access Roads

Access to water reservoirs located off Townleys Road relies on Kaikorai Valley Road being open. The Kaikorai Stream is bridged by Townleys Road and is susceptible to severe flooding conditions.

Mt Grand Water Treatment Station can be accessed from Dalziel Road by Three Mile Hill Road or Brockville Road. This access does not appear to be at risk from hazards other than meteorological with snow and ice presenting major problems in this area.

Access to Ross Creek is via Malvern Street to Tanner Road. Malvern Street is located off George Street and is in the potential flood area of the Water of Leith. Alternate routes from Wakari and Maori Hill are subject to landslipping and to adverse weather conditions.

Highcliff Road on the Peninsula gives access to radio and telecommunication facilities. The major hazard is snow, ice and dense fogs that are common as well as landslip due to earthquake shaking.

The service roads for Swampy Summit and Mount Cargill are at high elevations and therefore exposed to extremes of weather which can render them impassable. They are generally not susceptible to earthquake but some land movement could occur.

City Bridges

Natural disasters which may impact on bridges are flood, earthquake and tsunami or storm surge.

Location of Structure	Damage expectation
Highgate/Stuart Street Overbridge	Loss of embankment, some structural damage in severe shaking with potential collapse over road.
Brighton Road - Kaikorai Estuary	Loss of embankment in flood or tsunami, structural damage in severe shaking and approach embankment subsidence.
Brighton Road/Otokia Stream	Flood or tsunami loss of right embankment, structural damage and failure of right embankment in severe shaking.
Kaikorai Valley Road/Kaikorai Stream	Flood loss of embankment in severe event, structural damage due to enhanced shaking in earthquake.
Kaikorai Valley Road/Frazer Creek	Flood loss of embankment and similar loss in earthquake.
Burnside Rail Overbridge	Some structural damage in severe earthquake shaking event.
Dundas Street/Water of Leith	Severe structural damage or failure in flood or earthquake.
Malvern Street/Water of Leith	Severe structural damage or failure in flood or earthquake.

ROADING - MITIGATION STRATEGIES

State Highways

Transit New Zealand has developed a comprehensive response programme to undertake remedial work immediately following a hazard event.

This has been adopted as the means of recovery rather than by initiation of direct mitigatory action because it has been found impractical to determine specific locations for expenditure of large sums of money on a cost effective basis.

The exception to this philosophy can be the bridging elements of the State Highways where, in some instances, effective work may be done on upgrading. Bridges frequently present barriers to movement which are difficult to circumvent and are not easy or cheap to replace or repair even on a temporary basis.

Neither in depth examination nor structural calculation have been made in the identification of mitigation works, but a number of bridges have been nominated for further structural analysis to determine the need for and aspects of mitigation. Among these bridges are:

- Taieri River Bridge SH87
- Deep Stream Bridge SH87
- Lee Stream Bridge SH87
- Waikouaiti River Bridge SH1
- Waitati River Bridge SH1
- George Street Overbridge SH1
- King Edward Street Bridge SH1
- Taieri River Bridge SH1

The bridges have been reviewed on the basis of hazard maps, bridge photos and the bridge descriptive inventory only. This data provides only a general review of the bridge and its foundation type. The bridge drawings were not available at this stage so information on linkage arrangements, pile sizes, inclination of piles (raking), number of piles, abutment widths, pier detailing and borehole logs etc, was not examined. These details have a major effect on the damage to any bridge and the strength of the individual elements. Consequently the type and extent of damage to the bridges is only guesstimated from a generic structural type and individual damage and strengthening requirements for any bridge may differ widely from that assumed.

For the majority of the bridges a site specific study is required together with a design review. This will determine understrength elements, the extent of probable damage and the most cost effective method of strengthening where required. For the small single span bridges and box culverts it may only be necessary to review the drawings.

Conclusions

General observation on pavements is that maintenance, as currently provided, represents the most cost effective solution to protection of the roading system.

Bridges, particularly those mentioned above, need further examination in detail to determine whether mitigatory work is appropriate and at what cost. Transit New Zealand has a current investigation budget which may permit such work to be undertaken.

Recommendations

Continue the well established general maintenance programme and review of critical structures on the State Highway network.

Major City Connector Routes

From the Vulnerability Analysis it is clear that the highest risk posed to the road network is on the southern coast (Brighton - Taieri Mouth Road), Stuart Street in and Three Mile Hill Road.

Measures to be used to minimise the effect of natural disasters are in themselves not enough to maintain the lifeline. Strategies must also include how to open the lifeline once disaster has struck. The previous stages of the lifelines project have identified alternative routes for most major connector routes and in particular those identified as having a high vulnerability.

Ongoing access and pavement upgrades and improvements are budgeted items and form part of the City Council 20 year strategic plan.

Mitigation Measures

- Review structural standards for all major city connector routes.
- Identify sources of plant and machinery for use in recovery operations. These are to be categorised by the nearest location to a vulnerable lifeline.
- Slip prone areas on the suburban hills, Abbotsford, Green Island, East Taieri are to be examined for the need for retaining structures.
- Identify strategically important service lines (power, water) buried beneath roads. Work with the service authorities to ascertain vulnerability.
- Review construction methods for services located within roads (pavements, overlays and backfilling) and examine their vulnerability. Prepare a remedial list of repair works for trenches and pavement upgrade.
- Overhead services can be hazardous in an event. Investigate expanding the 'undergrounding' program for power supply.
- Formulate a response strategy to a natural disaster. All plant, machinery, personnel, and materials that are required are to be defined and identified.
- Service roads to water and power supply operations shall be examined and upgraded in accordance with their vulnerability.
- Prepare diversion plans for key routes to avoid known hazard areas.
- Formulate debris clearance plans for Brighton Road, Kaikorai Valley Road, Stuart Street. The plan may also be applied to unforeseen damage to other roads in the network.
- At particular risk from snow storms is Three Mile Hill Road. Historically, clearing of this road has been difficult and measures should include a recovery plan for severe snow storm and for subsequent gritting.

Suburban Link Routes

From the vulnerability analysis, the most at-risk suburban linking routes and rural links are Portobello Road, Coast Road, King Edward Street, Portsmouth Drive, Macandrew Road, Victoria Road, Andersons Bay Road and Highcliff Road. There are others that have a moderate risk to natural disasters, but strategically these roads are of less importance.

The majority of the risk seems to be in the South Dunedin area and around the coastal fringe (liquefaction, shaking, amplification and tsunami). It is likely that the most at-risk areas would need to be evacuated in the event of a tsunami warning and would require extensive recovery resources in the event of a severe earthquake. Some risk is also seen on the hill suburbs but this is less severe.

Mitigation Measures

Tsunami or Storm Surge

- Give priority for recovery to Portobello Road, Portsmouth Drive, Macandrew Road, Victoria Street and Andersons Bay Road
- Formulate an evacuation route to the hill suburbs which takes account of numbers of residents in effected areas and the capacity of the roadway. One-way and intersection controls may need to be utilised.

Earthquake

- Clearing of debris and repair to roads are priorities.
- Formulate a recovery plan for effected areas and important lifeline roads.
- Investigate current lateral resistance of the underlying subgrade. This identifies the location of power sources, fuel sources and plant, emergency labour and machinery for recovery operations.
- Formulate a plan for crossing structures for failed road surfaces. Identify the location of resources for crossing structures and a methodology for placement.
- Prepare a recovery plan to be used to open alternate routes to State Highway or major connector routes if these are unable to be used. Prioritise sequence of work for road network lifeline recovery.

Service Access Roads

The majority of these roads consist of unsealed access for service providers and are themselves accessed from suburban connector or link routes. Because of their constant use by service providers they are generally well maintained but it is not possible to pre-determine the risk element which may impact on access, nor the location of damage because of the extensive route length involved.

Mitigation Measures

Mitigation strategy is largely based upon giving priority repair status to such damage as may occur to service access roads. While little pre-planning will be effective, identification of localities which may require disaster management is a valuable mitigation objective in itself.

Recognised as of particular significance are access routes leading to water supply and treatment works and to communication services.

City Bridges

All major city connector routes are exposed to some degree of risk by natural hazards. Some city bridges are likely to be significantly at risk from earthquake shaking, liquefaction and landslip. The extent to which this exposure can effect the loss of a lifeline is proportional to the mitigation of effects that Dunedin City Council needs to consider with respect to bridges and the routes they service.

Dunedin City Council has a bridge renewal and upgrading program that will implement many of the suggested investigations for the bridges contained in high priority lifelines.

Bridges at risk and mitigation strategies are:

Location of Structure	Mitigation
Highgate/Stuart Street	Examine strengthening of the embankment for lateral and longitudinal strength
Brighton Road/ Kaikorai Estuary	Stabilise embankment and protect footings from washout
Brighton Road/Otokia Stream	Examine options for upgrading right embankment for flood impact and slope failure from shaking
Kaikorai Valley Rd/ Kaikorai Stream	Investigate structural strength for lateral movement.
Burnside Rail Overbridge	Examine structural strength upgrade for lateral movement
Kaikorai Valley Road/ Frasers Creek	Investigate strengthening of footings and embankment against impact of flooding.
Dundas Street/ Water of Leith	Investigate structural integrity of footings and embankments for failure potential in severe flooding/ earthquake event.
Malvern Street/Water of Leith	Investigate structural integrity of footings, sub/super structure connections and embankment retaining for failure potential in severe flooding or earthquake event.

Mitigation Measures

- Investigate bridges on major city connector routes and identify alternative routes.
- Identify strategically important bridge structures and undertake a technical assessment of structures in accordance with vulnerability analysis of lifeline routes.
- Where appropriate strengthen structures for both lateral and longitudinal movement and stress.
- Examine bridge structure connections to road structure, columns and retaining structures and strengthen as required.

Conclusions

The Greater Dunedin City area is generally susceptible to earthquake hazard which makes it impossible to be cost effectively selective in mitigation of damage to the roading network whether this be state highways or other routes. While it is recognised that some routes are more susceptible to hazard damage than others it is considered more appropriate to manage any reconstruction measures to carriageways rather than commit large capital expenditure to mitigate in these areas.

Bridge structures are more readily identified as being at-risk, but modes of failure are particularly difficult to predict and it is considered that, while some strengthening may be undertaken, planning for restitution is, in many cases, the best course of action.

Asset managers are alert to the need for continual improvements of the overall transport network and the Lifelines project has enhanced awareness of the impact of natural hazards in general.

Recommendations

Both Transit New Zealand and Dunedin City Council propose to continue their existing management planning with ongoing pavement, bridge and general access improvement.

HARBOUR - DESCRIPTION OF SERVICE

Sea Channel

Entrance Channel to Port Chalmers

The entrance channel of length 4.2km terminates just inside the line of Aramoana Beach. This section is in an open seaway and extends through the coastal sand littoral drift system. The channel has a least depth of 13.2m and a minimum bottom width of 180 metres. Under the influence of Taiaroa Head on the south side and the rubble mound training wall or mole on the north side it is largely self scouring.

The lower harbour channel extends from Harington bend just inside the beach line to Port Chalmers, a distance of 8.7 km. This section is in sheltered waters and has a least depth of 12.2 metres and a minimum bottom width of 180 metres. A number of training walls hold the channel in position at Harington bend. From there to Port Chalmers the channel is effectively defined by the headlands to the bays. The lower harbour channel terminates at the 350 metre diameter swinging basin off the Port Chalmers wharfs. The bed of the channel is fine to medium sand and dredging is required to clear sand from the inside of the bends, sucked up the channel from the littoral drift system by tidal currents.

Inner Channel to Dunedin.

A short, deep 1.6 kilometre section of channel links Port Chalmers to the narrow passage between Goat and Quarantine Islands. The Victoria Channel (9.8 kilometres) extends from the islands to the 280 metre swinging basin off Victoria Wharf. Victoria Channel has a least depth of 7.5 metres and a minimum bottom width of 80 metres. Bed conditions are mostly sandy but with mud from Ravensbourne to Dunedin. As for the lower harbour, fine sands worked up the channel by tidal currents have to be dredged from the inside of bends. A half tide rubble mound training wall on the eastern flank assists with scour and prevents ingress of material to the channel.

Marine Control

The Taiaroa Head Signal Station is the controlling agent for shipping in the harbour. No ship can enter the harbour without the approval of the signal station which also acts as an observatory on sea and weather

conditions for pilotage staff. It records and broadcasts hazards within the harbour and the immediate coastal zone. The signal station is extensively equipped with radio, radar and telephone communications equipment.

The Taiaroa Head lighthouse serves as a navigation aid for ships making coastal passages and the landfall tower (a spar buoy) located at the outer end of the channel is a homing beacon for ships approaching the harbour wishing to find the entrance channel and pick up a pilot. Once in the entrance channel, a sector light on Hautai Hill keeps ships on the channel centre line and within the harbour. Beacons on both sides mark the channel.

The Port Company has tide gauges at the harbour entrance, Port Chalmers and Dunedin with telemetric links to Taiaroa Head and wind gauges installed at Taiaroa Head, Goat Island and Victoria Wharf are also linked to Taiaroa Head. The information from both sources is needed to make pilotage decisions.

Navigation Beacons

In the lower harbour there are 29 beacons and a light on the mole end to delineate the channel. The beacons line both sides of the channel from 400 to 1,400 metres apart. All beacons are fitted with radar reflectors and lights for night passages. The lights are powered either by photo voltaic cells and batteries or by shore-based power. Some beacons are wooden piled dolphin type structures and others are a single steel tube pile. The channel from Port Chalmers to Dunedin is marked by 77 beacons, ranging from 600 metres to 250 metres apart.

Berthing Facilities



Container Terminal and Beach Street Wharf, Port Chalmers - Port Otago

for bunkering vessels with either diesel or light oil. The jetty structure comprises timber piles and substructure with a reinforced concrete deck. The jetty can accommodate vessels up to 30,000 tonnes dead weight and 8.0 metres draught and is linked to the storage facilities of each of the four major oil companies by a land based pipe line.

A dedicated fish import berth at Victoria Wharf (north), with cold storage facilities alongside is a timber breastwork structure with a reinforced concrete deck.

Port Chalmers

The Container Terminal has two heavy duty reinforced concrete breastwork type wharfs, each accommodating cellular and multi-purpose vessels up to around 50,000 tonnes dead weight and 12.0 metres draught. A heavy duty paved back-up area of 10.0 hectares is available for cargo storage.

The Beach Street forestry terminal has two berths handling vessels up to 40,000 tonnes dead weight and 11.0 metres draught. The wharf is a reinforced concrete caisson, solid quay wall type structure. A heavy duty paved back up area of 10.5 hectares is provided for cargo storage.

Dunedin

A dedicated LPG import berth and storage facility has a dolphin type wharf structure for vessels up to about 10,000 tonnes dead weight.

An oil jetty for imported petrol, diesel, light fuel oil and bitumen products is also used

A general purpose berth at Victoria Wharf (south) is a solid quay wall structure of steel sheet piling and relieving slab. A heavy duty concrete deck is placed behind the sheet pile wall. The berth is equipped with wharf cranes and transit sheds.

Lay-up berthage is provided at Rattray Wharf which is an old timber breastwork wharf and a dedicated fish import berth at Birch Street wharf, with fish processing and cold store facilities alongside, is of timber breastwork with a reinforced concrete deck. The outer end is used as a lay-up berth for ship repair and servicing.

Elsewhere

At Ravensbourne there is an import fertiliser berth. The wharf which is adjacent to the channel is a timber piled and decked structure with a reinforced concrete steel pile supported frontage. The wharf is linked to the shore by an all timber access jetty. The wharf is dedicated to the fertiliser processing works ashore and vessels up to 30,000 tonnes dead weight and 8.0 metres draught can be accommodated.

Commercial inshore fishing berths and infrastructure are provided at Careys Bay.

Cargo Handling

Port Chalmers

At the container terminal there are two container handling gantry cranes for loading containers to and from ships. The cranes are capable of lifting up to 45 tonnes at a maximum outreach of 34 metres. They will handle containers up to 12.2 metres long. Internal cargo handling plant includes 10 straddle carriers, three full-container handling forklifts, and three empty-container handling forklifts. There are electrical power outlets to serve 938 refrigerated containers in two separate container stacks.

At Beach Street wharf, two level luffing wharf cranes with a lifting capacity of 5 tonnes at 22 metres maximum outreach are available. Bulk cargo storage is available in the form of Cargo Shed A with a floor area of 2,400 square metres. A further shed with a floor area of 6,000 square metres is presently under construction (Spring 1997). A woodchip storage facility of 40,000 tonnes capacity, comprising elevator, distribution gantry and towers is located at the inner end of Beach Street.

The stevedoring and log marshalling companies provide three to four large forklifts capable of handling containers or large wood packs, three to four large specialist log handling forklifts, three truck/trailer units for transporting logs and a number of log butting tractors.

Dunedin

The Victoria Wharf (south) general purpose berth is equipped with two 5 tonne level luffing electric wharf cranes with a maximum outreach of 22 metres. Under-cover cargo storage capacity is provided by two transit sheds, each with a floor area of 1,800 square metres. At the north end of the berth is a cement silo of 1,000 tonnes capacity.

The Victoria Wharf (north) fish berth has two cargo storage sheds each with a floor area of 1,800 square metres and a central cold store with an internal volume of around 4,500 cubic metres.

The Leith Wharf apple export facility has two large cool stores and one cold store alongside the wharf, each with a volume of around 20,000 cubic metres.

The LPG berth is fitted with specialist LPG unloading arms and a pipe line linkage to the storage tanks ashore.

The oil jetty uses rubber hose links for ship-to-shore transfers but there are permanent commodity pipe lines along the wharf and ashore which link with the inland storage tanks.

Cargo handling plant (forklifts etc) for Dunedin operations is not specifically provided by the Port Company but is hired on an as-and-when required basis from other sources including the Port Chalmers Container Terminal.

Elsewhere

The Ravensbourne Wharf is fitted with four wharf hoppers and a belt unloading conveyor extending right into the works. The nominal capacity of the conveyor is 600 tonnes an hour.

Buildings

Administration

The port as a whole is controlled and administered from the Port Company head office in Beach Street, Port Chalmers. The Port Company's management functions are carried out within its head office building which is also a home to the regional staff of shipping companies using the port and provides amenity facilities for cargo workers employed by the company. From this building the control of commercial shipping, including the company's own pilot launches, tugs and dredges is exercised.

An essential link in this process is the company's signal station at Taiaroa Head which communicates instructions to shipping. As well, Taiaroa Head provides a weather and sea information service and warning of any marine hazards within the port area.

There are a number of other administration buildings for port related activities on the waterfront. Otago Stevedores has a general office and cargo worker amenity building at Beach Street, Port Chalmers. Owens Services, the log marshalling company, has a similar building in Beach Street, Port Chalmers.

At Dunedin the Apple and Pear Board has offices adjacent to its cool stores on the Leith Wharf; Liquigas have an office and control centre close to the LPG wharf; Sealord have offices and amenities in Birch Street behind the wharf; and Milburn Cement have offices alongside the cement silo at Victoria Wharf (south).

Amenities

In addition to the amenity facilities provided as part of administration/ office buildings there are a number of specialist amenity buildings, including an amenity block for cargo workers on the outer end of Beach Street Wharf, Port Chalmers; an amenity block for cargo workers on Ravensbourne Wharf; and an amenity block for cargo workers in S shed at Victoria Wharf (south) and G shed on Birch Street Wharf.

Garage/Workshop Facilities

A specialist straddle carrier repair facility and general plant repair facility is situated close to Macandrew Road in the container terminal, Port Chalmers. Also at the southern end of the terminal are located specialist refrigeration unit repair and testing facilities, container repair facilities and reefer container washing and drying facilities.

Owens Services has a log loader and plant repair workshops alongside A Shed in Beach Street, Port Chalmers and Sims Engineering has workshop facilities adjacent to the large slipway at the outer end of Birch Street Wharf, Dunedin.

Transport Links

Rail

A rail transfer facility is located in the Port Chalmers Container Terminal adjacent to Macandrew Road. It is capable of holding 29 wagons or 58 TEU. (containers), with rail tracks are provided on both the multipurpose and container wharfs and at the Beach Street forestry terminal a rail transfer siding has been installed at Back Beach. The siding has a holding capacity of 10 log wagons.

The Port Chalmers wharfs are connected from the Sawyers Bay yards through the Port Chalmers tunnel under Gray Street.

In Dunedin the Victoria Wharf south berth has three rail sidings on the wharf apron. The Victoria Wharf (north) berth has a siding behind the transit sheds. A rail siding with a holding capacity of 6 to 7 UK wagons is provided in the South Freight terminal close to the Leith Wharf. All the Dunedin sidings are fed from the Dunedin yards by the Wickliffe Street back shunt. The Ravensbourne fertiliser works has a rail siding.

Road

The Port Chalmers Container Terminal has a road entry point and gate house for documentation purposes at the end of George Street adjacent to the administration building. Queuing space for trucks awaiting clearance at the gate house is provided and a defined area of the terminal yard is set aside for road transfers.

At the Beach Street forestry terminal, road vehicles have a controlled entry point at Back Beach through a tally and documentation shed. The transfer of cargo to stack takes place alongside individual stack positions.

Access to Dunedin wharfs is generally by way of the Anzac Avenue or Cumberland Street overbridges. Road access to both the Victoria Wharf berths and the Leith Wharf is available and road access to Birch Street Wharf is possible but is strictly controlled. Road access is available to the LPG terminal but not the wharf. Road access to the Ravensbourne fertiliser works is available but not to the wharf.

Utilities

Fresh Water

Water is provided at all wharfs for fire fighting, ships bunkering and wharf cleaning purposes. All are fed directly from the City Council domestic water reticulation system. The main wharfs have back-flow preventers fitted at the point of connection to protect the city water supply from possible contamination from ships' bunkers.

Sewerage

Port administration buildings and amenity blocks toilets are connected into the city sewerage reticulation system.

Electrical

At Port Chalmers, 11,000 volt high tension power is taken from the substation on Cemetery Hill into the port's main incoming substation on Macandrew Road. From there power is reticulated to three other substations within the terminal and a fourth at Beach Street wharf. The high tension supply is used directly to power the container cranes, but otherwise is broken down to 400 volt three phase power which is used for the following purposes:

- Ships supply to avoid using ship generators in port.
- Refrigeration power outlets.
- Power for chip loader and stock pile elevator and gantry.
- Electrical machinery used on wharf frontage e.g. wharf cranes.
- Domestic power for amenities workshops etc.

Port users such as Otago Stevedores, Owens Services etc. have their own independent connection to the Dunedin Electricity network for their domestic power requirements.

At Dunedin, low tension 400 volt three phase power is taken at five points around the harbour and used for the same purposes as already described. Frequently port users are also connected to the same point of supply. The five supply points are:

- | | |
|---------------------------------|--|
| • Birch Street outer | Supply slipway, wharf crane & Birch Street wharf |
| • Birch Street inner | Supply Dunedin office, marina and tug berths |
| • Rattray Street (S shed) | Supply Rattray wharf and sheds |
| • Victoria Wharf south (T shed) | Supply transit sheds, wharf and cranes |
| • Victoria Wharf north (X shed) | Supply transit sheds, Sealord cool store wharf supply, oil jetty and parts of Leith Wharf. |

The Apple and Pear Board has an independent supply for its cool stores at Leith Wharf and the electrical power supply on the Ravensbourne Wharf is drawn from the fertiliser works substation.

Communications

Radio communication is vital to the operation of the port. The Taiaroa Head signal station is the main radio communication centre and is equipped with radar and marine band and VHF radio. As well as shipping control Taiaroa Head undertakes commercial radio calls to shipping on behalf of shipping companies, ships agents etc. Taiaroa Head has an automatic stand by generator should there be a power failure.

Most of the decisions in relation to shipping control are made by piloting staff in the Port Chalmers administration building or on the harbour tugs or pilot launches. There needs therefore to be good internal radio communication between administration, signal station and floating plant.

The company's tugs and pilot launches and the administration building have both marine band and VHF radio equipment and a vital element in the radio system is the aerial on Hautai Hill close to the signal station, which gives coverage of the whole harbour.

As well as the normal telephone links, including fax and E-mail to the administration building, the company operates an Air Time NZ two-way cell phone system which connects the company vehicles and floating plant with the company's telephone network. The operation of this system is dependent on Air Time NZ's transmitter on Swampy Summit.

Other Facilities

Floating Plant

The operation of the port is dependent on a number of items of floating plant owned and controlled by the Port Company. Two Schottel harbour tugs of 2,000 horsepower each are available to assist the berthing of ships and, when not in use are moored at Rattray Wharf, Dunedin. Two pilot launches are kept at a specialist berth at Boiler Point in Careys Bay and the company operates a small split hopper trailer suction dredge and a dumb barge grab crane dredge with attendant tug and spoil disposal barges. When not in use they are moored at Boiler Point, Careys Bay.

Bunkering for small vessels is available at the fishermen's wharfs at Careys Bay. Bunkering of large vessels is available at the oil wharf, Dunedin. At some of the Port Chalmers and Dunedin wharfs bunkering by road tanker is permitted.

Ship Repair and Servicing

The port owns a nominal 500 tonne slipway at the end of Birch Street Wharf, primarily for servicing its own plant, but also available for other vessels. Lay-up wharfage for ship repair is provided adjacent to the slipway at the Birch Street outer and Kitchener Street wharfs. The facility is leased to Sims Engineering, who operate it. Slipways and repair for smaller vessels are available at Miller and Tunnage's boat yards, Careys Bay.

HARBOUR - ASSESSMENT OF VULNERABILITY

Sea Channel

The vulnerability of the navigable channel to the port with respect to natural hazard is not great and it is difficult to conceive major disruption to the passage of vessels of modest draught for protracted periods. The worst scenario envisaged would likely be the shallowing of the channels due to earthquake shake, which may involve extensive dredging to re-establish sea bed profile and possible re-survey of existing beacon layout.

While there is little likelihood of damage to the Taiaroa Head lighthouse and the function which it performs, sector lights, beacons and the radio communications equipment associated with reception of vessels may suffer from derangement and need adjustment.

Otago Harbour is divided in two by the Halfway Islands - Goat Island and Quarantine Island and the possible effects of an earthquake on the beacons is different in each part of the harbour. The lower harbour from the landfall beacon to the channel between the halfway islands will be considered first.

The landfall beacon is a major structure, designed to remain in place during the worst storms that nature can produce, so it is possible that it will remain in place in all but the most severe earthquake or tsunami. The channel beacons, however, could easily be dislodged in an earthquake and the channel itself could be filled in by movement of the mainly sand and mud bottom of the harbour, resulting in obstruction or closure of the channel from Port Chalmers to the sea to ships of up to 12.5m draft and 260m LOA (length). Provided that one of the two pilot cutters "Potiki" and "Ototoa", and work-boat "Kapu", survive the earthquake, the channel could be surveyed reasonably quickly and a navigable channel found. With modern equipment, one of these three vessels could guide and escort ships to and from Port Chalmers during daylight hours in reasonable weather, even if all the beacons had been dislodged or destroyed.

The loss of the channel beacons in the upper harbour would be a more serious matter, as the main channel in the upper harbour, Victoria Channel, is not a natural channel but is dredged, and has a training or restraining wall on the southern and eastern side for most of its length. In a major earthquake it is quite possible for this training wall to collapse into the Victoria Channel, taking some or all of the beacons with it. As this channel is narrow and shallow (ships using it are restricted to 8.0m draft, 29.0m beam and 185m LOA) a collapse of the wall could have serious repercussions and vessels would not be able to use it until it had been fully

surveyed and dredged. Any ships at the wharfs at Dunedin and Ravensbourne, including tankers at the Oil Jetty, and LPG tanker at the Liquigas Terminal, could be effectively trapped until the channel is cleared. It is probable that the beacons marking the shallow-draft Eastern Channel would survive even a serious earthquake. This is a natural channel and can be used during daylight hours at or near high tide by small vessels with shallow draft.

Finally, one other part of the harbour where beacons could be lost in an earthquake is the swinging basin opposite the Port Chalmers wharfs. The edge of this basin has been dredged to just over 12.0m, with a very steep, almost vertical side and in an earthquake, this edge could tumble into the basin, taking beacons with it, which could greatly hinder the larger vessels such as container ships using the Port Chalmers wharfs.

Harbour access is likely to be limited until revised channel and sea bed profiles can be established.

Berthing Facilities

In terms of importance to the port, the Port Chalmers berthing facilities are seen to be at greater risk than those in the upper harbour. Because of the influence of filled ground and inferred proximity to fault lines running up the harbour, the container wharf, multipurpose wharf and outer Beach Street wharf are vulnerable to earthquake. The principal cause of failure in credible earthquake conditions would be due to settlement combined with sliding induced by liquefaction, which would, in turn, be influences upon mechanical equipment and underground services in the area. Repairs to these facilities, which represent vital economic assets to the port and city economy could be lengthy.

So far as the Dunedin wharfs are concerned, there is likely to be severe damage to the older piled wharfs due to settlement and horizontal translation of walls and fill beneath the structures. From an economic view, the Ravensbourne, LPG and Oil wharfs are especially important and will suffer from a limited amount of structural and mechanical failure in the same way as the internal Dunedin wharfs, but with the need for re-establishment being greater due to the unique nature of the services which they offer.

In all locations we must anticipate disruption of road access and hardstanding areas adjacent to wharfage due to settlement, liquefaction and heave. Particularly badly damaged areas are likely to occur in the old timber wharf areas of the extreme upper harbour, which will suffer from mechanical failure of piles, transoms and decking to an extent that repair would be difficult.

The ship repair slipway (Sims Engineering) is likely to suffer extensive damage in credible earthquake conditions and reinstatement will be required because of the unique nature of the facilities.

Cargo Handling

Examination of equipment used in cargo handling reveals a considerable risk to container gantry cranes, which may be damaged due to shaking combined with settlement of the wharf track upon which they run, or by direct overturning due to earthquake shake. It may be expected that buckling of crane legs will occur, with derangement of mechanical running gear and jib extensions being a major cause of severe damage in credible earthquake conditions.

Straddle carriers and other mobile equipment is at similar risk to the gantry cranes but, because of their numbers, the overall vulnerability is lowered.

Oil product storage tanks may be distorted by settlement and "slop failure" of the walls in earthquake shaking. Due to the configuration of storage, LPG storage should be less heavily damaged. Cement import facilities are potentially subject to damage due to settlement and wall failure and cold storage may suffer from panel dislodgement, foundation settlement (because of proximity to wharf frontage) and general mechanical derangement.

Tugs and dredges are thought to be reasonably secure from earthquake effects but may be subjected to damage due to falling equipment, wharf faces etc, and to the effect of tsunamis.

Buildings and Hardstandings

Subject to vulnerability from earthquake shaking and liquefaction are the hardstanding areas of the container storage yard and the log stacking area. Because of the nature of the fill and location of these areas, settlement

and liquefaction damage will occur and be more serious for the container hardstanding than for the log area because of its finished surface and drainage channel formation and the extensive underground electrical services in the refrigerated container area which will probably need to be relaid.

Newer buildings, designed for earthquake resistance, are likely to survive earthquake with some damage to the internal hardstanding. Older buildings, such as the Victoria and Birch Street wharf sheds, are likely to suffer considerable damage and may be irreparable, although operable in the short term.

Transport Links

Road access to Dunedin is likely to suffer from earthquake shaking, liquefaction and landslip along its length and other transport routes are likely to be in worse condition. The disruption is expected to be of relatively short duration, measured in days rather than weeks.

Rail traffic is likely to suffer in much the same way as the roading, but with more serious effect upon the track and grade. It is anticipated the disruption will be extensive due to faulting, shake, settlement and, in some instances, to liquefaction. There is also the prospect of some damage by tidal surge or tsunami, but with a low probability. Extensive rebuilding of the embankments which cross the various bays between Dunedin and Port Chalmers may be required.

Utilities

The supply of water, fuel, gas services and removal of waste water will be disrupted by earthquake and are deserving of careful individual appreciation.

Supply of electricity or standby facilities needs to be reviewed, as severing of cables and toppling of overhead supply will effectively close the port. Currently the port has no standby power facilities.

Operations such as container cleansing, maintenance of temperature (for reefer and other frozen cargoes) and repair facilities are matters for consideration as general derangement is to be expected unless special arrangements to prevent fracture or other mechanical failures is in place.

Communications networks are essential to the proper operation of the port and these are likely to be seriously disrupted by any significant seismic or tidal event.

Other Facilities

The floating plant is considered to be relatively secure, with widely dispersed locations and offering minimal risk from all hazard events except tsunami.

Ship repair and servicing facilities are subject to damage from earthquake and it may be expected that wharfs and mechanical equipment will suffer damage.

Electronic equipment installed in the signal station at Taiaroa Head will suffer from seismic shaking.

HARBOUR - MITIGATION STRATEGIES

Sea Channel

Because of the nature of the sea channel, it is considered that no commercially viable mitigatory work may be undertaken which might significantly increase the survivability of the dredged slopes. In the event of a major earthquake it would be necessary to dredge the channel to restore depth and this operation could extend over several months.

Loss of navigational channel beacons is probable in a severe earthquake event, but as with the channel slopes, it is not practical to undertake any mitigatory work. Rapid reinstatement following dredging would need to be managed, but inevitably the upper harbour would need the most urgent treatment if the fuel wharfs are to be kept open.

Berthing Facilities

There is likely to be only moderate and fairly superficial damage to the container wharfs which have been designed for earthquake impact, but the Victoria wharf in the upper harbour is likely to suffer extensively. No mitigatory action will be undertaken on either of the wharf systems; Victoria wharf on economic grounds and the container wharfs because they are already designed to high standards.

Cargo Handling

Consideration of potential damage to the two container gantry cranes from earthquake shaking leads to the conclusion that mitigation measures are likely to be largely ineffective and that the best method to adopt is management of repair work on a basis of urgency. The possible modification of cranes involving braking and holding-down improvements is currently under investigation. Similar policies relate to the straddle carrier fleet and other mobile equipment, with a number of minor items such as securing of tankage and further review of port installations underway.

Buildings

Newer buildings at Port Chalmers and in the upper Dunedin harbour area are not in need of further upgrading, but some older structures at the Victoria and Birch Street wharfs will be damaged but it is not considered that mitigation works would be cost effective.

External storage areas have been examined and mitigation in the form of managed repair after the event is the adopted strategy.

It is recognised that there will be extensive superficial damage to many port structures but it is impossible to determine location of inherent weaknesses with any certainty and expenditure on universal mitigation engineering would be prohibitive.

Transport Links

Damage occasioned by earthquake shaking, liquefaction and consequent settlement of both road and rail connections will be repaired following the event as it is considered to be impossible to cost effectively protect the systems by meaningful mitigation engineering. Track and roading within the port area will be restored in a planned exercise involving equipment owned by or leased to Port Otago Limited.

Utilities

Some disruption of services in the supply of water, fuel etc. and removal of waste products is expected as a result of earthquake shaking, but there is currently no guidance available as to where these services might be damaged and accordingly it is proposed to manage the reinstatement following the event.

Note has been made of potential for damage by settlement between piled wharf structures and filled ground and future design work will incorporate protective measures.

The supply of electrical power for refrigerated container outlets and motive power for the container cranes is a critical aspect of port working, so provision of an alternative power supply to assure a minimum supply for these activities is to be addressed as a priority.

Other Facilities

There are no mitigation activities planned for dredges, dumb barges and other floating equipment as it is believed these elements will survive most natural hazards without damage.

Ship repair installations at Port Chalmers and in the upper harbour at Birch and Kitchener Street wharfs will not have any further strengthening works carried out for economic reasons.

Examination of Taiaroa Head lighthouse leads to the conclusion that some work should be done in securing the essential communications equipment, which may be achieved at very modest cost. Planning towards duplication of signal station function should be considered and funding secured.

Conclusions

The study has indicated that there are a number of harbour and port assets which are vulnerable to earthquakes and other extreme events. The port area in Dunedin is older and more vulnerable than the newer facilities at Port Chalmers, but as it is only able to accommodate vessels of 8m draught or less, Dunedin is less critical.

Access to the berths from the sea as well as land will be crucial after a hazard event as many relief provisions will probably be brought in by sea. In this regard the areas of critical concern are the navigational channels, the container berth at Port Chalmers and the Victoria Wharf in Dunedin.

The interdependency of the port facilities with other services such as road and rail access, power, water and communications connections is crucial for the recovery of the city and region after a hazard event. These links and interdependencies need to be recorded and reinforced by regular meetings and re-evaluations.

Recommendations

It is essential that the port company designs for hazard events in all new facilities and that it be sensitive to the need for attention to the existing operations, structures and equipment. Of particular concern is equipment such as computers which is critical for the successful operation of a modern port. It is essential that such equipment is properly located and secured to ensure it is safe from all but the severest hazard events.

There is a need for continued review of potential structural weaknesses and development of improved contingency planning to deal with hazard events, the results of which are not predictable.

It is recommended that Port Otago Limited continue to be involved in all the meetings arranged by the Lifelines Project.

RAIL SYSTEMS - DESCRIPTION OF SERVICE

General Description

Dunedin is connected to the railway by the Main South Line which runs from Lyttelton to Bluff. There are two short branch lines in the Dunedin area, the Port Chalmers industrial line which runs from Sawyers Bay to Port Chalmers and the Taieri branch which commences at Wingatui. In Dunedin itself there are many private sidings, a large marshalling yard and the E Yard Freight Branch site on Strathallan Street.

Main Trunk Line - North

Track

The line running north from Dunedin follows the harbour edge on a man-made causeway to Sawyers Bay where it then climbs firstly over the hills to Waitati and secondly over the hills to Merton. There are crossing loops and storage tracks at several places en route, including Sawyers Bay, Waitati, Seacliff, Merton and Waikouaiti. The line runs at low level alongside Blueskin Bay between Waitati and Evansdale.

Bridges

Significant bridges north of Dunedin are over the Leith Stream, Waitati Stream, Waikouaiti estuary and the Shag river beyond Palmerston.

Tunnels

There are five tunnels between Dunedin and Oamaru:

- Tunnel 8, Roseneath Tunnel (320m) between Sawyers Bay and St Leonards.
- Tunnel 7, Mansford Tunnel (200m) at upper Port Chalmers.
- Tunnel 5, Mihiwaka (1300m) between Purakanui and Sawyers Bay.
- Tunnel 4, Cliffs Tunnel (280m) between Waitati and Purakanui.
- Tunnel 2 at Otepopo (220m) between Hampden and Waianakarua.

and one other on the Port Chalmers branch.

Main Trunk Line - South

Track

The line south of Dunedin runs through Caversham to Green Island, then to Wingatui, Mosgiel and over the Taieri Plains to Milton. The track follows an easy route through Caversham Valley, the Caversham Tunnel to Burnside, then east of Fairfield, through the Wingatui Tunnel to Wingatui. The track then generally follows the State Highway to Milton. There are connections to Hillside workshops, and storage or crossing tracks at Burnside, Green Island, Mosgiel and Milton. The Taieri branch connects at Wingatui and this then joins to the Taieri Gorge Railway.

Bridges

There are few significant bridges on the Main Trunk Line - South with the exception of the Taieri and Waipori River bridges near Henley.

Tunnels

The Caversham Tunnel (1,400m) from Caversham to Burnside is cut in sandstone and is unlined. It was built as a two track tunnel but is now only one track. The Wingatui Tunnel (900m) is cut through schist rock, is brick lined and was built to carry two tracks, now reduced to one.

Rail Operations

Railway Yards

There are three main concentrations of yard tracks in Dunedin:

- The passenger yard track at the Railway Station - primarily used for storage.
- The marshalling yard - used exclusively for making up and breaking up main line trains and shunts.
- The freight branch yards - used for loading and unloading freight and containers into or onto wagons.

There is also siding space at Sawyers Bay, Port Chalmers, Burnside and Mosgiel.

Local rail operations are controlled from the Dunedin Operations Terminal. There are two levels of control; all local shunt movements are directed by local Operations Controllers and all main line movements (shunts and main line trains) are controlled by Train Control. Dunedin Train Control coverage extends from Oamaru to Bluff, including all branch lines. Many aspects of train management, ie equipment allocation, are organised in Head Office in Wellington.

Locomotive Maintenance Depot

The Cumberland Street Locomotive Depot is used for servicing (fuelling etc), maintenance and repair of locomotives. It has two servicing tracks in the fuelling bay and three tracks in the repair depot, two of which are elevated, allowing easy access to underframe componentry.

Mechanical Maintenance

There are maintenance staff located at the depot on Cumberland Street and at the crane depot on the freight branch site. In addition there is a mobile wagon maintenance team which travels from siding to siding checking and repairing wagons. This team has heavy lifting traversing jacks available for use in rerailling locomotives and wagons. Hillside Workshops on Hillside Road, constructs new wagons and carries out heavy repairs. Major locomotive repairs are carried out in Christchurch.

Track, Structures, Signals and Communications

Staff responsible for track, structures, signals and communications maintenance are located at the Locomotive Department on Cumberland Street. There are also track maintenance gangs located at Balclutha and Waitati which use hi-rail trucks, some equipped with machinery for cutting and bolting rails.

Tranz Rail has an Ericsson telephone exchange located at its Operations Terminal and operates its own telephone network nationwide. It also has a radio network for train control and for use by shunters and maintenance staff.

Freight Handling Facilities

The E Yard Freight Centre has several large warehouse-type buildings and is fully equipped with a forklift fleet varying in capability from 2 1/2 tonnes to 30 tonnes capacity and a fixed gantry for transferring containers. Tranz Rail has an owner/driver truck fleet.

Administration Buildings

The area is run from the Area Office at 27 Wharf Street with Operation Control located in the Terminal Building at 1 Strathallan Street. The freight branch is controlled from the Strathallan Street E Yard offices.

RAIL SYSTEMS - ASSESSMENT OF VULNERABILITY

General Description

The railway network is inherently susceptible to disruption due to the need to maintain well conditioned "line and level" over considerable length in locations which are particularly prone to hazards of one type or another.

Main Trunk Line - North

Track

Much of the line running north from Dunedin Railway Station lies upon filled ground and will suffer from distortion and settlement due to shaking and/or liquefaction during earthquake. In particular, the length from the station through to Port Chalmers is likely to suffer settlement in those sections on causeway and some lengths are susceptible to land slipping. Bearing in mind the (as yet unconfirmed) probability that there is major active faulting running down the harbour parallel to the line, this particular length is highly likely to suffer severe damage and the area around the Leith Bridge crossing particularly so.

The climb from Sawyers Bay to Mihiwaka Tunnel, and thence down to Waitati is not expected to suffer greatly from distortion due to shaking, but it is expected that there will be many slips which will require engineering work.

The line from Waitati through to Waikouaiti traverses low-lying ground and beyond Warrington rises on poor grade slip country, making this length susceptible to shaking, liquefaction, slip and possible tsunami effect. Some lengths of the high country line present a major damage potential due to slipping. At Cherry Farm there is a high potential of flooding and liquefaction settlement.

From Waikouaiti onwards to the city boundary, the line runs through country which is prone to slipping, but apart from short sections alongside Hawkesbury Lagoon this should not be a significant problem.



Railway Bridge over Water of Leith - Civil Defence

Bridges

The Leith Stream Bridge is close to a fault line and is likely to suffer settlement damage which, because of the short span may be readily reinstated unless the beams fail under lateral movement. There will be disruption to communication and signalling services, but it should be noted that this bridge also carries a number of other lifeline services.

The rail-over-road bridge at Sawyers Bay is considered to be at risk from earthquake shaking which may cause the box structures of the way-beams to slip from their supports, closing the line to the north.

The older road-over-rail bridge at Borlases Road may collapse across the track and the upper Port Chalmers rail bridge, located below the Scott Memorial, is also subject to damage by earthquake, though these are considered to be low risk events.

Bridges at Waitati and Warrington are of timber construction and may also be damaged by shaking, but are likely to be readily restored.

The structure at the Waikouaiti Estuary will present more serious problems for reinstatement in view of the length of crossing and its vulnerability to shaking, liquefaction effects and flooding. Slips will occur on both approaches so access may be difficult and repair work extended. Similar problems will be encountered at the Shag River bridge which lies further north.

Tunnels

Tunnels are expected to suffer damage to portals and internal failure of linings at points of weakness. Portal damage is expected to be particularly severe at the Mansford Tunnel and the Port Chalmers branch access tunnel, with lesser damage at Roseneath. Damage to Mihiwaka Tunnel is expected to be relatively minor.

The Cliffs Tunnel is most likely to be affected by rock falls blocking the line.

Main Trunk Line - South

Track

The line running south from Dunedin Railway Station is at risk from earthquake shaking and liquefaction effects in the area lying beyond Green Island, and considerable damage to line alignment and some settlement is expected.

Beyond Green Island to the city boundary, the line will be subject to derangement due to shaking and is also susceptible to flooding at certain locations. Through the hilly terrain from Green Island to Mosgiel, there are areas of potential slipping at cuttings.

Bridges

In the central city area, the Cumberland Street overpass is a modern construction which is expected to survive enhanced earthquake impact and, though it is anticipated that there may be carriageway damage to the bridge, this is unlikely to cause more than minor temporary interruption of rail services.

Close to the city, the Andersons Bay Road rail-bridge has been strengthened in recent years, but presents a possible risk of damage due to earthquake in view of its proximity to a fault line. Possible lateral displacement of the heavy steel support beams could cause failure. A similar risk applies to the Glen overbridge, which is within 500 metres of an active fault line. Neither bridge is considered to present a very high level of risk, but both are subject to damage in credible earthquake conditions because of enhanced shaking and are both critical to rail operations to the south.

The rail bridges over the Taieri and Waipori rivers are both substantial and are expected to survive earthquake shaking and flood with minimal damage.

Several road over-rail-bridges exist, which may cause temporary disruption to rail service in the event that they collapse on to the track. In general, they are likely to cause obstruction due to abutment displacement and consequent collapse of spans in locations such as Kaikorai Valley Road, Abbotsford, South Road, Caversham and possibly at Wingatui. The more modern bridge over the rail at Allanton is likely to be slightly damaged at beam connections, but is considered unlikely to collapse on to the track.

Tunnels

The tunnels at Caversham and Wingatui are expected to cope reasonably well with the effects of earthquake, although the proximity of a fault line through Kaikorai Valley may induce severe damage to the portals of the Caversham tunnel and slipping adjacent to it. Wingatui Tunnel will probably suffer less damage, but some linings may be dislodged. Both tunnels should be readily re-instated.

Rail Operations

Railway Yards

All of the yards within the centre city area, together with those at Sawyers Bay, Port Chalmers, Mosgiel and Burnside, will suffer from distortion of the track due to earthquake and, in the event of high intensity shaking, areas of liquefaction will cause ground settlement. Disruption of services in these areas may be extensive, though the reinstatement time will not be great if access can be achieved.

Mechanical Maintenance/ Locomotive Maintenance Depot/ Freight Handling Facilities

Similar effects to those experienced in the railway yards will occur at these facilities, with disruption of services due to toppling of gantry structures and derangement of cranes likely to cause problems for maintenance.

Damage to pavement areas will affect the operation of forklift trucks and other freight handling equipment, seriously disrupting operations. Depending upon the priorities established for repair, this may not result in prolonged incapacity.

Damage to the locomotive turntable and diesel storage tanks will cause significant operating difficulty and the earthquake effect upon the turntable structure and alignment of rotational gear may be extensive and time consuming to repair.

Flooding of many of these areas is possible as most of the land is low-lying and possibly prone to tsunami.

Administration Buildings/ Hillside Workshops

All of these lie within an area which is susceptible to enhanced earthquake shaking and liquefaction, which is likely to cause some structural damage to buildings, particularly with respect to services and much inconvenience with respect to general access, storage etc. Heavy equipment in workshops will be damaged by misalignment and overturning and will take major restoration effort.

RAIL SYSTEMS - MITIGATION STRATEGIES

General Description

Tranz Rail New Zealand has adopted a high standard maintenance operation over their system throughout the southern area of New Zealand and believes that management of reinstatement of hazard damage presents the most economical and efficient means of mitigation.

There are a number of predominant at-risk elements within the system and strenuous efforts have been made, and continue to be made, to eliminate the worst of these with a view to shortening any periods of closure.

Vulnerability analysis has provided a good review of the potential weakness in the system components, but it is recognised that the extent of the required mitigation measures is not practical or likely to be cost effective.

Main Trunk Line - North

The track to the north is potentially the most susceptible part of the system because it encompasses steep gradients, tight curvature, tunnels, coastal causeways and areas of ground susceptible to landslip.

Typical of elements which require constant review and which may be progressively improved upon are:

- Leith rail bridge crossing structure.
- Mihiwaka tunnel portals/linings.
- Track stability from Mihiwaka tunnel to Waitati/Warrington.
- Kilmog track stability (continuing mitigation).
- Waikouaiti rail bridge.

These elements form the basis of current mitigation review.

Main Trunk Line - South

Generally at less risk than the northern route, there are elements which are susceptible to flooding. Much effort has been put into the control of flooding on the Taieri but it is unlikely that any measure by Tranz Rail other than total elevation of the track would be more effective than the work already carried out.

Examination of the Caversham tunnel portals and linings and the bridges over the Taieri and Waipori rivers may reveal minor elements of these structures which would benefit from mitigation.

Rail Operations

It is considered that any work on rail yards within the city area is likely to be ineffective and costly. Accordingly, any damage done to track and surface would be repaired after the event.

Reviewing the stability of buildings which control rail operations and securing of control systems is an ongoing function of operational staff and may be given greater prominence, particularly with reference to the principal office which stands on landfill prone to enhanced shaking and liquefaction.

The communications system operated by Tranz Rail represents a very important function in control and emergency contact. Accordingly, this element of the railway system should be critically reviewed and any mitigation designed to protect equipment and signalling functions.

Conclusions

Tranz Rail has a good preventative maintenance system in operation but intends to review elements of the “vulnerability analysis” to establish if more can be done to protect systems whilst maintaining cost effectiveness.

Recommendations

Continue the current maintenance programme and undertake progressive review of system weaknesses in respect of hazards.

AIR TRANSPORT - DESCRIPTION OF SERVICE

Dunedin Airport

General Description

Dunedin Airport is a public airport owned and administered by Dunedin Airport Limited and situated 11 nautical miles west of Dunedin City.

Runway

The runway is a modern sealed surface some 1,900 metres long and 46 metres wide, capable of accepting heavy, jet engined aircraft. Normal services can handle Boeing 767 aircraft and in emergency conditions larger aircraft can be accommodated.

Terminal Building and Offices

The terminal building has a ground floor area, first floor administration offices, two first floor air bridges, serving commercial airlines and the new international departure lounge.

Buildings have been developed since the original construction in the 1960's and consist of a steel frame, with timber and steel faced walls, which are substantially braced. Recent developments have added the international departure area and a separate modern single-story building for international arrivals and customs. Other buildings within the airport area are:

- Tower annex (Airways Corporation)
- Rescue fire garage and offices
- Three hangers
- Control tower / technical workshop (Airways Corporation)
- Power centre (Airways Corporation)
- Water treatment building
- Sewerage plant

Power

Mains supply is via two separate lines; one from Berwick the other from Outram. These services are overhead lines which terminate at a transformer point located about 200 metres from the main terminal. There is no standby power available, other than for the Airways Corporation building and facilities associated with air traffic control. The terminal building switchgear is in the power centre.

Water

Mains water is supplied from the West Taieri Rural Water Scheme. This is supplied as treated water which is distributed to the terminal building and other locations by a pneumatic pressure system. The water is pressurised and pumped electrically and a standby diesel pump is located in the pumphouse for firefighting and back-up domestic service. The pumphouse is located some 200 metres from the terminal building and is contained in a block wall and concrete structure. All pipe work is in steel.

Sewerage

Waste water is treated on site at the airport sewerage plant located some 500 meters north-west of the terminal building. Sewerage from the airport village is also processed here. Treatment involves primary settlement and oxidation pond retention, with sewage pumped electrically from pumping sumps located close to the airport buildings.

Drainage

Surface water within the airport boundary is collected by gravity drains which run parallel to each side of the runway into a collection channel which runs at right angles to the runway halfway along its length. This surface water is removed by pumping from an intake structure which delivers directly to an Otago Regional Council open channel to the west of the airport. Pumping is by five electric pumps which are served by the general power supply and which have no standby power.

Further drains collect run off from the north and south ends of the runway and discharge by gravity to the open drainage channel on the west.

Rescue Fire

Two Unipower rescue fire vehicles are permanently based at the airport with three dedicated staff. No other emergency services are based at the airport, but local services are on call.

The terminal and hanger buildings are protected by sprinkler systems connected to the water supply. The water supply can be supplemented from that held in concrete tanks adjacent to the pumphouse.

Fuelling and Servicing

Supplies of aviation fuel are available from a modern tank and pumping system located some 200 metres south-west of the control tower building. Tanks and pumping equipment are protected by a concrete bund and provide Jet A1 and Avgas to aircraft by direct pumping or by tanker. Servicing and storage facilities for light aircraft are at the northern end of the complex.

Communications

Telephone lines service Dunedin Airport Limited, Mainland Air, Air New Zealand, Ansett New Zealand, and Flightline Aviation.

A public address system within the terminal building and UHF radios are operated by Dunedin Airport Limited and Airways Corporation of New Zealand Ltd.

Ground to aircraft radio communication is operated by Airways Corporation Limited.

Other Landing Facilities**Taieri Airfield**

This is a non-certificated private airfield operated by Otago Aero Club Inc. and situated six nautical miles west of Dunedin City on the northern boundary of Mosgiel township. There is no runway lighting and no night flying is possible without using flare canisters. The grass runway can accommodate machines of capacity up to and including Group 7 aircraft.

Dunedin City Heliport

A non-certificated heliport operated by the Dunedin City Council is situated at Kitchener Street, adjacent to the harbour.

Dunedin Hospital Heliport

A recent development has been the construction of a heliport on the roof of Dunedin Hospital.

Fuelling and Servicing

Limited supplies of Jet A1 and Avgas fuel, along with general service facilities are available at Taieri Airport, but neither the Dunedin City nor Dunedin Hospital heliport have fuel or servicing capability.

Communications

Taieri Airfield and both helipads use the standard unattended aerodrome procedures on VHF radio frequency 119.1 MHz.

Airways Control System

General Description

Dunedin Air Traffic Control, operated by Airways Corporation of New Zealand Limited, supplies aerodrome and approach control services within its associated CTR (Control Zone) and TMA (Terminal Approach Area).

Control Tower and Other Buildings

The control tower, situated at the southern end of the main terminal building, is constructed of reinforced concrete on a floating foundation. It is some 20m high in four levels. The tower cab is the operational control position, the second and third levels are offices and the ground floor is the technical centre. Located to the south west of the tower building is an annex housing the airport caterers.

Power Centre and Standby Power

The main electrical distribution centre and the standby generator are in the power centre adjacent to the control tower. Standby power is available immediately and automatically on the failure of both mains power sources. All on-airport navigational aids, airfield lighting and essential operational data processing are provided with emergency power. Standby battery power is available to the Mosgiel and Henley NDB navigational aids and to essential circle guidance lights.

Runway Lighting

The runway and approach lighting is arranged in two separate circuits, each of which is capable of giving adequate night operational capacity. Runway and taxiway lighting may be operated by remote ground control.

Communications

Communications to the control tower is by telephone and by radio for aviation control, using the following frequencies:

- 120.7 MHz (long range).
- 122.4 MHz (short range).
- 119.5 MHz.

AIR TRANSPORT - ASSESSMENT OF VULNERABILITY

Dunedin Airport

General Description

Located on the flood-plain of the Taieri, the airport has some history of flooding and notwithstanding major engineering works designed to alleviate this particular hazard, there remains a probability of recurrence.

The airport and the approach roads lie within an enhanced earthquake shaking area and there is some possibility of liquefaction if the shaking intensity exceeds MMVIII on the Modified Mercalli scale.

Runway

The runway is constructed on Taieri Plain alluvium with a substantial asphaltic sealed base course.

The flooding of 1980 was observed to do little damage to the pavement and the surface survived well. The generally high water table is persistent and prevention of inundation is dependant upon pumping and open channel flow and these elements of drainage are particularly susceptible to hazard damage.

Because of the generally uniform alluvial strata of the Taieri Plain and the form of construction of the runway, it is considered that flooding will cause little surface deviation or settlement.

The effect of earthquake shaking and liquefaction settlement associated with high intensity earthquake may be more selective, but it is again expected that there will be minimal differential settlement of the runway. Some cracking of asphaltic runway surface may be expected, but repair is likely to be relatively easy and the runway will not be out of service for lengthy periods.

Hardstanding Areas

The hardstanding areas in front of the buildings and at the hangers will possibly suffer from more damage than the runway in an earthquake, principally at expansion jointing and in the surrounding areas where

fuel systems are built into the sub-grade. These vulnerabilities are not seen as having a long-standing effect on air transport.

Terminal Buildings and Offices

The airport terminal buildings and offices are subject to flooding which will render them inoperative. This is likely to be of relatively short duration and, though destructive, will not be excessively costly to the structural fabric.

The building is likely to survive earthquake shaking but with some internal damage to services, drainage and communication equipment. Damage to the upper office levels due to shaking will be confined to displacement of equipment and probably destruction of glass in windows etc. The air-bridge system may be damaged and the electrical services made inoperable for a short term following an earthquake.

Vulnerability to meteorological hazard is well understood by airport administration and appropriate operating procedures are already in place, with closure of the airport as the ultimate solution in most cases. Damage has historically been relatively light and there appears to be no significant improvement to structures which might be made to enhance survivability of the service. Random damage by windstorm, cessation of service due to snow and ice and the incidence of heavy rainfall are all likely to be of short duration and readily repaired.

Other Buildings

The main hangers, international arrival building, water treatment building and sewage disposal system are all expected to suffer minimal damage due to flood or earthquake. Reticulation systems will be fractured in some building connections and will require repair before operating. In all cases, the damage will be repairable in the short term.

Power Supply

Both electrical substations which service the airport are subject to flooding and pole mounted electrical equipment is liable to damage by shaking due to earthquake.

Water and Sewerage Systems

The principal damage to the water supply system is likely to be caused by earthquake effect upon the pipeline delivering treated water to the airport, with the length of supply line being essentially non-redundant, raising the vulnerability. The three storage tanks for raw water supply are below ground level and therefore reasonably secure against shaking, but are expected to settle, causing damage to inlet and outlet pipework. Flooding may pollute the water system.

Domestic water supply and fire fighting system pumps are in the same building and are likely to survive earthquake. Pumping may be provided to the domestic system by the firefighting diesel pump system in the absence of mains power, with pumping dependent on continued diesel fuel supply.

Sewage disposal to the airport treatment plant will be subject to earthquake damage at pipe junctions with the buildings and may suffer from some joint failures due to enhanced shaking of the pipeline to the treatment plant. Major damage to the treatment plant itself is not expected, but there may be some derangement of the equipment which will require adjustment.

Airport Drainage

There is expected to be little damage from earthquake to the open drainage system which serves the airport area. Some displacement of drain crossings may occur and there are likely to be minor bank face slippages due to shaking. The pumping station at the south end of the collector system and gravity drains are likewise susceptible to damage by shaking.

Other Landing Facilities

Taieri Airfield

Operation of this airfield may be impossible for limited periods due to either flooding from the Silverstream or enhanced earthquake shaking.

Access to the airfield may be made difficult due to flooding or displacement of the access bridge, but the overall period to re-establish services may be short. Generally speaking, the use of the airfield by helicopters and fixed wing aircraft will be easily re-established provided road access is available.

Dunedin City Heliport

This is on filled ground, subject to enhanced earthquake shaking and potential liquefaction. Located on the foreshore, it is an area which may also be at hazard from tsunamis.

Dunedin Hospital Heliport

The Dunedin Hospital helipad is of robust construction and designed to seismic standards. It is however particularly vulnerable to short term meteorological influences.

Airways Control System

General Description

The control system oversees most normal operations at Dunedin Airport and the surrounding area, but in an emergency situation its vulnerability does not restrict airport use, which can be continued under manual control.

Control Tower

Robustly constructed, the control tower is expected to be resistant to earthquake effects, though there is likely to be some minor damage to the reinforced concrete at a number of locations. Worst effects are likely to be due to equipment damage through insecure fixings and damage to glass.

Standby Power

Most buildings in the Airways Corporation control system are expected to suffer only minor damage in an earthquake with the worst damage being due to unrestrained movement of plant. In this respect, particular importance is directed to the standby generator and automatic start-up equipment which controls the emergency power supply.

Battery standby power for NDB navigation aids may be lost due to shaking, though reinstatement should be readily achieved provided access is available to the sites.

Runway Lighting and Navigational Aids

These are subject to dislocation of cable jointing and derangement of approach lighting from earthquake shaking. Re-alignment of navigational equipment will be required and close examination of all circuitry made before recommissioning of service, as it is expected that some cable damage may occur between building and exterior runs.

Particular recognition needs to be given to landing aids at Swampy Summit and approach lighting masts which are at risk of being affected by earthquake, flooding and severe weather conditions. Although much has been done to protect these installations, some damage is expected and, because of poor accessibility it may be difficult to reinstate services quickly.

AIR TRANSPORT- MITIGATION STRATEGIES

Dunedin Airport

Earthquake

The primary function of the airport depends upon the ability to land fixed wing aircraft on the runway and provision of an operable hardstanding area for parking and loading. Both the runway and hardstanding areas are of good quality flexible construction on consistent sub-grade and there is no evidence that differential settlement is probable. The nature of earthquake impact is likely to be uniform over these areas, with any effects due to settlement being unlikely to inhibit use. There is a possibility of some random surface deformation which would cause relatively short term closure, but it is impossible to determine where this might occur and the resulting problem would need to be addressed following impact. No meaningful mitigation work is likely to effectively improve survivability.

The buildings at the airport have been examined and although they may suffer some superficial damage to the fabric (including loss of glass and ceiling fittings), it is not expected to be of major consequence to operations, as repair work would be readily achieved. The building would continue to service the principal purpose of the airport but to a reduced level of convenience pending repair. The fittings and fixtures associated

with passenger handling, communications, air conditioning and fire prevention are likely to suffer most by shaking and, as these are relatively cheap to secure, this work should be undertaken as soon as possible (if not already completed).

There is expected to be damage to connections of water supply, sewage and power in the airport terminal caused by differential settlement between the buildings and the external connections and it may be possible to provide flexible joints to reduce loss of service. Securing pumps, meters, header tanks and hot water cylinders will be of considerable advantage. A more detailed examination of these systems is necessary in order to determine where cost effective work may be undertaken.

Flooding

Susceptibility to flooding remains a serious hazard consideration to airport operation but is a difficult and costly event to mitigate.

The incidence of heavy rainfall over a prolonged period is likely to cause concern because of the inability to rapidly and effectively drain the very considerable area of flat land outside the airport boundary. The airport area is capable of being drained by existing pumping systems but problems arise from back-flow when the external catchment is saturated. The solution of providing an enclosed airport peripheral bund is considered unacceptable on cost grounds, when related to the level of incidents, and in consideration of the relatively brief period of disruption usually involved.

The flood risk has been partially addressed by Otago Regional Council since the floods of 1980, but probably the best protection to the airport from flood is to ensure that all on-site drainage channels are kept clear and power supply for the pumps being made secure by installation of a standby generator.

Meteorological Effects

There are no effective mitigation strategies for wind or snow hazard on buildings, so it may be expected that some damage will occur to doors, canopies and the like from time to time, which will be dealt with by normal repair procedures. Items such as transmission aerials, lighting masts and the air bridges should be re-examined critically and strengthened where necessary against wind storm and snow loading damage. These facilities are not essential in the operation of the airport and incidental damage may be managed as repair work.

Technological Hazards

Examination of the airport area has not exposed any significant technological hazards which might seriously affect the operation of the service and incidental matters of security, protection of gas cylinders and fuel lines are regularly reviewed and adequately policed. The relatively isolated location and constant presence of security and operating staff ensure that limited opportunity exists for sabotage, and no further mitigatory action appears necessary.

Other Landing Facilities

Taieri Airfield

There is little which may be done to mitigate earthquake or flood damage to this airfield. In the event of earthquake it may be necessary to repair the undulations which could occur, but there is no way of assessing the extent of damage, nor where this may happen. Drainage runs naturally towards the Silverstream and mitigatory sub-surface drainage is not warranted in terms of cost effectiveness for this secondary airfield.

Dunedin City & Dunedin Hospital Heliports

In major emergency circumstances, alternative sites which are in less exposed locations will be used for helicopter operations. There is no cost effective mitigation warranted at either site.

Airways Control System

A review has been undertaken of the effects of the principal hazards of earthquake and flooding upon the functions of control. The impact of meteorological conditions and technological incidents are already part of the overall security system covering operational aspects of area control. As a result, there are no major physical mitigatory actions to be taken with respect to the control building, contents and standby facilities, all of which are expected to be adequate to resist earthquake and flooding hazards. Regular checks of seismic restraint of equipment are recommended.

Loss of airfield lighting, predominantly to the runway and hardstanding areas, has been identified as being temporarily correctable by the use of runway flares held at Taieri aerodrome and no further action is necessary in mitigation.

Termination of the two independent power supply lines to the airways control system at a common point on the south west edge of the airport administration area makes this location vulnerable and consideration should be given to separating the services to provide redundancy.

Conclusions

Examination of landing facilities, cargo handling and passenger processing has revealed that few practical mitigation measures need to be added to those currently in place.

Due to earlier experience with reference to flooding, a great deal has been learnt and measures put in place to reduce the impact of this hazard in the future.

Building systems and operational equipment, together with services such as water and sewage disposal may need improvement against earthquake shaking and this should be progressively undertaken following a physical review.

Power input and the provision of standby power supply needs review, particularly with reference to stormwater pumping.

Loss of access by road through Allanton, Outram and Henley may be a significant impediment to airport operations and should be reviewed.

Recommendations

In order to facilitate progress towards mitigation of earthquake and flooding hazards Dunedin Airport Limited intends to prepare a schedule of activity and commission a review of:

- Duplication of power supply to the airport area in general.
- Establishment of standby emergency power generation, with particular reference to stormwater pumping.
- Water supply and sewage system security against earthquake and flooding.
- Security of computer, control equipment, passenger handling and luggage systems, audio and visual equipment etc. with reference to earthquake shaking damage.
- Fire system, alarms, air conditioning and mechanical services for security from earthquake and flood.
- A schedule of spare component holdings and emergency lighting facilities within the terminal.

Dunedin Airport Limited has an existing emergency services plan which should be re-visited in respect of the findings of this review. Particular reference should be made to arrangements for testing and recovery of the runway and hardstanding facilities following earthquake or flood.

PUBLIC TRANSPORT/HEAVY HAULAGE - DESCRIPTION OF SERVICE

Introduction

The movement of people and goods is a critical function during and after a disaster. The availability of resources for this function are therefore considered as lifeline services.

Passenger Services

Dunedin has a range of passenger transport vehicles operating and available for the transfer of people from any hazard area. There are approximately 120 buses and 160 taxis operated by five bus companies and a number of small passenger services in the city. With minimal warning a range of vehicles can be made available for the collection and transfer of people within the emergency area.

Capacity of buses ranges up to a maximum load of about 70 passengers but difficulty may be experienced in cases where people have mobility problems. In this case the use of ambulances or specialist vehicles could

be required. Where high water or ground clearance is required, there are trucks available in the local fleet to meet the need.

Taxis companies operate radio dispatch communication systems to all their vehicles but bus operators tend to have more limited contact with their vehicles.

Heavy Haulage

In the Dunedin city area there are approximately 220 vehicles classed as heavy vehicles, ranging from one-tonne utilities through to 'B' train truck and trailer units up to 44 tonnes. Rigged trucks, articulated trucks and 'B' trains are the most common.

Because of the mobile nature of their use, it cannot be pre-determined where any operator's vehicles will be at the time of an emergency, although it can be assumed that a percentage will be at operators' depots and further percentage will be on main roads either north or south of Dunedin.

Heavy Vehicle Fleet Maintenance

Garaging

Most operators of heavy vehicles have their own yards which are located throughout the industrial areas of Dunedin. There is sufficient space in most to cater for extra vehicles so that problems in one area that might affect depot or vehicle availability can be addressed by sourcing or storing vehicles at another site. Not all sites have covered storage for vehicles but most have access to administration areas and workshop space.

Servicing of Vehicles

Servicing facilities are maintained by most operators with pit or hoist access on most sites. Comprehensive facilities that can cope with large numbers of vehicles are to be found in the industrial areas close to transport operators bases with easy access to the main vehicle thoroughfare. Parts availability, because of the different makes of vehicles, may not be easy, given the trend towards smaller stock holdings and the reliance on nationally centralised parts supplies. General servicing can be done by most competent diesel mechanics and there is a co-operative approach to problem solving in this industry that would see most vehicles back on the road in a relatively short time. Fuel supplies are available at recognised truck shops, service stations and operators yards.

NZ. Army Facilities

Transport under the control of NZ Army is not always available due to the exigencies of the service. The Bridgeman Street barracks is an ageing brick-built structure which is susceptible to enhanced earthquake shaking and may also be liable to flooding, due to the low lying surrounding ground and high water table

PUBLIC TRANSPORT & HEAVY HAULAGE - ASSESSMENT OF VULNERABILITY

Passenger Services

Services are geographically dispersed throughout the city and it is not anticipated that hazard impact will seriously deplete the stock of buses or taxis. The principal factors which will affect use of the fleet will be their dependence upon serviceable roads and a sufficiency of fuels.

A secondary factor which increases operational vulnerability is the loss of servicing facilities due to collapse of servicing structures from earthquake or isolation during flooding.

The Citibus Newton depot is just outside the enhanced earthquake area and probably less susceptible to flooding than other garages. Green Island, Mosgiel and Sawyers Bay depots are likewise reasonably secure from enhanced shaking and the overall picture is one of low vulnerability due to widespread resources.

Heavy Haulage

The vulnerability of some specialist vehicles, including cranes, to earthquake and flooding risk appears to be higher than the passenger service vehicles and other heavy haulage vehicles due to the fact that they are

generally resident in the industrial areas of the city which have a larger exposure to enhanced earthquake shaking, liquefaction and flooding. The overall risk, however, is still considered to be relatively low.

Heavy Vehicle Fleet Maintenance

Maintenance centres are well dispersed throughout the city, although some of the principal heavy haulage garages are in the industrial area where the effects of earthquake and flooding will cause greater damage to structures and to gantry cranes. An example of this is the heavy railway workshop in Hillside Road, but in general we would expect damage to be of low impact upon maintenance of fleets, with many reciprocal service arrangements in place.

PUBLIC TRANSPORT AND HEAVY HAULAGE - MITIGATION STRATEGIES

Passenger Services

Protection of passenger vehicles from the impact of hazard events in order to ensure their availability for evacuation purposes and transportation of workers in the period immediately following disaster depends largely upon location. The diversity of parking locations, will by itself, offer immunity from total loss of service and, as many vehicles are parked outside, there is little which may be done to mitigate damage. Consideration might be given to parking away from trees and structures such as high walls etc, which may collapse on vehicles and avoiding locations where flooding is known to occur.

There is a possibility of risk to fleet vehicles due to building or retaining wall collapse and there may be some mitigation measures which might be undertaken to upgrade workshops and the control systems involved in the operation of passenger services.

Fuel supply systems, particularly where overhead tanks are involved, should be re-examined for seismic restraint and, where gas or diesel heaters are installed in garages, the security of fixtures reviewed and strategies for protection from loss by fire should be considered.

Heavy Haulage

The wide diversity of garaging and location of working haulage vehicles make them less likely to be at risk by other than random hazard events. Because of the probable shortage of special use vehicles such as heavy cranes, crawler tractors, pumping vehicles etc, particular care is recommended with respect to their parking locations. Flooding maybe of more concern than earthquake in some locations.

Heavy Vehicle Fleet Maintenance

Owners have advised, through their assessment of vulnerability, that there is a wide distribution of locations at which maintenance is carried out and that the greatest risk to their facilities lies in enhanced earthquake shaking causing damage to buildings used for maintenance purposes with the worst feature being loss of gantry craneage and associated collapse upon vehicles. Owners should examine the stability of their buildings and incoming services.

Conclusion

Diversity of garaging location and maintenance depots renders the vehicle fleet at relatively low risk from natural hazards.

Matters which should be examined for mitigation are building structures, fuel supply tanks, cranes, operating systems and spares.

So far as has been reported by owners, mitigation action is likely to be centred upon a wide range of relatively minor expenditure on these elements. Transportation facilities remain vital to recovery of the city and surrounding area within an acceptable time scale and will contribute markedly to this being achieved.

Recommendations

Individual owners should review their operations and take appropriate steps to protect vital transportation resources from hazard events.