NETWORKS EXCURSION REPORT

Semester III Alternative Assessment

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12 Mathematics B

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12 MATHEMATICS B

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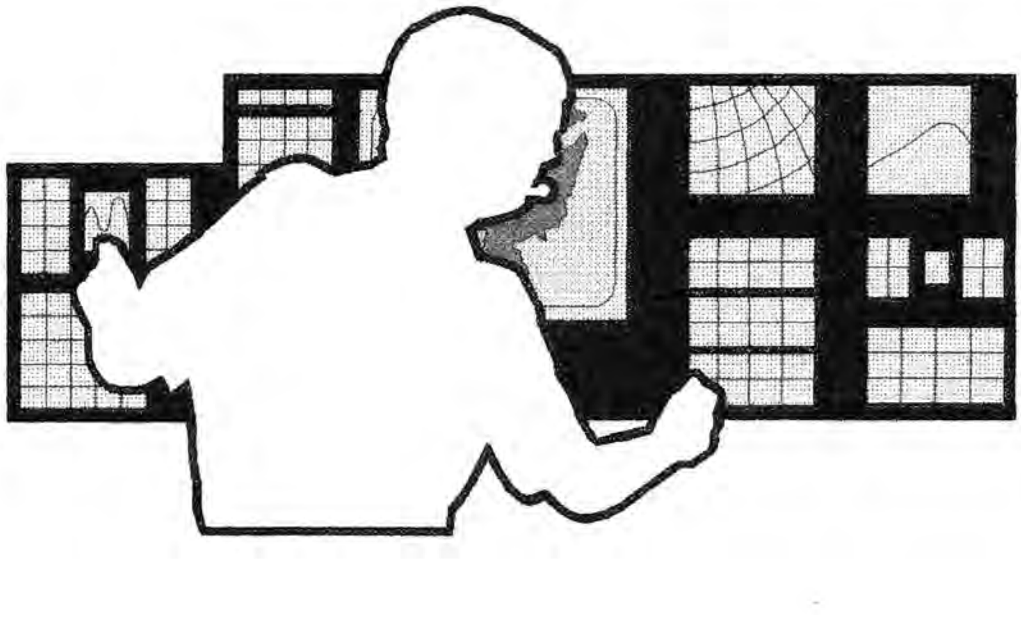
1. Introduction

On 26 April, 1996, the senior Mathematics B classes travelled to Rockhampton to investigate the use of networks in the modern world. We discovered that we are surrounded by networks including our state railway, the power generation and transmission system in Queensland and in the flight paths of aeroplanes. We learnt that the problems relating to the supply of such services can also be seen as mathematical network problems.



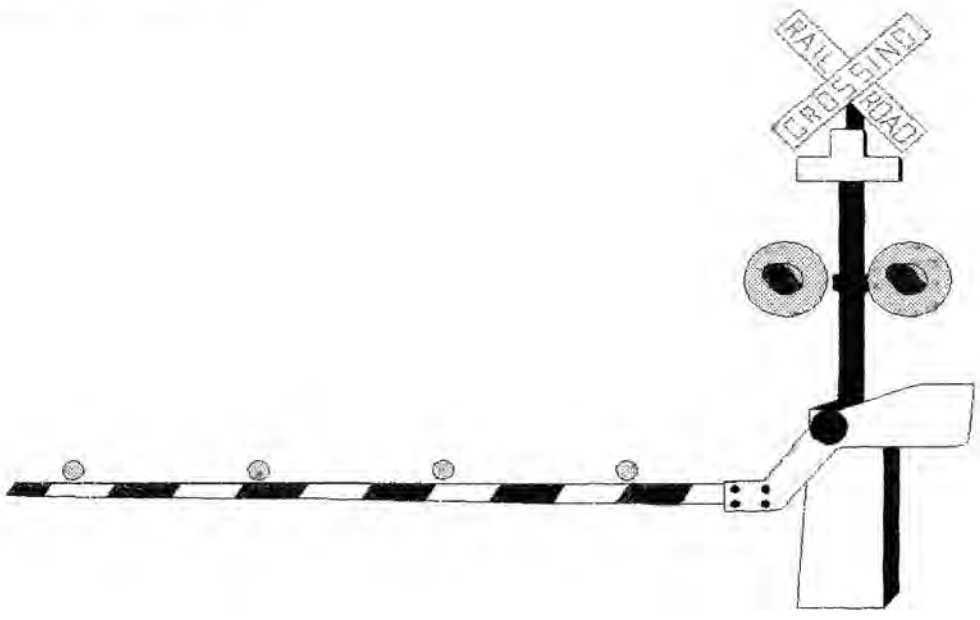
2.1 Queensland Rail

Investigate the control system for the network of trains and line throughout Central Queensland ...

Queensland Rail (Rockhampton) is responsible for controlling the "train traffic" on Central Queensland's railways lines. It is understood that it is vitally important for Queensland Rail to monitor and direct the flow of such traffic when we remember that trains travel on a single line, and without such direction the risk of collisions would be significantly high. This control is achieved by the use of relatively sophisticated computer equipment and radio messages which relay back to the command centre the information necessary in planning, directing and monitoring trains in their travels throughout our regional railway network.

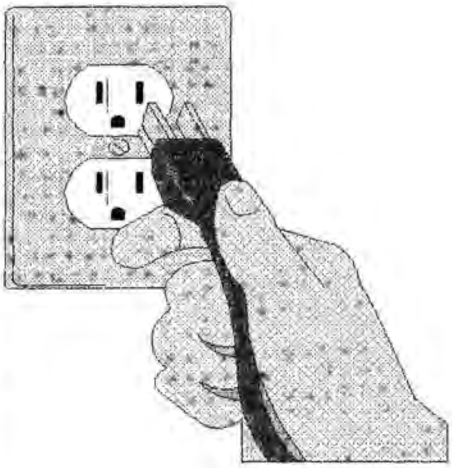
The control system operated by Queensland Rail is capable of permitting a single operator to control all train movements over distances of up to several hundred kilometres, however in the interest of safety, operators are only responsible for certain areas of the C.Q. rail network. This computerised control system reaches into virtually all aspects of railroad operations, from yard control and dispatching to information about car movements and inventory control. The primary aim of the system is to satisfy cost factors regarding train speed and efficiency while still ensuring that safety requirements are maintained.

In the command centre, the control system's current status and functions are displayed on a large panel lit with LED's. This panel represents the Central Queensland rail network with the track displayed as a directed network of edges; the direction of the edges being decided by the controller. Arrows near the edges are used to identify the destination of the train. Each station is thought of as a node and has a light on the panel which corresponds to it. Another light, representing the train, travels along this network, through the nodes - its speed and route determined by the operator's control of the various components of the railway's control system, as is the train's overall efficiency and safety.



2.2 Austa Electric's Stanwell Power Station

Investigate monitoring and control systems within in the station to ensure its efficient functioning and its place in the Queensland electricity grid ...



Stanwell Power Station, operated by Austa Electric and located twenty-eight kilometres west of Rockhampton, is a 1400 megawatt station that plays a key role in providing Queensland with reliable low-cost power. To ensure its efficient functioning, computerised control systems have been installed and are praised as being among the most technologically advanced in the world.

Video display screens and light pens make up the user interface to Stanwell's control and operating system and these devices are used to control individual items of the plant, when not being carried out automatically. Due to the advanced technology, the ergonomically efficient design of the control centre and the graphical interpretation of the power station's operation network (visual diagrammatic plan) (see appendix i), all routine functions are capable of being monitored by one person, and such is the case on weekends and public holidays.

Stanwell Power Station, a privately-operated plant, was designed with efficiency and cost effectiveness in mind. To reduce labour costs and for the long-term optimisation of the plant, the operating system consists of digital computer systems, linked to each other via coaxial cable and a CS275 bus network (see appendix ii). Each node of the network represents a part of the operating system, whether it be a computer terminal or an automatic processor, and the edges of this network depict the CS275 bus.

Furthermore, the operating system reflects the operations of the power plant with graphical plant mimic displays. These mimic displays form a picture of the power generation network, with turbines, pumps, motors and fans being represented by nodes and the edges depicting the heating, cooling and power transportation systems between them. The nodes are coloured, and can indicate whether the device is operating or not (ie. red for on, green for off). The controller, using this network representation, can easily determine and isolate any problem or error that arises during the plant's processes. Therefore, this innovative control system results in prompt and efficient maintenance of the plant's automatic power generation and ensures Stanwell operates at its full capacity.

In addition, it was quickly evident that Stanwell plays a major part in the power generation and transmission network in Queensland (see appendix iii).

2.3 Air Services Australia - Air Traffic Control

Investigate the place of Rockhampton in the national aviation network and the control tower's place in ensuring the safety of aircraft and efficient use of the airport and air space ...

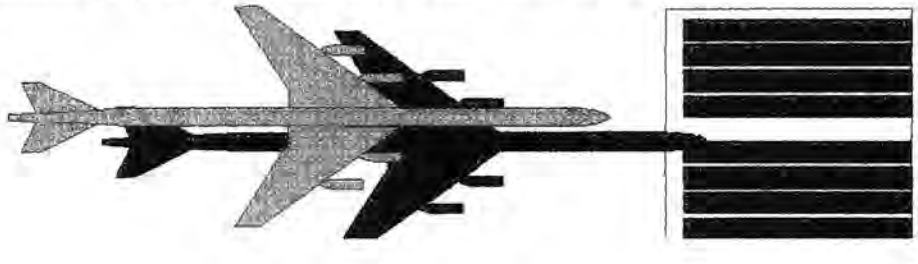
The most important structure at any airport is the traffic control tower. Located near the centre of the runway, the control tower is high enough to permit a clear view of landing, takeoff and loading areas. It contains a complex of communications and electronic surveillance gear, in addition to human-eye visual tracking, by which airport controllers monitor and direct all plane movements on or near the field.

All commercial airlines and most general-aviation flights operate according to flight plans. Prepared by pilots before their departure, flight plans are filed with the originating airport's traffic control and are then transmitted to the airport of destination. The mission statement of Air Services Australia provides for the "safe, orderly and expeditious flow of air traffic". This is achieved by ensuring flights follow predetermined networked routes, and reports being made from checkpoints along the airways.

Unlike conventional networks, flight plans are three-dimensional networks with edges having vertical height in addition to horizontal distance. Air Traffic Control therefore must give detailed landing instructions to pilots, in addition to their instructions whilst in the air. Approach routes to be followed, rate of descent, proximity of other aircraft, weather conditions and designated landing runways add to the factors which must be provided for when optimising an aeroplane's flight plan. For additional safety and flight efficiency, most advanced aircraft have precision navigation systems, either self-contained systems such as the inertial and Doppler systems or systems that rely on external help: VOR (Very high frequency Omnidirectional Radio), radar navigation, and systems using the Global Positioning Satellite System (GPS). Thus aircraft can maintain their position on fixed routes accurately, usually flying at known and reported flight levels (height above ground), and in the neighbourhood of airports can be controlled with the utmost precision by air traffic controllers.

When the multitude of flight plans are mapped, the implementation of networks can most clearly be recognised. Airports are depicted as nodes, and the flight path the aeroplanes follow are represented by directed edges. Special rules govern separation of traffic on different routes, therefore this network's edges have directed racetrack network (see appendix iv) to ensure that no two aeroplanes are ever travelling towards each other. To maintain this safety requirement, it is essential that no two planes ever be within one nautical mile of each other.

By following these objectives and rules, Air Traffic Control live up to their mission statement and provide the safe and orderly flow of air traffic in our skies.



3. Queensland Rail

Write a more detailed report with relation to the networks involved.

As stated previously, Queensland Rail's Central Queensland railway can be seen as a branch of mathematical networking. The command centre that controls "train traffic" has a computerised geometrical display representing our regional railway network. The track itself is identified as a directed network of edges; stations are in the form of nodes. The network is controlled by an operator, irrespective of whether it is an electric train system or that for diesel locomotives. The primary aim of the controller is to ensure efficiency and safety is maintained.

Mathematics relates to the Queensland Rail network in cost optimisation and time and distance efficiency. Dynamic programming is essential to the forward planning and calculation of train efficiency and Dijkstra's shortest-path algorithm can be used in a number of ways here. It is essential for a controller to find the shortest path in the railway network from one station (node) to another. One path that is vitally important is that which represents the lowest cost for the excursion. The costs involved include the cost of fuel for the locomotive or the amount of power required for an electric train to reach its destination. This can generally be found by taking into account two other paths, those of the shortest distance and the shortest time. The shortest distance is directly proportional to the lowest cost for the train to reach its destination, and the shortest time is usually proportional to the shortest distance path as well. Therefore, the command centre carefully plans a train's route from its beginning station to its destination with distances and cost optimisation in mind, finding the shortest path between nodes.

While the electric railway control system can alert the command centre of a problem or error within a kilometre or two of the cause or disruption to the system, the diesel locomotive's network must be checked manually by Queensland Rail servicemen. To do this, each track must be checked for damage. Postman circuits are effective here in allowing these railmen to cover each track (edge) at least once. At its most efficient, a Eulerian circuit would be required yet since every node on the Central Queensland railway network is not of an even degree, this is not possible. Therefore, Queensland Rail uses the postman problem to find the shortest circuit that permits the railmen to check every edge at least once, thereby maintaining efficiency in labour hours and wages.

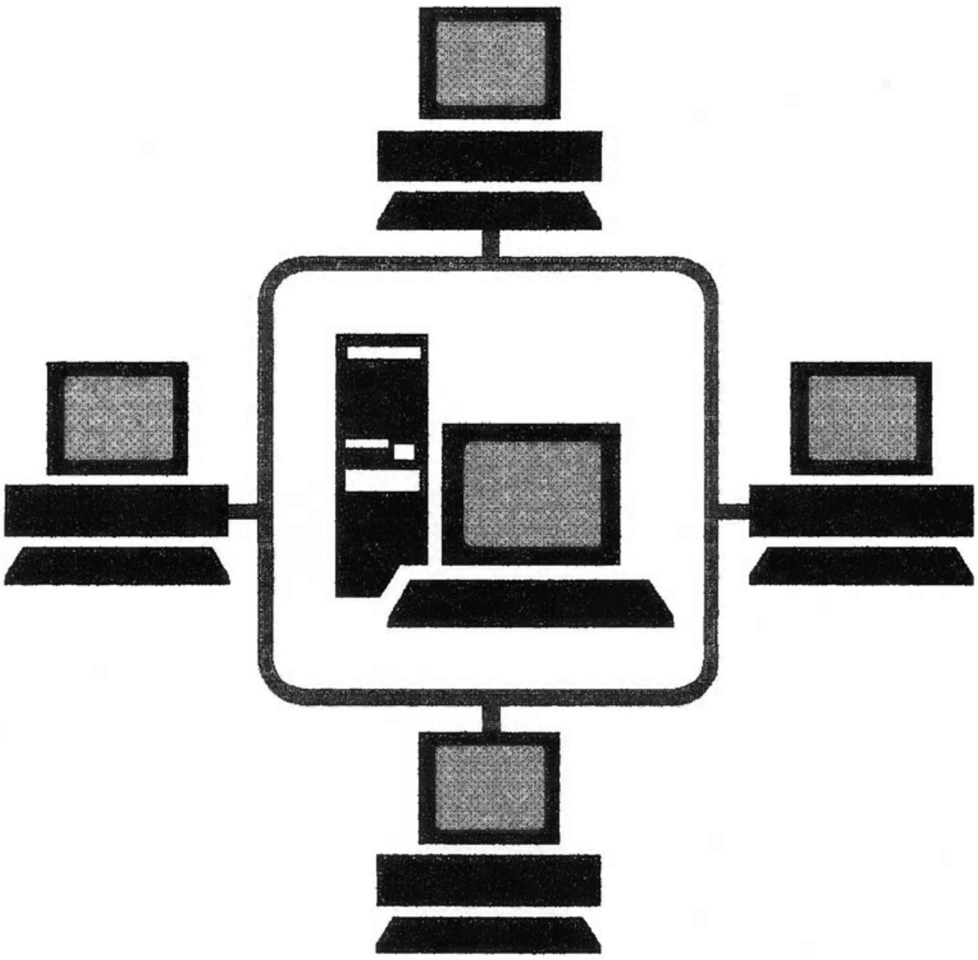
Similarly, Queensland Rail must maintain an efficient system where passengers travelling by rail may travel to a number of different destinations without the command centre having to have a large number of trains travelling at once. Salesman circuits are effective here in the planning of passenger trains along their networked routes. Due to the nature of the region's railway network, where only one or two tracks may exist between stations, a Hamiltonian circuit could not possibly be considered. Yet, the general salesman problem remains an effective way of ensuring efficient routes are planned and taken where possible for passenger trains, resulting in higher returns for Queensland Rail on excursions undertaken.

The critical path is a method used by Queensland Rail to find the minimum time necessary to complete an excursion from one destination to another. Any delay to the excursion causes the excursion to take longer to complete. The critical path is drawn graphically by one train controller in the command centre, who, by communicating with train drivers and station masters by radio, sketches the critical path for each train's excursion. Any delays encountered results in the controller having to sketch another critical path graph, which updates the estimated time of arrival/completion for each train's excursion. This information can then be relayed back by radio to station masters, who in turn, depending on the nature of the train's excursion, passes the information on to passengers or the like awaiting the arrival of a train at its destination. Therefore, the critical path method is an essential element in the planning of a train's ETA for its excursion on the railway network.

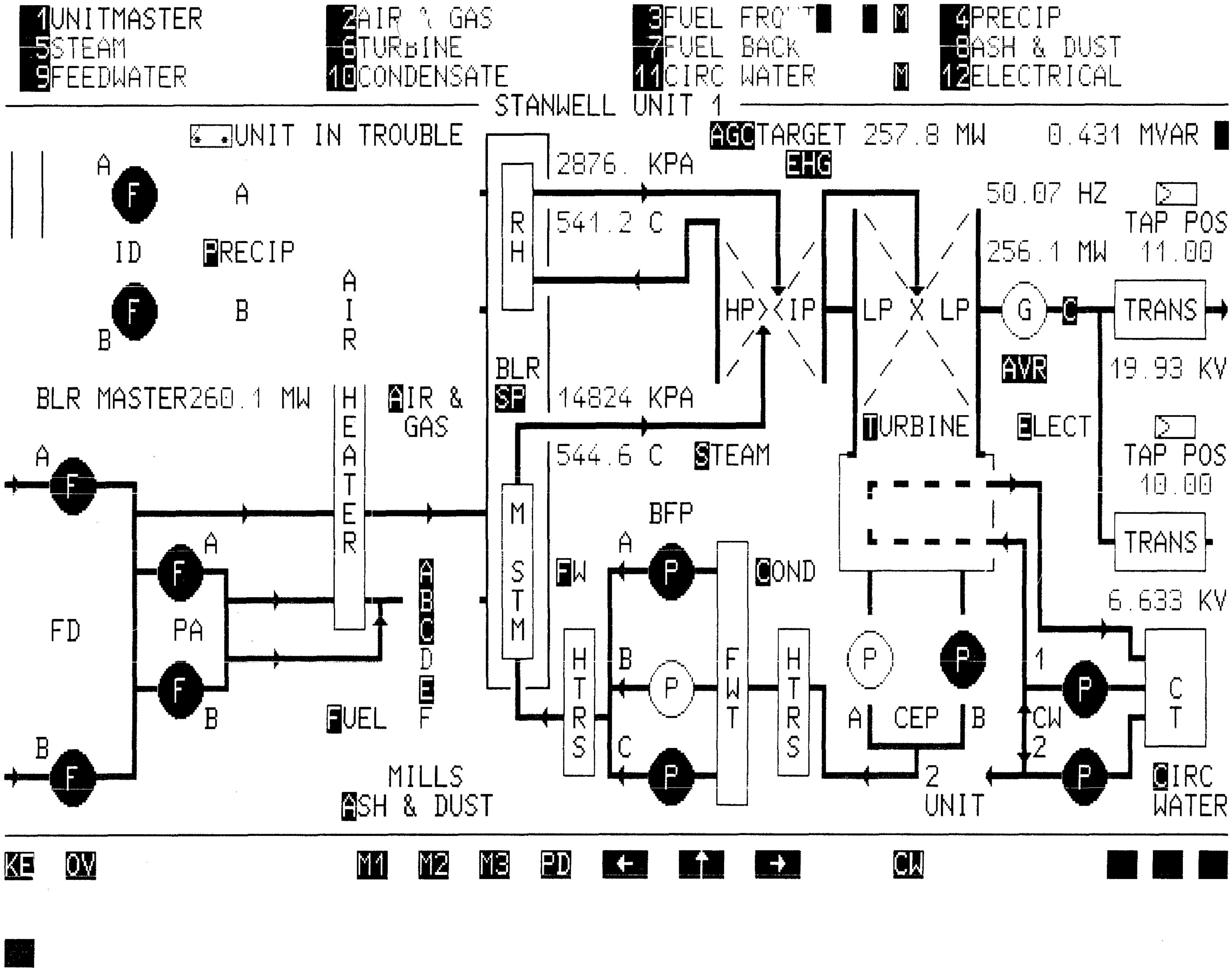
Clearly, many different facets of networking are used in the planning, monitoring and control of trains on their travels over our regional railway. Problems relating to the costs, distances and time spent on excursions can be seen as mathematical problems, which are solved every hour of every day using the computerised graphical represented network of our Central Queensland railway.

4. Conclusion

The senior Mathematics B excursion to Rockhampton opened our eyes to the variety of networks around us in the modern world. By looking at a number of examples, and by examining one such example in detail, it was easy to see that problems relating to cost optimisation, time and distance efficiency can also be seen as mathematical problems. We learnt that the way to solve such problems was to use a branch of geometry - the study of networks - and we saw that network problem solving techniques were used every day in a variety of different ways.



Appendix 1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2AIR & GAS
3FUEL FRONT
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4PRECIP
5STEAM
6TURBINE
7FUEL BACK
8ASH & DUST
9FEEDWATER
10CONDENSATE
11CIRC WATER
M
12ELECTRICAL
STANWELL UNIT 1
UNIT IN TROUBLE
AGCTARGET 257.8 MW
0.431 MVAR
EHG
2876. KPA
541.2 C
14824 KPA
544.6 C
50.07 HZ
256.1 MW
TAP POS 11.00
TAP POS 10.00
19.93 KV
6.633 KV
ID
PRECIP
A
B
F
AIR HEATER
BLR MASTER260.1 MW
AIR & GAS
BLR SP
RH
HP
IP
LP
LP
G
C
TRANS
TRANS
AVR
TURBINE
ELECT
STEAM
FD
PA
M STM
FW
BFP
COND
HTRS
FWT
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1
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CT
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M2
M3
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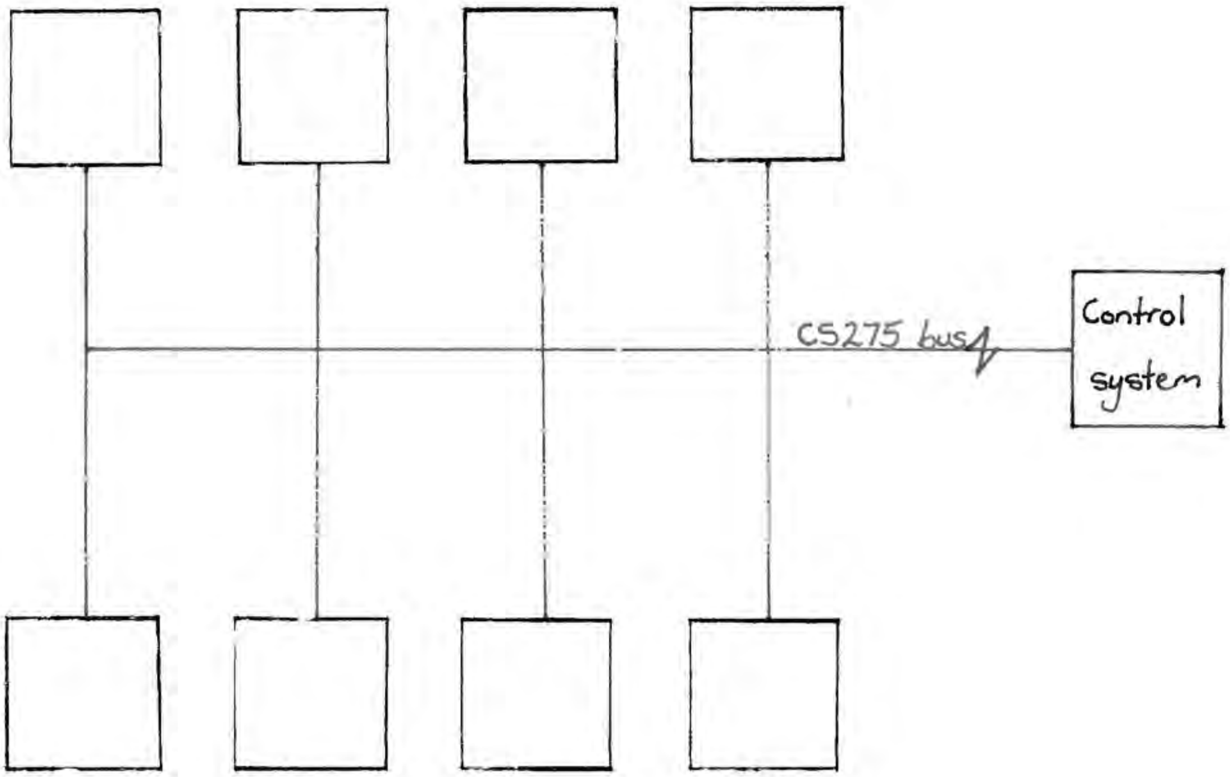
Appendix ii



Stanwell Power Station O.S.

Appendix iii

MAJOR POWER GENERATION AND TRANSMISSION SYSTEM IN QUEENSLAND

AUSTA ELECTRIC L[illegible]CATIONS

Business and Admin Centre
61 Mary St Brisbane Q 4000
GPO Box 636 Brisbane Q 4001
Telephone (07) 3228 7111
Fax (07) 3228 7100

Barron Gorge Power Station
PO Box 841 Cairns Q 4870
Telephone (070) 35 3213
Fax (070) 35 3467

Callide Power Station
PO Box 392 Biloela Q 4715
Telephone (079) 92 9329
Fax (079) 92 9328

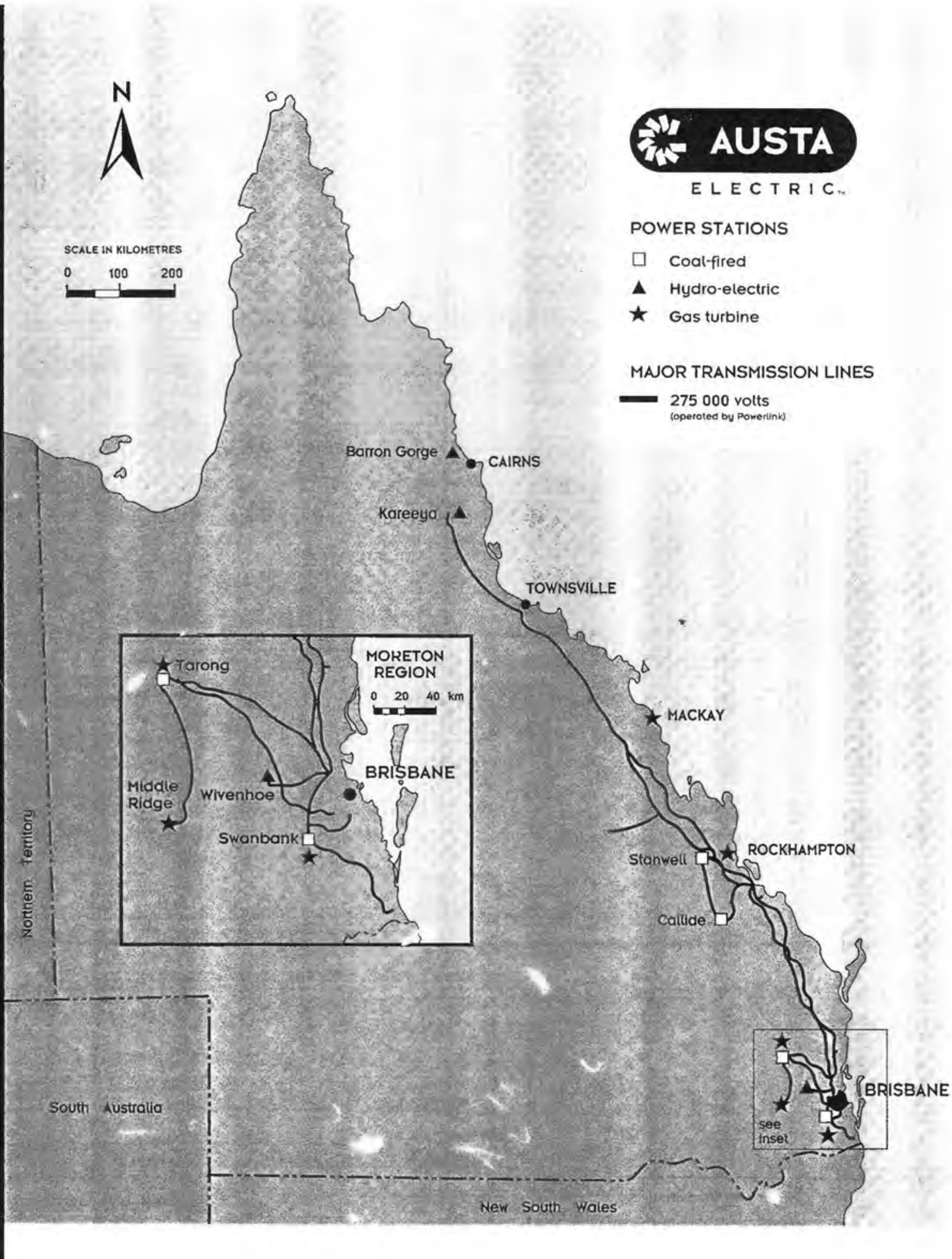
Kareeya Power Station
PO Box 398 Tully Q 4854
Te[illegible]hone (070) 68 1633
F[illegible]0) 68 4223

Stanwell Power Station
PO Box 5895 Rockhampton
Mail Centre Q 4702
Telephone (079) 34 9300
Fax (079) 34 9224

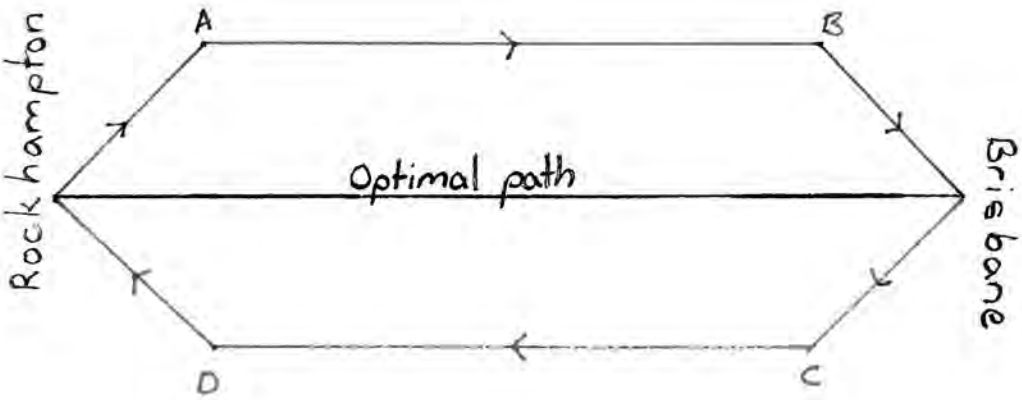
Swanbank Power Station
MS 460 Ipswich Q 4306
Telephone (07) 3280 8800
Fax (07) 3280 8777

Tarong Power Station
PO Box 15 Nanango Q 4615
Telephone (071) 63 4222
Fax (071) 63 7174

Wivenhoe Power Station
PO Box 38 Fernvale Q 4306
Telephone (074) 26 7455
Fax (074) 26 7453



Appendix iv



Race-track flight paths