1973/184
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DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RESTRICTED

Record 1973/184

DARWIN SECOND STEAM POWER STATION
STAGE 1 - SITE INVESTIGATION
REPORT OF FIELD VISIT 5-10 AUGUST 1973

by

A.T. Laws

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SUMMARY

The Bureau of Mineral Resources is providing geological assistance with the site investigations for the proposed second steam power station for Darwin, N.T. This report is based on data gathered during a visit to the site in August 1973.*

The proposed site is approximately 6 km southeast of the existing power station and is located at Quarantine Island. Near-horizontal beds of sandstone and conglomeratic sandstone of the Lower Cretaceous Mullaman Beds unconformably overlie steeply dipping micaceous siltstones grading to phyllite of the Lower Proterozoic Noltenius Formation. Thin skeletal soils cover most of the area; few outcrops occur at the site. No major faulting was detected.

The sandstone is moderately to highly weathered; the conglomeratic sandstone is rarely more than moderately weathered, and the siltstone/phyllite is highly to completely weathered.

Excavation of the phyllite may require light blasting but the overlying sandstones will require heavier blasting. No seismic data are available for the prediction of limits of rippability.

No groundwater had been struck in preliminary drilling and it is unlikely that significant amounts of groundwater exist in the area.

Recommendations have been made for detailed mapping during excavation to base level and for mapping of costeans. Recommendations have also been made concerning the procedures for drilling, and for logging of the drill cores. Laboratory and field tests for settlement analysis, and seismic refraction traverses have also been recommended.

A meeting to review progress of the investigations should be convened after the completion of about ten (10) drill holes.

INTRODUCTION

The existing plant for generating electricity in the Darwin area is at the Stokes Hill Power Station (see Fig. 1); however, on the basis of load forecasts this station will be at full capacity by 1979, and a second station will be required. The Northern Territory Branch of the Department of Works has recommended the commissioning of the first stage of a second thermal power station at Quarantine Island, East Arm, in 1979/80 (see Fig. 1).

The Bureau of Mineral Resources (BMR) was requested by the Commonwealth Department of Works (CDW) to provide engineering geological assistance with the site investigations, the extent of advice to include siting of drill holes, the logging and interpretation of the core, and an overall assessment of the site. Drilling had commenced when the author visited the area shortly after the request was received, and the drill hole sites had already been selected.

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* Subsequent to the completion of this report and prior to its release a meeting to review progress was held in Melbourne. Comments on the data presented at the meeting are given in an addendum at the end of this report.

LOCATION

The proposed site at Quarantine Island is approximately 6.1 km southeast of the existing power station, and is on the East Arm of Darwin Harbour. A former RAAF Station for Catalina aircraft had been located on the site during the Second World War. Access to the site is by road via the Stuart Highway to the Berrimah crossroads, then south to Quarantine Island.

GENERAL GEOLOGY

Noltenius Formation

Quarantine Island is underlain by sediments of the Lower Proterozoic Noltenius Formation; the Formation includes turbidites, mainly quartz greywacke, greywacke, and siltstone, and also conglomeratic-sandstone, arkose, claystone, micaceous greywacke, siltstone, and quartz siltstone. The information has been described in detail by Walpole, Crohn, Dunn & Randal (1968).

Mullaman Beds

Overlying the Noltenius Formation unconformably are the near horizontal Lower Cretaceous Mullaman Beds. These beds are described by Skwarko (in Walpole et al 1968) as including a gravel or conglomerate which is overlain by up to 8 m of highly weathered quartz sandstone and in turn by up to 11 m of silicified fossiliferous claystone. In the Darwin area all outcrops are reddish coloured, attributed to lateritization.

Soils

Thin residual skeletal soils on Quarantine Island contain numerous rock fragments (see Photograph 1), and are generally less than one (1) metre thick.

GEOLOGY OF THE SITE

The few outcrops in the immediate site area are shown on Plate 1. The first drill hole was in progress at the time of the site investigation.

Three major rock units were mapped at the site; these are a sub-horizontal fine to medium grained quartz sandstone conformably overlying a conglomeratic sandstone, which in turn unconformably overlies a micaceous siltstone. The latter formation grades to a phyllite with depth.

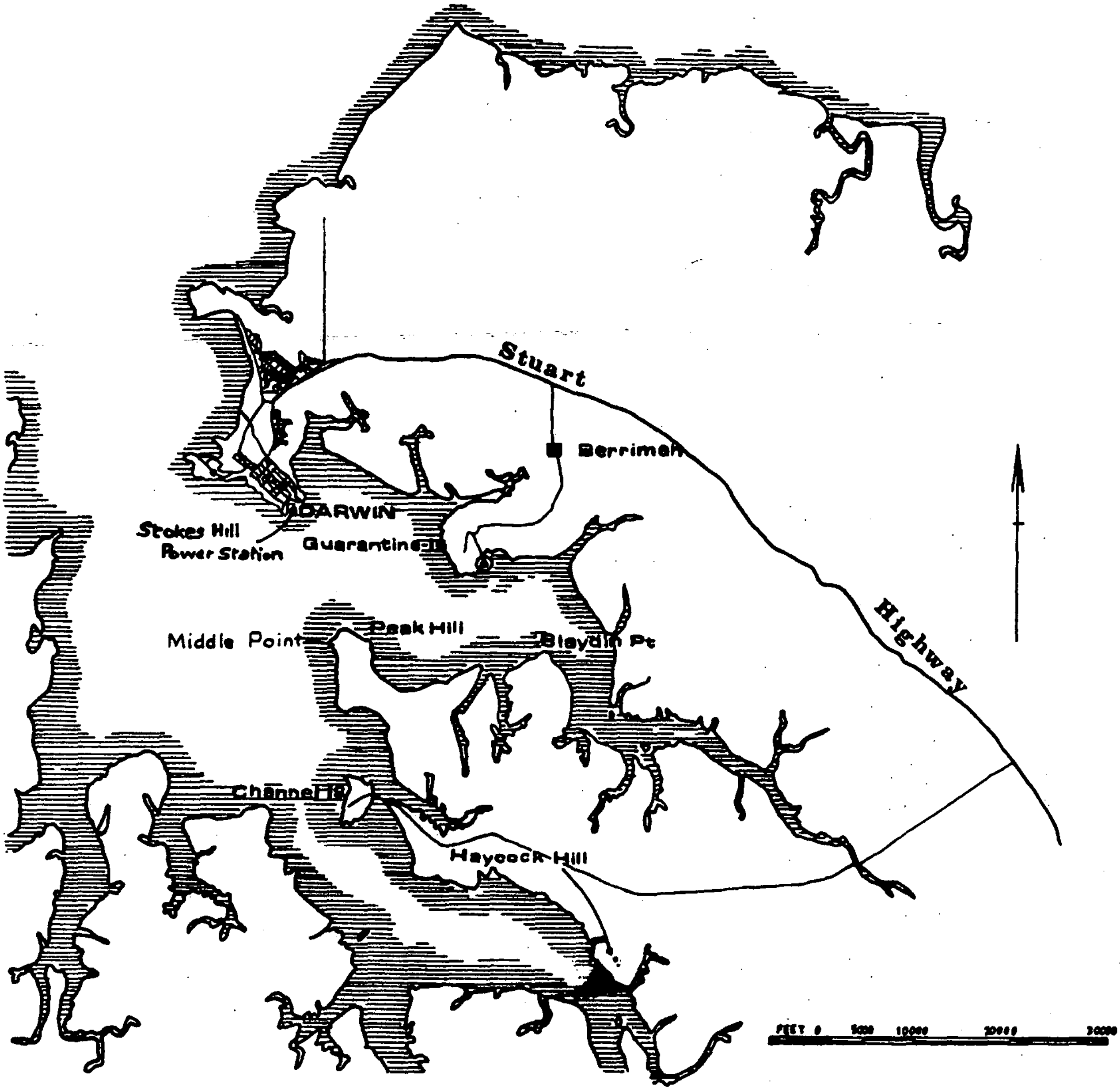
It is considered that the quartz sandstone and conglomeratic sandstone are partly eroded remnants of the Mullaman Beds, and that the micaceous siltstone/phyllite is part of the Noltenius Formation.

Mullaman Beds

The quartz sandstone is slightly weathered in outcrop, but where covered by topsoil it is moderately to highly weathered. Near the proposed drill hole 20 (Plate 1) a shallow cut had been made into the side of the hill exposing up to 1.2 m of red-brown quartz sandstone beneath approximately 0.3 m of skeletal topsoil (site h). Here the sandstone is fine to medium-grained,

Fig.1

DARWIN
SECOND POWER STATION
QUARANTINE ISLAND SITE



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highly weathered, and strongly and irregularly fractured. The irregularity of the fractures is mainly attributable to tree roots (see photograph 2).

The underlying conglomeratic sandstone was only visible at locality d (see photograph 3) giving the appearance of a faulted contact between the conglomerate and the overlying sandstone; however there was no indication of the amount of movement. In the core of Hole 24F the contact between the two sandstones was sharp, but showed no evidence of an unconformity (Photograph 6).

Noltenius Formation

In the core of hole 24F, the Noltenius Formation is a micaceous siltstone with a steeply dipping cleavage ranging from 70 to 80°. At the unconformable contact with the conglomeratic sandstone (Photograph 9), the siltstone was completely weathered to a clay, and did not improve in quality beyond highly weathered except where thin bands of sandstone occurred.

The two outcrops of siltstone show evidence of metamorphism to phyllite; at outcrop f (see Pl. 1) the phyllite had been worn into a wave-cut platform (see Photograph 4); it was highly weathered and very soft, and bedding was not discernible. At outcrop I (see Pl. 1) the phyllite outcrop was above the main highwater mark but was strongly contorted; once more bedding was not discernible. At both outcrops the phyllite was highly weathered and soft and no structural data on S planes were measurable; some bands had been completely weathered to clay, and some bands of fine-grained sandstone were generally moderately weathered.

Structures

Bedding in the sandstone and the conglomerate sandstone both in outcrop and core was not measurable, but both had undergone strong jointing. Two major joint sets were mapped, one set had a general strike ranging from 342° to 025° with very steep dips ranging from 65°E to vertical. The other set had a general strike of 252° to 305° with dips ranging from 24°S to 75°N.

The only joint measurable in the highly weathered phyllite at outcrops f and I had a strike of 350° and a near-vertical dip; cleavage could not be measured.

No surface evidence of major faulting was discovered either from aerial photograph interpretation or from surface mapping. A minor fault was noted at outcrop d (see Photograph 3) but the amount of movement was not determinable.

ENGINEERING GEOLOGY

Rock Strength and condition

Rock strength depends on the type of rock and degree of weathering and alteration (definitions of rock strength, quality, and alteration are given in Appendix 1). The strength of the rock mass depends on the previously mentioned properties and the incidence of structural defects such as joints, faults, and shear zones.

In outcrop the upper sandstone and the conglomeratic sandstone of the Mullaman Beds sequence on Quarantine Island is slightly weathered; however, beneath topsoil the sandstone is moderately to highly weathered and consequently the hardness and strength of the rock is decreased. The conglomeratic sandstone at depth retains most of its strength and is rarely more than moderately weathered.

The underlying micaceous siltstone and phyllite are completely to highly weathered to at least a depth of 27 m below ground surface as indicated in the core for Hole 24F, except where minor lenses of sandstone occur. In places the phyllite has been weathered and silicified and is strong, but subsequent leaching and alteration of the rock has resulted in decreased strength.

Ease of excavation

Seismic refraction surveys have not been undertaken to investigate the weathering profile and to determine the depth to fresh rock. If the degree of weathering in the phyllite, as shown in core of Hole 24, is representative of the area, it would be possible to excavate using light blasting in places only, followed by jackpicking and ancilliary earthmoving equipment. The overlying conglomerate sandstone will require heavier blasting.

The results of seismic refraction traverses are expected to verify the above conclusions. Seismic velocities of up to 2000 m/sec would indicate the requirement of some preliminary light blasting with heavier blasting being essential when hard rock bars are intersected.

Groundwater

Groundwater was not intersected in Hole 24F. Water Resources Branch, Department of the Northern Territory, provided data from a bore hole drilled in 1944 for a water supply for the Catalina base; water was not struck until approximately fifty (50) metres from the surface and the supply was salty. A minor soak was reported at 19.5 m.

No springs or seepages were found.

It is unlikely that groundwater will be intersected in any drill holes that are completed above sea level. It is considered that the water table will be near sea level on Quarantine Island and that any freshwater aquifer will be thin and will overlie salt water. Drill holes penetrating below sea level may intersect supplies of salty water, but the potentiometric level to which water in the drill holes would rise is unknown; it is likely, however, that it would be above the base level of the power station. Because of the problems associated with groundwater, particularly saline groundwater, it is essential that any intersection of groundwater is noted, that samples be taken for analysis, and that regular measurement of water-levels be carried out twice daily.

Foundations

No details are as yet available as to the type of foundation envisaged by CDW for the power station, although loads of up to 0.5 MPa have been suggested (M. Verplak, CDW, pers. comm.).

Vibrations induced in the structure may cause some settlement within the foundations. Any settlement however, must be maintained within design limits. Because foundation settlement is so critical to the project, it is important that the subsurface investigation should be thorough.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were arrived at following field inspection and discussions with the site engineer, the supervising engineer, and staff from the Commonwealth Testing and Research Laboratories (CTRL).

Geological Mapping

1. Three rock types are present on Quarantine Island, but outcrop is poor; however, detailed mapping is not required at this stage.

2. The three rock types show differing degrees of weathering but the phyllite, in which most of the foundation will be set, is generally highly to completely weathered to a depth of approximately 13 m below the excavation RL (as indicated by the core of hole 24).

3. Two and possibly three costeans should be excavated in order to obtain more detailed information on the succession in the area. The locations of these costeans are shown on Plate 1. There is no particular order of preference.

4. The site should be mapped in detail during the levelling of the hill to the required base level. Preliminary results indicate that the foundations are liable to be in the Noltenius Formation, and it is essential that all structural weaknesses should be known and evaluated.

Drilling and logging

1. As no surface evidence of faulting or other subsurface movements were detected, there is at present no need to relocate any of the drill hole sites. At the time of the visit the first hole was in progress (see photograph 5) and no evidence was seen in the core of faulting and/or extensive shearing.

2. The method of logging drill cores showed some weaknesses in methodology. These was no reference to strength (estimated) nor was there any fracture log, and the method of describing the varying degrees of weathering was inadequate. Core losses were not being shown in the core trays by the insertion of wooden blocks and a false impression of core recovery was being obtained (see photographs 6 to 12).

3. The subsurface investigation should evaluate the factors relevant to foundation settlement. Provision should be made to move the location of existing sites, and vary the attitude and location of any holes in order to trace any fault and shear zones that are intersected.

4. The holes should be drilled below the base of the excavation for the plant to a depth of 1.5 times the width of the power plant.

5. Deeper drilling may be necessary at the location of the chimney stack; the chimney foundations are liable to be eccentrically loaded by wind, and possibly by earthquake movement, and will impose variable loads on the supporting materials.

6. It was recommended to the site engineer and CTRL personnel that the following items should be covered in the logging of the drill core:

1. Lithology
2. Graphic log
3. Core recovery per run
*4. Strength (estimated)
*5. Hardness
*6. Weathering
7. Fracture log
8. Structures
9. Provision for water pressure testing if necessary

7. It was also suggested that the Northern Territory Geological Survey be requested to make a brief geological inspection and appraisal of the core at regular intervals to check the reliability of the logging.

8. It was also recommended that the core be photographed in colour in the split tube, as soon as the core barrel is removed from the hole. The core should then be checked again a few days later for any evidence of fretting.

Testing

1. Testing related to settlement evaluation will be essential, and should be aimed at determining the compressive strength of the rocks and their safe bearing capacities.

2. The highly cleaved rock of the Noltenius Formation is anisotropic, and the orientation of rock defects such as bedding and cleavage is likely to vary from place to place within the site. It follows that the reaction of test pieces to laboratory tests will vary with changes in the orientation of rock defects relative to the direction of applied stress. Laboratory testing alone of the Noltenius Formation would be inadequate for foundation testing, and in situ field tests are essential for a true evaluation of its mechanical properties.

3. Comprehensive field tests are required to assess the foundation characteristics of the Noltenius Formation.

4. If the foundations are to be set in the Noltenius Formation, testing should be restricted to this formation.

5. If excavation to base level indicates that conglomeratic sandstone is also present in the foundations, the likelihood of differential settlement should be assessed, and consideration should be given to setting the foundations in only one rock type.

* See Appendix 1 for criteria for assessment.

6. If the foundations are entirely in the conglomeratic sandstone, testing should be carried out on the underlying siltstone/phyllite as well as on the conglomeratic sandstone, and an analysis should be made of their composite reaction to the structures.

7. Seismic refraction traverses should be run over the area to determine depths of weathering and limits of rippability in the sandstones; it is further recommended that longitudinal and transverse velocities be measured on closely spaced geophones (say 4 m) and that longitudinal velocities be measured in the laboratory from the cores. From the ratio of the two longitudinal velocities an assessment of the amount of jointing in the field can be obtained (E. Polak pers. comm.).

8. Finally it is recommended that drilling data and all other existing data be reviewed after the completion of the tenth hole, and a progress meeting be convened.

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APPENDIX 1

DEFINITIONS OF TERMS USED IN GEOLOGICAL DRILL LOGS

WEATHERING OF ROCK

FRESH	:	No discolouration or loss in strength.
FRESH STAINED	:	Limonitic staining along fractures, rock otherwise fresh and shows no loss of strength.
SLIGHTLY WEATHERED	:	Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock.
MODERATELY WEATHERED	:	Rock is discoloured and noticeably weakened; N - size drill core generally cannot be broken by hand across the rock fabric.
HIGHLY WEATHERED	:	Rock is discoloured and weakened; N - size drill core can generally be broken by hand across the rock fabric.
COMPLETELY WEATHERED	:	Rock is decomposed to a soil, but the original rock fabric is mostly preserved.

PERCUSSIVE STRENGTH OF ROCK

STRONG TO VERY STRONG	:	Cannot be broken by repeated blows with a hammer.
MODERATELY STRONG	:	Rock broken by 3 or 4 blows.
WEAK	:	Rock broken by one blow.

HARDNESS OF ROCK

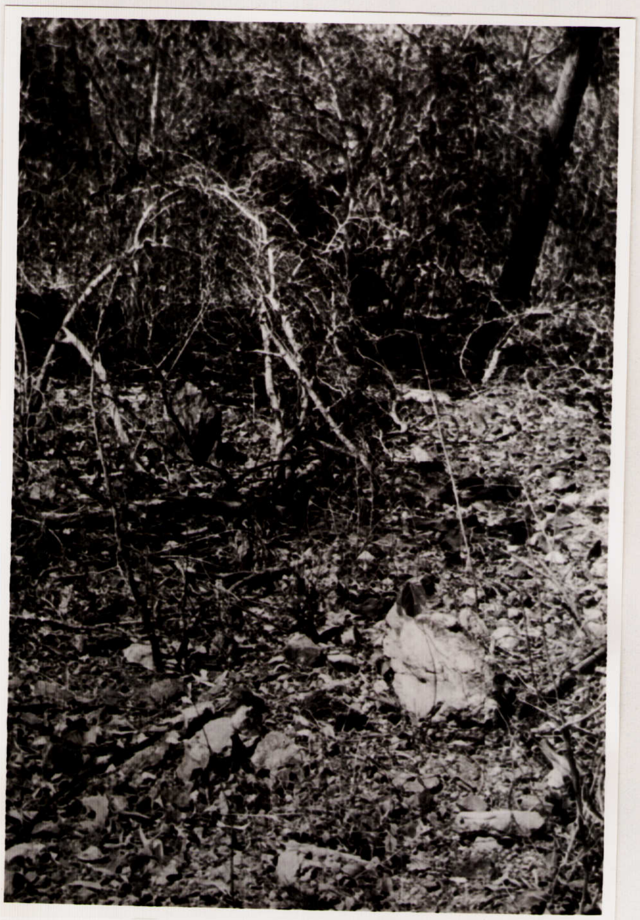
HARD TO VERY HARD	:	Impossible to scratch with knife blade.
MODERATELY HARD	:	Shallow scratches with knife blade.
SOFT	:	Deep scratches with knife blade.

BEDDING

LAMINATED	:	Less than 10 mm thick.
THINLY BEDDED	:	10 to 100 mm thick.
THICKLY BEDDED	:	Greater than 100 mm thick.

APPENDIX 2

PHOTOGRAPHS



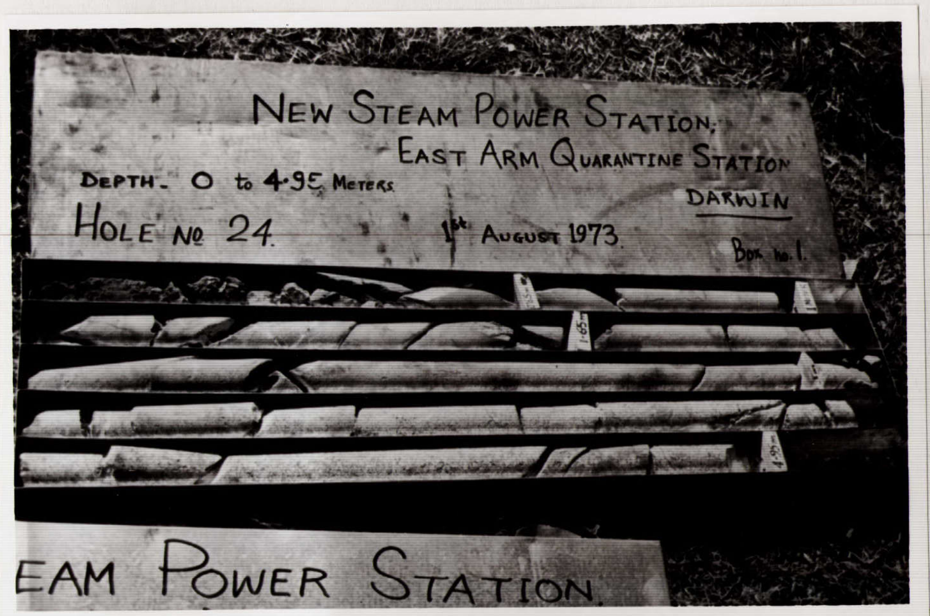
Photograph 1 (D52/4/107)
Thin skeletal soils containing small boulders and numerous rock fragments

Photograph 2 (D52/4/108)
Costean near proposed drill hole 20F, showing highly weathered sandstone of Mullaman Beds

<u>Photograph 3</u> (D52/4/109)
Outcrop at locality d (see text) - shows faulted contact between medium-grained sandstone and conglomeratic sandstone

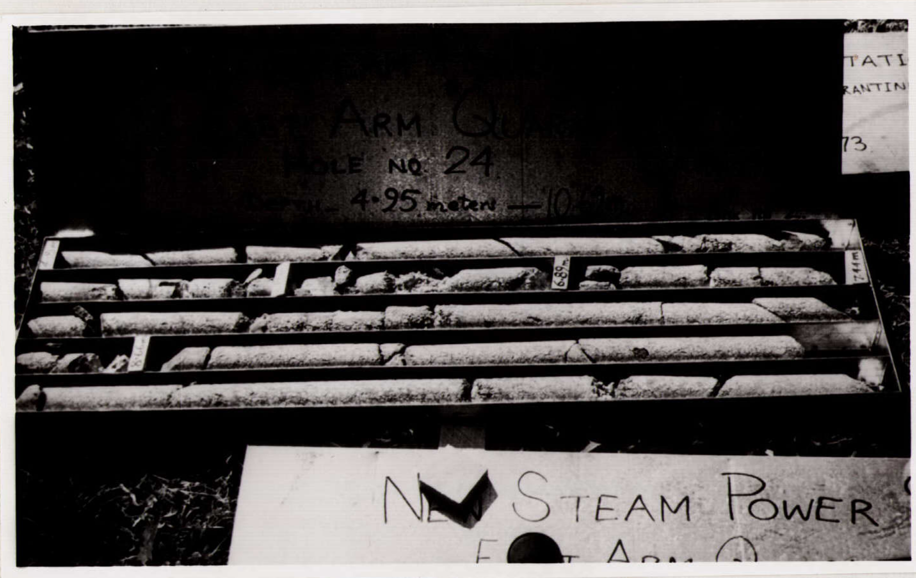
<u>Photograph 4</u> (D52/4/110)
Outcrop at locality f (see text) - showing wavecut platform in completely weathered phyllite of the Noltenius Formation

Photograph 5 (D52/4/111)
Drilling in progress at
Hole 24F,
Drilling rig is a Fox Mobile

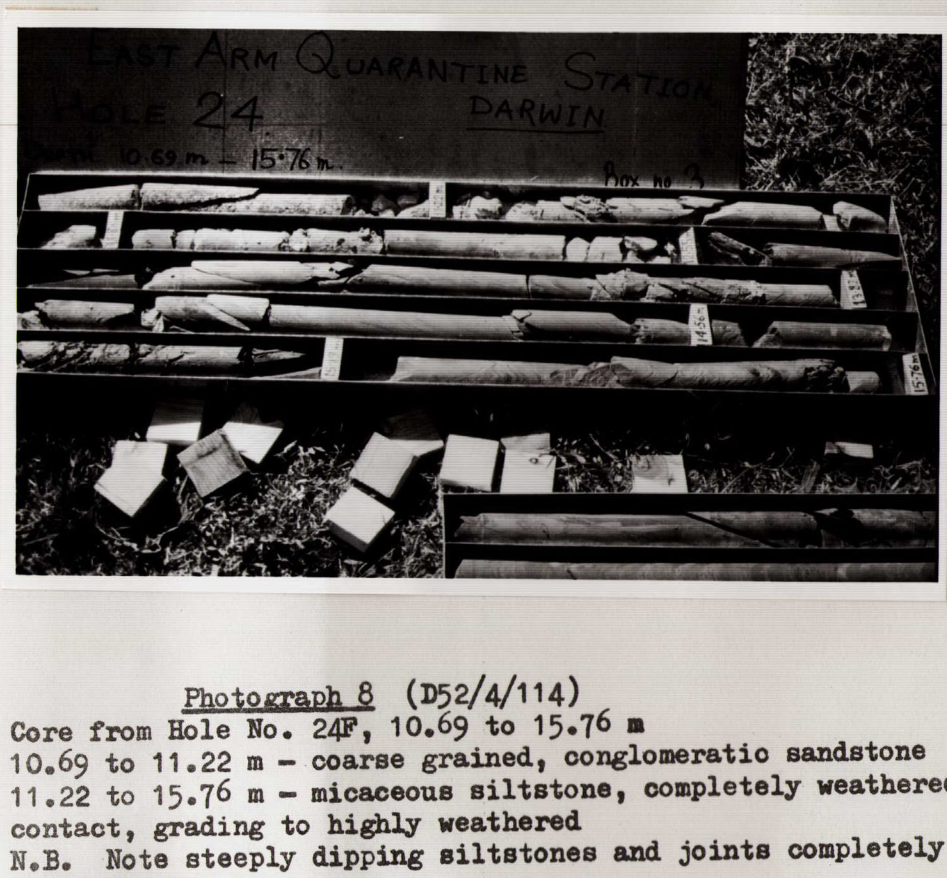


Photograph 6 (D52/4/112)
Core from Hole No. 24F, 0 - 4.95 m.

0 - 0.3 m	topsoil and rock fragments
0.3 - 3.0	medium-grained sandstone, moderately weathered
3.0 - 4.95	coarse-grained conglomeratic sandstone



Photograph 7 (D52/4/113)
Core from Hole No. 24F, 4.95 m - 10.69 m
4.95 m - 10.69 m - coarse grained, conglomeratic sandstone moderately weathered
N.B. Note regular, steeply dipping joints



Photograph 8 (D52/4/114)
Core from Hole No. 24F, 10.69 to 15.76 m
10.69 to 11.22 m - coarse grained, conglomeratic sandstone
11.22 to 15.76 m - micaceous siltstone, completely weathered at contact, grading to highly weathered
N.B. Note steeply dipping siltstones and joints completely weathered to clay

<u>Photograph 9</u> (D52/4/115)
Close-up of contact between conglomeratic sandstone and micaceous siltstone. Note complete weathering to a white clay, and other joints completely weathered to clay

<u>Photograph 10</u> (D52/4/116)
Close-up of micaceous siltstone
Note steep bedding and highly to completely weathered state of the siltstone

Photograph 11 (D52/4/117)
Close-up of shear zone in highly weathered micaceous siltstone

Photograph 12 (D52/4/118)
Close-up of sample of core of coarse-grained conglomeratic sandstone

ADDENDUM

Subsequent to the completion of this report and prior to its release a review of progress meeting was held in Melbourne on 17 September. The following comments are based on the data presented at that meeting.

Since the author's visit to Darwin three more holes have been drilled and a fourth is in progress. Data from the logs indicate that the contact between the conglomeratic sandstone and the underlying Noltenius Formation has a larger number of fine-grained sandstone lenses within the siltstone than previously thought.

The final excavation level was given as RL 10.67 m and only core from Hole 24F indicated that the Noltenius Formation would be exposed; Holes 21F and 9F indicated the foundations would be in conglomeratic sandstone.

Complete loss of drilling water was reported in Hole 21F at 27 m and losses in drilling water were also reported in Hole 9F, both bores are reported as having struck quartz reefs.

Some seismic refraction results were available but no interpretation had been carried out; it was stated that it was impossible to delineate the boundary between the Mullaman Beds and the Noltenius Formation because a higher velocity layer (the conglomeratic sandstone) was superimposed on a lower velocity layer (the siltstone).

Conclusions

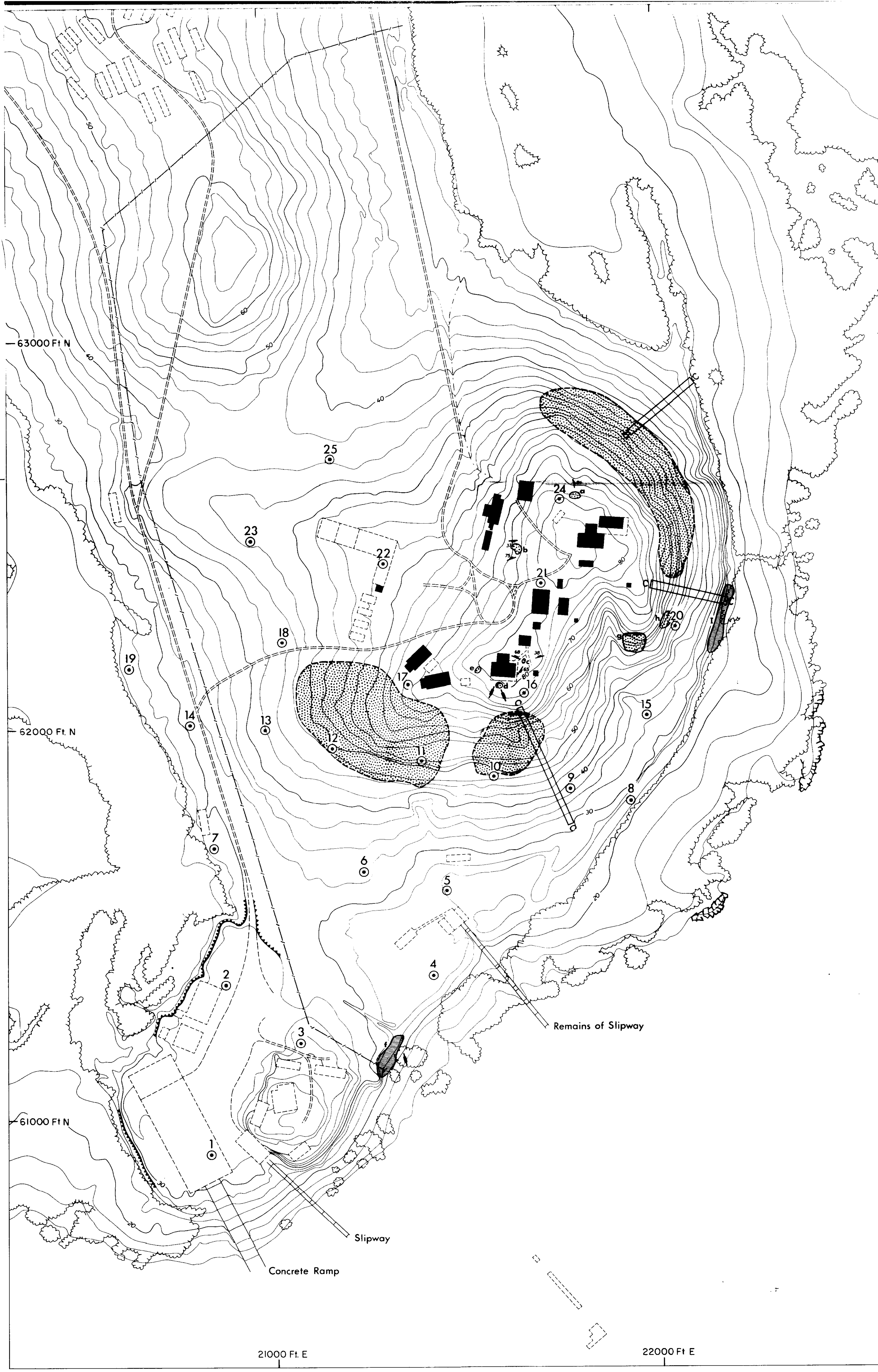
1. From the limited drilling it now appears that the foundations may be partly in the conglomeratic sandstone of the Mullaman Beds and partly in highly weathered siltstone of the Noltenius Formation. If this is so, the problem of differential settlements within the foundations requires close attention.

2. The loss of drilling water into a zone of quartz reefs is disturbing, but may not be serious. The apparent lack of fluctuations in water levels that would be expected because of tidal influences, suggests that the water in the holes could be undispersed drilling water. A simple test would be to pump out the holes. Recovery of the water level would prove the presence of groundwater, and measurements of the water levels during recovery should be taken and permeabilities calculated.

3. It is expected that aquifers will be below the excavation RL and will not effect excavation of the foundations. The total loss of drilling water in hole 21F took place at 27 m, approximately 13.5 metres below the RL of the base of the excavation.

4. Few conclusions can be made about the seismic results. It is recommended, however, that resistivity depth probing be attempted to delineate the boundary between the Mullaman Beds and the Noltenius Formation.

QUARANTINE ISLAND – GEOLOGY AND DRILL HOLE LOCATION



0 100 200 300 400 500 600 Feet
0 25 50 75 100 125 150 175 Metres

Continuous outcrop, letter referred to in text

Scattered boulders

Medium grained sandstone (See outcrop d) — MULLAMAN BEDS
Conglomeritic sandstone — MULLAMAN BEDS

Phyllite — NOLTENIUS FORMATION

Recommended locations for costeans

Joint, vertical

Joint with dip

Drill hole location

Contours in feet

Fence

Track

Remains of Catalina station

Mangroves

Grid Coordinates are in feet based on Australian National Grid
Easting and northing coordinates in feet
Datum of levels is Admiralty Datum, i.e. 12·6 feet below mean sea level

TN MN

PLATE I

COMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE QUARANTINE ISLAND – GEOLOGY AND DRILL HOLE LOCATION

PROJECT DARWIN SECOND STEAM POWER STATION STAGE I – SITE INVESTIGATION

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