

10. Second Derwent Crossing Study. Magnetic and seismic survey: Dowsings Point area.

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The Joint Expert Advisory Committee set up to examine potential sites and designs for a second Derwent crossing has requested examination of two 200 m wide bands across the river near Dowsings Point. The alignment of the nearby temporary bridge is also discussed. Location of the study areas is indicated in Figure 23.

#### SEISMIC SURVEY

The seismic survey was undertaken using a 180 m hydrophone cable and Geospace GT2B refraction seismograph; hydrophone separation was 15 m. Survey technique varied according to the section of river under examination. Some spreads were anchored on shore while others were managed from a boat anchored in mid-stream. In each case shot extensions up to 350 m were fired. Anchoring positions and, where possible, the shot position have been surveyed. The transit alignment of the cable and any curvature was also noted.

The refraction technique is not an ideal approach to the problems of the River Derwent (see Leaman, 1977 and appendix 1). Difficulties may arise due to position, orientation or catenary errors but these are generally very minor. A more serious problem relates to spread location. Due to the vagaries of currents, tides and winds spreads can rarely be placed exactly where needed or preferred and in consequence a broad blanket cover is obtained. Although this provides a general areal sketch there is usually a preferred orientation in the spreads which tends to parallel the structures needing assessment and is therefore less informative. Interpretations tend to lack definition as a result. Another problem is due to the seismic velocity of the river bed silt and this is discussed in the above reference. In shallow water situations where there is a thin silt cover the above problems are of little consequence but where up to 15 m of water and up to 40 m of silt are present they are accentuated. Pending some drill control the form and scale of interpreted features should be treated with caution. The interpretation for this area has benefited from some previous drilling control (Jennings, 1964) but some problems persist (see below).

The magnetic survey was made using a gimbals-mounted McPhar M700 flux-gate magnetometer. Although the nominal precision of the instrument is 10 nT only 50 nT can be claimed when mounted in a small boat.

A summary of knowledge, both factual and deduced, about the region is given by Leaman (1977). In the case of Area 1, and the temporary bridge, sandstone bedrock may be presumed from the eastern side of the river to close inshore near Dowsings Point. In the case of Area 2 no such presumption is possible since the river bed geology is totally unknown. Basalt is present on the southern bank and dolerite on the northern. In both cases the bedrock is covered by up to 12-15 m of water and at least as much silt. A partial profile is available for Area 1 (Jennings, 1964; Leaman, 1977).

The magnetic survey was undertaken to gain an indication of the general distribution of the various rock types, in particular the dolerite. The seismic survey was necessary to provide information on the thickness of silt and the character of the bedrock. A reference scale of velocities was given in Leaman (1977). Note correction to this scale as discussed under Area 1, Spread 2.

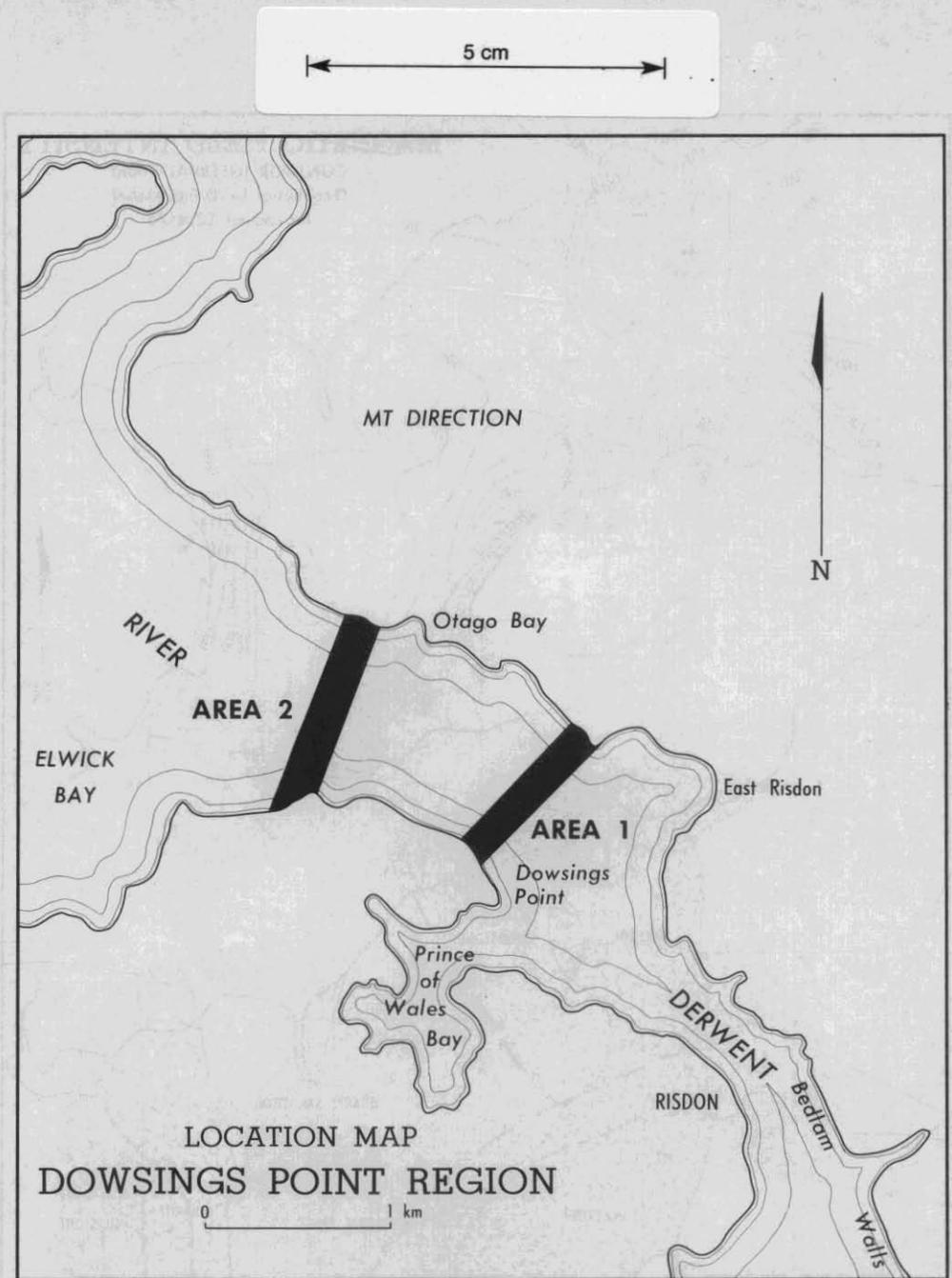


Figure 23.

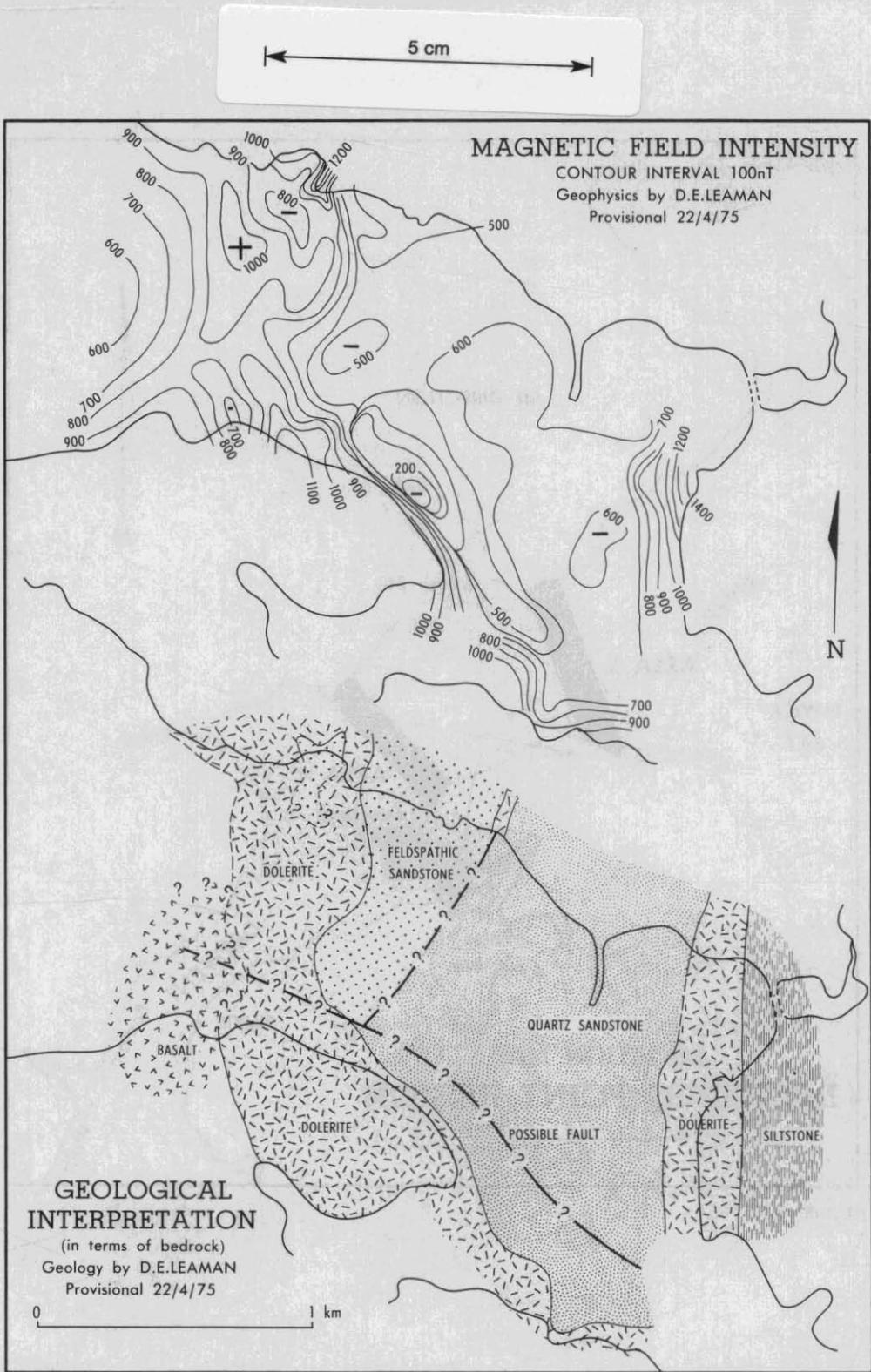


Figure 24.

## MAGNETIC SURVEY

Contours of magnetic field intensity and an uncontrolled interpretation are given in Figure 24. The deductions made concerning the dolerite and basalt boundaries of Area 2 are those most in doubt and until some drilling is undertaken in this area this interpretation can only be regarded as a very basic guide. The more relevant and reliable conclusions are mentioned in respect of the particular areas.

Traverse positions (not shown in Figure 24) were surveyed using eye transits of topographic or other features. Position accuracy is estimated at 20-30 m for mid-river features.

Some general comments may be made about the structures in the area on the basis of this survey.

- (1) It appears that the dolerite at Otago Bay, Dowsings Point and Abattoirs Point forms one intrusion. This was also implied in the regional gravity survey of Leaman (1972).
- (2) It is unlikely that the Dowsings Point dolerite is simply faulted offshore. On the basis of the distribution of the contours, and the position of the buried escarpment (see discussions, Area 1, Spreads 1-3, 22 below) the dolerite here forms a sill-sheet intrusion roughly parallel to the bedding of the sandstone.
- (3) At least one fault, downthrowing to the east, is implied mid-river if comment (2) is valid. Its possible position is indicated in Figure 24. (An intrusion transgressive both to east and west could modify this conclusion).
- (4) It seems that only lower zone dolerite is present in the area and that the contacts observed onshore are intrusion bases.
- (5) The very low field intensity offshore at Dowsings Point is believed to be due to two factors; the greatest depth to bedrock occurs in this region and the bedrock interface here may be nearly vertical resulting in a reduction in the field due to topographic effects.

## INTERPRETATION

### Area 1

The seismic interpretation from the twenty-two spreads fired in this area is summarised in Figure 25. The positions of the spreads are shown in Figure 26. The interpretation confirms the presence of a gently dipping bedrock surface from the east, with a steepening mid-river, while on the western side there is a very abrupt step.

All depths are with respect to the water surface (assumed MSL).

In order to detail particular features not apparent in the summary and indicate the reliability of the information across the area the interpretation of each spread is described below.

*Spread 1.* With the first hydrophone 40 m offshore at Dowsings Point no refractor was recorded. Assuming a refractor with a velocity of 3000 m/s and that the end of the time distance graph represented a critical point a minimum depth to bedrock of 69-72 m is implied. This spread overlaps Holes

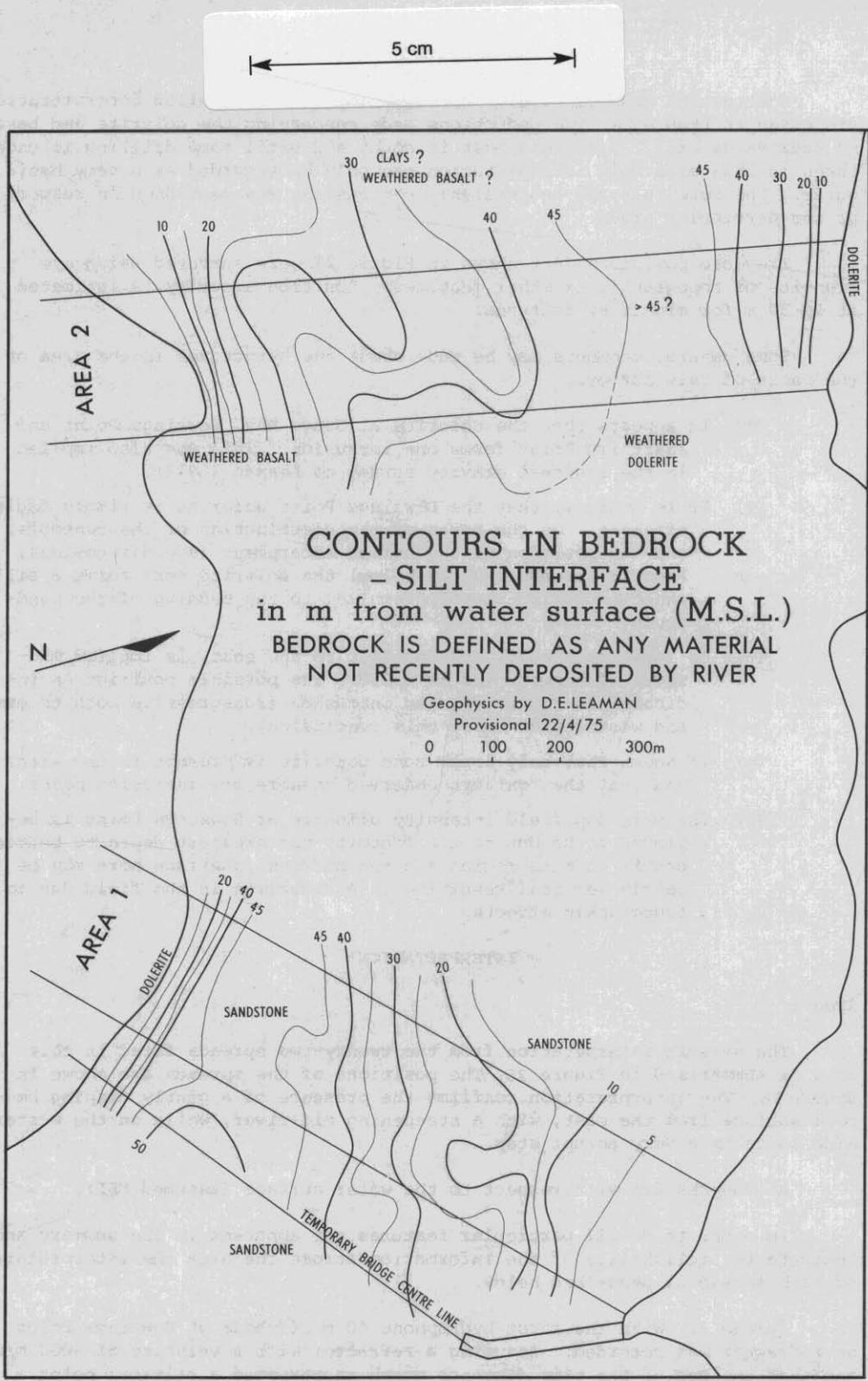


Figure 25.

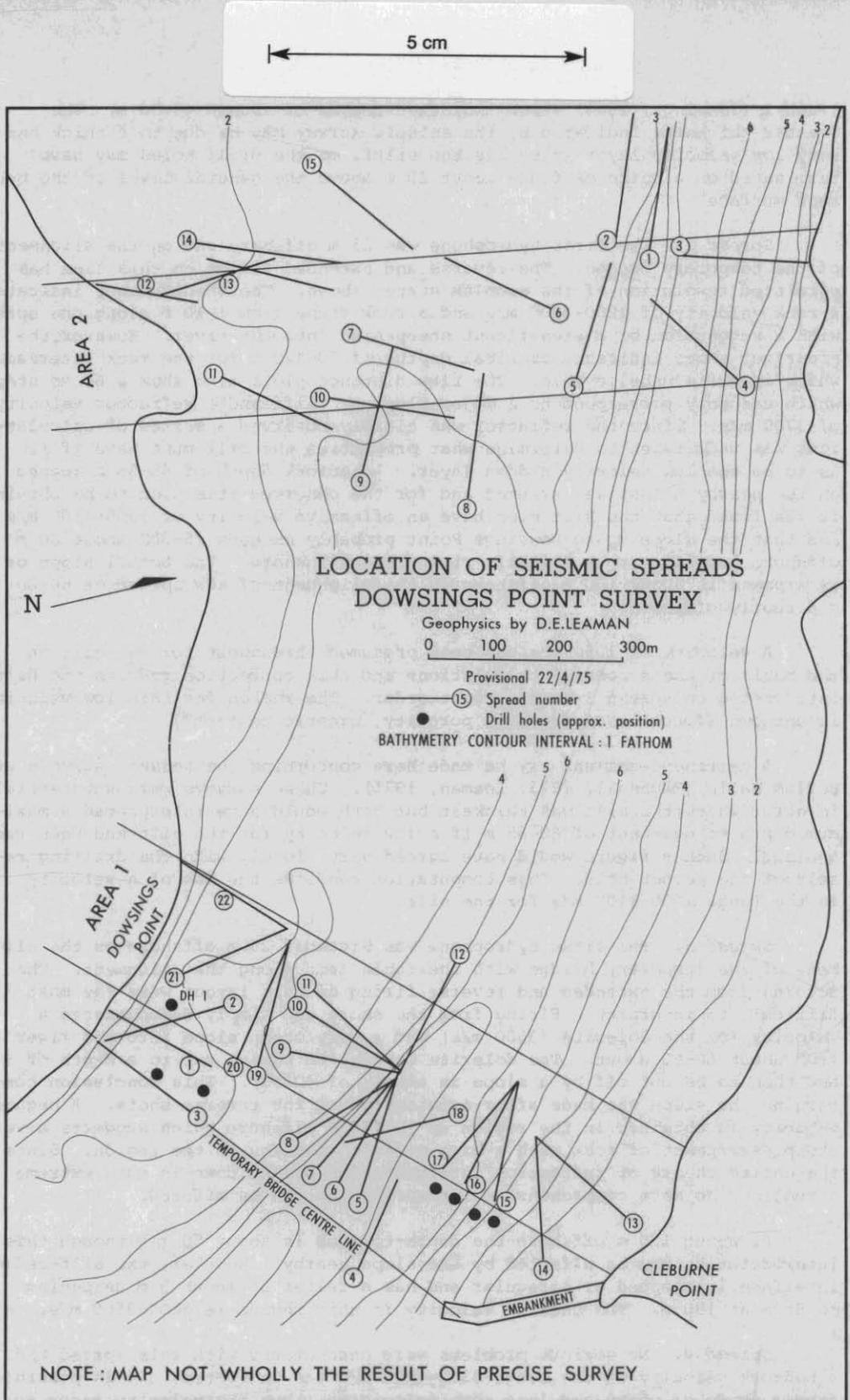


Figure 26.

1 and 2 (Jennings, 1964) which indicated depths of around 45-50 m. The greater thickness indicated by the seismic survey may be due to a thick and very low velocity layer (possibly the silt), or the drill holes may have terminated on a spine or ridge about 20 m above the general level of the bedrock surface.

*Spread 2.* The first hydrophone was 25 m offshore and on the alignment of the temporary bridge. The reverse and extended firing on this line has permitted resolution of the problem stated above. The onshore shot indicated a rock velocity of 2200-3000 m/s and a rock slope from 1-10 m along the spread with a suggestion of a significant steepening into the river. However the mid-river shots indicated critical depths of 70-120 m for the rock interface which is quite unbelievable. The time distance plots also show a 60 ms step which can only correspond to a major slope or cliff and a refractor velocity of 3700 m/s. Since the refractor was clearly observed a series of calculations was undertaken to determine what properties the silt must have if it is to be the low velocity hidden layer. A bedrock depth of 45-58 m (based on the nearby holes) was assumed and for the observed time plot to be obtained it was found that the silt must have an effective velocity of 1000-1100 m/s and that the slope up to Dowsings Point probably exceeds 25-30° about 80 m offshore levelling up to a slightly rising bench inshore. The actual slope or escarpment is about 100 m offshore on the alignment of the spread or 60-80 m directly offshore.

A velocity of 1050 m/s has been presumed throughout for the silt on the basis of these control calculations and this correction reduces the depth interpreted on Spread 1 to the right order. The reason for this low velocity is unknown (function of density, porosity, organic content?).

A pertinent comment may be made here concerning the seismic surveys at Bedlam Walls (Maunsell, 1973; Leaman, 1975). These surveys were substantially in error where the silt was thickest but both would have interpreted a maximum depth to basement of 60-65 m if a low velocity for the silt had been recognised. Such a figure would have agreed very closely with the drilling result of the second hole. This computation confirms the use of a velocity in the range 1000-1100 m/s for the silt.

*Spread 3.* The first hydrophone was situated 25 m offshore on the alignment of the temporary bridge with the cable laid along the alignment. The records from the extended and reverse firing of this layout were the most difficult to interpret. Firing from the shore end simply demonstrated a velocity for the dolerite (3500 m/s) and a very steep slope into the river from about 60-80 m out. The dolerite appears to shelve out to a depth of 5 m and then to be cut off by a slope in excess of 40-50°. This conclusion concerning the slope was made after examination of the reverse shots. A negative velocity is obtained in the region up to 115 m offshore which suggests a very steep escarpment of rock with a high seismic velocity in the region. Since the entire theory of refraction interpretation breaks down in such extreme situations no more comprehensive interpretation can be offered.

At about 120 m offshore the depth to rock is about 50 m although this interpretation may be affected by the slope nearby. However, the silt-bedrock interface is stepped or irregular and has a relief of about 5 m deepening to 55 m at 190 m. The bedrock velocity in this region is 3000-3500 m/s.

*Spread 4.* No serious problems were encountered with this spread and a bedrock velocity in the range 3300-4800 m/s was indicated. It is possible, from a study of short and long shot velocities, that the velocity range recorded reflects the range of weathering in the sandstone. Velocities of

3300-3500 m/s are deduced for the upper zone and 4200-4800 m/s for the 'fresh' rock. There is no evidence for deep or destructive weathering.

The bedrock interface dips eastward in this region, from 29 to 35 m depth. Since the depth of water is 12-14 m the thickness of silt ranged from about 17-22 m. The general relief on the bedrock is about 2 m although a 5 m downstep was recorded at the eastern end of the spread.

*Spread 5.* Only a minimum depth to rock can be estimated from this spread due to observation of some unusually high velocities which suggests that another scarp or slope may be nearby. The indicated depth to sandstone exceeds 37 m.

*Spread 6.* Similar comments apply to Spreads 5 and 6. In this case the higher velocity and velocity range were better defined as 6000 m/s and 3000-7000 m/s respectively. The 7000 figure can only result from a down-dip situation and is unreal. However, the range in velocity recorded is greater than normally observed even in metamorphosed sandstone and it is suspected that there is a change in bedrock (basalt or, more likely, dolerite). A variation in bedrock is also suggested by the magnetic survey. The field in this region shows a low amplitude but a broad positive zone which could imply dolerite at shallow depth, probably as a minor intrusion. Since there is no indication of these high velocities in any of Spreads 7-12 any such bedrock change must be very restricted. An additional possibility is that a dolerite intrusion was detected beneath a cover of 5-10 m of sandstone (velocity 3000 m/s). The depth of weathered rock (or sandstone) is about 30 m and no irregularities are indicated.

*Spread 7.* Little information about the bedrock was obtained but the depth exceeds 35 m.

*Spread 8.* This spread showed clearly why Spread 7 was relatively unproductive. A bedrock velocity of 3300 m/s was clearly indicated as was a steepening slope to the south-west. The bedrock dips from 30-35 m at the northern end of the spread to at least 40-45 m at the southern end. The maximum depth is unknown.

*Spread 9.* Depths of 40-45 m to sandstone (seismic velocity 3300-3500 m/s) are interpreted in this region, increasing southward. The profile is irregular near the northern end of the spread where marked variations (relief up to 10 m) are indicated.

*Spread 10.* As for Spread 9 in general except that curiously there is no indication of the marked depth variations near the eastern end of the spread. The maximum depth to bedrock is estimated at 1-2 m less than in Spread 9.

*Spread 11.* Spread 11 produced results very similar in form to those of Spread 9 with definite accentuation of bedrock slopes. Bedrock with a seismic velocity of 2700 m/s appears at 30-33 m at the eastern end of the spread but then dips sharply to around 40-45 m. Bedrock velocity at the western end of the spread is 4000 m/s. In addition there appears to be a slight reduction of bedrock depth westward to approximately 40-42 m. All velocities are consistent with the material being sandstone.

*Spread 12.* Spread 12 confirmed many of the suggestions of previous spreads and indicated a further 7-9 m step. In general, bedrock occurs at depths of 14-23 m along the northern two-thirds of the spread and must be very nearly exposed on the river bed on the northern side of the Area 1 band.

However, there is an abrupt step within 30 m of the southern end of the spread. Bedrock seismic velocities range from 2500-3700 m/s and probably simply reflect up and down dip components of a real velocity of about 3000-3200 m/s.

*Spread 13.* Spread 13 was located near inshore at Cleburne Point. Bedrock velocities of around 3000 m/s were recorded with depths to bedrock ranging from 3-8 m (increasing westward) along the spread.

*Spread 14.* In general results were similar to those from Spread 13 but two bedrock velocities were indicated. An upper and possibly slightly weathered rock with a seismic velocity of 3000-3250 m/s overlies rock with a velocity in excess of 4500 m/s. This latter figure would imply that the bedrock, if sandstone, is very massive. The thickness of bedrock with the lower seismic velocity is about 10-15 m. The depth to bedrock is approximately 5 m, deepening to about 10 m.

*Spread 15.* Spread 15 was fired across a slight steepening in bedrock slope and confirmed a variation of 10 m in the general slope. The general depth to bedrock is about 25 m although there is a general increase from about 20-27 m eastward. Bedrock velocity was again in the range 2750-3000 m/s.

*Spread 16.* The results from Spread 16 were curious in that there was little similarity with Spread 15. The interpreted depth to bedrock ranged from 20-27 m which is shallower than in the region of Spread 15. Bedrock velocities again ranged from 3200-3500 m/s to 4500 m/s.

*Spread 17.* Spread 17 confirmed the findings of Spread 16 and clearly revealed the presence of a sandstone bedrock 'rise'. Depths of the order of 20 m have been interpreted to bedrock with a seismic velocity of 3200-3500 m/s.

*Spread 18.* Spread 18 yielded very similar results to Spread 17.

*Spread 19.* Spread 19 was fired across the region of thick silt indicated by Spreads 1 and 3. The presence of thick silt was confirmed and a depth to bedrock of 45 m was indicated. The interpretation is not absolute and a variation of  $\pm 5$  m is possible. A further complication was the indication of a slope up to the east with a relief of at least 10 m (compare Spreads 10, 11).

*Spread 20.* The interpretation of Spread 19 was basically confirmed with a maximum bedrock depth of about 48 m.

*Spread 21.* Spread 21 was orientated parallel to the trough of silt indicated by previous spreads and by recording arrivals at the limit of the standard adjustments of the seismograph a bottom was implied at 54 m  $\pm 5$  m. The velocity of the bedrock is uncertain but is approximately 3000 m/s.

*Spread 22.* The information from Spread 22 was very similar to Spreads 2 and 3. The velocity indicated for the dolerite inshore ranged from 2300 m/s upwards. The low value commonly noted inshore implies much fracturing and possibly weathering. The spread was also at right angles to the dolerite edge-escarpment as indicated by the magnetic survey. At this point the magnetic survey suggested a very abrupt feature and the refraction time-distance graphs certainly confirmed this. In addition the steep slope appears to begin very close inshore (30-45 m from the high water mark) and falls to about -50 m. The escarpment may be nearly vertical in this region.

## Area 2

The seismic interpretation of the spreads fired in this area is summarised in Figure 25. The first series of spreads placed in this area (1-11) indicated a number of problems which would make reliable or consistent refraction interpretation difficult. The initial series of spreads was fired with extensions of up to 400 m, a distance which was more than adequate in all parts of Area 1. However, in all instances where a velocity could be ascribed to bedrock, or material underlying water, silt or both, it was generally less than 2500 m/s. Thus the velocity contrast between the water and rock paths is minimal. Consequently more energetic shots and longer shot distances are required. This poses three problems.

- (1) Minor modification of the seismograph is required in order to record the extended arrival times with a consequent loss of accuracy.
- (2) Difficulties are experienced in obtaining reverse firings with the shot distances required, especially near shore where the information may be critical.
- (3) Where steeply dipping interfaces and slow velocity wedges are present such long extensions make interpretation of the exact location of the features very difficult.

It is in this type of situation that reflection methods are more suitable. However the second series of spreads sought to obtain some data about the bedrock despite these deficiencies.

*Spread 1.* No bedrock was recorded in firings in this position and a minimum depth to bedrock is 45 m.

*Spread 2.* Bedrock with a seismic velocity of 3000 m/s was implied at a depth of 90 m even allowing for the low velocity of the silt. This extremely high value is inconsistent with the base level depths of Area 1. It may reflect a second hidden layer of clay and sand beneath the silt with a seismic velocity of 1500-1700 m/s.

*Spread 3.* Spread 3 covered 180 m offshore from low water mark. It produced complex results very similar to those of Spreads 1, 3 and 22 of Area 1. On the basis of these results it seems likely that the river channel is eroded to, or close to, bedrock in this zone. However, at a point about 60-75 m offshore the bedrock slope steepens and continues to a depth of about 45 m. The bedrock seismic velocity recorded was 2000-2500 m/s implying significant fracturing or weathering.

*Spread 4.* No definitive indication of bedrock was obtained but its depth is in excess of 45 m.

*Spread 5.* As for Spread 2. Bedrock is in excess of 50 m and may be at 90 m on the basis of the assumptions used (bedrock seismic velocity 3000 m/s, see Spread 2). However if the bedrock has a much lower true velocity (in the region of 2000-2500 m/s) then the 50-55 m figure could be a maximum. If it is presumed that the history of the river surmised by Leaman (1977) is valid then the base level in this reach would be about 50-55 m. On such an argument it could be said that the velocity of about 2250 m/s is implied with the further suggestion that the bedrock in this area is deeply weathered. Consistency of results and explanation of recording difficulties would be obtained on this basis.

*Spread 6.* Spread 6 offered a firm indication that the above argument may be sound. A relatively low velocity bedrock was observed with a moderate slope from about -45 m to -35 m. The dip was north-eastward.

*Spread 7.* Spread 7 produced results very similar to Spread 6 although implying bedrock depths of 10 m less.

*Spread 8.* No firm details were obtained about bedrock and a depth of 40-45 m is estimated.

*Spread 9.* As for Spread 8 although the implied depth to bedrock is 2-3 m greater.

*Spread 10.* As for Spreads 8 and 9. Depth to bedrock is estimated at 40-45 m.

*Spread 11.* Although fired relatively close inshore on the southern side of the river little information was obtained concerning the bedrock. A bedrock seismic velocity of about 2000 m/s was determined from spread and it is suggested that the basalt nearby has this velocity. Deep weathering may be assumed. As suggested in the magnetic interpretation (fig.24) the basalt may extend well into the river in this area and the results of Spreads 6-10 may reflect unevenly weathered basalt as bedrock. The depth to bedrock is estimated at 25-30 m. A significant bedrock slope from the shore is implied.

Spreads 12-15 represent the second series of spreads placed in this area. In each case the longest possible shot extensions were fired (the maximum shot-hydrophone distance was 630 m) and the seismograph adjusted to provide clear information on the extended timing and nature of the arrivals. With the method and equipment extended to critical limits further details about the bedrock interface were obtained as described below. However, the information is far from complete and cannot be readily upgraded.

*Spread 12.* The southern end of the spread was placed onshore in order to assess the presence of inshore slopes. The basalt bedrock exposed on the nearby promontory was observed to have a seismic velocity of 2500-2700 m/s and to dip shallowly northward into the river to a depth of about 3 m at 35 m offshore. Beyond this distance the slope can only be estimated as exceeding 10-15° with bedrock at more than 10 m on the northern end of the spread.

*Spread 13.* This spread demonstrated the awkwardness of the refraction method in what has been shown to be a very complex area, geologically and seismically. The time distance curves may be interpreted in two ways. A variable bedrock seismic velocity in the range 1900-2200 m/s at a depth of approximately 30 m with minor (3-5 m) relief may be indicated. Alternatively the quasi-sinusoidal nature of the curves may reflect small measurement errors on a base velocity of 1700-1800 m/s. The reading of the curves is critical implying weathered basalt in one instance and clay and sand in the other. It must also be observed that Spreads 6-10 could also be interpreted in this way since the velocity detail was ambiguous. If clayey sediments are present they are probably overlain by only about 20-25 m of water and silt.

*Spread 14.* A clear recording of an 1800 m/s velocity was provided for the first time. A wedge of material with this seismic velocity is overlain by at least 10-20 m of water and silt and apparently underlain by a higher velocity medium (>2500 m/s, basalt?). There appears to be a quite steep slope from around 3-5 m to >15 m at about 90-100 m offshore. The slope indicated could possibly be interpreted as an abrupt subvertical interface between the 2500 and 1800 m/s materials and hence the detailed structural interpretation

is again uncertain. Dolerite and not basalt may underlie the clayey sediments but this could only be determined by drilling.

*Spread 15.* Two classes of bedrock were revealed by the final spread. The clayey sedimentary base with a seismic velocity of about 1800 m/s was recorded as depths of around 30 m and found to overlie a very firm bedrock with a velocity in excess of 5000 m/s. The thickness of material with a velocity of 1800 m/s is interpreted at some 40-50 m wedging out markedly to the north and east.

#### SUMMARY

##### Area 1

The principal bedrock across most of this area, and that of the adjacent temporary bridge, is quartz sandstone. The sandstone appears to be in good condition with little seismic indication of deep or extreme weathering. The normal seismic velocity range is 3000-4500 m/s.

The dolerite at Dowsings Point is fractured and moderately weathered (velocity 2200-3000 m/s) and forms the basal part of an intrusion. The geological interpretation is indicated in Figure 27. On the basis of some apparently abnormal velocities, and increased magnetic field, mid-river it is possible that further dolerite may be encountered as small intrusions in the sandstone. The magnetic results may indicate local accumulations of boulders beneath the silt whereas the much higher than normal velocities can only reflect slope conditions or more massive and denser rock.

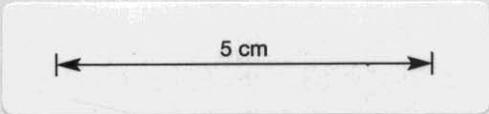
The cover of silt is variable but reaches a maximum thickness of 50-55 m about 100 m north of Dowsings Point. It has a velocity of about 1050 m/s implying a modulus of about  $1.9 \times 10^9 \text{ kg m}^{-1}\text{s}^{-2}$  (a density of  $1700 \text{ kg m}^{-3}$  was presumed).

The interpretations presented for this area are regarded as relatively straightforward; there being good velocity contrasts and ample drilling control. Any deficiencies within the interpretation will be related to the seismic velocity assigned to the silt and while the value quoted was implied from the available drilling control and cross-evaluated with the Bedlam Walls situation there may be locally significant velocity variations.

##### Area 2

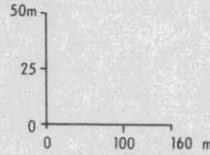
The geological conditions in this region are far from simple but need not pose significant foundational problems. On the north-eastern side of the area the bedrock is dolerite. It forms a continuous mass across river and is weathered or fractured (seismic velocity 2500-3000 m/s). However the south-western side of the area is very different. Basalt overlies dolerite onshore and extends some distance into the river. It is very weathered (velocity 2000-2200 m/s). The basalt is probably underlain by clay and sand with a seismic velocity of 1800 m/s. The 1800 m/s velocity could be interpreted as representing very deeply weathered basalt or dolerite although, in view of the regional geology sediments are more likely. A suggested section is given in Figure 27. The smoothing of the magnetic field to the west also suggests that the dolerite is covered by other materials and does not form the total bedrock. The response of the basalt was minimal inshore and it may be a cover on the dolerite right across river.

The cover of silt is again variable but reaches an estimated maximum thickness of 50-55 m about 150-250 m south of the northern end of Area 2.

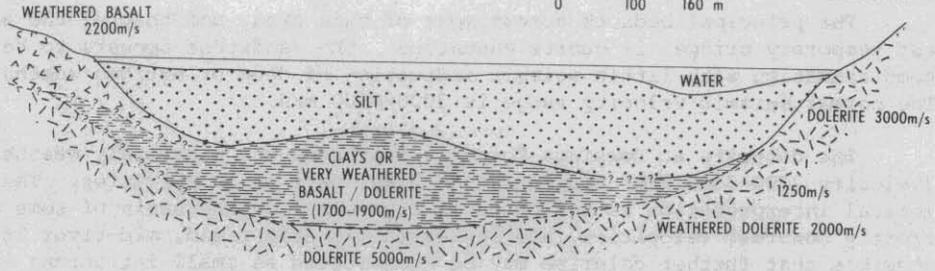


SECTION : CENTRE AREA 2

SOUTH

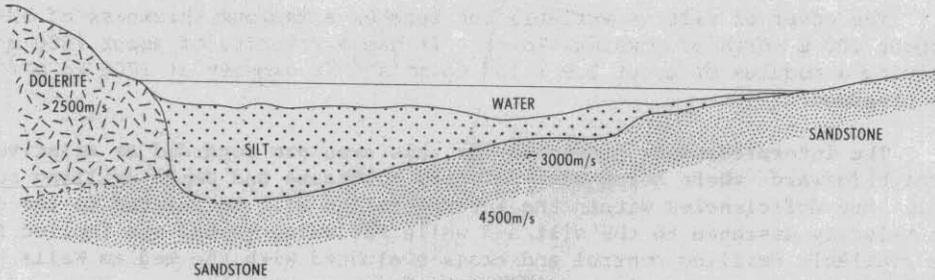


NORTH



NOTE : WEDGE OF 1700-1900m/s MATERIAL TOWARD ELWICK BAY AND THINS TO THE EAST.

SECTION : CENTRE AREA 1



SECTIONS  
SEISMIC INTERPRETATION  
RIVER DERWENT : DOWSINGS POINT REGION

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Figure 27.

The seismic velocity presumed for the silt was 1050 m/s and any first order weakness in the interpretation would be related to variations from this value. In addition, the presence of low velocity materials under such a 'hidden' layer pose major operational and interpretational difficulties. The quality of the conclusions offered in Figure 25 is much lower than that for Area 1.

#### COMMENTS AND RECOMMENDATIONS

##### Area 1

No general foundational problems are anticipated although the method of piling selected is likely to be very important. On the basis of the present information indicating an abrupt bedrock interface, driven piles may not be satisfactory. The dolerite offshore from Dowsings Point should be avoided if possible due to the presence of intense fracturing and the steep escarpment.

Little further drilling could be recommended other than to establish properties of the materials (especially the silt and the rock interface) and to confirm the smaller northern escarpment. The construction of the temporary bridge nearby will resolve these matters and no further drilling is recommended at this stage. Prior to any construction, abutment conditions at Dowsings Point should be assessed by an onshore seismic survey and at least one shallow (>10 m) drill hole.

##### Area 2

Again no general problems are anticipated although foundation and piling conditions will be very different due to the presence of substantial amounts of soft or deeply weathered materials.

The dolerite offshore on the northern end of Area 2 should be avoided, if possible, due to the presence of a highly fractured escarpment.

At least four drill holes are recommended, in river, in this area. They should be equidistant so as to provide general coverage and allow assessment of the rather confused seismic interpretation.

Abutment conditions to north and south should also be assessed by onshore seismic surveys and at least one shallow drill hole.

#### REFERENCES

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