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# Special Instability Problems in the Illawarra and Warringah Shire Areas of New South Wales

by

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**SUMMARY.** The stability of several areas of the Illawarra and Warringah Shire in New South Wales are examined with a view to demonstrating the similarity between the very large number of earth movements which have occurred in these regions. The similarity in the type and mechanism of failures in these two heavily populated areas is believed to stem from a special geological and hydro-geological condition common to both areas. The very difficult social and legal problems arising from these widespread failures is discussed.

## 1 INTRODUCTION

Instability of earth slopes in the Illawarra and Warringah Shire areas of New South Wales (Fig. 1) may be directly related to a special inter-relationship between the geological sequence of rock strata, a soil cover of talus material and an elevated source of seepage water. The inter-relationship between these basic ingredients over a large number of locations throughout the Illawarra and Warringah Shire areas is spelling disaster and economic ruin to a growing number of individuals. These individuals have unwittingly built on the talus slopes in these areas and are paying a high price in major renovations to damaged houses and, in some cases, are faced with the total loss of their homes due to land slides. The number of individuals affected will increase dramatically in both areas unless the development of these slopes is controlled and the root causes of the failures are understood and respected by those in a position to control future growth.

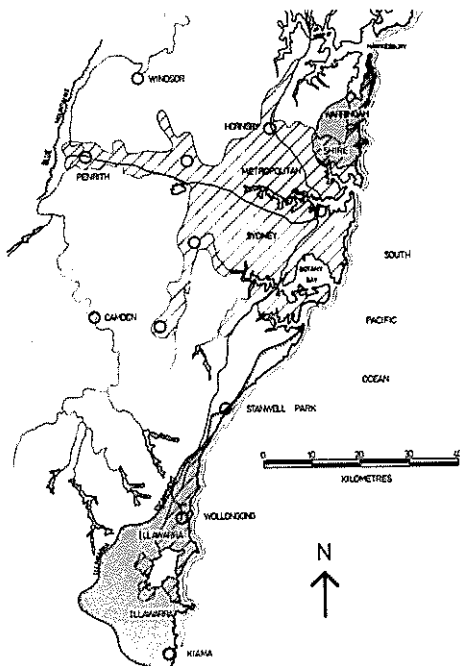


Fig. 1 Subject Areas

In this paper, an outline of the special conditions existing in the Illawarra and Warringah Shire areas are examined and several case histories are reviewed to illustrate the mechanics and importance of the various factors involved in the apparent general instability of these areas. Comment is also made on the social aspect of slope failures in the Illawarra and Warringah Shire areas.

## 2 SPECIAL GEOLOGICAL SEQUENCE

The sandstone escarpment and slopes which front the near vertical cliff faces in the Illawarra and Warringah Shire areas consist of a succession of sedimentary rock strata laid down during the Permian and Triassic Periods between about 200 and 300 million years ago. A schematic section through a typical profile of this rock sequence is shown on Fig. 2.

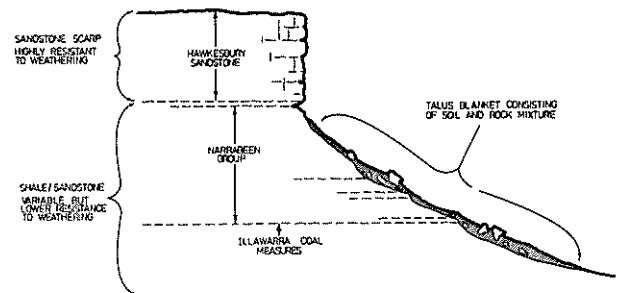


Fig. 2 Schematic Section through Illawarra Escarpment

A simplified stratigraphic sequence of the major rock formations represented in Fig. 2 is given with selected relevant properties in Table 1.

The sequence of rock strata exposed along the Illawarra Escarpment and in Warringah Shire was deposited in an area roughly bounded by what is referred to as the Sydney Basin. This area is bounded on the east by the coastline extending from about Bateman's Bay to Port Stephens, on the west by a line drawn approximately north-west from Bateman's Bay to Ulan and thence easterly along the Goulburn River to the Hunter River and south-easterly to Port Stephens. Warping of the Sydney

TABLE I

## MAJOR ROCK FORMATION AND RELEVANT PROPERTIES

Rock Units	Basic Constituents	Relevant Properties	Comments
Hawkesbury Sandstone	Quartz sandstone, minor shale lenses	Very high strength (often >3,000 psi) and high resistance to weathering	48 gph "take" over 50 ft. length of core hole in one test on top of escarpment*
Narrabeen Group	Sandstones, shales, claystones and siltstones	Large variation in strength (10 psi to 6,000 psi). Generally low resistance to weathering	Apparent high variation in permeability. "Take" varied from 30 to 600 gph in successive 50 ft. lengths of core hole on top of escarpment*
Illawarra Coal Measures	Mostly sandstones with interbedded coal seams, shales and siltstones	Large variation in strength. Generally low resistance to weathering as a whole	High variation in permeability. "Take" varied from 36 to 540 gph in successive 50 ft. lengths of core hole*

\* M.W.S. & D.B. data (unpublished) from pressure packer tests carried out in core holes drilled in the vicinity of Cordeaux Dam

Basin about 10 million years ago (Pliocene) resulted in uplift of the Woronora Plateau, the eastern limit of which is represented by the Illawarra Escarpment which has eroded westwards to its present position. During this same period, deep erosion channels were carved through the Hawkesbury Sandstone and Narrabeen Group rocks in the Warringah Shire area to form local sandstone capped plateaux.

A further deposit which is represented below the cliff or escarpment faces in these two areas is the talus material which mantles a significant portion of the slopes below the scarp as shown schematically on Fig. 2. Talus is the unconsolidated sediment (debris) formed at the base of the scarp due to retreat of the rock face. This material is formed from the erosion of claystone, shales, coals and other less resistant rocks which eventually undermine the more resistant siltstones and sandstones which, in turn, break off and fall to the bottom of the near vertical scarp. These materials form a mixture comprised of the constituents of the parent escarpment rocks and the underlying less resistant Narrabeen Group and/or Illawarra Coal Measure rocks.

Some relevant engineering properties of representative samples of talus from several sites are given in Table II.

### 3 GENERAL CHARACTERISTICS OF TALUS SLIDES

The general characteristics of many earth slides in the Illawarra are best seen in the essentially cleared farm land on the foothills or talus slopes below the escarpment as it is here that old and recent movements may be seen without the disguise or interference of trees, houses, roadways etc. Two such tracts of land have been examined in some detail in the Figtree and Unanderra areas using low level aerial photography, extensive seismic traverses in conjunction with borings and test pits as well as a detailed surface survey of drainage features. Areas of old

and recent earth movements within extensive tracts of land (having areas of some 45 hectares and 160 hectares) are shown on Figures 3 and 4 respectively.



Fig. 3 Unstable areas within 45 hectare site, Figtree (Illawarra)

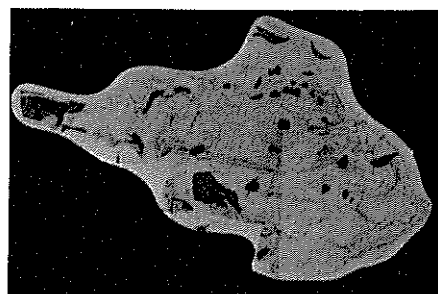


Fig. 4 Unstable areas within 160 hectare site, Unanderra (Illawarra)

Some physical details of these slides are given on Table III.

TABLE II  
ENGINEERING PROPERTIES OF TALUS MATERIAL

Location	LL	PL	PI	LS	% #200	Classification	$\phi_r$
Woonona Heights, Illawarra	42-78	15-33	17-45	13-17		CL-CH	
Mt. Nebo, Figtree, Illawarra	48-115	25-34	14-90	8		CL-CH	
Central Kembla, Unanderra, Illawarra	31-55	22-31	4-28	7-10		CL-CH	
Mt. Brown, Dapto, Illawarra*	37-88	19-25	18-63	10-18		CL-CH	10°
Gerringong, Illawarra	42-74	35-42	12-39	7-15	14-91%	CL-CH	12°-14°
Belinda Place, Newport, Warringah Shire	30-55	14-29	14-26		14-65%	CL-CH	

TABLE III  
PHYSICAL CHARACTERISTICS OF EARTH SLIDES, FIGTREE AND UNANDERRA, ILLAWARRA

Area of Slide (hectares)	Depth of Soil in Slide Area (metres)	Average Slope Angle	Comment
FIGTREE SITE - Percentage of unstable area = 35% (15 hectares out of 43.5 hectares)			
4.1	0 - 3	15°	. within old slide area - springs evident
1.8	1½ - 4½	12°	. within old slide area - springs evident
1.3	0 - 3	14°	. within old slide area
3.7	1½ - 3	16°	. within old slide area - springs evident
1.5	1½ - 6	15°	. within old slide area
1.5	3 - 6	15°	. within old slide area
0.4	1½ - 4½	11°	
0.1		16°	
0.7		12°	. within old slide area
UNANDERRA SITE - Percentage of unstable area = 9.2% (14.7 hectares out of 160 hectares)			
3.78	0 - 3	20°	. within old slide area - springs evident
0.36	1½ - 3	22°	. within old slide area - springs evident
0.06	0 - 3	18°	
0.09	0 - 3	18°	
0.40	0 - 3	20°	
0.11	0 - 3	21°	. springs evident
0.11	0 - 3	22°	. springs evident
0.28	0 - 3	22°	
0.16	0 - 3	19°	
0.15	0 - 3	22°	
0.17	0 - 3	16°	
0.24	1½ - 3	15°	. within old slide area - seepage evident

As with most of the earth slides in the Illawarra the area of these movements is large in comparison with their depth. As may be seen from Table III the depth of these slides is generally less than 5 metres and often less than 3 metres. It is considered that the major portion of these movements fall into the category of "sheet slides" or "earthworks" (Zaruba, 1969). Two typical and related features of these movements are the apparent extensive internal movements within the moving earth mass (as evidenced by closely spaced tension cracks, see Fig. 5) and the obvious "flow" pattern resulting from the slide (see Fig. 6).



Fig. 5 Coledale Heights, Illawarra - Note closely spaced tension cracks within failed area

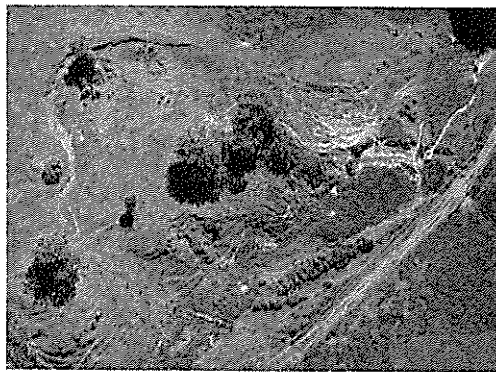


Fig. 6 Gerringong area, Illawarra - Note "flow" pattern of "sheet" type slide

From the social and legal point of view, it is of more than passing interest that many of the shallow surface soil movements cover large areas.

Other common factors noted in studying the slide areas within the large tracts of land shown on Figures 3 and 4 were the prevalence of springs within the failed areas and the fact that the underlying bedrock surface was invariably sloping and mostly paralleled the overburden surface profile. The source of water for such springs is virtually unlimited with the combination of higher plateau land to the west and plentiful rainfall. The transmission of this water to spring areas is also well taken care of by the extensive underlying nearly horizontally bedded sedimentary rock

strata described above. On the slopes themselves the release of this percolating water through natural seepage is generally restricted by the relatively impervious clayey mantle of talus material.

#### 4 CASE HISTORIES

##### (a) Coalcliff (Illawarra)

An earth slide to the immediate north of Coalcliff Railway Station (Fig. 7 below) on the South Coast (Mile 36) exhibits several features typical of the slides described above. A mass of soil having a plan area of approximately 9 hectares an average depth of approximately 7 metres (determined from borings and a seismic survey) and a ground surface slope of about 7° (1 vertical to 8 horizontal) has moved progressively to the east on a sloping rock surface of approximately the same angle of inclination. Groundwater level fluctuations of up to 4 metres have been recorded in borings within the slide area by the Rail Division of the Public Transport Commission of N.S.W. (unpublished report). Continuous pumping from a single row of well points discharging an average of about 7 gpm over a four month period was successful in lowering the groundwater level some 1 to 1½ metres. During this period a total of approximately 4,800 points of rain fell at the nearby Stanwell Park monitoring station. In addition to the single line of well points extending into the underlying rock a series of horizontal drains have been installed through the fill and talus overburden and into the shale/sandstone bedrock. The most successful of these drains yielded an average of some 4 gpm during the very wet period from October, 1973 to July, 1974. In general the total yield from the rock formation and overburden soils was not large but this approach does show promise in lowering the groundwater level in this area and in helping to control the land slip.

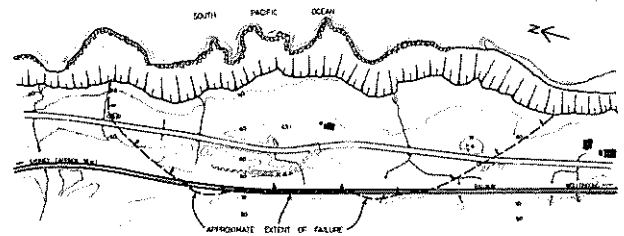


Fig. 7 Slide area of 9 hectares involving railway line and main road, Coalcliff (Illawarra)

It has been noted by Public Transport Commission Engineers investigating this slide that movements often occur two to four days after heavy rain even though the intensity of storm runoff in this area is very high and the duration correspondingly short. The rise in the groundwater level (and possibly excessive hydrostatic pressures) appears to be related to subsurface seepage through the rock and/or along the soil rock interface from a source remote from the slide area.

##### (b) Mount Ousley (Illawarra)

An old failure in the Mount Ousley area (Fig. 8) has become active again during the period from March, 1972 to at least August, 1974 after heavy rains. The area of this obviously unstable area was about 3 hectares in 1972 but is now about 4 hectares. The depth of the unstable area appears to be about 4 to 6 metres and the average slope of

the talus soil cover is less than 10 degrees.

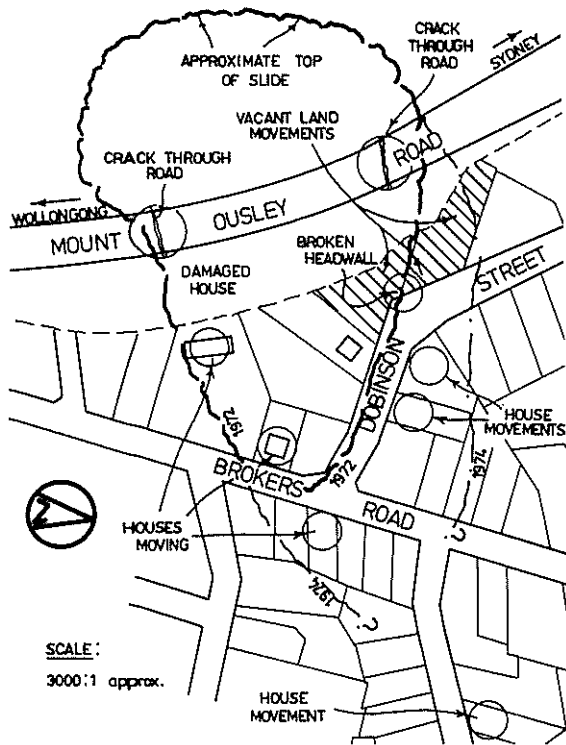


Fig. 8 Large slide in built-up area of Mt. Ousley, Wollongong (Illawarra) involving several properties.

A combination of low soil strength with perhaps a "residual" angle of internal friction of between 8 to 12 degrees and an artesian groundwater condition are considered to be responsible for the continued movement of this earth slide. The use of "residual" strength parameters in this case are justified by the fact that this is an old slide with records of previous movements dating back to at least 1951. The existence of an artesian condition was demonstrated during drilling operations on a nearby property when water was encountered at a depth of 5½ metres in an underlying coal seam, rose up the open hole and flowed out at ground surface.

It is also believed that the source of this seepage water is remote from the slide area itself since major movements of the soil mass (as determined by survey measurements on a house within the slide area) tend to occur three to four days after heavy rain. It is hypothesised that water enters the rock formation at locations above the slide area, seeps through the rock mass towards the east and becomes trapped beneath the relatively impervious blanket of clayey talus. It is further hypothesised that the hydrostatic pressure beneath and within the talus increases to a maximum some days after the rainfall (and peak surface water runoff) thus causing the delay in movement.

In view of the very large capital investment that has already been made in this slip area (a major state highway, two Council Streets, at least 11 private properties and ancillary water supply and electricity installations) it is obviously important to arrest this movement. Although technically feasible, very little effort has been made to prevent further movements. It is believed that the basic reason for this inactivity is the complex legal situation whereby State, Local Government and private individuals are all caught

up in a common problem requiring concerted group action but are discouraged from acting because of the uncertain responsibilities under the law.

(c) Belinda Place, Newport (Warringah Shire)

One of the more tragic earth slides to take place in talus material in either the Illawarra or Warringah Shire areas in recent years is that which occurred during the early months of 1972 in Newport (Fig. 9).



Fig. 9 Aerial View, Belinda Place Slide, Newport (Warringah Shire)

The area of the slide is approximately 0.37 hectares and has effected some seven private properties, two Council Streets and a Council footpath. Two new homes have been completely lost to date and another home is on the verge of being lost. The average depth of the sliding earth mass before failure was estimated to be 4 to 5 metres and the average slope angle 21 degrees. The depth of the soil cover was determined by means of borings and seismic traverses.

As with the vast majority of slides investigated in the Illawarra this failure occurred along the interface between the underlying sloping rock surface and the talus overburden following heavy rain. This slide is also similar to many others investigated in the Wollongong area in that the underlying rock is near horizontally bedded and there is an elevated plateau uphill of the site which acts as a catchment for water percolating into the rock mass. The free drainage of this percolating water from the bedrock is hampered and restricted by the clayey talus material.

(d) Dapto (Illawarra)

During the heavy rains of early 1974 an earth slide occurred on an 8 degree slope towards the base of Mount Brown in Dapto. The area of the slide was about 0.6 to 1 hectare and the average depth of the sliding earth mass was about 4 metres.

The soil cover in this case is colluvium consisting essentially of silty clay (CH) and the underlying rock is siltstone. An examination of the site immediately after failure revealed several local "springs" where water was bubbling out of the ground, evidently under a slight excess hydrostatic "head" relative to ground surface.

The shape of the land in the slide area indicates that this area had failed at some time in the past and it is therefore considered that residual strength parameters would be applicable

in the analysis of this case.

The results of a sensitivity analysis carried out on this failure are given in Fig. 10 where it may be seen that failure would occur when the groundwater level reached ground surface for a  $\phi_r$  value equal to about 12 degrees. For a  $\phi_r$  value in excess of 16 or more degrees, failure would still occur if a hydrostatic head equivalent to a water level above ground surface developed along the failure plane.

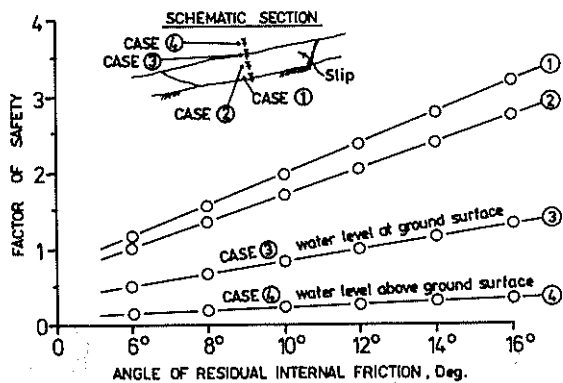


Fig. 10 Sensitivity analysis of slide area, Dapto (Illawarra) involving several building blocks

The extensive upper area of Mount Brown with its shallow soil cover and bedrock outcroppings provides an ideal catchment for water to feed the groundwater table within the rock core of this hill. As with the talus slopes below the Illawarra Escarpment the lower slopes of Mount Brown contain numerous natural springs which indicate a local relief point or outlet for a high water table condition.

## 5 SOCIAL PROBLEMS

With the supply of good land in the Illawarra and Warringah Shire areas becoming ever scarcer and the pressure to develop even more of the talus slopes increasing, there is an urgent need for extensive and intensive studies of yet undeveloped land before it is released and, particularly, before it is subdivided and sold to individuals for private home development.

Where land has already been subdivided and an individual homeowner finds that his block is moving or is in imminent danger of moving, it is very difficult for him to act. The removal or addition of fill to his block could, on the one hand remove support from the toe of a neighbour's sloping block or on the other hand, add weight to the top of another neighbour's block.

Similarly, the installation of drains on one block may improve a local area but invariably concentrates the discharge onto another (neighbours) area. Further, the existence of houses, fences, retaining walls, streets etc., hinders any joint action.

Action by a group of homeowners and council would require the coming together of all parties involved within an earth slip area as well as abutters immediately adjacent to the slipped land. The solution may involve an investigation of the whole area and the development of an overall plan of remedial measures possibly extending well outside the actual slip area.

There are numerous practical problems involved with this approach ("without prejudice" solution binding all parties) such as the physical interference of houses, roads, retaining walls etc., to any remedial works as well as the very difficult legal problems of responsibility and perhaps the almost impossible task of achieving general agreement on an acceptable course of action. The latter task becomes even more difficult when it is realised that some individuals will obviously have less to gain from a concerted group action than others and hence would be reluctant to put up an equal amount of money for an investigation and required restoration works.

Remedial action by a developer to stabilize slopes before land in a suspect area is subdivided and before council has accepted responsibility for road and service maintenance is considered the only practical approach to land slide problems. The actual planning of a subdivision should take into account the fact of potential instability in suspect areas and the design should proceed only after sufficient evidence is gathered to ensure that the subdivision layout is rational.

Before proceeding to final design on larger subdivisions on sloping land in areas of known instability, a "stability map" should be compiled from a field reconnaissance survey and air photos. This should normally be supplemented by field investigation studies including test pits, boreholes and seismic traverses to provide an overall appreciation of the soil overburden characteristics over the site. The results of such a study will tend to dictate the final "shape" of the subdivision or development such that housing, streets, parks, etc., are sited on a rational basis in so far as stability is concerned.

With the ever increasing number of individuals being caught up in major losses in necessary renovation work, and, sometimes complete loss of property, it should be mandatory for the stability of a site to be taken into account before development.

## 6 SUMMARY

The Illawarra and Warringah Shire areas of N.S.W. are plagued with problems of landslip which are related to a distinct set of physical and climatic conditions as follows:-

- . the slopes are backed by extensive elevated rock plateaux areas which act as catchments to replenish the groundwater table within the rock mass.
- . the slopes are underlain by a horizontally bedded sloping rock profile and are blanketed with talus material consisting essentially of relatively impervious clayey soil.
- . both areas are subject to heavy seasonal rainfall.
- . due to the mechanism of formation of the scree slopes, large portions of the talus slopes have previously moved and hence the shear strength of the soil available to resist further movement is likely to approximate the residual strength of the soil.

- . due to the features described above, artesian groundwater conditions are common along the talus slopes in both areas.

The character of these slides are such that they cover large areas, often in excess of one hectare, and consequently encompass several individual properties when they occur in built-up areas. The social and legal consequences of such failures are difficult to solve even when a technical solution is at hand.

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