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# A Predictive Landslip Survey and its Social Impact

by

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**SUMMARY.** The Tamar Valley in Northern Tasmania is a basin of Tertiary clay, sand and basalts, which has been eroded as a ria estuary.

The resulting slopes are subject to extensive landslip and increasing development has made this hazard more serious. Over forty houses have been destroyed since 1958.

A programme of investigation starting from geological and geomorphic mapping has enabled the construction of landslip zone maps which record past and present landslip events and attempts to predict the probability of future failure. A geomechanical study is in progress but is not reported here.

Legislation has in the past attempted to deal with landslip damage as an "Act of God" event but the predictive element of the zone map has changed this. A new style of legislation has been introduced which gives power to enforce better building practices. More predictive planning is also possible.

New building regulations have been written and a code of practice is in preparation. The regulations are so graded as to bear most heavily on areas of greatest hazard.

## 1 INTRODUCTION

The Tamar Valley, of northern Tasmania runs 70 km inland from the north central coast of the island and averages 12 km wide. The city of Launceston (34 000 population) lies near the head of the valley at the confluence of the North and South Esk Rivers. They combine to flow as the Tamar River, a sinuous tidal estuary, to Bass Strait. The fast growing town of George Town and its port of Bell Bay and the town of Beauty Point lie on opposite sides near the mouth (fig. 1). The area is one of the fastest developing parts of the State and the Tamar Plan has been published (Ref. 1) advocating the division of the whole valley into regions devoted to port and industrial activities, tourist and scenic use, secondary and tertiary industries, and urban and administrative centres. Planning is carried out by the Tamar Regional Master Planning Authority. The population of the whole Tamar region is 84 000.

## 2 GEOLOGY AND MORPHOLOGY

The basement rock and framework of the area is Jurassic dolerite in the form of a sill about 300 m thick, faulted along NNW-SSE lines and tilted towards the west to produce several parallel asymmetrical fault troughs (Ref. 2). Wedges of older rocks are contained by the dolerite intrusion and faulting, and exist beneath the sill but have little influence on the present topography within the region.

After the major faulting of the dolerite, the complex fault troughs were filled by a sedimentary succession of clay, sand and gravel in Tertiary time. The depositional environment appears to have been a series of freshwater lakes deriving run-off from nearby under warm, humid and therefore heavily vegetated conditions. The sediments are not well known, but show clear derivation from the dolerite, as well as the slate, mudstone, granite and sandstone of the present catchment.

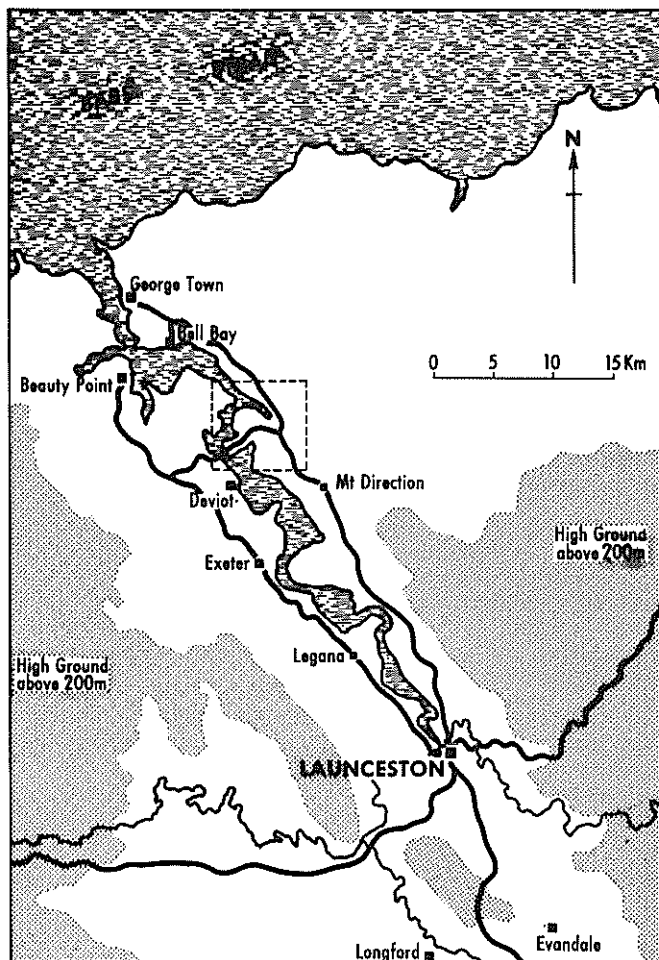


Fig. 1 The Tamar Region  
The small square indicates the area covered by Fig. 2

Johnstone (Ref. 3) has recorded the succession in the Carr Villa bore in south Launceston and has remarked on the great variability of the sediments both laterally and vertically. Such a condition is not unexpected in restricted basin deposition and is confirmed by the logs of bore holes in the Windmill Hill area of Launceston (Aitchison and Gill, unpublished). The present study has concentrated on bore holes of less than 20 m although deeper holes are intended as the work continues.

Longman and Leaman (Ref. 4) indicated a depth below sea level for the base of the Tertiary basin about mid-Tamar in excess of 500 m. Their results, from a gravity survey, suggest that the presence of a significant thickness of basalt in the column would increase this estimate. They confirm the fault wedge nature of the trough and show that cross faulting has probably formed rock bars to divide the whole trough into discrete basins in depth.

Interbedded with the sediments are basalt flows at several horizons (Sutherland, Ref. 5). The eruptive centres are not obvious but appear from mapping to emanate from the trough faults.

The modern topography has its origin in the partial exhumation of the dolerite floor from the overlying sheet of Tertiary rocks so that these form slopes on either side of the valley up to 300 m above sea level, while the now exposed dolerite rises beyond this. The original thickness of the Tertiary sequence is unknown.

The sediments are mainly grey, red and mottled plastic clays, strongly fissured and over-consolidated, with interbedded lenticular bodies of sandy clay and lithic sands. Some properties of the clays are given in the Appendix. Thin quartzite gravels and occasionally thick dolerite gravels are also present. The sands are often secondarily cemented into thin ironstones, and they, the gravels, and the interbedded basalts make terrace features on the valley sides as shown diagrammatically in Figure 2.

The details of the geology are not easy to see because the soft nature of most of the rocks makes outcrops uncommon, and mass movement makes their relationships always uncertain.

The downcutting to a sea level base along the Tamar has been quite severe and has resulted in an oversteepened and therefore unstable topography. It is instructive to compare the Tamar Valley with the higher reaches of the South Esk in the Longford Basin where, above a dolerite rock bar which has so far limited downcutting, Tertiary clay sediments form a wide plain with little relief and very stable landforms.

The presence of a landslip hazard has been known in the region for over a hundred years. Friend (Ref. 6) described the occurrence of landslips on the slopes of the Tamar, and his analysis has a familiar ring, and Johnstone (Ref. 3) mention 'huge landslips' at Breadalbane in the south of the area.

Occasional damage to houses was reported in the past, but in the period 1958 to 1961 twenty-two houses were destroyed in the Lawrence Vale Road area of Launceston by an extensive mass movement. Since that time movements at Beauty Point, Deviot, St Leonards and at several other places both in the Tamar and elsewhere in the State have caused or threatened destruction of buildings and damage to installations.

Since 1970 the Geological Survey of Tasmania has been working continuously on the problem although many departmental reports date from before this time.

The aim of the investigation was initially to reveal the extent and magnitude of the hazard, and to this end a slope analysis map was prepared. Regional geological sheets on one inch to one mile are available for the whole of the area. The slope map showed all areas where both Tertiary sediments or basalts existed, the ground slope was greater than nine degrees on sediments, or the ground slope was greater than nineteen degrees on basalts or basalt talus.

These angles were chosen as slips had been observed at these slopes in these rocks. The areas were outlined by measuring contour spacings on two inches to one mile maps. This simple technique showed that considerable areas of clay slope were present, and it gave a passing warning and a basis for the subsequent zone mapping.

#### (a) The Zone Mapping

The evolution of the next stage of mapping was hastened by the now obvious severity of the hazard and the rapidly advancing development of the region. The map was required to be as far as possible self-explanatory, self-justifying, and to be advisory in nature. The zones were chosen and the boundaries drawn on field observation and the whole map took 2½ man-years to prepare. The zones have shown their natural utility after several years of use and increasing familiarity to planning authorities, government departments, local councils, land companies, and private members of the public.

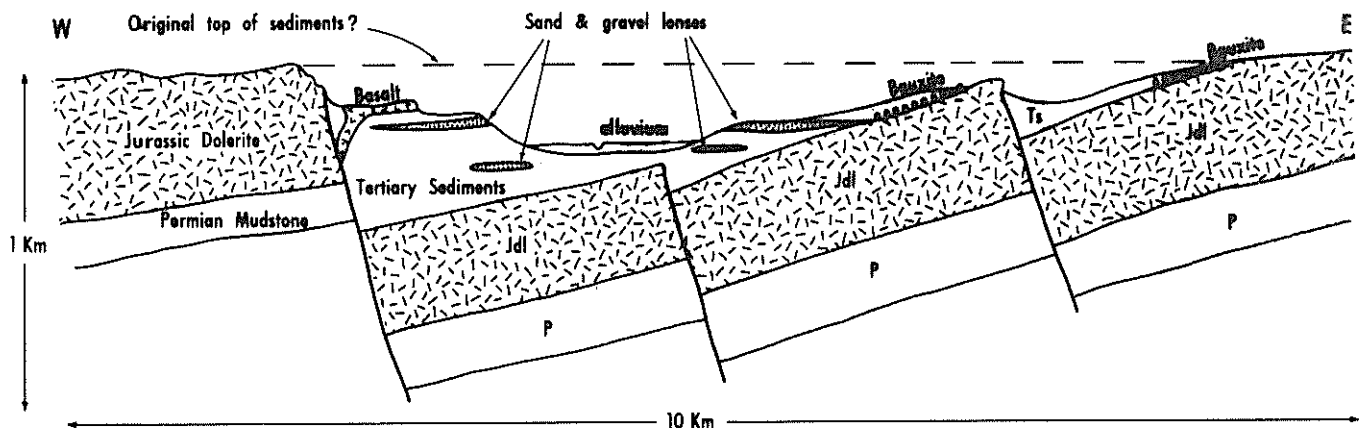


Fig. 2 Diagrammatic section across the Tamar Valley showing the nature of the Tertiary rocks, their effect on the topography and their relativity with the older structure.

(b) Tamar Valley Landslip Zones

- (i) Zone I. Stable ground on hard rocks. No abnormal problems or risks.

These areas are usually on dolerite or basalt. In framing the brief description of this zone, the concept of an abnormal risk is used because many of the hard rock areas are topographically steep, and narrow zones of deep soft weathering particularly in the dolerite are not uncommon. These could produce 'expected' landslips if ignored but unexpected landslip is unlikely.

- (ii) Zone II. Stable ground but on soft rocks. Strict adherence to existing building code.

These areas are usually on Tertiary and Quaternary sand, clay or gravel on slopes of less than six degrees. The stability of the land with respect to mass movement is not in doubt but many of the clays are expansive and foundation cracking is common enough to be accepted as normal in some areas. Settlement is also a problem.

- (iii) Zone III. Potential landslip areas. Building methods in accordance with a special code.

These areas are on Tertiary sediments or on deeply weathered basalt talus at slopes greater than six degrees and as high as thirty degrees. The steeper slopes are often but not invariably found where sands and gravels predominate and the problem of apparently stable slopes in clay is a complex one. Zone III implies that no surface disruption or other evidence of landslip has been recognised, but is in respect of geology and slope angle similar to disrupted areas.

- (iv) Zone IV. Old landslips and adjacent areas. No building without specialised investigation and design.

These are areas on Tertiary sediment or talus of greater slope than six degrees where surface disruption has been clearly recognised but is not currently active. Areas adjacent are included because of the tendency of landslips to spread laterally and uphill by progressive failure of support and down hill by earthflow.

- (v) Zone V. Active landslip and adjacent areas. No building without specialised investigation and design.

These areas were in active failure when mapped or were adjacent to such areas.

Zone III presents a dilemma, for arguments may be brought which say that as the zone is not known to have failed in the past then there should be no expectation of it doing so in the future. On the other hand, it may be suggested that if the phenomenon follows a long term cycle then areas apparently undisrupted may be just about to enter a new phase. The dilemma is however false, because in a developing area, the slopes may be subjected to stresses that they have never encountered before, and therefore failure may take place ab initio.

Zone IV also presents a difficulty, but of a different kind, and this will be treated as The Age Problem below.

Zone V is in many ways an easy one because failure leaves little doubt of its presence. The known examples are a valuable asset to one attempting to investigate the problem, and there are about 200

active slips in the valley. Simple, small, and supposedly young slips show an annual activity, with a maximum in the Spring and early Summer, but with advancing age the slip becomes complex and may be multiple, and then activity does not follow such an obvious simple pattern.

The zone map was originally published on a scale of one inch to one mile but has subsequently been revised and produced on four inches to one mile. The map has been lodged with State and local government authorities concerned with the area. It has caused some comment, not all well-informed, but the policy has been to display the map freely to any interested enquirers, private or corporate, and to ask public bodies who have copies to do the same.

#### 4 LANDSLIP LOCI

Implicit in the map is the recognition of landslip loci. These are of the kinds shown in Figure 2 and are detailed below, Varnes' (Ref. 7) terms being attached as appropriate.

##### (a) Clay Slopes

Clays in areas where relief is imposed by uplift, may be eroded by rainwash and soil creep processes and need not be subject to landslipping. The essential ingredient in our case seems to be over-consolidation. When eroded the reduction of load causes expansion and fissuring, and this ensures that when slopes fail they do so in large masses rather than grain by grain. The expansive nature of the clay too, ensures that rainwater has good access to the fissures by way of annual desiccation cracks. For simple clay slopes Rotational Slump and Earthflow, or Slow Earthflow are favoured modes of failure.

Clay slopes undercut by wave or river action, or by human agency in road or rail construction may be regarded as special cases of (a).

Clay slopes capped by basalt may be partially protected by the cap rock and will support it. The edge of the cap is vulnerable and retreats by rock-fall, and the clay slope beneath will then be attacked freely. The basalt is often an aquifer, and springs issuing at the basalt-clay interface will aid the rapid failure of the clays. Rotational Slump or Block Glide is a common mode of failure and produces large structures.

Sands and gravels capping clay slopes will also be aquifers and the resulting springs will aid the failure of the clay as Rotational Slumps and Earthflows.

Sand lenses interbedded with clays often contain connate or meteoric water which, if it can discharge will bring about failure by loading and softening as above. If the water is confined, the pore pressure in the sand and in fissures will rise, producing uplift, and failure will occur by Lateral Spreading Rotational Slump or Slow Earthflow. This is probably the most common cause of landslip in the Tamar.

##### (b) Basalt Slopes

Basalt slopes, either of solid rock or of talus, can be converted by a chemical reduction process below the water table to a plastic grey clay, much like the sediments but showing vesicular structure, and this can then fail in a way similar to the sediments, by Rotational Slump.

##### (c) Sand Slopes

The sand parts of the succession are not usually

much indurated and take part in failures on steep slopes in a few places by Soilfall or Sand Run.

Combinations of these simple patterns are most common. The relative simplicity of the rotational slump, for instance, is usually followed by degradation of the heaved toe, and the resulting slow earthflow is well known in both active and dormant slides.

## 5 THE AGE PROBLEM

Estimation of the age of dormant slides is a problem that has attracted much attention in the study but has not yet yielded to any of the available methods. Active slides are known to have a life of at least several decades, as recorded by newspaper accounts. The more complex and extensive slides have had a longer life and development. The extensive earthflow area that exists in the town of Beauty Point has been active for at least seventy years, and this is itself parasitic on a large rotational structure that must be prehistoric. A smaller slip such as Lawrence Vale was apparently unknown before 1958 but has been continually although slowly active since then. Many apparently new slips do occur, but usually enquiry into their origin shows some human cause, often acting as a trigger. The potential for slip seems to exist in many places, only becoming active when triggered by some minor action, such as the blocking of a culvert or the separation of concrete drain pipe sections. It is this potential that gives Zone III its critical significance.

The concept of cyclical change has been a fruitful one in geomorphology and it is appropriate to introduce it here. Both Selby (Ref. 8) and Carson and Kirkby (Ref. 9) have seen the value of the idea in dealing with mass movements and the latter have produced a model for landslips which accords well with the pattern seen in the Tamar.

Each slip seen in the field may be regarded as a stage in a cycle. An apparently undeformed slope after some extreme of stress caused by weather or human hand, fails. It fails in some simple mode, and produces say a head scarp and a heaved toe which themselves are unstable and progressively fail. The slip spreads uphill, down hill and laterally with many delays and dormant periods, eventually affecting the whole landscape element which takes up a form of lower, but still significant energy, and so becomes for the time being, stable. The features produced by the initial and resulting failures blur and the slope slowly attains what was the initial state of an apparently undeformed slope, only to fail again, given an adequate cause.

Activity in some slips is spasmodic so that three or four dry winters may pass without any movement, and the rapid disappearance of all but the grossest features during this time (often aided by deliberate or coincidental ploughing or bulldozing) makes the estimation of the age of those slips only known in the dormant stage very difficult. A few slips are historically recorded but the exact location and a knowledge of which part of a complex was concerned is usually unclear from contemporary accounts. Thus the actual dating of a specific part of a slip has not been possible over a period longer than about 16 years, although more vague accounts span 80 years. These few occurrences do offer some fixed points in trying to set up a time scale and this relative dating method of classical geology appears to offer the best chance of success. The indications seem to be that other than the very large rotational features, the average size slip feature can hardly be more than 200 to 300 years old. This might suggest that our present phase of mass movement is related to the land clearance that has taken place over part of this time.

It must be mentioned in passing that even a small insignificant looking slip parasitic on an older larger structure can be totally destructive if it impinges on a building.

## 6 SUBSURFACE INVESTIGATION

Because of the social need the zone map has been produced ahead of the subsurface investigation. This apparent reversal is not in fact illogical because the map is concerned with effects and has been used without reference to causes. Nevertheless, any complete investigation must consider causes so that isolation, prevention, or cure can be attempted in suitable circumstances.

The subsurface investigation is in progress and will be reported elsewhere. The following table gives an idea of the scope and methods employed.

## 7 THE SOCIAL IMPACT

The major mass movements in the Lawrence Vale area of Launceston in the period 1958-1961 caused heavy financial and social loss. The Tasmanian State Government of the day accepted an obligation to support those persons who lost property and brought in the Lawrence Vale Landslip Act of 1961 (Ref. 10). This provided that the land which moved and destroyed houses should be acquired by the City of Launceston and the previous owners compensated to the extent of 75% of the valuation of the land and houses. The Act only applied to dwelling houses which were permanently owner occupied. No other property was considered.

In retrospect, this humane measure implicitly accepts the "Act of God" view that the movements were a unique occurrence unlikely to be repeated elsewhere, although many similar although less destructive events had been recorded previously. When ground movements destroyed houses in Beauty Point at the other end of the Tamar in 1970, the precedent was followed and compensation was again paid (Beauty Point Landslip Act 1970, Ref. 11). There was a small although significant change in the clauses of the Act in that no compensation was paid to anyone who knew or ought to have known that the area was subject to movement before he bought his house.

When a third area distant from either of the other areas failed in 1971 (Ref. 12), the same procedure was followed, but it had become plain that the landslip problem was not an isolated one, but was widespread. This was the point at which the zone map was conceived and the investigation begun.

When the areas at risk were revealed by the mapping, the Director of Mines was given power by an amendment to the Local Government Act 1962 to recommend the proclamation of Landslip Areas. The effect of this was to prohibit building, and three such areas were proclaimed, but it soon became clear that the measure was too harsh because it left no room for those areas described under Zone III of the map. These are areas where although some grounds for doubt of the stability exists, building could be allowed if closely controlled. A change to the principal Act by the Local Government Act 1973 (Ref. 13) has now been made and landslip areas can now be proclaimed as 'A' or 'B' areas. 'A' areas are those where active movement is taking place or where movement is judged to be dormant, and 'B' areas are those where although the requisite geology and slopes are present, no past movements are known to have taken place. The 'A' areas correspond to Zone V and IV and the 'B' areas to Zone III.

No building is permitted in 'A' areas with the

exception of minor extensions to an existing dwelling. In 'B' areas the controls are to be incorporated as a set of special building regulations. In essence these control the size of dwellings, uses of dwellings, drainage, both of storm- and foul water, siting of dwellings, cut and fill and the size of storage tanks, including swimming pools; placing these in the responsibility of the municipal engineer. Waivers of any of these regulations requires the certificate of a civil engineer 'specialising in geomechanics'.

The zone map has now taken on more than a purely advisory role and has become a guide to the legal control of land use and building. Review, appeal and revocation procedures have been set up so that land use can be kept abreast of developments in the scientific study. Control has now been established over the geological hazard presented by landslips.

An attempt is being made to inform corporate bodies concerned of the geological basis, investigations, methods, criteria and powers of the investigation so that the broadest possible understanding of the problem exists. By far the best way of doing this has been by meetings, where one or more of the geologists who have been working on the problem speak and answer questions. Meetings have been held with local councils, progress associations, professional groups such as the Institution of Engineers, the Real Estate Institute or the Surveyors and Health Inspectors Association. In the writer's experience, this type of meeting which in prospect looks like a confrontation, results in a discussion which benefits, if not satisfies, all parties. Information is couched in geological terms at the outset and is well supported by coloured slides of the effect of landslips on landscape and housing. It usually appears that few of the listeners have ever seen a landslip or its effects. On this basis, an exposition of the zoning criteria and then the land use effect of this zoning is introduced. Criticism often centres on the accuracy of the zone boundaries, but as they generally correspond to topographic changes of slope they can be pointed out in the field if need be.

It is usually necessary to allude to the long time scale of a geomorphic process, and to compare

this with the life of a house as an investment. The impossibility of deterministic prediction has to be made clear, and the probabilistic nature of the zone as predictions explained.

The extent of public awareness of the landslip hazard can readily be judged from this kind of meeting, and the low level of it even amongst people in the land business is surprising. A measure of 'not wanting to know' is even apparent. This is not unexpected however when the Press contribution amounts to 'Dream House slips into River' (Launceston Examiner, 18-9-71), or 'Launceston Could Move' (Hobart Mercury, 17-12-70). These sensational articles last for a few days, but they contribute nothing to a reasoned proportioned account of the phenomenon, and do not point out the natural, limited but inexorable nature of it.

The geologists working on the investigation provide an advisory service to members of the public. The progress of discussions is not dissimilar, and clear information is always welcomed. The problem is more real because the person is probably an owner, buyer or vendor of property and the control exercised by the zone map even in its advisory form is real. Few areas have been proclaimed at the time of writing, but the intention to recommend proclamation has been stated.

The financial impact of the map has been made much of in the Press, but the writer, as a layman in property matters has not been able to distinguish any changes in land values attributable to it, although admittedly against a background of credit squeeze and general lack of market confidence. The lesson of Burnie is interesting in this connection. This town in North-western Tasmania has a landslip problem allied to that in the Tamar, and an advisory map showing unstable zones was published in 1963 (Ref. 14). Slight controversy heralded its appearance, but since then buyers, builders, but particularly banks and other lending institutions have lent according to the advice of the map and very little trouble to either the citizens or the landscape has resulted. It remains to be seen whether this pattern will be repeated in the Tamar.

TABLE I

SUBSURFACE INVESTIGATION PLAN

- |       |  |
|-------|--|
| (i)   | Detailed surface geological mapping in representative areas.   |
| (ii)  | Deep (500 m) cored diamond drill holes for lithological and stratigraphic information.   |
| (iii) | Proline power auger drilling to 20 m to provide disturbed and drive tube samples for Atterberg limits, sizing, triaxial tests drained and undrained, shear box tests, X-ray diffraction for clay mineralogy.   |
| (iv)  | Auger drilling for installation of piezometers for water pressure and rainfall correlation, plastic tube deformation gauges, string and block shear plane gauges, water quality samples and pump-out permeability tests.   |
| (v)   | Geophysical methods <ul style="list-style-type: none"> <li>Refraction seismic for locating slip planes.</li> <li>Electrical resistivity for locating slip planes.</li> <li>Resonant vibration studies to detect incipient or past failure in the dormant state.</li> <li>Magnetometer surveys for basalt-involved slip structures.</li> <li>Gravity surveys for major bedrock structures.</li> </ul> |
| (vi)  | Miscellaneous techniques <ul style="list-style-type: none"> <li>Rainfall studies by running average.</li> <li>Historical study in newspaper files and other written sources.</li> </ul>  |
| (vii) | Special investigations in selected critical active and high potential areas.   |

