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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Contents

1. Summary

Basic land resource data are provided in this report to assist an investigation of the effect of contour banking on surface runoff in the Berkshire Valley experimental catchment. Brief descriptions of the catchment's geology, soils and their inferred hydrological significance are provided and a 1:2000 scale map produced. Of major significance to the hydrologic study is the fact that soil depth and internal drainage conditions were found to be not related to landscape position, but rather to the varying resistance of the underlying rock type to weathering.

2. Introduction

The Berkshire Valley experimental catchment is located 18 km north-east of Moora (Figure 1). It is 25 ha. in area and is bounded by natural ridges, except along one side where a formed road diverts a 6 ha. subsiduary catchment. (See map). Rainfall and runoff were continuously measured over the catchment for four years before contour banks were constructed in 1965. The measurements have been continued since then in order to observe any effects of the contour banking on surface runoff (Bligh 1983).

In 1971 a brief inspection of the catchment by CSIRO determined that effectively only one soil type occurred over the catchment area. (Bettenay 1971). This soil was classified as a hard setting red duplex soil (Dr 2.33) although a subdominant salinised version (Dr 1.33) was considered to occur in the main drainage line. However this work was insufficiently detailed to aid in the interpretation of hydrographs from the catchment. A two-day survey of the soils and geology of the catchment was therefore conducted to provide further details on the nature of the land resources and their possible effects on hydrology.

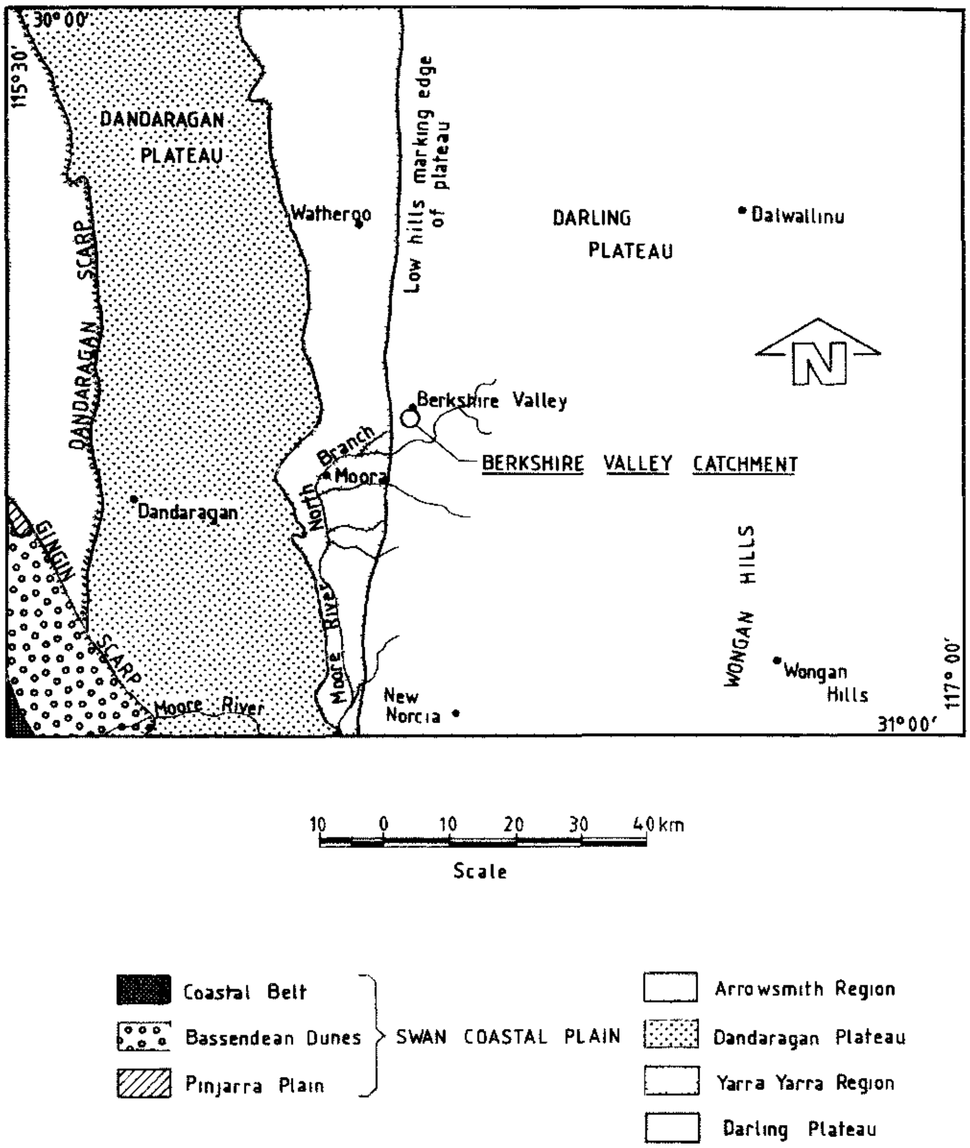
The survey was conducted in mid-July following a period of heavy rain. Eleven sites within the catchment were examined and in addition to constructing a soil/geology map, an estimate was carried out of the extent of similar landforms on the Moora and Perth 1:250 000 geological mapping sheets.

3. Underlying Geology

Rock outcrops occur over about 10 per cent of the catchment as indicated in Table 1 which should be read in conjunction with the map (in pocket). The main rock type that is exposed is a quartz-feldspar-biotite-(hornblende) gneiss which is occasionally leucocratic (rich in quartz and feldspar). The main ridge in the south-east of the catchment is composed of quartzite (metamorphosed sandstone) while medium to coarse grained dolerite outcrops or subcrops on the north-east ridge, below the south-east ridge and along the waterway. The strike of the dolerite intrusives appears to parallel the foliation in the gneiss (i.e. due north). The dip of the gneissic succession was estimated to be about 50°W. Amphibolite scree occurs immediately below the measuring weir (situated where the main drainage line, F, leaves the catchment) while large outcrops of migmatite occur just over the divide to the north-east of the catchment.

Fig. 1

LOCATION OF BERKSHIRE VALLEY CATCHMENT



: after Carter and Lipple. (1982)

TABLE 1: Details of map units

Map Unit	**Geology**	**Landform/site conditions**	**Soils**	**Hydrologic significance**
A	Outcrops of quartzite, dolerite or gneiss.	Ridges and crests within catchment hillslopes, with up to 40% rock and stone outcrop. Slopes 1-3%. Non arable land	Shallow (<30cm) stony brown or red loams Um 6.22. Surface texture, sandy clay loam.	Areas unable to retain water due to shallowness and rock outcrop. Water moves away by overland or subsurface flow.
B	Gneissic rocks of varying competency. Resistant or competent areas occur as 'basement highs' under the mantle of weathered soil material.	Hillslopes (3-5%) with variable surface stone cover (up to 10%). Seepage areas appear scattered across the hillslopes but are believed to occur behind, and up-slope, of the areas of more competent rock types. In these areas the position of the 'basement highs' have interfered with the subsurface downslope flow of water following rains.	Dominantly shallow to moderately deep (30-60cm) red loams Urn 6.13, with readily slaking sandy clay loam surfaces. Less commonly in wetter areas deeper non-cracking clays may occur.	The predisposition to slaking will result in the formation of a surface seal in summer which may exacerbate runoff from early rains. In seepage areas soil saturation will be reached quickly following the onset of rain.
C	Gneissic rocks of low competency (low resistance to weathering).	Variable positions on catchment hillslopes of 3-6% gradient. Most areas are cultivated.	Deep (>lm) red or brown duplex soils with sandy clay loam surfaces over light to medium clay alkaline subsoils. Surface soil tends to slake readily forming a hardsetting crust in summer.	As with unit B these soils are subject to surface sealing and hence rapid runoff during rain events. They will however, store and retain water for greater periods, due to their greater depth and higher clay content.
D	Doleritic 'pods' across the catchment.	Upper and mid hillslope areas dominantly within the north and north-western portion of the catchment. Cultivated areas with 4-6% slope.	Deep red non-cracking friable clays with strongly structured, self mulching surfaces and calcareous subsoils.	Despite high clay contents these soils should be reasonably permeable due to the strong soil structure and lack of surface sealing tendencies. Initial surface runoff following rains would be expected to be less than for unit C soils and infiltration rates should be greater.

TABLE 1 Continued

Map Unit	Geology	Landform/site conditions	Soils	Hydrologic significance
E	Areas of doleritic rock where weathering has occurred under chemically 'reduced' situations.	Mid to lower hillslope areas generally in the southern portion of the catchment. The major part of this area is used as a 2-7% sloping (once grassed) waterway.	Deep dark grey non-cracking clays which are moderate to strongly structured and have alkaline calcareous subsoils.	Similar comments to D above.
F	Variable	Drainage channels and wet seepage areas at base of catchment.	Variable, eroded red duplex soils and uniform loams.	Provides almost instantaneous runoff during rainfall and contributes slow seepage flow between rain events.

The northerly strike of the gneisses is sub-parallel to the topographic contours over much of the catchment. The presence of bands within the gneiss which are more resistant to weathering results in basement highs which are overlain by thin, immature soil. It is possible that the gneissic succession represents a metamorphosed acid volcanic pile (flows and tuffs) which would explain their mineralogy and across-strike variability.

The gneisses in the catchment are part of the Berkshire Valley succession (Carter and Lipple 1982) which occupies just under 10 per cent of the Moora 1:250 000 sheet. The equivalent successions on the Perth 1:250 000 sheet (Jimperding and Chittering Metamorphic Belts) occupy about 18 per cent of the area (Wilde and LOW 1978). Smaller occurrences of the succession occur on the Pinjarra and Corrigin 1:250 000 sheets.

4. Soils

Eleven profiles were described and classified in the field using the factual key notation of Northcote (1979). The location of these sites are shown on the map accompanying this report, and profile descriptions are available from the Division. A description of the map units delineated as a result of the survey is given in Table 1.

The previous soil investigation by Bettenay (1971) was found to be essentially correct in that the main soil type in the area is a hard-setting red duplex (texture contrast) soil. Variations do however occur within the catchment due to differences in depth to either rock 'floaters' in the profile or to weathered parent material. Likewise, the description by Bligh (1983) of a 'sandy clay loam catchment' is correct as this survey found that the dominant surface soil texture over much of the catchment was sandy clay loam.

The soil variations mapped here at 1:2000 scale bear a reasonably close relationship to the underlying geology. The soils are discussed here in terms of two groups; soils formed from predominantly gneissic rocks, and those formed from predominantly doleritic rocks.

4.1 Soils formed from predominantly gneissic parent materials

Between map units B and C, and some areas of A, differences occur in soil depth, surface stone cover and topographic position. These units may be considered as variants within Bettenay's red duplex soil grouping. Soils from these units are formed from gneissic rocks of varying competency (resistance to weathering) with the deeper duplex soils occurring over the least resistant rock types.

The soils generally exhibit brown to reddish-brown surface colours with light sandy clay loam textures. In minor, wetter seepage areas colours may be somewhat darker and the textures more clayey. The surface soils generally show little tilth and tend to slake readily to form a surface seal. Subsoils of the deeper soils are more brown to yellowish-red in colour and in the duplex types, medium clay textures occur within B horizons. Soil pH tends to increase with depth from being slightly acidic (pH 5.5 - 6.5) at the surface to alkaline (pH > 8.0) in the duplex subsoils.

In shallow areas, most commonly near ridges of rock outcrop and along the crest of the catchment, up to 10% by volume of angular quartz grit and gravels may occur within the profile. Loose surface stones, up to 25 cm in diameter, occur commonly within unit A but are also scattered across unit B (up to 15% cover in places). Pew, if any, surface stones occur over the deeper duplex soils of unit C.

Although the shallower soils are well drained, the subsoil clays of the deeper duplex soils may tend to restrict internal drainage for periods during the winter months.

A typical profile for the shallower variants is:

Factual key notation Urn 6.24 Shallow red friable loam

Horizon	Depth (cm)	Description
A	0-10	Reddish-brown (SYR 4/4) light sandy clay loam, dry slightly hard consistence, weak structure with earthy fabric, pH 5.5, gradual boundary to
B	10-30	Yellowish-red (SYR 4/8) sandy clay loam, moist friable consistence, moderate subangular blocky structure with rough ped fabric, pH 6.0, with 2% angular quartz gravels up to 15mm diameter, abrupt boundary to
C	30+	Yellowish-red, friable weathered parent material

A typical profile of the deeper duplex soils is:

Factual key notation Dr 2.53 Hard setting red duplex soil.

Horizon	Depth (cm)	Description
A	0-15	Dark reddish-brown (5YR 3/4) sandy clay loam, moist friable consistence, moderate crumb structure with rough ped fabric, pH 6.0, clear boundary to
B1	15-45	Yellowish-red (5YR 4/6) light-medium clay, moist plastic consistence, weak subangular blocky structure with rough ped fabric, pH 8.5, amorphous $CaCC_3$ and 2% subangular fragments of parent material up to 10mm diameter present, gradual boundary to
B2	45-90	Reddish-yellow (5YR 6/6) gritty light-medium clay, dry hard consistence with similar structure, pH and inclusions to B1, gradual boundary to
C	90-120	Reddish-yellow (7.5 YR 7/6) gritty light clay with much weathered parent material

4.2 Soils formed from predominantly doleritic parent materials

Deep non-cracking red and dark grey clays have formed from weathering of doleritic rocks in the catchment. These soils are uniformly fine (clayey) in texture, well structured, and are alkaline at depth. Surface colours vary from dark reddish brown to very dark grey brown and top-soil pH's are neutral (6.0 -7.0). The darker grey clays (map unit E) are believed to have formed from doleritic rocks under slightly wetter (i.e. more reducing) conditions than the redder (unit D) soils.

Unlike the soils formed from predominantly gneissic materials, the red and dark grey clays are relatively non-dispersive and exhibit a good tilth or crumb structure at the surface. The strong degree of structure continues into the subsoil which allows the soils to be moderately well drained despite high subsoil clay contents.

Shallow red, friable loams occur within map unit A where surface dolerite is present. These differ little from the shallow loams already described on gneissic parent materials except that fewer, if any gravels, are present and the surfaces do not slake readily.

A typical profile for the red clay soils is:

Factual key notation Uf 6.12 Red friable non cracking clay

Horizon	Depth (cm)	Description
A	0-15	Dark reddish-brown (SYR 3/4) light clay, moist friable consistence, strong crumb structure with rough ped fabric, pH 7.0, 2% angular quart?, fragments and amorphous CaCOj present, gradual boundary to
B1	15-35	Yellowish-red (5YR 4/6) medium clay, moist plastic consistence, strong subangular blocky structure with rough ped fabric, pH 8.0, inclusions as for A horizon, gradual boundary to
B2	35-90	Red (2.5YR 4/6) medium clay, moist plastic consistence, structure and inclusions as for Bl, pH 8.5, gradual boundary to
C	90-110+	Reddish-brown (5YR 4/4) friable clayey weathered parent material pH 9.0

A typical profile for the dark grey clay soils is:

Factual key notation Uf 6.11 Dark grey friable non-cracking clay

Horizon	Depth (cm)	Description
A	0-10	Very dark greyish-brown (10YR 3/2) medium clay, moist slightly plastic, strong subangular blocky structure with rough ped fabric, pH 6.0, gradual boundary to
B	10-100+	Very dark grey (10YR 3/1) medium clay, moist plastic consistence, strong angular blocky structure with rough ped fabric, pH 8.5

5. Influence of Soils and Underlying Geology on Hydrology

Although largely beyond the scope of this report, some comments follow on the influence of soils and underlying geology on hydrology.

1. Overland flow from seepage areas

In areas where surface soils are saturated, infiltration of rainfall will be negligible and overland flow will occur regardless of underlying soil texture. Following the onset of rains, seepage areas with low storage characteristics will immediately contribute overland flow whereas surrounding areas of soil will only contribute if the rate of rainfall exceeds the rate of surface infiltration and surface storages are exceeded.

2. Water storage capacity

Soil water storage capacity will depend upon soil depth and clay content. Deeper soils will be able to store more water and if clayey, will retain it within the profile for longer periods relative to more sandy soils. Hence, assuming relatively little initial water movement through the deeper parts of the regolith and underlying rocks during a rain event, saturation followed by overland flow would be expected to occur quite quickly in the shallow loamy soils relative to the deeper well-structured clays. Hence the water storage capacities of the main mapping units may be roughly ordered from highest to lowest as follows; E, D > C > B > A.

The Berkshire Valley catchment can be considered to be a "York surface" (Mulcahy and Kingston 1961) in that the lateritic profile has been removed to reveal fresh rock. The catchment therefore does not have the large water-and salt-storage capacity that is common in areas of the wheatbelt which retain all or part of the laterite profile.

3. Surface infiltration

The tendency for soils formed from gneissic rocks to slake readily and form a surface seal greatly reduces the number of pathways for water to penetrate into the subsoil. Hence infiltration is restricted and a greater amount of water is contributed to overland flow.

The hardsetting nature of the duplex soils was difficult to observe due to relatively recent cultivation. However in an uncultivated situation a hard-set surface would also restrict surface infiltration and lead to increased overland flow.

Soil structure will also affect the rate of water movement into a soil. Strongly structured soils can be expected to allow infiltration through preferred pathways between soil peds. Hence non-swelling clay soils that are well structured can still have moderately high infiltration rates despite having a high proportion of fine (clayey) soil particles.

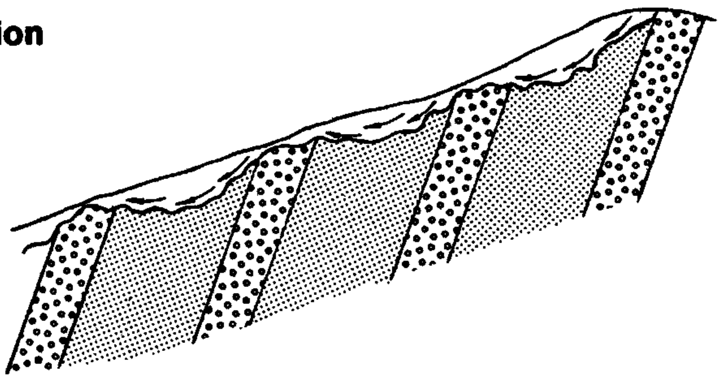
Limited amounts of stone and gravel within the soil surface also serve to break up the soil and permit infiltration of water into weakly structured soils.

4 Subsurface flow and location of seepage areas

The location of surface seepage areas was examined in relation to soil depth and the incidence and strike of rock exposures in the catchment. It is suggested that the predominant parent material (gneiss) is of varying hardness or competency and hence the depth of soil varies as a result of weathering. As the direction of foliation in the gneiss appears to be concordant with the strike of the associated dolerite, it is reasoned that bands of competent and less competent rocks run across the catchment in a N-S direction.

In areas where shallow soils occur over a relatively little weathered, competent band of gneiss the underlying rock forms a basement 'high1 which can be expected to interfere with the subsurface flow of water downslope through the soil (figure 2a). The groundwater levels in these areas will rise and in some cases the watertable will intercept the surface and result in a seepage area. The soil surface will also be saturated where the capillary fringe above the water table intercepts the soil surface. The locations of some seepage areas observed during the survey are shown on the attached map. By considering the subsurface water flow relative to the speculated position of the basement 'highs' in figure 2b it is apparent that the greatest impedance to the water flow will occur when the strike of the competent basement high is perpendicular to the direction of downslope water movement. Hence in these areas there is the greatest likelihood of perched watertables rising towards the surface and forming seepage areas. This is exacerbated where contour banks have removed some of the surface soil.

Fig. 2a
Schematic cross section of sub-surface flow



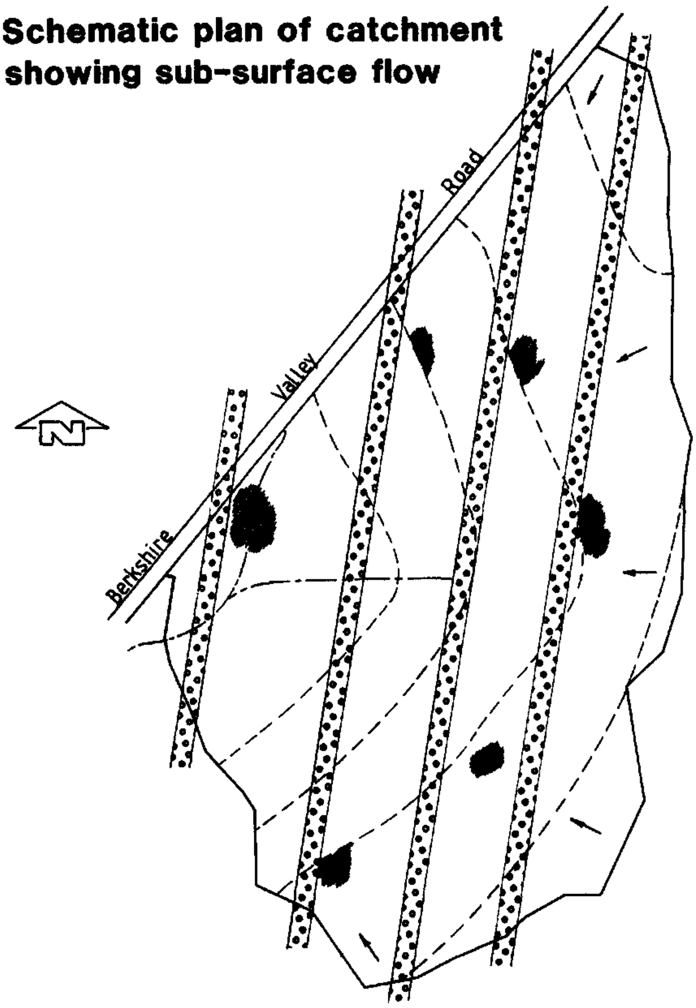
Variable gneissic rocks beneath soil mantle

Less competent rock, (weaker) weathering more rapidly to form deep soils.

More competent rock, (resistant) weathering more slowly leaving basement 'highs'.

Water moving down slope through the soil under the influence of grávity is forced upwards and forms seepage areas behind basement 'highs'.

Fig. 2b
Schematic plan of catchment showing sub-surface flow



Water course

Contour lines

Observed seepage areas

Gravitational flow direction

Suggested positions of basement highs

The wetter areas occur where flow is impeded by shallower soils over a basement 'high'. The greater the angle between gravitational flow and the strike direction of the more competent rocks, the greater the impedance to water flow and hence greater likelihood of water appearing at the surface as a seepage area.

6. References

Bettenay, E. (1971). Berkshire Valley catchment above station 617 600 Unpublished. CSIRO Report.

Bligh, K.J. (1983). Progress report on effects of contour banking on surface runoff at the Berkshire Valley experimental catchment (near Moora(1961-82. Technical Report No. 11. Division of Resource Management.

Carter, J.D. and Lipple, S.L. (1982). Explanatory notes on the Moora 1:250 000 geological sheet. Geological Survey of Western Australia.

Mulcahy, M.J. and Kingston, F.J. (1961). The development and distribution of soils of the York-Quairading area, Western Australia, in relation to landscape evolution, CSIRO soils Publ. No. 17.

Northcote, K.H. (1979). A factual key for the recognition of Australian soils. Rellim Technical Publications, Adelaide S.A.

Wilde, S.A. and Low, G.H. (1978). Explanatory notes on the Perth 1:250 000 geological sheet. Geological Survey of Western Australia.