CONTENTS

SUMMARY

A detailed soil survey of the new site for the Renewable Natural Resources Research Centre, Jakar at Bathpalathang farm was carried out during October- November 1997. This was the second soil survey done by the newly formed Bhutan Soil Survey Project, and was used as field training exercise.

The site covers about 30 ha (75 acres) on the east bank of the main valley of Chamkar Chhu. It is about 2 km north of Jakar bridge. Most of the site is located on the flat tops of a series of river terraces and on the connecting slopes between them. Along the eastern and northern boundaries of the survey area there are the lower slopes of spurs from the surrounding hills. At present the site is used for improved pastures, rough grazing and some forestry of the blue pine woodlands.

The soils were examined in 71 routine observations and 14 detailed description and sampling profiles. The soils are divided into three main topography/drainage groups: well drained hill soils; well drained terrace soils; and soils with impeded drainage. These groups are further subdivided to give 11 soil classes.

There are three classes of well drained hill soils; shallow reddish - brown soils; deep reddish - brown soils; and pale coloured soils. The hill soils are all only slightly acid, but are highly leached and have poor base status.

The well drained terrace soils are a variable group. The in-extensive and discontinuous lowest terrace has grey, slightly wet, coarse textured soils with boulders at shallow depths. The soils of the flat tops of the middle and upper terraces are deep, brownish, and predominantly medium textured, but show textural variation and layering. The soils of the steep slopes between the different terrace levels are shallow and stony overlying dense beds of hard, round, old river boulders. All of the terrace soils are slightly to moderately acid, and base status decreases with increasing height and age of terrace.

The soils with impeded drainage are subdivided according to topographic position and degree of drainage constraint. The four classes are: poorly drained soils on terrace flats; poorly drained soils on hillsides; imperfectly drained soils on hillsides; and imperfectly drained soils on old landslips. Chemically these soils are similar to the well drained classes, except that their topsoils tend to have higher contents of organic matter.

The draft soils map was available to the RNR-RC in time for their preliminary planning of the site in November 1997. They have provisionally located the main buildings and agricultural research areas on the well drained soils of the flat tops of the upper and middle terrace (Tu and Tm). The hill soils are earmarked for forestry and fodder. The steep slopes and bouldery soils of the terrace risers (Rx) are initially to be left under their natural vegetation. The proposed research areas appear to be located on appropriate soils, as terrace soils are important for arable agriculture in the Bumthang valley, and the hills are mainly used for forestry.

ACKNOWLEDGEMENT

The field work for this soil survey was done by Kado Tshering, H.B. Tamang, Ian Baillie and Tsheten Dorji. The report was prepared by Pema Wangmo. The mapping was done by Deki Wangmo of the Geographic Information System Unit of the Land Use and Statistics Section of the Planning and Policy Division of the Ministry of Agriculture in Thimphu.

We are grateful to the Officer in Charge, research staff, and technicians of the Jakar RNR-RC for their logistic support and assistance during the fieldwork. The physical work done by the technical staff in digging the profile pits is particularly appreciated. The research staff contributed in the development of the soil classification. We are grateful to Chencho Norbu for helpful comments on the draft. These were particularly important because this is one of the early reports by the Bhutan Soil Survey Project and we are anxious to establish a report format that is useful to researchers, planners and other soil managers.

ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
AHT	Agrar - and Hydrotechnik, GmbH, (Germany).
Alluvial fan	Poorly stratified and sorted material deposited by tributary mountain stream as it reaches flatter part of the valley.
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
Av	Available
AWC	Available water capacity
amsl	Above mean seal level
BP	Before present
BS%	Base saturation percentage
BSSP	Bhutan Soil Survey Project
C	Clay
CEC	Cation exchange capacity
Chhu	Stream or river
CL	Clay loam
Colluvium	Local hillwash, moved by surface erosion or slow non-glacial creep processes.
Danida	Danish International Development Assistance.
Dzongkhag	Administrative district
EC	Electrical conductivity
ESCAP	Economic and Social Commission for Asia and the Pacific, United Nations.
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FAO	Food and Agriculture Organisation of United Nations
fe	fine earth (particle size < 2mm)
FYM	Farmyard manure
Gewog	Block or subdistrict, administrative subdivision of Dzongkhag.
GIS	Geographical information system
Gley	Soil that is permanently wet, poorly aerated and has predominantly greyish colours, due to reduction of free iron to ferrous valency state. May have local oxidising conditions giving rust - coloured mottles, especially around root channels.
Gompa	Monastery
GPS	Global positioning system
ha	Hectare
HCl	Hydrochloric acid
JICA	Japanese International Cooperation Agency
L	Loam
LUPP	Land Use Planning Project, in PPD
LUPS	Land Use Planning Section, in PPD
LUSS	Land Use and Statistics Section, in PPD
me%	milliequivalents per 100 g fine earth
MoA	Ministry of Agriculture
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)

MTI	Ministry of Trade and Industry.
MUMTI	Meteorological Unit of MTI
NH_4OAC	Ammonium acetate
NRTI	National Resources Training Institute, Lobeysa
NS	Not suitable (in land suitability classification)
OC	Organic carbon
OM	Organic matter
P	Phosphate
PCI	Pacific Consultants International (Japan)
pH	Measure of acidity - alkalinity
PM	Parent material
PPD	Planning and Policy Division, MoA
ppm	Parts per million
PSC	Particle size class (Soil Taxonomy)
REID	Research, Extension and Irrigation Division (of MoA)
RGOB	Royal Government of Bhutan
RMS	Root mean square
RNR	Renewable natural resources - agriculture, animal husbandry and forestry.
RNR-RC	RNR Research Centre.
S	Sand
Saprolite	Soft weathered rock beneath solum, often reddish.
Shogshing	Forested land from which needle or leaves are collected for livestock bedding and compost.
Si	Silt
Sk	Skeletal (high stone content)
SMU	Soil mapping unit
SoB	Survey of Bhutan
Solifluction	Downslope movement in summer of saturated thawed topsoil over permafrost in periglacial areas.
SP	Superphosphate
Solum	True soil with no remaining rock structures.
SPAL	Soils and Plant Analysis Laboratory, Semtokha.
SSF&PNMP	Sustainable Soil Fertility & Plant Nutrition Management Project.
SSS	Soil Survey Staff (of USDA)
ST	Soil Taxonomy (US system of soil classification)
TE	Trace elements
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
TLB	True left bank (facing downstream)
TRB	True right bank (facing downstream)
USDA	United States Department of Agriculture
v/v	% by volume
WR	Weathered rock
w/w	% by weight
X	Exchangeable (for cation)
Z,Zi	Silt

1. INTRODUCTION

1.1 Bhutan Soil Survey Project

The Soil Survey Project was set up by an Agreement signed in September 1996 by the Royal Government of Bhutan (RGOB) and Danish International Development Assistance (Danida). It was initiated because of a perceived need for systematic information about the nature and distribution of the soils of Bhutan. The Project is part of the Soils Services Centre of the Research, Extension and Irrigation Division (REID) of the Ministry of Agriculture (MoA). It began field activities in June 1997.

The emphasis in the initial stages of the Project is on training Bhutanese nationals as soil surveyors, and the establishment of a functioning Soil Survey organisation. The main method of training is on-the-job instruction and close supervision of actual soil surveys, carried through from initial planning to final presentation. In the early stages detailed surveys are best for instruction purposes. They enable soil patterns to be worked out by direct observation and with the minimum of extrapolation and assumptions. This survey of the site of the new site for the Jakar Renewable Natural Resources Research Centre (RNR-RC) is the second of the detailed surveys/training exercises. This is the full technical report of the survey. Those requiring a less detailed summary of the main findings and implications are referred to the General Report (BSSP 1998 (a)).

1.2 Jakar RNR-RC

Jakar is one of the four main RNR Research Centres in REID. It has a national mandate to coordinate all research in livestock and fodder production, and in the high altitude field crops and pastures for the whole country. It also has a regional mandate to coordinate all RNR research in the East Central region. Jakar has an outlying subcentre at Bhur in Sarpang Dzongkhag, which specialises in subtropical rice, fruit and fodder crops, and an outreach substation at Tingtingbi in Zhemgang Dzongkhag, which specialises in subtropical wet - and dryland agriculture, fodder, cardamom, and soil conservation. As with the other RNR-RC's, Jakar coordinates its research with extension activities in its region (REID 1995 & 1997).

At present the Centre is housed in temporary office accommodation on west bank of Chamkar Chhu, and has no land for research trials, demonstration plots or seed production. The Ministry of Agriculture has released a block of 30 ha on the Bathpalathang Farm on the eastern (opposite) bank of Chamkar Chhu for the establishment of a new Centre, to include offices, workshops stores, and some land for plots. The site has been demarcated and topographically surveyed at large scale. This detailed soil survey was undertaken establish the types and distribution of the soils on the new site. As of June 1998, a new access road and one building have been constructed, and new areas of trial plots have been established.

Aims of the Bathpalathang soil survey

This detailed soil survey was undertaken with objectives of:

Continued training in soil survey techniques for BSSP staff.
Continued adjustment of standard soil survey practices to suit Bhutan conditions.

Providing Jakar RNR-RC with detailed information on the nature and distribution of the soils of their new site.
Indicating the extent of the applicability of research results on the soils of the new site to soils in other parts of the region.
Providing BSSP with further data for the development of a national soil classification, and of national and regional soil maps.

2. SURVEY AREA

2.1 Location and extent

The site is located in the valley of river Chamkar Chhu on the east (true left) bank about 2 km north of Jakar Bridge. It stretches from latitude 27 ^{o} 33.2‘ to 27 ^{o} 34.0 N and from longitude 90 ^{o} 44.8' to 90^{o} .45.2' E. It is in Chhokor gewog in Bumthang Dzongkhag, and within the East Central region. The site is approximately rectangular, with a maximum N-S length of about 850 m and a maximum E- W width of about 500 m. It covers 30.2 ha (74.8 acres).

The site was transferred from Bathpalathang Farm to the RNR-RC in 1996, and the land remains in the ownership of the Ministry of Agriculture, RGOB. Before the transfer the land was part of a large MoA unit and was mostly used for improved pastures, dairy production, and the breeding of Brown Swiss cattle, Haflinger horses and various local crosses from them. The bulk of the area will remain part of the MoA Bathpalathang Farm unit.

2.2 Climate

Bathpalathang Farm has maintained a meteorological station since 1981, and its records for rainfall and temperature are continuous from 1981 to the present. They are summarised in Table 2.1, from data supplied by the RNR-RC.

Bathpalathang Farm has a cool temperate climate. Although at a similar altitude (ca 2600 m a.s.l.) and in the same natural ecological zone (Blue pine belt), Bathpalathang Farm appears to be distinctly cooler than the Yusipang RNR-RC in the Western region. Bathpalathang Farm has a mean daily temperature of about 4^{0} C in December - January, rising to about 17 - 18^{0} C in June - August. The mean annual rainfall is about 740 mm, of which about 550 mm (about 75%) fall in the monsoon months June - September. Because it is located in one of Bhutan's main North - South river valleys, the site is windy. There are strong ‘Troll’ winds up the valley in the later part of many days.

The dominant aspect of the site is westwards. The site therefore probably receives about average insolation during the dry months but below average during the monsoon, when there is a tendency for an afternoon - evening buildup of cloud and rainfall.

2.3 Geology and soil parent materials

The most recent geological summary of Bhutan, based on the collected field data of the Geological Survey of India (Bhargava 1995), indicates that the site is underlain by rocks of the Thimphu Group. This accords with ESCAP (1991). This group consists of highly metamorphosed rocks, mainly gneiss with mixed muscovite and biotite micas, plagioclase feldspars, and quartz as the main minerals. However Gansser (1983) maps the area as the older Paro Formation schists, which are less highly metamorphosed. Both of these formations were folded and sheared in the thrusting from the north during the intense Himalayan compressions and uplifts in the Tertiary. Both formations have many quartzite beds and quartz veins.

The soils on the hill along the northern boundary of the site are residual and have shallow sola overlying weathered metamorphics. Considerable quantities of ferric iron compounds have been liberated by the weathering. These give the saprolite (weathered rock) red, orange and yellow colours.

There is also an area of light grey - white hill soils. The colours do not appear to be caused by impeded drainage, and may be due to low iron contents in the local bedrock.

There is also a ridge along the eastern boundary, the side slopes of which are mantled with deep colluvium. This includes rounded alluvial boulders, indicating that the colluvium is at least partly derived from old, high terrace alluvium as well as from local bedrock.

Over two thirds of the survey area is underlain by alluvial deposits. There are at least three distinct levels of river terrace in the survey area, in the addition to the floodplain which just intrudes across the western boundary. The floodplain is 1 – 4m above the river bed and the three main terraces in the survey area are at about 10m, 40m and 70m relative elevations. There are also higher level alluvial deposits at up to 120m above river level, but these occur outside the survey area. However they contribute to the colluvial soil parent materials on the eastern ridge.

The alluvium of the floodplain consists of moderately shallow, relatively stone-free upper coarse and medium textured layers overlying massive beds of highly rounded, fresh and hard boulders and cobbles. The depth to the boulder layer varies from about 30 cm to over 1 m. The 10 m terrace material is somewhat similar, with grey sandy loam over boulders within one metre. The 40 and 70 m terraces are also underlain by boulder beds, which outcrop prominently on the connecting slopes below and between them. However the flat tops of the terraces are covered with stone-free alluvia to depths of at least 2.5 m. The alluvium on the 40 m terrace is clearly layered and heterogeneous, ranging from loamy sand to clay. The depth of alluvium on this terrace is mostly greater than 5 m, judging from road cuttings. However there are places where the alluvium was deposited over knolls and outcrops and is only a metre or so over metamorphic rocks (e.g. profile PK015 in Appendix B). The alluvium forming the 70 m terrace appears to be more uniformly deep. It is also more homogeneous, and has a narrower range of size classes, from fine sandy loam to silty clay.

The stone-free upper layers of alluvium on the 40 and 70 m terraces is covered by reddish yellow friable sandy loam. This is thought to be an aeolian (wind blown) deposit, possibly dating from the late Holocene (ca 2-4000 years BP) (Gratzer and Rai 1997).

Table 2.1 Climatic summary for Bathpalathang farm

	J	F	M	A	M	J	J	A	S	O	N	D	Year average / total
Mean daily temperature (^{0}C)													
1990-1996	3.7	5.5	8.6	11.0	14.2	16.7	17.8	17.7	15.9	12.8	7.7	4.3	11.3
Average rain fall (mm)													
1981-1996	6.7	14.7	27.3	40.8	69.8	127.9	164.3	160.9	113.0	38.7	12.6	1.3	741.2

Source: Data supplied by Jakar RNR-RC, 1997.

2.4 Topography and drainage

The survey area is located on the eastern slopes of the main valley of Chamkar Chhu. This section of the Chamkar Chhu is referred to as the Bumthang valley. This section of the valley is wider than either

up - or downstream, and forms a relatively wide basin of moderately sloping land. This extensive area of gentle topography has long attracted relatively dense settlement and intensive cultivation.

The Bumthang valley is characterized by a complex set of landforms. The main valley is flanked by a sequence of river terraces, which range from the current floodplain at 1-4 m above the river bed to a fluvial boulder deposit found at more than 300 m relative elevation. It is possible that there are deposits at even greater elevations, but these have not yet been seen. In addition the valley has alluvial fans issuing out of some of the main side valleys. There are also extensive areas of colluvial/residual hillslopes, covered by hill wash and creep deposits, or having bluffs of hard rock outcrops.

The present survey area is located mainly on three of the lower river terraces. There is a narrow slice of the current floodplain along the southwestern boundary but the main terraces in the survey area are those at about 10 m, 40 m and 70 m above the current river level. The 10m terrace is discontinuous within the survey area, and occurs as two isolated benches on the main connecting slope up to the 40 m terrace. The upper two terraces are more extensive. They are fronted by steep (gradients up to 100%) rectilinear connecting slopes, which have many rounded boulders and cobbles outcropping at the surface. The terrace tops are relatively flat, with back-to-front slopes of only 3-10%. Thin deposits and the occurrence of the subsurface shallow rock layers have no effect on the morphology of the tops of the terraces, and there are no rock outcrops. There are locally steeper slopes near drainage lines. However these have not yet incised deeply, and the terrace topography is no more than undulating. Even near drainage lines slopes are less than 20%.

There is a low (ca 130m above river level) ridge along the eastern, inland boundary of the area. This has convex upper and straight - slightly concave lower slopes. The break of slope at the base, to the upper terrace, is fairly distinct. There is a higher (up to 150 m relative elevation) spur running along the northern boundary of the survey area. This has steeper side slopes (up to 70%) which are more irregular than on the eastern ridge. The break of slope to the upper terrace is also quite distinct.

There are shallow declivitives running up-down slope on both of the ridges. These are areas of deeper colluvium and of concentrated surface and subsurface runoff. The subsurface component (throughflow) destabilises the colluvial and alluvial mantle, and facilitates landslips. There is a distinct landslip scar and runout area on the flank of the eastern ridge.

There also are areas of impeded drainage on the terrace tops and slopes. These do not appear to have caused substantial slips, and the limited erosion of the terrace tops is thought to be mainly by surface runoff.

The main drainage line is the unnamed stream that runs down southwestwards, curving to westwards, from the northeastern corner of the survey area. It has dissected the middle terrace deeply, and the upper terrace slightly. It is hardly incised at all in the hillslope, and its course is marked by a swampy area rather than a distinct valley.

2.5 Land use and vegetation.

The natural vegetation of the site is blue pine *(Pinus wallichiana)* forest. This appears to have been greatly disturbed on the eastern ridge and northern ridges but not actually cleared. There are few large trees remaining and the area has been exploited for construction and household timber, fuel wood and fire splints. Under dense stands of young pine stems the ground vegetation is sparse. There is more ground vegetation where the trees are larger and more widely spaced. The main understorey shrubs are

young pines, rose *(Rosa sericea),* and a few poplar *(Populus).* In wet areas there are dense stands of bamboo (*Yushania* spp), often with sedges *(Juncus* spp*)* on the imperfectly drained fringes.

The northeastern corner of the survey area is in the drainage line between the northern and eastern ridges. The forest has been cleared, presumably for pasture. As it is poorly drained, the area has been densely invaded by bamboos and sedges.

All of the flat upper surfaces of the 40 m and 70 m terraces, parts of the side of the eastern ridge (including the old landslip area) and some of the steep connecting slopes between different levels of terraces have been cleared. Most of the flatter areas have been planted to improved pastures of exotic forage species, such as the grasses Cocksfoot and perennial ryegrass, and the legume white clover. There are a few small enclosures for trials of other crops such as rye and pulses. The very recent enclosure on the 70 m terrace is for testing a wider range of crops, including high altitude rice.

The range of crops that can be grown appears to be partly limited by the cool temperatures. Soft and stone-fruits do not appear to thrive in the Bumthang valley, but can be produced at similar altitudes at Yusipang in the Western region.

3. PREVIOUS SOILS INFORMATION

As far as is known, there have been no previous soil surveys of the site, or anywhere else in the Bumthang valley. Soil samples were collected from four points in or very near to the survey area in the mid 1970's. They were analysed in the Switzerland, and the results are summarised in Table 3.1. The results cannot be compared directly with those from SPAL for our 1997 samples, because of the different analytical methods. However they show that, in general terms, the two terrace soils and the sandy floodplain soils are slightly acid and have low contents of available P and K. The floodplain soil, which has a silty loam top over a much sandier lower subsoil, is acid (pH 5 or just lower) and also has low contents of available P and K. The acid floodplain soil has an organic topsoil, with a humus content of 21 %, but the other soils have low-moderate humus levels. Boron levels are low in all soils. Ca:Mg ratios are mostly satisfactory but are a little high (>6) in two of the topsoils.

Table 3.1 Soil analyses of samples from Bathpalathang farm, Jakar

Topo-graphy	Top or sub soil	Sample no.	pH	Lime %	Av* P2O5 ppm	Av* K2O ppm	Mn ppm	Mg ppm	Ca ppm	B ppm	Humus %	Clay %	Silt %	Sand %
Flood plain	T	2A	6.1	0	0.3	3.3	350	107	818	<0.2	3.4	5	13	79
"	S	2B	6.2	0	0.04	1.4	68	34	138	"	0.7	2	2	96
"	T	6A	4.9	0	0.3	3.7	20	155	948	0.4	21.2	18	36	25
"	S	6B1	4.8	0	0.3	0.8	10	93	278	<0.2	5.5	26	28	41
"	S	6B2	5.2	0	0.1	1.4	10	73	454	"	6.6	17	39	37
"	S	6B3	4.9	0	0.05	1.2	4	44	127	"	0.9	4	8	87
"	S	6B4	4.5	0	0	1.8	9	61	386	"	6.0	8	10	76
"	S	6B5	4.6	0	0.04	1.8	5	35	125	"	1.0	2	4	94
Terrace	T	34A	6.0	0	0.2	3.8	84	117	640	"	3.1	16	18	63
"	S	34B1	5.7	0	0.02	1.6	34	120	400	"	0.7	20	19	60
"	S	34B2	5.7	0	0.02	1.6	64	95	286	"	0.3	10	12	77
"	T	35A	6.0	0	0.4	2.7	83	93	780	"	2.8	17	19	51
"	S	35B1	6.3	0	0.1	1.7	83	130	558	"	1.9	21	19	60
"	S	35B2	6.0	0	0.1	0.8	302	130	702	"	2.2	25	36	36
"	S	35B3	6.0	0	0.3	0.7	200	130	576	"	0.7	29	33	36

* Ranges :	Poor	Weak	Enough	Excess
Av P_2O_5 ppm	0 – 3.5	3.5 – 7.5	8 – 16	> 16
Av K_2O ppm	0 – 0.9	1 – 1.5	2 – 4	> 4

Source: Analysed in Switzerland, 1976; data supplied by RNR-RC Jakar, 1997.

4. METHOD

4.1 Field

This survey was undertaken partly as a field training exercise. As the soil surveyors have several months of field experience, they did much of the routine fieldwork independently. The time taken for this survey was much shorter (2.5 team/weeks) than for the Yusipang RNR-RC soil survey (BSSP 1998 (b).

The soils were examined on a routine basis at 71 sites, mainly with a 1.2 m Edelman auger, fitted with a 7 cm combination head where possible, but switching to a 7cm stony soil head where necessary. Duplicate augering were done at 19 of the sites where the first attempt was stopped by stones at less than 50 cm. Some routine examinations were done in road cuttings, cut back at least 15 cm to expose fresh soil. The sites were located at measured intervals along compass traverses started at points along the western boundary that could be identified on the available large scale maps. Some locations at the beginning, midpoints and ends of traverses were checked with a Magellan GPS.

For routine soil observations the following site data were collected:

Location, GPS; general topography, site position; the angle (in %), aspect, length and form of the slope; solid and drift parent material; general land use and crops/vegetation; irrigation and type; artificial land shaping features; fertiliser use, if known; surface stones; and site drainage.

The soils were described by natural layers (= horizons) as shown on the auger, with the following data collected for each horizon:

Munsell colour of matrix (in field moisture condition); number, size, contrast and colour of mottles; field texture; number, size and type of stones; moisture condition; and consistence on the auger.

The soils were described in more detail at 14 sites. Six of the detailed descriptions were done in freshly exposed cuttings and the rest in purpose-dug profile pits. The site data were the same as for the routine sites, with addition of a detailed description of surface features, including:

Microrelief, rock outcrops; litter, faunal activity, cracks, and capping.

The soils were described by horizons according to international conventions (FAO 1990). The data collected for each horizon were as in the routine descriptions, with the addition of:

Strength, size and type of soil structure; number and size of pores, presence strength and continuity of cutans (shiny coatings on surfaces of soil structural units); consistence *in situ* and in hand; number size and type of roots; reaction to HCl (to test for presence of free carbonate minerals); concretions of iron, manganese or other secondary formations; presence and effects of animals (wormcasts etc.); any other features (e.g. charcoal); clarity and shape of lower boundary.

Samples were collected for laboratory analysis from the main horizons of the 14 described profiles.

In addition to the systematic routine and detailed soil observations used for the original mapping, soils were examined briefly in a further 24 observations to check on the location of some boundaries and to examine aspects of morphological short range variability in the depth of the aeolian cover in the 70 m terrace soils.

4.2 Mapping

The site is covered by the Survey of Bhutan (SoB) topographic sheet # 78 I-14, at scale 1:50 000. The basic topographic data were collected by the Survey of India in the 1960's. Because of the non-availability of SoB maps at the time of our fieldwork, the version digitised and produced by the Land Use and Statistics Section of the Ministry of Agriculture in 1997 was used as the general map of the area. The scale of this is too small to be used as a base for a 1:2500 soil map. However the survey area has been mapped at large scale, by SoB in 1996-1997.

The original survey scale is 1:1000 but there is a version at 1:2500, and this was used as our base map. It shows contours at 2m vertical interval for the floodplain and at 10m on the terraces and hills. The contours are not related to a national datum, but are measured from an arbitrary local base, the identity of which is not indicated. The form lines seem to be highly accurate and give a very good indication of the topography as it appears in the field. The detailed survey is also not tied into a national x-y spatial frame and no control points are shown. This means that, although it can be used as the base of a free-floating drawing, it is difficult to slot this into the national spatial frame in the LUSS GIS. In order to relate the base map to the geo-referencing spatial frame in the GIS, GPS readings (averages of 20) were taken on the ground at 17 easily identified stations. It is clear that the GPS readings were not particularly satisfactory. They had high PDOP and RMS values and distorted the map. They have therefore been ignored and the present (September 1998) version of the map is a free floating drawing. The Cadastral Section of SoB have supplied some control points, and these will be used to locate later versions of our map.

The infrastructure, sites of the soil augerings and profile pits, and the soil boundaries were plotted on the hard copy base map. The data were then digitised as three separate covers; infrastructure, inspection sites, and soil boundaries. The printing scale of the map in the end pocket of this report is 1:1600.

4.3 Laboratory

The 78 soil samples were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the Research, Extension and Irrigation Division of the Ministry of Agriculture at Simtokha. The methods of analysis used by SPAL are summarised in Appendix A.

The only chemical methodological points that need to be mentioned here concern the measurement of cation exchange capacity (CEC) and calculation of base saturation (BS%). CEC can be measured by saturating the soil with ammonium cations, and then displacing and measuring the amount adsorbed. This is referred to as CEC (NH_4OAC). An alternative is to estimate CEC by summing the total exchangeable bases (Ca + Mg + K + Na = TEB), and the extractable aluminium. This is known as the 'effective cation exchange capacity' (ECEC). SPAL does not measure extractable Al in soils with pH (water) greater than 4.5. As none of our Bathpalathang samples are sufficiently acid, there are no determinations for extractable Al. In such cases the ECEC is identical with the TEB, and therefore adds no useful information. It has not been given in this report. Base saturation is the quotient TEB/CEC. If the TEB and the ECEC are identical (as is the case where there is no extractable aluminium), the 'effective base saturation' (EBS %) is automatically 100 %. These values are also not useful, and have not been given in this report. The base saturations in the soil class descriptions in section 5.2, Table 5.2 and in the profile data in Appendix B therefore refer to TEB/CEC (NH_4OAC).

5. SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION

5.1 Soil classification

The soils of the survey area are classified into three main topographic and drainage groups: well drained residual and colluvial soils of the hills; well drained alluvial soils of the terraces; and poorly drained soils. These groups are further subdivided on criteria of depth, colour, topography, and severity of drainage impedance, to give a total of 11 soil classes, as summarised in Table 5.1.

5.2 Characteristic of soil classes at Bathpalathang.

The well drained hill soils are subdivided into three classes:

5.2.1 Shallow brown - reddish yellow hill soils (Hs).

These soils occupy the steep slopes of the northern spur. They were examined in detail in two profiles (see PH010 and PK 017 in Appendix B).

The topsoil is brown-greyish brown sandy loam in undisturbed sites. It has a moderate crumb structure and reasonable porosity. The colour is rarely very dark and can be quite light in sites that have been truncated by logging, roads, or other forms of erosion. The subsoil is reddish yellow to strong brown, sandy loam to sandy loam + in texture, and has moderately developed subangular blocky structures. These do not have significant clayskins. The subsoil contains fragments of weathered gneiss, schist and hard quartzite. The depth to weathered rock is, by definition, less than 1 m and may be as little as 15 cm. The weathered rock varies from soft and reddish yellow - strong brown to hard and greyish - white.

Organic matter levels are low, with organic carbon below 3.2% in PH010 and below 2% in PK017. C:N ratios are satisfactory, in the range 8 - 14. The soils are neutral or slightly acid (pH 6 - 7), but of low - moderate base status (base saturation ranging from 30 - 60%). There is some trace of Ca enrichment in the topsoil but exchangeable Ca is still low (ca 2.5 me %). Available phosphate contents are very low (1ppm) throughout both profiles.

Table 5.1 Soil classes at RNR-RC site, Bathpalathang farm, Jakar.

SOIL CLASS		Main Features	Representative profile and analyses (see App. B)
Code	Name		
Well drained hill soils.			
Hs	Shallow brown reddish yellow hill soil	Dark brown sandy loam topsoil, over reddish yellow - strong brown sandy loam - sandy clay loam, over weathered rock within 1 m.	PH010 PK017
Hd	Deep brown - reddish yellow hill soil	Dark brown sandy loam topsoil, over reddish yellow - yellowish red sandy clay blocky subsoil with clayskins, occasional rounded boulders: weathered rock > 1 m deep.	PK016 PK018
Hw	Grey well - drained hill soil	Grey brown sandy loam topsoil, over grey - white sandy loam - sandy clay loam blocky subsoil. Depth to weathered rock variable	PH012.

Well drained terrace soils.			
Tl	Lower terrace soil	Dark grey sandy loam topsoil over layered grey sandy clay; over bed of rounded boulders within 1 m.	PK010
Tm	Middle terrace soil	Dark brown topsoil over deep reddish yellow - pale brown layered compact subsoil of variable texture, sand - clay; rarely boulders within 2 m. Occasionally with shallow rock layers.	PK011 PK014 PK015
Tu	Upper terrace soil	Dark brown topsoil over deep reddish yellow - pale brown very compact subsoil with clayskins; moderately variable texture, loamy sand - silty clay loam; no boulders within 2m.	PH007 PK013
Rx	Stony soil on connecting riser slope	Dark grey - brown sandy loam topsoil over brown - reddish yellow rounded bouldery sandy loam - sandy clay loam	PH008
Poorly drained soils.			
Tg	Terrace gley	Wet, grey, loamy sand - sandy clay on terrace flats and slopes	None
Hg	Hillside gley	Very wet, grey, loamy sand - sandy clay on hills	PK020
Hi	Imperfectly drained hill soil	Dark grey - dark brown friable sandy loam - sandy clay loam to 50 - 100 cm, over wet grey sandy clay	PH009
Li	Imperfectly drained soil in landslip area.	Dark brown, slightly mottled, moist sandy loam, over wet, grey, strongly mottled sandy loam - sandy clay loam with mixed angular and rounded stones.	PH011

5.2.2 Deep brown - reddish yellow hill soils (Hd)

These soils cover most of the flank slopes of the eastern ridge. They were examined in detail in two profiles (see PK016 and PK018 in Appendix B). At present most of these soils are under blue pine, but some pastures of exotic forage species have been established and appear to be thriving.

The topsoil consists of dark brown - greyish brown sandy loam - sandy clay loam. It has a friable and porous moderate crumb structure, sometimes aggregated into weak fine subangular blocky compound units. The subsoil is strong brown – yellowish red and is little mottled. The structure is generally moderately firm subangular blocky, breaking to friable and porous fine blocky or coarse crumb. In some profiles there are weak discontinuous clayskins. In profiles over weathered *in situ* rock the subsoil may be slightly stony, with the stone content increasing with depth, until weathered rock predominates at depths of more than 1 m. Some profiles are in deep colluvium and the subsoil is more complex, with textural and colour layering from different phases of deposition. There may also be concentrations of colluvial stones, including some that are highly rounded, indicating that they are of alluvial origin, and derived from high terrace deposits up-slope beyond the boundary of the survey area.

Topsoil organic matter levels are moderate in PK016 (organic carbon > 3%) but low in PK0018 (OC < 2%). All C:N ratios are satisfactory, at about 10. PK016 is neutral or slightly acid (pH 6 - 7) and PK018 is slightly - very acid (pH 5.3 - 6.4). Both profiles have low base saturation levels (ranging 25 - 45%). PK016 shows very distinct Ca enrichment in the topsoil (exchangeable Ca about 9 me %) but this effect is not apparent in PK018. Both soils have low to moderate potassium levels, but very low available phosphate (1 ppm throughout).

5.2.3 Grey well - drained hill soil (Hw)

These soils occur on the eastern slope of the northern spur. One profile (see PH012 in Appendix B) was examined in detail. They occur on steep slopes (mostly > 30%), from which the original vegetation has been cleared and now carry rough pastures and regenerating blue pine scrub. Their topsoils are similar to those of the other well - drained hill soils, consisting of dark brown - greyish brown sandy loam with friable and porous crumb structures. Their subsoils are grey - light grey in colour, with many faint yellow and brown mottles. These are blotchy, rather than linear, and look more like incomplete weathering than impeded drainage. Subsoil textures are generally slightly coarser than in the topsoils. The structure is firm, moderate subangular blocky, with some tendency to break to finer and more friable subangular blocky units. The subsoils have high contents of fine muscovite flakes. These soils are of variable depth, but the subsoils become more stony with depth, and generally grade into pale coloured weathered rock at less than 1.5 m.

The profile in this soil (PH012) is chemically distinct from the reddish yellow hill soils, with 100% base saturation in all of the subsoil horizons. However the cation exchange capacity is low, due to the very coarse textures. Organic carbon contents are moderate to low. The C:N ratios are satisfactory in the upper horizons. However available P levels are very low (4 ppm in the topsoil, and only 1 ppm in the subsoil).

Terrace soils

The soils of the flat tops of the terraces have been divided according to the relative height and age of the deposits. These differences are associated with the degree of profile development and characteristics of the soils. There was some debate about whether the soils of the middle and upper terraces warrant separation. However the staff of the RNR-RC confirmed that the visible morphological differences in the soil profiles are paralleled by differences in their management characteristics, so the distinction has been retained. The shallow stony soils of the steep connecting slopes of the risers between all of the terraces are treated as a single class, irrespective of elevation.

5.2.4 Lower terrace soils (Tl).

These are in-extensive soils, occurring on the two isolated remnants of the 10 m river terrace. One profile was examined in detail (see PK010 in Appendix B). The topsoil is dark greyish brown sandy loam with common reddish brown mottles, particularly along old root channels. It is weakly structured crumb, friable and moderately porous. The upper subsoil is similar in appearance but the grey matrix is lighter coloured, the mottles are more distinct, the texture is slightly finer, mainly sandy loam +, and the structure is more blocky. Although of slightly firm consistence the subsoil is moderately porous. The profile examined in detail was fairly wet, fed by throughflow seepage in the upper subsoil. The lower subsoil is a bed of alluvial boulders and cobbles. These are hard, grey and highly rounded and have been little weathered since deposition. The interstitial fine material is slightly wet, light grey, unmottled, coarse and medium sand. It has little structure and crumbles easily to loose single grains.

This horizon was not easy to dig and was not examined to great depth, but the moisture appears to originate mainly from lateral throughflow seepage.

The one profile (PK010) is only slightly acid (pH 6.1 - 6.5), but has low exchangeable base status, with base saturation ranging from 30 to 60% of low - very low cation exchange capacities (2 - 10 me%). Organic carbon contents are low (< 2% throughout), but C:N ratios are satisfactory. Available P is very low, (1 - 5 ppm) but slightly better than in the hill soils and in some of the soils on the higher and older terraces.

5.2.5 Middle terrace soils (Tm)

These soils occupy the relatively flat top of the 40 m terrace. They form an almost continuous strip through the site. They were examined in detail in three profiles (see PK011, PK014 and PK015 in Appendix B). The topsoil is reddish yellow fine sandy-loam. This is quite distinct from the underlying horizons, and is thought to be an aeolian deposit. It is more or less unmottled, has a moderate crumb structure, and is friable and porous. The underlying alluvial subsoil horizons have predominantly brownish yellow - olive yellow matrix colours, and have fine faint reddish brown and orange mottling. They have weak blocky structures, which tend to massive in the finer textured horizons. There are also weak discontinuous clayskins in some of the finer textured horizons. There are scattered soft black manganiferous stains but these are not concentrated as a manganese pan. Textures vary considerably according to the alluvial layering, and range from medium sand to clay, and include silty and very fine sandy horizons. Most of the finer textured subsoil horizons are moderately compact and firm, especially those with high silt and fine sand contents. Although no wet horizons or water were encountered in these profiles, the muted subsoil mottling indicates that drainage is slightly impeded. Profile PK015 is an example where normal - looking upper horizons overlies rock at relatively shallow depths. Such soils are not extensive.

The analyses show that these soils are slightly acid or neutral (pH 6 - 7). The cation exchange capacities are low to moderate, with values 12 - 18 me % in the topsoil and 6 - 12 me% in the subsoils. Base status is moderate, with base saturations mostly in the range 45 - 80%. Topsoil organic carbon contents are moderate, mainly due to the use of all three profile sites for permanent improved pastures. C:N ratios are satisfactory. In all profiles the upper horizons have low to moderate available P contents, but these rise to moderate levels in the subsoil. This rise is often associated with increases in clay content and, in profile PK014, organic matter.

5.2.6 Upper terrace soils (Tu).

These soils occupy the flat top of the 70 m terrace, and form an almost continuous N - S strip through the site. They were examined in detail in two profiles (see PH007 and PK013 in Appendix B). Their profiles have similarities with those of the middle terrace soils (Tm). They have a friable, crumb structured reddish yellow fine sandy loam topsoil, which is thought to be of aeolian origin, and contrasts strongly with the more yellowish and compact river alluvium forming the subsoil. The aeolian topsoil appears to be deeper, possibly because this terrace is older and has been exposed to more and longer phases of deposition. Augering at 5 m intervals along a mini-transect across the terrace through profile PH013 showed that the depth varies from 35 cm to 95 cm. It appears to be deeper at the lower, front edge of the terrace, possibly because of redistribution by surface wash since deposition.

As in the middle terrace soils, the subsoil horizons are more yellow and compact than the topsoil. The degree of compaction is considerably greater, and these horizons are very-extremely firm, and were very difficult to dig. Structures are weak-moderate blocky, tending to massive. There are patchy but strong clayskins in some subsoil horizons. The subsoil is texturally more homogeneous than the subsoils of the middle terrace soils, ranging from fine sandy loam to silty clay loam. The generally high silt and very fine sand contents contribute to the firmness and compaction. These horizons have fine and faint-moderate rust mottling. There is also a horizon with distinct dark brown-black manganese mottling, some of which are concentrated enough to constitute fine, soft concretions. The textural homogeneity, compaction, clayskins and the incipient manganese pan are thought to result from the age and stability of the alluvial deposits and the relatively prolonged pedogenesis. No soils were seen on this terrace with rock at shallow depths.

The aeolian topsoils of both of the analysed profiles have moderate levels of organic carbon (at about 3%) and good C:N ratios (< 10). They are slightly acid or neutral (pH 6 - 7) and have moderate contents of exchangeable calcium (4 - 7 me %) and moderately high base saturations (50 - 70 %). One of the topsoils (PK013) also has high exchangeable magnesium (> 4 me %). Available phosphate levels are very low (only 1 – 2 ppm). The alluvial subsoils all have low organic carbon and available phosphate. They vary in their base status. One profile (PK013) is very acid and base deficient, with pH about 5, total exchangeable bases of less than 1 me %, and base saturations of less than 10%. The other (PH007) is less base deficient. It has neutral pH values (6.5 - 7) and low rather but nor very low contents of exchangeable bases (total exchangeable bases vary between 4 and 6 me %), although base saturation levels are still very low (about 30%).

5.2.7 Terrace riser soils (Rx)

These extensive soils occupy the steep connecting slopes between the floodplain and the different levels of terraces. They form a continuous N-S delineation through the survey area. One profile has been examined in detail (see PH008 in Appendix B). These soils are visually very distinct with high contents of hard rounded boulders sticking out of the steep slopes. The profiles are simple, with dark brown sandy loam-sandy clay loam, crumb structured, friable topsoils overlying very stony and bouldery subsoils. The interstitial fines in the subsoils are mostly coarse or medium textured, ranging from loamy coarse sand to fine sandy loam. The interstitial fines have weak or moderate fine subangular blocky and crumb structures, are porous, and are friable or loose.

The topsoil of the analysed profile (PH008) has moderately high contents of organic matter (organic carbon ca 4.5 %) but medium C:N ratios (10 - 18). The profile has slightly acid - near neutral pH values (6 - 7), but the base saturation drops markedly from moderate (about 65 %) in the topsoil to low levels of 40% or less in the subsoil. Exchangeable calcium is moderate (ca 6 me %) and exchangeable magnesium is moderate or high (> 2 me %) in the topsoil, giving a Ca:Mg ratio of about 2.5. Available P is very low (1 ppm) in all horizons.

<u>Poorly drained soils.</u>

Initially the soils with impeded drainage were divided into only two classes according to the intensity of the drainage constraint, i.e. imperfectly and poorly drained. However the staff of the RNR-RC indicated that they perceived differences in production potential and management problems within these broadly defined classes, and requested further refinement and subdivision. These soils are therefore now divided into four classes.

5.2.8 Terrace gley soils (Tg)

There are a few very small patches on the terrace flats and on the lower riser slopes, mainly on the 40 m terrace, that are poorly drained. These soils are in-extensive, and no profiles were examined in detail or sampled. The topsoil is dark grey or brownish grey, wet, sandy loam - silty loam, almost organic enough to be mucky in places. The subsoil is wet, grey, rust mottled, and poorly structured sandy loam - sandy clay loam.

5.2.9 Hillside gley soils (Hg)

These are the soils of the marshy areas on the hillsides in the northeastern section of the survey area. One profile was examined in detail (see PK020 in Appendix B). The topsoil is grey - dark grey wet humic - mucky sandy loam - sandy clay loam. The topsoil is often densely rooted with sedges and *Yushania* bamboo, giving a root-bound crumb structure. The subsoil is wet, grey, sandy loam - sandy clay, often with olive and pale yellow mottles and streaks. These soils are often quite shallow, and wet, soft and grey micaceous weathered rock may be found within the top metre.

The dark grey colours are mostly due to gleying, and organic matter contents in the mineral horizons (beneath the deep, wet, mucky surface layer) are low (organic carbon < 1%). The soil is slightly acid (pH about 6) and of low base status (base saturation < 40%). Available phosphorus levels are low in both sampled horizons. Presumably because of the organic blanketing effect, there are no signs of Ca and Mg enrichment by aeolian deposition.

5.2.10 Imperfectly drained hill soils (Hi)

These soils occur as a belt fringing the wet marshy areas of the true hillside gleys. Their vegetation is dominated by *Juncus* spp sedges rather than *Yushania* spp bamboos. One profile has been examined in detail (see PH009 in Appendix B). The topsoil is dark brown-dark grey humic sandy loam-sandy clay loam. It is not organic enough to qualify as muck. It is moist, friable and porous and has a weak - moderate crumb structure. It overlies brown - grey sandy clay loam with dark reddish brown and orange rust mottling. This has a moderate medium subangular blocky porous structure. It is moist rather than wet, although there are moisture films on some ped faces. An earthworm was seen in this horizon and it appears to be imperfectly, rather than poorly, drained. It reaches to depths of between 50 and 100 cm. It overlies a truly gleyed, wet, lower subsoil. This is bluish grey in colour and has few, if any, mottles, and these tend to be olive yellow rather than rust coloured. This horizon is medium textured, ranging from sandy loam+ to sandy clay. It contains colluvial fragments of grey and silvery weathered gneiss and schist. It tends to be massive in structure, but has some parting faces with strong moisture films.

The topsoil of sampled profile (PH009) has a moderate-low level of organic matter (organic carbon about 2.5 - 3 %), and a moderately good C:N ratio (about 11). The dark grey lower subsoil horizon (at 73 - 88 cm) is not particularly organic. The soils are slightly acid or neutral, with pH values between 6 and 7. Base saturation varies erratically with depth from very high (almost 90%) to low (25%). The two topsoil samples have moderate levels of exchangeable calcium (about 4 - 5 me %), but this decreases erratically with depth. All horizons have very low contents of available P.

Because of the relatively free drainage in the upper half metre or so, these soils can be drained and managed for annual crops and for improved pastures. In this respect they are agriculturally more flexible than the hillside gleys.

5.2.11 Imperfectly drained landslip soils (Li)

These soils have been identified and mapped in one area on the side slope of the eastern ridge. One profile has been examined in detail (see PH011 in Appendix B). At present these soils are used for improved cocksfoot - white clover pasture, but there has been some invasion by *Juncus* spp sedges and *Artemisia.*

The upper part of the profile is similar to that of the imperfectly drained hill soils (Hi). It consists of a dark coloured humic topsoil of medium texture and moderate - weak crumb structure. The upper subsoil is moist and imperfectly drained, with grey and brown matrix colours and some rust mottles. The lower subsoil is wet and grey, and has a loam - silty clay loam fine earth texture. It contains variable quantities of stones, which are not layered or sorted, and which are taken to indicate fairly recent mass movement. They are of mixed sizes and angularity, ranging from clearly colluvial angular gravel of weathered gneiss to clearly alluvial rounded quartzite cobbles.

Organic matter contents in profile PH011 are low to moderate (organic carbon < 3%), and C:N rations are satisfactory (about 10). The soil is slightly acid (pH 5.5 - 6.5) but base status is low, with base saturations mostly < 50%. There is little indication of aeolian enrichment with Ca in the topsoil (exchangeable Ca is only about 2 me %). Available phosphate levels are low throughout the profile (1 - 2 ppm).

The drainage of the upper half metre or so of these soils is moderately free, and they are usable for arable crops and improved pastures, although they tend to wetness. Care will be needed with cultivation and any operations involving wheeled traffic during wet weather.

5.2.12 Analytical summary

The chemical characteristics of the soil classes are summarised in Table 5.2. A striking feature of all of the analyses of the samples from this survey is the generally low content of available P. The top soils of areas have been under permanent pastures of Cocksfoot, white clover and other vigourous species have built up moderate – high organic carbon and total nitrogen levels but this has not been matched by a build-up of available P. Most of the soils are slightly acid-acid, and base saturations are moderately low to match.

Table 5.2 Chemical analyses, by soil classes, Bathpalathang site, Jakar RNR-RC

SOIL CLASS (number of profiles analysed)	TOPSOIL ONLY				TOPSOIL AND SUBSOIL (T/S)				
	Org. C (%)	Total N (%)	C:N	AvP (ppm)	pH	TEB me %	BS (%)	Exch K (me %)	AvK (ppm)
Hs (2)	1.4 - 2.5	0.07-0.18	8-10	1	6.1-6.6/ 6.0-6.6	2-3/1-2	31-62/ 29-37	0.1-0.5/ 0.2-0.3	6-12/ 6-13
Hd (2)	1.7-3.2	0.23-0.35	7-9	1-2	5.6-6.1/ 6.4-6.8	3-10/ 3-4	25-41/ 35-44	0.1-0.7/ 0.3	8-248/ 35-62
Hw (1)	2.4	0.20	11	4	6.2/6.7	5/3	70/100	0.1/0.2	16/17
TL (1)	1.6	0.21	8	3	6.1/6.5	3/3	33/48	0.1/0.1	16/3
Tm (3)	1.7-3.8	0.26-0.47	6-10	1-3	6.2-6.6/ 6.5-6.8	4-8/4-8	33-45/ 31-77	0.1-0.2/ 0.1-0.4	4-26/ 47-455
Tu (2)	0.2-3.2	0.08-0.39	3-8	1	6.1-6.9/ 5.3-6.9	7-8/1-5	56-70/ 2-28	0.2-0.3/ 0.1-0.3	5-6/ 12-13
Rx (1)	4.4	0.24	18	1	6.3/6.8	10/3	67/41	0.2/0.3	140/1
Hg (1)	0.5	0.02	25	1	6.1/6.1	2/3	39/32	0.1/0.3	9/62
Hi (1)	2.7	0.24	11	1	6.4/6.2	5/3	48/55	0.3/0.2	42/44
Li (1)	2.4	0.26	10	2	5.8/6.4	3/3	42/59	0.2/0.1	1/8

See Table APPA.1 in Appendix A for interpretation of these values.

5.3 Soil correlation.

5.3.1 Correlation with international soil classifications

The local classification used in Table 5.1 and in section 5.2 aims to be simple and to clearly indicate the main soil features to those interested specifically in the soils of Bhutan and Bathpalapathang. The classes are too generally defined to convey much to people outside Bhutan. The classes are therefore correlated with the two main international systems of soil classification in Table 5.3. There is discussion of the correlations in Appendix C.

5.3.2 Correlation with geotechnical classification of soils

Stability of soil terraces and water conveyance systems are critical features of soils for agricultural development in Bhutan. The Irrigation Section of REID of MOA has prepared a geotechnical classification of soils specifically for canal and terrace stability in Bhutan conditions. Although irrigated agriculture is not significant in Bumthang nor likely to be much investigated in RNR-RC trials on the Bathpalathang site, the classification is useful, as it indicates the general stability of the soils and their susceptibility to slumping and other forms of mass movements. Table 5.4 correlates the soil of Bathpalathang with the geotechnical classification.

Table 5.3 International correlation of Soil Classes at Bathpalathang site, Jakar RNR-RC

Soil Class		Subunit in FAO Soil Map of the World Legend of (FAO1974 & 1988)	Great group in USDA Soil Taxonomy (Soil Survey Staff 1975 & 1992) *[Family in italics*]
Code	Name		
Hs	Shallow reddish yellow hill soil	Humic or dystric Cambisol	Lithic, dystric or typic Ustochrept; [*mesic, coarse loamy, mixed*]
Hd	Deep reddish yellow hill soil	Dystric Regosol, Humic or dystric Cambisol;	Dystric or typic Ustochrept, Typic Ustorthent*; [mesic, coarse loamy, mixed]*
Hw	Grey well-drained hill soil	Dystric or eutric Cambisol, Haplic Acrisol)	Dystric or typic Ustochrept; Typic or ochreptic Haplustult; *[mesic, coarse loamy, mixed]*
Tl	Lower terrace soil	Dystric Fluvisol	Typic Ustifluvent *[mesic, loamy skeletal, mixed]*
Tm	Middle terrace soil	Dystric Cambisol (Dystric Fluvisol)	Dystric Ustochrept, Typic Ustifluvent *[mesic, loamy, mixed]*
Tu	Upper terrace soil	Dystric Cambisol. (Haplic Acrisol)	Dystric Ustochrept, Typic Haplustult *[mesic, fine loamy, mixed]*
Rx	Stony soil on connecting riser slope	Dystric Fluvisol, (Dystric Regosol)	Typic Ustifluvent or Ustorthent *[mesic, skeletal, mixed]*
Tg	Terrace gley	Dystric Gleysol	Typic or humic Endoaquept *[mesic, loamy, mixed]*
Hg	Poorly drained hillside gley	Mollic or dystric Gleysol; gleyic Cambisol	Mollic or humic Endoaquept, Typic Epiaquept, Cumulic Humaquept; Humaqueptic Epiaquent*; [mesic, loamy, mixed]*
Hi	Imperfectly drained hill soil	Dystric Gleysol; (Dystric Regosol)	Typic Endoaquept, Cumulic Humaquept; Humaqueptic or Aquic Ustorthent; *[mesic, coarse loamy or loamy skeletal, mixed]*
Li	Imperfectly drained soil in landslip area	Dystric Regosol	Typic Epiaquept, Cumulic Humaquept; Humaqueptic or Aquic Ustorthent; *[mesic, coarse loamy or loamy skeletal, mixed]*

Table 5.4 Geotechnical correlation of soils of Bathpalathang RNR-RC

Bathpalathang soil class	REID Irrigation Section Geotechnical Soil Classification	
	Land unit	Soil class
Hs	3B	SC (clayey sandy)
Hd	3A/3B	
Hw		
Tl	5A	CL & MH (inorganic clay and silt)
Tm		
Tu		
Rx	5B	GC (clayey gravel)
Tg	5A	SC (clayey sand)
Hg	4D	
Hi		
Li		

Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution.

Because the soil classification has a strong geomorphological basis, the distributions of the soil classes are closely related to topography. The shallow well drained hill soils predominate on the slopes of the northern spur. The deep brown - reddish yellow well drained hill soils predominate on the slopes of the eastern ridge. The terrace flat and riser soils occur where their names indicate. The poorly drained soils occur in depressions on the various landscape units, as their names indicate.

6.2 Soil mapping units.

It is possible to map all of the area as simple units in which one class of soil is predominant (consociation). The consociations are not pure, and contain minor inclusions of other soil classes. However there is no need for complex mapping units with two or more classes that are more or less coequal. The compositions of the mapping units are summarised in Table 6.1.

The soil map at scale 1:1600 is located in the end pocket of this report. The areas and proportions of the soil mapping units are summarised in Table 6.2

Table 6.1 Composition of soil mapping units at Bathpalathang site, Jakar RNR-RC

Mapping unit	Type	Main soil classes	Minor soil classes
Hs	Consociation.	Hs	Hw, Hd.
Hd	"	Hd	Hs, Hw
Hw	"	Hw	Hd, Hs.
Tl	"	Tl	Tg
Tm	"	Tm	Tg
Tu	"	Tu	Tg
Rx	"	Rx	-
Tg	"	Tg	Tl, Tm, Tu
Hg	"	Hg	Hi
Hi	"	Hi	Hg, Hd
Li	"	Li	Hd

Table 6.2 Areas of soil mapping units, Bathpalathang site, Jakar RNR-RC

Soil Mapping Unit	Area		
	Ha	Acres	Survey area %
Hs	1.8	4.3	5.8
Hd	4.4	10.9	14.6
Hw	1.5	3.8	5.1
Tl	0.4	0.9	1.2
Tm	3.3	8.2	11.0
Tu	6.5	16.0	21.4
Rx	10.0	25.0	33.4
Tg	0.6	1.6	2.1
Hg	1.0	2.5	3.3
Hi	0.5	1.3	1.7
Li	0.1	0.3	0.4
TOTAL	30.2	74.8	100.0

7. OVERVIEW AND IMPLICATIONS

7.1 Overview of soils.

The site encompasses a wide range of soils. They vary in texture from loamy sand to silty clay. Most of them are slightly acid or neutral and have moderate base saturations. Some of the older soils on the hills and higher terraces appear to have slight Ca enrichment in the upper horizons, possibly of aeolian origin. Organic matter contents are low or moderate. All the soils have low available P contents. The only exceptions are the subsoils of some of the older terrace alluvia. All of the soils are likely to give good responses to appropriately applied fertilisers.

The moisture status of the soils varies considerably. The shallow soils on steep, runoff-shedding sites on the hills and terrace riser slopes are liable to moisture stress during periods of dry weather. At the other end of the range, the poorly drained soils have excessive soil water and poor aeration for a large part of the year, especially during the main growing season in summer.

7.2 Implications of results

In additional to supplying general information on an important aspect of the production environment, the results of the soil survey can be applied to specific points about the suitability of the site as a Research Centre.

In particular the results can contribute to the following:

- Are the soils of the site found elsewhere, and to what extent will it be possible to extrapolate research findings on the site to other parts of the region?

- What trials should be located on which of the site's soils?

- What land, from a soils point of view, is best used for infrastructure and other non - trials uses?

The Soil Survey unit is just over a year old and this was only its second systematic survey. It has not yet seen anything of the soils elsewhere in the East Central Region. It therefore cannot pronounce on the first point listed above, i.e. the regional relevance of the site's soils. However river terraces are extensive in the Bumthang valley. Their main agricultural use is for dryland arable cropping and improved pastures. Although not as extensive, there are also some areas of apple orchards on the soils of the terraces. The terrace flats (map units Tm and Tu) could therefore be used for arable, pasture and fruit tree trials.

The hill soils, especially the deeper soils on the eastern ridge (map unit Hd) appear to be suitable for tree crop trials. Crops to be investigated might include cool temperate fruit trees, such as apples, and also timber species.

The poorly drained soils are less obviously suitable for the crops grown in the Bumthang valley at present. However they could be used for trials and demonstrations of methods for improving the productivity of such soils elsewhere in the region.

The staff of the RNR-RC had a copy of our first draft soils map for their preliminary planning of the site in November 1997. They have located the main building and agricultural research trial and demonstration areas on the flat tops of the upper and middle terraces (units Tu and Tm), kept most of the hill land for forestry and as reserves for forestry and fodder work, and left the steep connecting riser slopes between the terraces (unit Rx) as natural vegetation. These locations appear to be appropriate in soils terms. Construction work for the plan has already begun, and some new trials areas have already been established on the upper terrace soils (Tu).

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APPENDIX A - Summary of soil analysis methods

The full details of the methods used at SPAL are given in 'Soil Analysis' (SPAL 1993).

The SPAL methods vary slightly according to soil pH. The methods summarized below are those for soils of pH (water) > 4.5 and < 7, as these apply to all of the samples from Bathpalathang.

Sample preparation.

Samples are air-dried, aggregates are hand crushed, and the soil is sieved to 2 mm.

pH.

Soil pH is measured in suspensions of the soil in distilled water and 1 M KCl (1:2.5) using a PHM 83 automatic pH meter.

Soil extracts

The fine earth fraction is subject to a number of extraction procedures:

Total N is extracted and converted into ammonium form by micro-Kjeldahl digestion with H_2SO_4 and a Se-based catalyst

Ammonium – N and nitrate – N are extracted by shaking with 0.01 M $CaCl_2$ for two hours.

Available P is extracted by shaking 5 g of fine earth with 35 ml of the Bray and Kurtz extractant of 0.5 M HCl and 1 M NH_4F for 1 minute.

Available K is extracted by shaking 5 g of fine earth with 50 ml of 0.01 M $CaCl_2$ for 2 hours.

Exchangeable Ca, Mg, K and Na are extracted by leaching 5 g of fine earth with 100 ml of 1 M ammonium acetate (NH_4OAc).

The ammonium is extracted by leaching the soil with excess 1 M KCl, and measured to give the Cation Exchange Capacity.

Extractable Al and H are extracted from 5 g fine earth with 100 ml of 1 M acidified KCl.

Assays of extracts.

The NH_4 from the Total N digestion, and from the KCl leaching for CEC determination, the NH_4 – N, NO_3 – N, available P, available K, and exchangeable K and Na in the various extracts are measured with the Skalar Segmented Flow Analyser system which includes

Colourimeters for NH_4, NO_3 and available P, and a flame spectrophotometer for available K, and for exchangeable K and Na.

Exchangeable Ca and Mg in the NH_4OAc leachate are measured with a Unicam Atomic Adsorption Spectrophotometer.

Extractable acidity (Al + H) in the KCl leachate are measured by titration with 0.05 M NaOH, and extractable Al alone is measured by a second titration with 0.05 M HCl, after the addition of NaF.

Organic carbon

OC is measured by the Walkley – Black method of low temperature oxidation with acidified $K_2Cr_2O_7$ and titration of the excess dichromate.

Particle size analysis

Particle size fractions are measured by the pipette method after pre-treatment of the fine earth with H_2O_2 to remove organic binding effects, and with HCl to remove aggregation effects by carbonates, Fe and Al oxides, and other mineral cementing agents, and dispersion of the clay with sodium hexametaphosphate.

TEB, ECEC, BS and C:N.

Total exchangeable bases, Effective cation exchange capacity, base saturation, and C:N ratios are derived by simple computations, i.e.;

TEB = Exchangeable Ca + Mg + K + Na.

ECEC = TEB + Extractable Al.

BS (NH_4OAc) = TEB / CEC (NH_4OAc).

EBS = TEB / ECEC.

C:N = Organic C / Total N.

The analytical results from SPAL are interpreted as indicated in Table AppA.1.

Table APPA.1 Summary of 1995 recommendations for interpretation of SPAL soil analyses

	V. High	High	Moderate	Low	V. Low
pH	> 7.6 * (alkaline)	6.6 - 7.5 (neutral)	5.6 - 6.5 (s. acid)	4.6 - 5.5 (v. acid)	< 4.5 (ext. acid)
EC (mS/cm)	> 2.00	0.8 - 1.99	0.4 - 0.79	0.15 - 0.39	< 0.15
CEC (NH_4OAC) (me%)	> 40	25 - 39.9	15 - 24.9	5 - 14.9	< 5
XCa (me%)	> 20	10 - 19.9	5 - 9.9	2 - 4.9	< 2
XMg (me%)	> 8	3 - 7.9	1.5 - 2.9	0.5 - 1.4	< 0.5
XK (me%)	> 1.2	0.6 - 1.19	0.3 - 0.59	0.1 - 0.29	< 0.1
XNa (me%)	> 2	0.7 - 1.99	0.3 - 0.69	0.1 - 0.29	< 0.1
TEB (me%)	> 30	15 - 29.9	7.5 - 14.9	3 - 7.4	< 3
XAl (me%)	> 10	5 - 9.9	2 - 4.9	0.5 - 1.9	< 0.5
ECEC (me%)	> 30	20 - 29.9	12 - 19.9	4 - 11.9	< 4
BS % (NH_4OAc)	> 80	65 - 79	50 - 64	35 - 49	< 35
EBS (%)	> 80	50 - 79	35 - 49	20 - 34	< 20
Ca:Mg	> 10	6 - 9.9	2 - 5.9	0.8 - 1.9	< 0.8
AvK (ppm)	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP (ppm)	> 30		15 - 29	5 - 14	< 5
Org. C (%)	> 5	3.1 - 4.9	1.2 - 3	0.6 - 1.1	< 0.6
Total N (%)	> 1	0.5 - 0.99	0.2 - 0.49	0.1 - 0.19	< 0.1
C:N	> 50	20 - 49	15 - 19	10 - 14	< 10
NO_3 (ppm)	> 50	30 - 49	15 - 29	5 - 14	< 5
NH_4 (ppm)	> 50	30 - 49	15 - 29	5 - 14	< 5
Cu (ppm)	> 8	2.6 - 7.9	0.9 - 2.5	0.2 - 0.8	< 0.2
Fe (ppm)	> 175	35 - 174	18 - 34	3 - 17	< 3
Mn (ppm)	> 40	9 - 39	4 - 8	1 - 3	< 1
Zn (ppm)	> 10	3.5 - 9.9	2 - 3.4	0.8 - 1.9	< 0.8
B (ppm)	> 1	0.5 - 1	0.2 - 0.5	0.14 - 0.2	< 0.14
Mo (ppm)	> 1	0.1 - 1	< 0.1		
AWC (% v/v)	> 24	18 - 23	12 - 17	6 - 11	< 6

Source: AHT 1995.

APPENDIX B – Soil Profile descriptions and Analyses

This appendix includes the detailed descriptions and analyses of the 14 soil profiles. The profiles are in the sequence in Table AppB.I.

Table APPB.1 Summary of soil Bathpalathang profiles.

Profile no.	Bathpalathang soil class	Number of horizons analysed.
PH007	Tu	6
PH008	Rx	4
PH009	Hi	7
PH010	Hs	3
PH011	Li	4
PH012	Hw	5
PK010	Tl	4
PK013	Tu	5
PK014	Tm	4
PK015	Tm	2
PK016	Hd	5
PK017	Hs	2
PK018	Hd	5
PK020	Hg	2
PK011	Tm	6

Profile: PH007

Map unit: Tu

Soil classification: Provisional Bathpalathang soil class: Upper terrace soil (Tu)
Soil Taxonomy: Typic Haplustult
FAO: Haplic Acrisol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: 15m above augering Ad0054 (near silo clamp)
GPS: 27^0 33.83' N, 90^0 44.99' E.
Altitude: 2620 m a.s.l.

Described & sampled: 24.10.97, HB Tamang.

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Rainy

Regional topography: River valley.
Site position: Upper terrace

Slope: 5%, flat terrace, 400m long, aspect SW (240^0)
Site drainage: Good

Parent material: Solid: Mixed
Drift: Old alluvium

Land use: Improved pasture.
Vegetation: Cocksfoot, ryegrass, tall fescue, white clover.

Surface: Litter: None
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 13 7.5YR 5/4 (brown); fine sandy loam; weak medium subangular blocky breaking to fine crumb; moist & slightly friable; few fine tubular pores; many fine grass roots; clear regular boundary to: [Sample PH007/1 @ 0-10]

13 - 46 7.5YR 7/3 (pink) with common fine faint reddish brown & dark mottles; fine sandy loam+; moderate medium breaking to fine crumb; weak discontinuous clayskins; moist & firm; many fine & medium tubular pores; few fine roots; few black manganese stains; clear regular boundary to: [Sample PH007/2 @ 20 - 30]

46 - 61 2.5Y 6/6 (olive yellow) with common fine faint grey & dark brown mottles; coarse sandy loam+; weak medium subangular blocky; strong discontinuous clayskins; common fine tubular pores; moist & firm; many fine grass roots; few fine quartz stones; few black manganese stains; clear regular boundary to: [Sample PH007/3 @ 48-58]

61–104 Mixed 2.5Y 7/6 (yellow) & 10YR 5/3 (brown), with many medium faint dark brown mottles; fine sandy loam+; strong medium subangular blocky: weak discontinuous moisture films; no pores; moist & very firm; no roots; many fine soft reddish brown concretions and abundant black manganese stains; clear regular boundary to: [Sample PH007/4 @ 80-90]

104 –130 2.5Y 5/4 (light olive brown) with many medium distinct dark reddish, brown & orange mottles; medium sandy clay loam; moderate medium subangular blocky; no pores; moist & firm; no roots; many medium soft reddish brown & dark brown manganese stains & concretions; few flakes of muscovite; clear regular boundary to: [Sample PH007/5 @ 115 -125]

130 –145 2.5Y 6/4 (light yellowish brown) with common medium distinct reddish brown & dark mottles; fine sandy clay loam; moderate medium subangular blocky; no pores; moist, firm in face & friable in hand; no roots; few fine weathering gneiss; few black manganese stains: [Sample PH007/6 @ 133 - 143]

Comments: Moderate topsoil organic matter content due to permanent pasture. Subsoil compaction and manganese stains typical of upper terrace soils.

SPAL analytical results for BSS **Profile PH007** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH007/1	0 - 10	4322	6.1	4.7	1.4	-	1	3.2	0.39	8.2
/2	20 - 30	4323	6.2	4.5	1.7	-	1	0.2	0.03	6.6
/3	48 – 58	4324	6.6	4.8	1.8	-	1	0.2	0.03	6.6
/4	80 - 90	4325	6.8	5.2	1.6	-	1	0.2	4.00	0.0
/5	115 - 125	4326	6.9	5.4	1.5	-	1	0.3	0.03	10.0
/6	133 - 143	4327	6.8	5.4	1.4	-	1	0.2	0.01	20.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH007 /1	6.0	0.8	0.2	0.3	7.3	-	13.0	-	56	-
/2	2.3	1.5	0.2	0.1	4.1	-	5.1	-	80	-
/3	2.0	1.6	0.2	0.1	3.9	-	6.4	-	61	-
/4	3.2	1.8	0.2	0.2	5.4	-	16.2	-	34	-
/5	3.1	1.6	0.3	0.2	5.2	-	18.2	-	28	-
/6	3.1	1.6	0.3	0.2	5.2	-	18.8	-	28	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH007 /1						28.4	18.6	30.2	48.8	22.8	L
/2						36.1	17.3	26.9	44.2	19.8	L
/3						52.2	8.6	17.3	25.9	22.0	SCL
/4						36.4	12.8	26.9	39.7	24.0	L
/5						34.4	12.7	28.4	41.1	24.5	L
/6						43.7	9.3	23.4	32.7	23.5	L

Profile: PH008

Map unit: Rx

Soil classification: Provisional Bhutan name: Stony riser soil (Rx)
Soil Taxonomy: Dystric Ustorthent
FAO: Dystric Regosol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: Below PH007 on feeder track down to Bathpalathang Farm
GPS: 27^0 33.78'N, 90^0 45.01' E.
Altitude: ca 2660 m a.s.l.

Described & sampled: 24.10.97, H.B Tamang.

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Rainy

Regional topography: Main river valley.
Site position: Connecting slope between 40 m and 70 m terraces.
Slope: 60%+, rectilinear, 100 m long, aspect SW (230^0)
Site drainage: Good

Parent material: Solid: Mixed
Drift: Moderately old alluvium

Land use: Waste land.
Vegetation: Blue pine, Artimesia and natural grasses.
Surface: Litter: 1-3 cm grass and pine needles
Outcrops: None
Stones: Few medium rounded quartz & gneiss cobbles and stones
Cracks: None
Roots: None
Microrelief: Slightly wavy.
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 8 7.5YR 5/3 (brown); fine sandy clay loam +; strong fine crumb; many fine & medium pores; moist & slightly firm; abundant fine & medium roots; few medium hard rounded quartz stones; earthworm seen; common charcoal; gradual regular boundary to:[Sample PH008/1 @ 0-8]

8 - 19 7.5YR 5/4 (brown); fine sandy loam +; strong medium subangular blocky breaking to fine crumb; few fine pores; slightly dry & slightly hard; common fine roots; few medium hard rounded mixed stones; gradual regular boundary to: [Not sampled]

19 - 38 7.5YR 5/6 (strong brown); fine sandy clay loam +; moderate medium subangular blocky breaking to moderate fine crumb; common medium & fine pores; moist & slightly friable; few fine roots; common medium & coarse hard rounded mixed stones; few charcoal; diffuse boundary to: [Sample PH008/2 @ 25 - 35]

38 - 66 5YR 5/6 (yellowish red); fine sandy clay loam; moderate medium - coarse subangular blocky breaking to fine crumb; few medium pores; moist & friable; few fine roots; common medium & coarse hard rounded quartz & mixed stones; common earthworm casts; few charcoal; clear wavy boundary to: [Sample PH008/3 @ 45 - 55]

66 – 144+ 10 YR 6/6 (brownish yellow) with common fine faint yellow & orange mottles; very gravelly medium sandy loam +; stony with fine & medium interstitial subangular blocky; few medium pores; moist & interstitial fine earth slightly friable; few fine roots; abundant hard rounded medium & coarse gravel & pebbles; few charcoal: [Sample PH008/4 @ 90-100]

Comment: Bouldery horizon continues down for many meters in nearby road cuttings. Pine litter gives high topsoil organic carbon but fairly high (i.e. poor) C:N ratio. Stony subsoil horizons have poor base status, although more or less neutral pH.

SPAL analytical results for BSS **Profile PH008** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC mS/cm	Avail. P ppm	OrganicC%	Total N %	C:N
			H2O	KCl	Diff					
PH008 /1	0-8	4328	6.3	4.9	1.4	-	1	4.4	0.24	18.3
/2	25-35	4329	6.7	4.5	2.2	-	1	0.6	0.04	15.0
/3	45-55	4330	6.8	4.6	2.2	-	1	0.2	0.01	20.0
/4	90-100	4331	6.8	4.8	2.0	-	1	0.2	0.23	0.08

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH008 /1	6.4	2.5	0.2	0.9	9.9	-	14.9	-	67	-
/2	1.6	0.7	0.2	0.2	2.7	-	9.1	-	29	-
/3	1.3	0.9	0.2	0.1	2.5	-	6.1	-	41	-
/4	1.6	0.9	0.3	0.1	2.9	-	5.0	-	57	-

Fine earth granulometric.

BSS No.	Sand						Slit			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH008 /1						36.6	13.9	24.5	38.4	27.9	CL
/2						36.5	12.0	23.7	35.7	27.9	CL
/3						41.0	14.0	23.5	37.5	21.5	L
/4						48.7	12.4	21.0	33.4	17.9	L

Profile: PH009

Map unit: Hi

Soil classification: Provisional Bathpalathang soil class: Imperfectly drained hill soil (Hi)
Soil Taxonomy: Typic Endoaquept
FAO: Dystric Gleysol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: North Central section of site.
GPS: 27^0 34.02'N, $90^0$44. 95' E.
Altitude: 2710 m a.s.l.

Described & sampled: 28.10.97, H.B Tamang.

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Sunny

Regional topography: Main river valley.
Site position: Toeslope of hill, edge of non-incised drainage line.

Slope: ca 25%, 500 m long, rectilinear, aspect SW (ca 215^0)
Site drainage: Poor

Parent material: Solid: Mixed metamorphics
Drift: Colluvium over alluvium

Land use: Waste land.
Vegetation: Bamboo, sedges and Artimesia.

Surface: Litter: 1cm sedge and bamboo litter.
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 10 10YR 3/2 (very dark greyish brown) with few fine faint reddish brown mottles; fine sandy loam; weak medium subangular blocky; many fine pores; moist & friable; many fine & medium roots; few medium hard angular quartz stones; HCl negative; earthworm seen when digging; gradual slightly wavy boundary to: [Sample PH009/1 @ 0 -10]

10 - 55 10YR 4/2 (dark greyish brown) with common fine faint brown & yellow mottles; fine sandy loam; weak medium subangular blocky; many fine pores; moist & friable; many medium roots; HCl negative; earthworm seen when digging; clear regular boundary to: [Sample PH009/2 @ 30 - 40]

53 - 73 7.5YR 4/2 (brown) with few fine faint reddish brown mottles; very fine sandy loam; weak medium subangular blocky; many fine pores; moist & slightly friable; few fine roots; HCl negative; few flakes of muscovite; clear slightly wavy boundary to: [Sample PH009/3 @ 60 - 70]

73 - 88 2.5Y 4/1 (dark grey) with many medium distinct reddish brown & orange mottles; fine sandy clay loam; moderate medium angular blocky; few fine pores; moist & very firm; few fine roots; few fine hard rounded quartz gravel; HCl negative; few flakes of muscovite; clear slightly wavy boundary to: [Sample PH009/4 @ 75 - 85]

88 – 102 10B 1/5 (bluish grey) with common medium & fine reddish brown & orange mottles; medium sandy loam + (to silty loam), with pockets of sandy clay; weak medium subangular blocky; many fine pores; wet & slightly firm; few fine roots; few fine hard rounded gravel quartz; HCl negative; few flakes of muscovite; clear wavy boundary to: [Sample PH009/5 @ 90-100]

102 – 126 5Y 5/1 (grey) with few fine faint dark brown mottles; coarse sandy loam; weak medium subangular blocky; few fine pores; wet & slightly firm; few fine roots; few fine hard rounded quartz gravel; HCl negative; few flakes of muscovite; diffuse wavy boundary: [Sample PH009/6 @ 110-120]

126 – 166+10B 6/1 (bluish grey); coarse sandy loam with pockets of sandy clay; massive structure; wet and slightly firm; few fine hard rounded quartz gravel; HCl negative: [Sample PH009/7 @ 140-150]

Comments: The matrix colours, vegetation and the presence of earthworms indicate that this soil is moderately well drained down to about 70 cm. Below that it is poorly drained, apparently due to a local water table, rather than throughflow. The rounded quartz stones indicate that the lower horizons are derived from old alluvium, but the upper horizons are thought to have formed in locally-derived colluvium.

SPAL analytical results for BSS **Profile PH009** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	OrganicC%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PH009 /1	0-10	4332	6.4	4.8	1.6	-	1	2.7	0.24	11.2
/2	30-40	4333	6.9	4.0	2.9	-	1	0.9	0.13	6.9
/3	60-70	4334	6.9	4.9	2.0	-	3	1.0	0.09	11.1
/4	75-85	4335	6.2	4.8	1.4	-	1	0.7	0.01	70.0
/5	90-100	4336	6.2	4.3	1.9	-	1	0.2	0.02	10.0
/6	110-120	4337	6.1	3.9	2.2	-	1	0.2	0.02	10.0
/7	140-150	4338	6.7	4.3	2.4	-	1	0.1	0.03	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH009 /1	3.4	1.0	0.3	0.3	5.0	-	10.5	-	48	-
/2	4.8	1.0	0.1	0.2	6.1	-	6.9	-	89	-
/3	0.4	1.8	0.2	0.2	2.6	-	10.2	-	25	-
/4	5.4	1.2	0.2	0.2	7.0	-	12.1	-	58	-
/5	1.5	1.0	0.2	0.2	2.9	-	5.0	-	58	-
/6	0.5	0.7	0.2	0.2	1.6	-	2.9	-	55	-
/7	1.1	0.7	0.2	0.3	2.3	-	2.7	-	85	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH009 /1						61.7	7.9	17.8	25.7	12.6	SL
/2						58.8	10.7	17.5	28.2	13.0	SL
/3						56.6	21.1	8.5	29.6	13.8	SL
/4						54.4	9.0	19.8	28.8	16.8	SL
/5						74.7	8.2	11.4	19.6	5.7	LS
/6						69.5	9.8	12.1	21.9	8.5	SL
/7						76.5	7.2	11.9	19.1	4.4	LS

Profile: PH010

Map unit: Hs

Soil classification: Provisional Bathpalathang soil class: Shallow reddish yellow hill soil (Hs).
Soil Taxonomy: Dystric Ustochrept
FAO: Dystric Cambisol.

Survey area: Bathpalathang RNR-RC site, Jakar
Location: Lower hillslope path, near northern boundary.
GPS: 27^0 34.08'N, 90^0 44. 80' E.
Altitude: Ca 2650 m a.s.l.

Described & sampled: 28.10.97, H B Tamang.

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Sunny

Regional topography: Main river valley.
Site position: Toeslope of hill

Slope: 70+%, 300m, straight, facing south.
Site drainage: Good.

Parent material: Solid: Mixed metamorphics.
Drift: Colluvium

Land use: Waste land.
Vegetation: Blue pine, bracken and some native grasses, shrubs, and forbs.

Surface: Litter: None
Outcrops: Few
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 – 13 7.5YR 5/4 (brown); very fine sandy loam+; weak medium subangular blocky breaking to fine crumb; common fine pores; moist & friable in hand, firm in face; many fine roots; few fine hard angular quartz stones; HCl negative; gradual regular boundary to: [Sample PH010/1 @ 0-10 cm]

13 - 40 5YR 5/6 (yellowish red); gravelly sandy loam; weak medium subangular blocky breaking to fine crumb; in hand; few fine pores; moist, friable in hand, and firm in face; few fine roots; few fine & medium angular quartz stones; HCl negative; gradual wavy boundary to: [Sample PH010/2 @ 20 – 30 cm]

40 – 58 Mixed dark reddish brown, white & orange; weathered rock (hand textures as coarse sand); massive structure; few fine pores; moist, soft & friable; few fine roots; HCl negative; clear wavy boundary: [Sample PH010/3 @ 45 - 55 cm]

58 – 103+ White, yellow & orange soft weathered micaceous gneiss:

Comment: This is a typical profile for the shallow well drained reddish yellow hill soils. Subsoil base saturations are moderately low, although pH is only slightly acid.

SPAL analytical results for BSS **Profile PH010** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PH010 /1	0-10	4339	6.1	3.9	2.2	-	1	2.5	0.18	13.8
/2	20-30	4340	6.2	4.5	1.7	-	1	0.1	0.01	10.0
/3	54-55	4341	6.0	4.6	1.4	-	1	0.4	0.04	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH010 /1	0.7	0.7	0.1	0.4	1.9	-	3.0	-	62	-
/2	2.5	1.0	0.1	0.4	4.0	-	8.3	-	48	-
/3	0.7	0.7	0.2	0.5	2.1	-	5.6	-	37	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH010 /1						71.2	8.8	13.4	22.2	6.6	SL
/2						36.3	13.1	25.1	38.2	25.2	L
/3						58.3	8.9	13.1	22.0	19.8	SL

Profile:	Provisional Bathpalathang soil class:	Imperfectly drained landslip soil (Li)
	Soil Taxonomy:	Typic Epiaquept
	FAO:	Dystric Gleysol
Survey area:	Bathpalathang RNR-RC site, Jakar	
Location:	Close to eastern boundary	
GPS:	27^0 34.03'N, 90^0 45. 08, 2685.	
Altitude:	2685 m a.s.l.	
Described & sampled:	30.10.97, H B Tamang.	
Climate:	General:	Cool temperate, P = ca 750 mm pa
	Recent weather:	Sunny
Regional topography:	Main river valley	
Site position:	Old landslip area on lower hill slope.	
Slope:	37%, 600 m, straight, (aspect 226^0) SW.	
Site drainage:	Poor	
Parent material:	Solid:	Mixed metamorphics.
	Drift:	Colluvium from alluvium.
Land use:	Formerly improved pasture.	
Vegetation:	Cocksfoot, ryegrass, white clover, tall fescuse, with encroaching Artimesia and Juncus.	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Few medium hard quartz gravel and stones.
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0 – 7 7.5YR 3/2 (dark brown) with many fine faint light brown & dark grey mottles; fine sandy loam; moderate medium subangular blocky; medium fine pores; moist & friable; common fine roots; few fine hard quartz stones; HCl negative; earthworm seen; gradual regular boundary to: [Sample PH0011/1 @ 0 - 7]

7 - 20 7.5YR 4/2 (brown) with fine faint light brown & dark brown mottles; medium sandy loam; moderate medium subangular blocky; many fine pores; moist & friable; many fine roots; HCl negative; few earthworm seen; clear slightly wavy boundary to: [Sample PH0011/2 @ 10 - 20]

20 – 50/58 7.5YR 4/3 (brown) with common medium distinct reddish brown & orange mottles; fine sandy loam; weak medium subangular blocky breaking to fine crumb; common fine pores; moist & friable; few fine & medium roots; few medium & fine hard rounded quartz stones; HCl negative; clear wavy boundary to: [Sample PH0011/3 @ 35 - 45]

50/58 - 98 5Y 5/1 (grey) with common medium distinct reddish brown & orange mottles; coarse sandy loam & silty loam texture (weathered stones); massive structure; wet & slightly firm; few fine & medium roots; many fine & medium hard rounded quartz stones & slightly hard weathered laminated metamorphics; HCl negative; clear slightly wavy boundary to: [Sample PH0011/4 @ 70 - 80]

98 – 150+ 5Y 6/4 (pale olive) with medium & fine reddish brown & orange mottles; medium sandy loam (& silty loam); massive structure; wet & firm; many fine & medium hard rounded quartz stones; HCl negative: [Not sampled]

Comment: The presence of the hard rounded stones in the subsoils indicate that this colluvial/landslip deposit is at least partly derived from high level alluvium upslope beyond the survey area boundary. The main throughflow seepage is at about 50 cm, and the wetness in the lower horizons intensified after the pit was dug, due to infilling from seepage horizon.

SPAL analytical results for BSS **Profile PH011** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC	Avail.	OrganicC%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PH011/1	0-7	4342	6.5	4.3	2.2	-	1	2.4	0.26	9.5
/2	10-20	4343	5.8	4.7	1.1	-	2	0.2	0.02	10.0
/3	35-45	4344	6.4	4.7	1.7	-	1	1.5	0.13	11.5
/4	70-80	4345	6.4	4.8	1.6	-	2	1.1	0.12	9.1

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH011 /1	1.2	1.0	0.2	0.5	2.9	-	6.9	-	42	-
/2	1.9	0.5	0.1	0.4	2.9	-	7.7	-	38	-
/3	0.9	0.3	0.1	0.5	1.8	-	6.1	-	29	-
/4	2.0	0.4	0.1	0.4	2.9	-	4.9	-	59	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH011 /1						66.4	6.2	10.5	16.7	17.0	SL
/2						59.6	9.6	16.9	26.5	13.9	SL
/3						61.4	9.4	15.9	25.3	13.3	SL
/4						60.2	9.7	16.7	26.4	13.4	SL

Profile: PH012

Map unit: Hw

Soil classification: Provisional Bathpalathang soil class: Grey hill soil (Hw)
Soil Taxonomy: Typic Ustrochrept
FAO: Eutric Cambisol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: Close to track, 300m NE of PH009
GPS: 27^0 34.07 N, 89^0. 44. 99', E.
Altitude: 2640 m. a.s.l.

Described & sampled: 3.11.97, H.B Tamang.

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Dry for 4 days

Regional topography: Main valley
Site position: Footslope of hill

Slope: 35%, 1 km, straight, aspect SSW (205^0).
Site drainage: Imperfect.

Parent material: Solid: Mixed
Drift: Colluvium over alluvium.

Land use: Improved pasture.
Vegetation: Cockfoot and Artimesia.

Surface: Litter: Discontinuous grass litter 0 – 0.5cm.
Outcrops: None
Stones: None
Cracks: Few medium hard angular quartz & gneiss.
Roots: None
Microrelief: Slight stepping behind grass tussocks.
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 – 16 10YR 4/2 (dark greyish brown) with abundant fine faint reddish brown & grey brown mottles; medium sandy loam; moderate subangular blocky breaking to fine crumb; many fine pores; moist & friable; many fine roots; abundant fine mica grit; HCl negative; earthworm seen; gradual regular boundary to: [Sample PH0012/1 @ 0 -10]

16 - 31 7.5YR 3/2 (dark brown); medium sandy loam; moderate subangular blocky breaking to fine crumb; many fine pores; moist & very friable; common fine roots; abundant fine mica; HCl negative; clear slightly wavy boundary to: [Sample PH0012/2 @ 20 - 30]

31 – 42/47 10YR 3/1 (very dark grey) with many fine faint reddish brown mottles; coarse sandy loam; weak medium subangular blocky breaking to fine crumb; many fine pores; moist & friable; common fine roots; abundant fine mica & few angular hard medium quartz stones; HCl negative; clear wavy boundary to: [Sample PH0012/3 @ 31 - 42]

42/47 - 65 5Y 5/2 (olive grey) with common medium distinct orange & yellow brown mottles; fine sandy loam; weak coarse subangular blocky; common fine pores; moist & slightly firm; few fine roots; common hard angular quartz & gneiss stones; HCl negative; abundant fakes of muscovite; gradual regular boundary: [Sample PH0012/4 @ 50 - 60]

65 – 98/106 5Y 6/1 (grey) with common medium distinct orange & yellowish brown mottles; fine sandy loam+; weak coarse subangular blocky; strong continuous dark brown clayskins; common fine pores; moist & slightly firm; few fine roots; few angular hard quartz & gneiss stones; HCl negative; many flakes of muscovite; diffuse boundary to: [Sample PH0012/5 @ 75 - 85]

106 – 153 2.5Y 6/1 (light brownish grey) with abundant common medium distinct orange & yellowish brown mottles; loamy medium sand; weak coarse subangular blocky; strong continuous dark brown clayskins; common fine pores; moist - wet & slightly firm; few fine roots; few hard angular quartz & gneiss stones; HCl negative; many flakes of muscovite; diffuse boundary to: [Not sampled]

153 – 170 2.5Y 6/1 (light brownish grey) with common medium distinct orange & yellow brown mottles; loamy coarse sand; weak medium subangular blocky; common fine pores; moist - wet & slightly firm; few angular hard quartz & gneiss stones; HCl negative; clear regular boundary to: [Not sampled]

170 – 175+Soft weathered gneiss & quartzite, with grey, orange & yellowish brown colours; moist - wet & stony consistence; HCl negative: [Not sampled]

SPAL analytical results for BSS **Profile PH012** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH012/1	0-10	4346	6.2	4.8	1.4	-	4	2.4	0.20	11.4
/2	20-30	4347	6.6	4.9	1.7	-	1	1.3	0.14	9.2
/3	31-42	4348	6.6	4.7	1.9	-	1	0.8	0.05	16.0
/4	50-60	4349	6.7	4.5	2.2	-	1	0.8	0.02	40.0
/5	75-85	4350	6.5	4.4	2.1	-	1	0.1	0.01	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH012 /1	3.7	0.7	0.1	0.4	4.9	-	7.0	-	70	-
/2	3.6	1.2	0.1	0.4	5.3	-	8.7	-	61	-
/3	4.1	2.0	0.2	0.5	6.8	-	6.1	-	100	-
/4	1.2	1.1	0.2	0.6	3.1	-	2.4	-	100	-
/5	2.0	1.9	0.4	0.4	4.7	-	3.6	-	100	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH012 /1						54.3	22.6	13.3	35.9	9.7	SL
/2						57.0	12.6	14.9	27.5	15.4	SL
/3						57.7	15.0	12.0	27.0	15.2	SL
/4						76.4	3.9	14.8	18.7	4.9	LS
/5						61.9	9.7	15.7	25.4	12.8	SL

Profile: PK010

Map unit: Tl

Soil classification: Provisional Bhutan soil series: Lower terrace soil (Tl)
Soil Taxonomy: Aquic Ustifluvent
WRB: Dystric Fluvisol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: 10 m south of fence of pasture management trial.

GPS: $27^0$33. 76' N, $90^0$44.98' E, (PDOP 2.8)
Altitude: 2570 m. a. s. l.

Described & sampled: 23/10/97, K Tshering

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Sunny dry.

Regional topography: River valley
Site position: 20 m terrace.

Slope: 3 %, straight, ca 50 m long +, facing S (180^0)
Site drainage: Imperfect

Parent material: Solid: Mixed
Drift: Alluvium.

Land use: Waste land
Vegetation: White clover, Artemesia vulgaris & bracken.

Surface: Litter: Grass 0-0.5 cm.
Outcrops: None
Stones: Few coarse hard rounded boulders.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm

0 - 14 7.5YR 3/2 (dark brown) with few coarse, reddish brown & orange mottles; fine sandy loam; medium subangular blocky breaking to fine crumb; moist & friable; many fine pores; abundant grass roots; few fine & medium gneiss stones; very fine muscovite flakes; HCl negative; gradual slightly wavy boundary to; [Sample PK010/1 @ 0-10 cm]

14–30 7.5YR 4/1 (dark grey) with many medium fine reddish brown & orange mottles; fine sandy loam; moderate medium subangular blocky breaking to medium crumb; few fine pores, moist & very friable; common medium & fine roots; fine muscovite flakes; HCl negative; clear regular boundary to: [Sample PK010/2 @ 20-25 cm]

30-37 2.5Y 4/4 (olive brown) with common dark brown mottles; stony fine sandy clay loam; coarse-medium subangular blocky breaking to fine crumb; moist & friable; many weathered quartz & gneiss stones; common fine flakes of muscovite; few charcoal near the lower boundary; HCl negative; clear regular boundary to: [Sample PK010/3 @ 30-35 cm]

37 –58 2.5Y 5/1 (grey) with few coarse yellow & orange mottles; stony loamy coarse sand; single grain; moist & friable; medium coarse & fine pores; few medium & coarse & fine roots; many coarse rounded hard quartz & gneiss stones & few weathered granite & oxidised stones; few ants; HCl negative; gradual regular boundary to: [Sample PK010/4 @ 40-50 cm]

58 – 90+ 2.5Y 5/1 (grey) with few yellow & orange mottles; stony loamy coarse sand; single grain; many coarse & medium few pores, wet & loose; few coarse roots; many medium & fine weathered rounded stones of quartz & gneiss; HCl negative: [Not sampled]

Comments: The horizon at 37 - 58 cm is the main seepage zone, and many of stones are coated with moisture films. Note that this soil is less well drained than those of the middle and upper terraces. The slight acidity of this soil is matched by moderately low base saturations.

SPAL analytical results for BSS Profile PK010Survey area: Bathpalathang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK010/1	5-10	4354	6.1	4.7	1.4	Nd	3	1.6	0.21	7.6
/2	20-25	4355	6.5	4.7	1.8	Nd	3	1.1	0.10	11.0
/3	30-35	4356	6.5	4.6	1.9	Nd	5	1.1	0.09	12.2
/4	40-50	4357	6.5	4.6	1.9	nd	1	0.1	0.02	5.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK010 /1	2.0	0.6	0.1	0.5	3.2	Nd	9.7	Nd	33	Nd
/2	1.7	0.8	0.1	0.5	3.1	Nd	6.6	Nd	47	Nd
/3	1.9	1.0	0.1	0.5	3.5	Nd	7.3	Nd	48	Nd
/4	0.7	0.3	0.0	0.3	1.3	nd	2.3	nd	56	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK010 /1	Nd	nd	Nd	Nd	Nd	54.2	15.7	11.8	21.5	18.3	SL
/2	Nd	Nd	Nd	Nd	Nd	54.1	9.9	17.5	27.4	18.5	SL
/3	Nd	Nd	Nd	Nd	Nd	51.0	2.1	25.7	27.8	21.2	SCL
/4	nd	Nd	nd	nd	nd	77.1	10.9	7.2	18.1	4.8	LS

Profile: PK013

Map unit: Tu

Soil classification: Provisional Bhutan soil series: Upper terrace soil (Tu)
Soil Taxonomy: Typic Hapustult
WRB: Haplic Acrisol
Survey area: Bathpalathang RNR-RC site, Jakar
Location: 100 m south east of house at north end of area.
GPS: 27^0 34.05' N, 90^0 44.80' E, [(PDOP 4.3.(moderately poor)]
Altitude: 2721 m. a s.l.

Described & sampled: 27/10/97, K Tshering
Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Snow and rain 2 days previously.
Regional topography: River valley
Site position: Upper (70 m) terrace.

Slope: 6% straight, ca 50 m long, SW facing (210^0)
Site drainage: Good

Parent material: Solid: Mixed rocks
Drift: Old alluvium.

Land use: Improved pasture
Vegetation: Cockfoot, ryegrass, white clover.

Surface: Litter: None.
Outcrops: None
Stones: Few medium, hard subangular mixed stones.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 36 7.5 YR 4/3 (brown) with common medium faint dark reddish brown & orange mottles; fine sandy loam+; medium subangular blocky breaking to fine crumb; few coarse pores; moist & friable; common medium & fine grass roots; medium & fine rounded hard gneiss and quartz gravel; charcoal; gradual wavy boundary to: [Sample PK013/1@ 0-10 cm]

36 – 44 7.5YR 4/3 (brown) with common reddish brown & dark brown mottles; fine sandy loam +; medium subangular blocky breaking to fine crumb; many fine pores; moist & slightly friable; common fine grass roots; many fine subangular gneiss gravel; clear wavy boundary to: [Sample PK013/2 @ 36-44 cm]

44 – 60 10YR 5/3 (reddish brown) with abundant reddish yellow, orange & dark brown mottles, especially close to lower boundary; fine sandy loam; coarse angular blocky; common, medium & fine pores; moist & slightly firm; many medium & fine roots; HCl negative; gradual wavy boundary to: [Sample PK013/3 @ 45-55 cm]

60–77 7.5YR 4/3 (brown) with abundant fine dark brown mottles; silty clay; medium angular blocky; few fine discontinuous orange clayskins; many fine pores; slightly wet & slightly firm, sticky & plastic; medium fine roots; few fine angular quartz stones; gradual wavy boundary to: [Sample PK013/4 @ 65-70 cm]

77 – 102 2.5Y 6/3 (light yellowish brown) with abundant coarse & medium & faint dark brown & orange mottles; medium sandy clay; weak medium angular blocky breaking to moderate crumb - subangular blocky, common more or less continuous clayskins; common fine & medium pores; slightly wet & firm, plastic & slightly sticky; HCl negative; rare muscovite flakes; gradual wavy boundary to: [Sample PK013/5 @ 80-90 cm]

102 – 123 2.5Y 6/3 (light yellowish brown) with abundant common medium & faint dark brown, reddish brown & orange mottles; gravelly sandy clay; medium angular blocky breaking to fine crumb; few fine more or less continuous clayskins; abundant coarse; medium & fine pores; slightly moist & very hard; many fine hard gravel mostly of quartz and gneiss; HCl negative; fine muscovite flakes; clear regular boundary to: [Not sampled]

123 – 137 2.5Y 5/3 (light olive brown) with common medium faint dark reddish brown & orange mottles; sandy clay loam; moderate medium angular blocky breaking to fine subangular blocky; more or less moderate continuous clayskins; few medium & many fine pores; slightly wet & very firm, plastic but not sticky; no stones or roots; common medium black soft stains & concretions; HCl negative: [Not sampled]

Comment: Typical upper terrace soil with friable fine sandy loam topsoil, very compact lower subsoil with cutans and black Mn concretions. Depth of aeolian brown sandy loam varies from 55 to 95 cm within a few meters of this profile.

SPAL analytical results for BSS **Profile PK013** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK013 /1	5-30	4368	6.9	4.8	2.1	nd	1	0.2	0.08	3
/2	30-40	4369	4.9	1.1	nd	nd	2	nd	Tr	nd
/3	40-50	4370	5.1	4.5	0.6	nd	1	3.1	0.33	9
/4	65-70	4371	5.3	4.4	0.9	Nd	1	3.2	0.18	18
/5	80-100	4372	5.8	4.4	1.4	nd	1	0.7	0.09	8

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAC	EBS%
PK013 /1	3.5	4.1	0.3	0.4	8.2	nd	11.7	Nd	70	nd
/2	2.0	0.8	0.4	0.3	3.4	nd	32.6	Nd	11	nd
/3	0.1	0.3	0.1	0.3	0.8	nd	34.2	Nd	2	nd
/4	0.1	0.2	0.1	0.3	0.6	nd	24.6	nd	2	nd
/5	0.1	0.1	0.0	0.3	0.5	nd	11.8	nd	4	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK013 /1	Nd	Nd	Nd	Nd	Nd	27.1	15.7	25.6	41.3	31.6	CL
/2	Nd	Nd	Nd	Nd	Nd	42.0	11.7	24.4	36.1	22.0	L
/3	Nd	Nd	Nd	Nd	Nd	52.2	7.8	14.2	22.0	25.9	SCL
/4	Nd	Nd	Nd	Nd	Nd	53.8	13.9	nd	nd	nd	(SCL)
/5	nd	nd	nd	nd	nd	62.6	8.7	13.8	22.5	14.9	SL

Profile: PK014

Map unit: Tm

Soil classification: Provisional Bhutan soil series: Yusipang series — Middle terrace soil (Tm)
Soil Taxonomy: Fluventic Ustochrept
WRB: Dystric Cambisol

Survey area: Bathpalathang RNR-RC site, Jakar
Location: 100 m south east of stupa at north end of area
GPS: 27^0 34.02' N, 90^0 44.71' E, PDOP 4.0
Altitude: 2950 m a.s.l.

Described & sampled: 27/11/97, K Tshering

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Fine for 2 previous days.

Regional topography: River valley.
Site position: Middle terrace.

Slope: 30%, straight, ca 70 m long, SE facing (205^0)
Site drainage: Good

Parent material: Solid: Mixed rocks
Drift: Old alluvium.

Land use: Improved pasture
Vegetation: Cocksfoot, ryegrass, clover, few thistles and Artimesia weeds.

Surface: Litter: None.
Outcrops: None
Stones: Rare round hard pebbles of quartz & gneiss.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 8 7.5YR 5/4 (brown) with few fine faint orange & yellow mottles; fine sandy loam; medium fine crumb; few fine pores; moist & friable, many fine & medium roots; few fine rounded hard gneiss stones; HCl negative; gradual regular boundary to: [Sample PK014/1 @ 0 – 8]

8 – 40 7.5YR 4/4 (brown) with few medium orange & reddish brown mottles; fine sandy loam+; moderate coarse breaking to fine subangular blocky; common very fine, moist & friable; common fine pores; few fine hard gneiss gravel; HCl negative; pockets of dry litter at base; clear wavy boundary to: [Sample PK014/2 @ 20 – 30]

40 – 68 2.5Y 5/3 (light olive brown) with many medium distinct black, red, orange & pale brown mottles; silty clay; weak medium angular blocky; rare fine & few medium pores; moist & firm-very firm, few fine roots; common medium & fine hard quartz & gneiss stones and soft weathering rock; HCl negative; gradual regular boundary to: [Sample PK014/3 @ 50 –60]

68 – 90 10YR 6/3 (pale brown) with common medium faint patches of brown weathering rock colours; silty loam; medium massive to weak angular blocky; common fine pores; moist & firm – friable; no roots; HCl negative; clear regular boundary to: [Sample PK014/4 @ 75 – 85]

10YR 6/3 (pale brown) with common medium & coarse distinct dark brown & black mottles; stony very fine sandy loam; weak medium angular blocky; dark clayskins on top of stones and pore wall; many coarse pores; moist, stony but initerstitial is friable; few fine roots; abundant rounded coarse hard quartz, granite and gneiss cobbles; HCl negative; clear slightly wavy boundary to: [Not sampled]

101 – 115+ 10YR 5/4 (yellowish brown) with common medium distinct pale brown & black mottles; very gravelly coarse sandy clay loam; stony structure with interstitial fine crumb; discontinuous dark coatings against stones & on pore walls; abundant coarse & medium pores; few fine roots; abundant hard rounded coarse gneiss & quartz gravel & cobbles; HCl negative: [Not sampled]

Comment: This is typical middle terrace soil except that it has an alluvial cobble bed at shallow depth. The clasts are fairly weathered. The moderate available P contents of the lower horizons are inexplicable.

SPAL analytical results for BSS **Profile PK014** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK014/1	0-8	4373	6.2	4.7	1.5	-	3	3.8	0.47	8
/2	20-30	4374	6.3	4.6	1.7	-	1	0.1	0.27	0.3
/3	50-60	4375	6.1	4.6	1.5	-	21	0.9	Tr	Nd
/4	75-85	4376	6.5	4.7	1.8	-	10	0.9	Tr	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK014 /1	6.7	1.0	0.2	0.3	8.1	-	17.9	-	45	-
/2	1.5	0.6	0.2	0.3	2.5	-	12.1	-	21	-
/3	1.6	1.3	0.2	0.3	3.4	-	7.2	-	47	-
/4	2.3	1.2	0.1	0.3	3.9	-	6.1	-	64	-

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK014 /1	nd	nd	nd	nd	nd	32.3	21.9	30.6	52.5	15.1	ZL
/2	nd	nd	nd	nd	nd	29.5	20.3	33.8	54.1	16.4	ZL
/3	nd	nd	nd	nd	nd	52.1	17.5	16.0	33.5	14.3	L
/4	nd	nd	nd	nd	nd	67.1	11.5	5.8	17.3	15.8	SL

Profile:	PK015	
Map unit:	Tm	
Soil classification:	Provisional Bhutan soil series: Yusipang series	Middle terrace soil (Tm)
	Soil Taxonomy:	Fluventic Ustochrept
	WRB:	Dystric Cambisol
Survey area:	Bathpalathang RNR-RC site, Jakar	
Location:	100 m from junction on Tamshing road.	
GPS:	27^0 34.02 N, 90^0 44.73 E, [PDOP 4.1 (moderately poor)]	
Altitude:	2600 m a.s.l.	
Described & sampled:	29/10/97, K Tshering	
Climate:	General:	Cool temperate, P = ca 750 mm pa
	Recent weather:	Fine for previous 2 days.
Regional topography:	River valley.	
Site position:	Middle terrace.	
Slope:	60%, straight ca 100 m long, aspect S (190^0)	
Site drainage:	Good	
Parent material:	Solid:	Mixed rocks
	Drift:	Old alluvium.
Land use:	Waste land.	
Vegetation:	Artemesia vulgaris and local grasses.	
Surface:	Litter:	None.
	Outcrops:	None
	Stones:	None.
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)
cm

0 - 10 7.5YR 4/3 (brown) with few medium distinct yellowish brown mottles; silty loam; weak medium subangular blocky breaking to crumb; few fine pores; moist - dry & firm; abundant medium & fine roots; HCl negative; gradual regular boundary to: [Sample PK015/1 @ 5 – 10]

10 – 28 7.5YR 4/3 (brown) with few medium distinct yellowish brown mottles; silty loam, very weak medium crumb; few fine pores; moist & friable, few coarse medium & fine roots; common medium hard quartz & gneiss stones; HCl negative; grub burrows; gradual regular boundary to: [Sampled PK015/2 @ 15 – 20]

28 – 70 7.5YR 4/3 (brown) with no mottles; slightly stony medium sandy loam; structure stony & interstitial medium crumb; few fine faint pores; moist, stony & interstitial friable; common medium & fine roots; common medium hard quartz & gneiss stones; HCl negative; ant burrows; diffuse boundary to: [Not sampled]

70–104 7.5YR 4/5 (brown); very stony medium sandy loam; stony structure; moist, stony & interstitial friable; common medium & fine roots; abundant round hard quartz & gneiss gravel; HCl negative; clear oblique boundary to: [Not sampled]

104 – 115 + Flat bedded, greyish brown, yellow & orange soft gneiss:

Comment: This soil is an example of the shallow terrace soil over weathered in situ rock, presumably from an outcrop that was at or above river level for much of the depositional phase. However the soil is not derived from just aeolian material directly overlying the rock outcrop. The rounded gravel at 70-104 cm indicates that was some fluvial deposition.

SPAL analytical results for BSS **Profile PK015** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK015/1	5-10	4377	6.6	4.6	2.0	nd	1	1.7	0.28	6
/2	15-20	4378	6.5	4.6	1.9	nd	1	2.6	0.30	9

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK015 /1	1.6	0.5	0.2	0.4	2.7	nd	11.6	nd	23	nd
/2	2.9	0.8	0.4	0.4	4.5	nd	14.7	nd	31	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK015 /1	nd	nd	nd	nd	nd	30.4	17.1	30.7	47.8	21.7	L
/2	nd	nd	nd	nd	nd	31.3	19.5	31.7	51.2	17.5	ZL

Profile:	PK016	
Map unit:	Hd	
Soil classification:	Provisional Bhutan soil series: Bathpalathang series	Deep brown hill soil (Hd)
	Soil Taxonomy:	Typic Haplustult
	FAO:	Haplic Acrisol
Survey area:	Bathpalathang RNR-RC site, Jakar	
Location:	Centre of eastern boundary	
Altitude:	2830 m a.s.l.	
Described & sampled:	29/10/97, K Tshering	
Climate:	General:	Cool temperate, P = ca 750 mm pa
	Recent weather:	Dry for 3 days
Regional topography:	Main valley	
Site position:	Middle slope of low hill	
Slope:	30%, straight; ca 70 0 m long, SE facing (205^0)	
Site drainage:	Good	
Parent material:	Solid:	Gneiss & schist
	Drift:	Colluvium & old alluvium.
Land use:	Forest regrowth	
Vegetation:	Pinus wallichiana, Rosa sericea & natural grasses.	
Surface:	Litter:	3 – 4 cm half decomposed blue pine needles.
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0 - 5 10YR 4/1 (dark grey) few coarse orange & red mottles; medium sandy clay loam; weak medium subangular blocky; few medium discontinuous clayskins; many medium & fine pores; slightly moist & hard; abundant medium & fine roots; HCl negative; earthworm casts; clear regular boundary to: [Sample PK016/1 @ 0 – 5]

5 – 8 10YR 5/4 (greyish brown) many medium discontinuous orange, yellow, reddish brown & black mottles; weak medium subangular blocky; few medium discontinuous clayskins; many medium to fine pores; slightly wet, firm & sticky; abundant coarse, medium & fine white stones & grit; HCl negative; earthworm casts; coarse common decayed roots; gradual regular boundary to: [Sample PK016/2 @ 5 – 8]

8 – 70 7.5YR 5/4 (greyish brown) with many medium orange yellow, reddish brown & black mottles; medium sandy clay; weak medium angular breaking to medium subangular blocky; many medium & fine pores; slightly wet & hard; common medium & fine hard gneiss & granite stones; HCl negative; common gradual regular boundary to: [Sample PK016/3 @ 30-40]

70 – 100 10YR 6/6 (light brown grey) with few common reddish yellow orange & dark black mottles; sandy clay loam; weak medium angular blocky breaking to fine crumb; moderate discontinuous clayskins; slightly wet & friable; few medium roots; common coarse & many fine quartz & gneiss stones; HCl negative; few charcoal; gradual regular boundary to: [Sample PK016/4 @ 80 – 90]

100 – 144 10YR 6/6 (light brownish grey) with few fine faint reddish brown mottles; loamy medium sand; weak medium angular blocky breaking to fine crumb; many medium & fine discontinuous clayskins; slightly moist & friable; abundant coarse pores; many medium & fine roots; many moderate hard quartz & gneiss rounded stones; HCl negative; gradual wavy boundary to: [Sample PK016/5 @ 110 - 120]

144 – 176+ 10YR 6/8 (brownish yellow) mixed weathered granite, quartzite & gneiss; very soft; thick clayskins down cracks in weathered rock. [Not sampled]

Comment: The rounded stones at 100-144 indicated that some of the colluvial parent material is derived from old alluvium upslope.

SPAL analytical results for BSS **Profile PK016** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK016 /1	5-15	4379	6.1	4.5	1.6	nd	2	3.2	0.35	9.1
/2	15-25	4380	6.3	4.5	1.8	nd	1	2.0	0.09	22.2
/3	25-30	4381	6.6	4.7	1.9	nd	1	0.5	0.07	7.1
/4	35-45	4382	6.8	4.7	2.1	nd	1	0.1	Tr	nd
/5	50-60	4383	6.7	4.6	2.1	nd	1	0.1	Tr	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK016 /1	9.0	0.1	0.72	0.73	10.2	nd	25.0	nd	41	nd
/2	1.7	1.0	0.50	0.35	3.6	nd	8.5	nd	42	nd
/3	1.7	0.9	0.35	0.37	3.3	nd	10.0	nd	33	nd
/4	1.9	1.2	0.30	0.33	3.7	nd	8.4	nd	44	nd
/5	1.5	1.0	0.26	0.33	3.1	nd	7.3	nd	42	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK016 /1	nd	nd	nd	nd	nd	48.4	13.7	21.6	35.3	16.3	L
/2	nd	nd	nd	nd	nd	48.5	10.5	19.6	30.1	21.4	L
/3	nd	nd	nd	nd	nd	42.6	22.5	14.3	36.8	20.7	L
/4	nd	nd	nd	nd	nd	54.8	10.0	8.3	18.3	26.9	SCL
/5	nd	nd	nd	nd	nd	59.3	8.4	2.6	11.0	29.7	SCL

Profile:	PK017	
Map unit:	Hs	
Soil classification:	Provisional Bhutan soil series: yusipang series	Shallow brown hill soil (Hs)
	Soil Taxonomy:	Lithic Ustrochept
	WRB:	Lithic Cambisol
Survey area:	Bathpalathang RNR-RC site, Jakar	
Location:	Tamshing foot path	
GPS:	27^0 34.08'N, 90^0 44.84'E	
Altitude:	2830 m a.s.l.	
Described & sampled:	28/10/97, K Tshering	
Climate:	General:	Cool temperate, P = ca 750 mm pa
	Recent weather:	Sunny for 2 days
Regional topography:	Main valley	
Site position:	Major lower slope of medium spur.	
Slope:	50%, convex, ca 400 m long, SW facing (230^0)	
Site drainage:	Good	
Parent material:	Solid:	Mixed rocks
	Drift:	Residual
Land use:	Forest regrowth	
Vegetation:	Pinus wallichiana, Artimesia vulgaris and bracken.	
Surface:	Litter:	3 cm pine needle & grasses.
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Irregular discontinuous steps 10 cm.
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)
cm

0 – 6 7.5YR 5/4 (brown) with common fine faint dark yellow brown & dark orange mottles; medium sandy loam, medium crumb; many medium & fine pores; slightly dry - moist & friable; many fine roots; few fine & medium hard gneiss & quartz; HCl negative; many worm casts; few flakes of charcoal; clear regular boundary to: [Sample PK017/1 @ 0 - 6]

6 – 12/21 7.5YR 4/6 (strong brown); medium sandy loam +; moderate medium - fine subangular blocky - crumb; many fine pores; moist & friable, common medium roots; common grey, brown & orange weathered rock; HCl negative; clear wavy boundary to: [Sample PK017/2 @ 10 - 20 cm]

12/21 – 95 + Weathering gneiss dipping at about $30^{0.}$ patches of grey, brown & silver goes to soft red, orange & brown; patches of 7.5 YR 5/6 (strong brown) loamy coarse sand down cracks; also few patches of 5YR 4/6 (yellowish red) very fine sandy to silty loam. [Not sampled]

Comment: Extreme example of shallow hill soil. Slightly acid but low base saturations.

SPAL analytical results for BSS **Profile PK017** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK017/1	0-6	4384	6.6	4.7	1.9	nd	nd	nd	0.17	8.2
/2	10-20	4385	6.6	4.6	2.0	nd	Nd	nd	0.10	7.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK017 /1	1.7	0.8	0.5	0.3	3.3	nd	10.4	nd	31	nd
/2	0.8	0.7	0.7	0.3	2.5	nd	8.6	nd	29	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK017 /1	nd	nd	nd	nd	nd	37.1	16.5	23.4	39.4	23.0	L
/2	nd	Nd	nd	nd	nd	49.4	11.8	18.9	30.7	19.8	L

Profile: PK018

Map unit:	Hd	
Soil classification:	Provisional Bhutan soil series:	Deep hill soil (Hd).
	Soil Taxonomy:	Typic Haplustult
	WRB:	Haplic Acrisol
Survey area:	Bathpalathang RNR-RC site, Jakar	
Location:	25 m below prayer flag on eastern boundary	
GPS:	27^0 33.97 N, 90^0 45.03 E, (PDOP 21.2 (very poor))	
Altitude:	2680 m a.s.l.	
Described & sampled:	31/10/97, K Tshering	
Climate:	General:	Cool temperate, P = ca 750 mm pa
	Recent weather:	Cloudy day
Regional topography:	Main valley	
Site position:	Mid slope of low hill	
Slope:	31^0, straight, ca 300 m long, aspect (W) (285^0)	
Site drainage:	Good	
Parent material:	Solid:	Mixed rocks
	Drift:	Aeolian over old alluvium and colluvium
Land use:	Improved pasture land	
Vegetation:	Cockfoot, tall fescue, white clover and few *Artemesia* and ryegrass.	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)
cm

0 - 6 7.5YR 4/3 (brown) with few fine faint yellow & red mottles; coarse sandy loam+; moderate medium subangular blocky; many fine pores; moist & slightly friable; abundant medium & fine roots; common medium subangular hard quartz stones; HCl negative; earthworm casts; few charcoal; dead bracken roots; diffuse boundary to: [Sample PK 018/1 @ 0 – 6]

6 – 113 7.5YR 4/3 (brown) with common coarse & medium dark red & orange mottles, coarse sandy clay; weak medium - fine subangular blocky crumb; abundant medium tubular pores; moist & slightly firm; abundant fine & medium roots; common medium subangular & angular hard quartz; HCl negative; wormcasts; flakes of muscovite; gradual regular boundary to: [Sample PK018/2 @ 60 – 70]

113 – 137 7.5YR 3/2 (dark brown) with many medium distinct grey, red brown & orange mottles; fine sandy clay; weak medium to fine subangular blocky; weak discontinuous clayskins; many fine pores; slightly wet and friable; few fine pores; HCl negative; old ant burrows; charcoal; manganese stains; clear slightly wavy boundary to; [Sample PK 018/3 @ 120 - 130]

137–157 7.5YR 5/4 (brown) with no mottles; fine sandy clay; weak medium - fine subangular blocky; weak discontinuous clayskins; many coarse medium & fine pores; slightly wet & slightly firm; few fine roots; HCl negative; gradual regular boundary to: [Sample PK 018/4 @ 140 - 150]

157 – 218 +10YR 5/4 (yellowish brown) with few fine faint grey brown mottles; medium sandy clay; moderate medium subangular blocky; many medium & fine pores; slightly wet & slightly firm; HCl negative: [Sample PK018/5 @ 180 - 190]

Comment: Very deep example of deep hillsoil. Stones appear to the mostly short - travelled colluvium, but some are rounded, and presumably from old alluvium upslope. Acid soil with low base saturation.

SPAL analytical results for BSS **Profile PK018** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK018/1	0-5	4386	5.6	4.6	1.0		1	1.7	0.23	7.3
/2	60-70	4387	5.5	4.4	1.1		1	0.8	0.15	5.3
/3	120-130	4388	5.7	4.3	1.4		1	0.1	0.11	0.9
/4	140-150	4389	6.4	4.7	1.7		1	0.2	0.04	5.0
/5	180-190	4390	5.3	4.2	1.1		1	1.0	0.03	33.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAC	EBS%
PK018 /1	2.0	0.3	0.1	0.4	2.8	nd	nd	nd	25	nd
/2	1.5	0.6	0.1	0.3	2.5	Nd	nd	nd	27	nd
/3	2.3	1.3	0.3	0.4	4.2	Nd	nd	nd	32	nd
/4	1.7	1.2	0.3	0.4	3.6	Nd	nd	nd	35	nd
/5	1.5	1.0	0.3	0.3	3.1	nd	nd	nd	39	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK018 /1	nd	nd	nd	nd	nd	47.0	26.6	14.2	40.8	12.2	L
/2	nd	nd	nd	nd	nd	44.2	24.9	13.4	38.3	17.5	L
/3	nd	nd	nd	nd	nd	25.6	31.3	17.0	48.3	26.1	L
/4	nd	nd	nd	nd	nd	26.6	31.8	17.3	49.1	24.3	L
/5	nd	nd	nd	nd	nd	34.3	29.6	18.6	48.2	17.4	L

Profile: PK020

Map unit: Hg

Soil classification: Provisional Bhutan soil series: Thimphulem series Hillside gley (Hg)
Soil Taxonomy: Humic Endoaquept
FAO: Dystric Gleysol

Survey area: Bathpalathang RNR-RC site Jakar, Bumthang.
Location: Northeastern tractor road.
GPS: 27^0 34.07 N, 90^0 44.99 E,
Altimetery 2610 m a. s. l.

Described & sampled: 5/11/97, K Tshering

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Sunny

Regional topography: Low mountain
Site position: Non-incised drainage line between two hills

Slope: 30%, rectilinear, 1 km long, aspect SW (226^o)
Site drainage: Very poor

Parent material: Solid: Mixed
Drift: Alluvium over colluvium

Land use: Marshy wasteland
Vegetation: Yushania macrophylla with some Pinus wallichiana & Artemesia vulgaris.

Surface: Litter: None
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are wet unless indicated)
cm

0 - 45 7.5 YR 3/3 (dark brown); humic fine sandy loam; crumb bounded by roots; rare cutans; abundant medium & fine pores; wet & firm; abundant coarse & many medium & fine roots, & many decayed roots; HCl negative; clear gradual boundary to:
[Not sampled]

45 – 80 5BG 4/10 (dark greenish grey) with many medium distinct reddish brown mottles; fine sandy loam; weak medium subangular blocky; many fine pores, wet & slightly firm & sticky; abundant medium & fine roots; HCl negative; many fine muscovite flakes; clear gradual boundary to:
[Sample PK 020/1 @ 50 – 60]

80 – 120+ 5B 5/1 (bluish grey) with few fine & medium brown, orange & reddish mottles; fine sandy loam +; moderate medium subangular blocky; common fine pores; wet & friable; many medium & fine roots; common angular & subangular medium hard quartz & gneiss stones; HCl negative:
[Sample PK020/2 @ 90 - 100]

Comment: Very wet humose topsoil over wet & highly gleyed subsoil. These soils are fed by seepage from upslope, hence their occurrence on steep slopes.

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SPAL analytical results for BSS **Profile PK020** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK020 /1	50-60	4395	6.1	4.7	1.4	nd	1	0.5	Tr	nd
/2	90-100	4396	6.1	4.7	1.4	nd	1	0.1	Tr	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK020 /1	0.8	0.6	0.1	0.4	1.9	nd	4.8	nd	39	nd
/2	0.5	1.7	0.3	0.2	2.7	nd	8.5	nd	32	Nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK020 /1	nd	nd	nd	nd	nd	84.9	5.7	5.9	11.6	3.5	LS
/2	nd	nd	nd	nd	nd	49.7	19.2	7.0	26.2	24.1	SCL

Profile: PK011

Map unit: Tm

Soil classification: Provisional Bhutan soil series: Bathpalathang series Middle terrace soil (Tm)
Soil Taxonomy: Fluventic Ustochrept
WRB: Dystric Cambisol

Survey area: Bathpalathang
Location: ca 15 m N from N fence of arable trial.
GPS: 27^0 33. 80' N, 98^0 44.92' E (PDOP 9.6 (poor)
Altitude: 2895 m. a. s. l.

Described & sampled: 23/10/97, K Tshering

Climate: General: Cool temperate, P = ca 750 mm pa
Recent weather: Sunny & dry

Regional topography: River valley
Site position: 40 m terrace
Slope: 3%, straight, ca 500 m long +, facing SW (220^0)
Site drainage: Good

Parent material: Solid: Mixed
Drift: Alluvium

Land use: Improved pasture
Vegetation: White clover, ryegrass

Surface: Litter: Discontinuous grass & clover litter 0-0.5 cm.
Outcrops: None
Stones: Rare hard cobbles, up to 15 cm diameter.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 26 7.5 YR 4/3 (brown); fine sandy loam; medium moderate to fine subangular blocky & angular blocky; abundant fine pores; moist & friable, common fine grass roots; few rounded pebbles; few muscovite flakes; HCl negative; clear regular boundary to: [Sample PK011/1 @ 0-10 cm]

26-40 10YR 5/3 (brown) with abundant fine faint dark brown mottles; coarse sandy loam+; weak medium & fine angular blocky; many medium & fine pores; moist & friable; few fine roots; HCl negative; few muscovite flakes; clear regular boundary to: [Not sampled]

40-69 10YR 5/2 (greyish brown) with many faint medium orange & reddish brown mottles; fine sandy loam; medium coarse angular blocky; many fine, medium & coarse pores; moist & very firm, common fine roots; insects seen; common muscovite flakes HCl negative; clear regular boundary to: [Sample PK011/2 @ 50-60 cm]

69–80 10YR 5/3 (brown) with abundant faint orange & reddish brown mottles; coarse sandy loamy; weak medium to fine, angular blocky; moderate medium & fine pores; moist to wet slightly & firm; few fine roots; HCl negative; clear regular boundary to: [Sample PK011/3 @ 70-80 cm]

80 –93 2.5Y 6/3 (light yellowish brown) with abundant yellowish, reddish brown & orange mottles; very fine sandy to silty clay; weak medium angular blocky breaking to fine crumb; many fine pores; moist & firm; few fine roots; few Faecal pellets; few coarse fragments of charcoal; HCl negative; gradual regular boundary to [Sample PK011/4 @ 80-90 cm]

93 – 103 2.5Y 6/3 (light yellowish brown) with few coarse yellowish & brown mottles; sandy clay loam; weak medium subangular blocky breaking to fine crumb; many medium & fine pores; slightly wet & slightly firm; rare very fine roots; HCl negative; gradual regular boundary to: [Not sampled]

103 – 124 2.5Y 6/1 (light grey) abundant reddish brown & yellowish orange mottles; very fine sandy to silty clay; massive; strong continuous clayskins & moisture films; many medium & fine pores, slightly wet & very firm & sticky; no roots; HCl negative; clear regular boundary to: Not sampled]

124 – 160 10YR 4/3 (brown) with abundant yellowish orange & light brown mottles; sandy clay loam +; moderate medium subangular blocky breaking to fine crumb; abundant coarse, medium & fine pores; slightly wet & slightly friable; many muscovite flakes; HCl negative; clear regular boundary to: [Sample PK011/5 @ 140-150 cm]

160 – 175 2.5Y 7/1 (light grey) with few medium dark reddish brown mottles; silty clay; very fine granules; few fine pores; moist to wet & friable & very plastic & very sticky; HCl negative; clear wavy boundary to: [Not sampled]

175 – 195+ 2.5Y 6/1 (light grey) with few distinct reddish brown & yellow mottles; silty clay loam; massive, single grain few fine pores; moist to wet & very plastic & very sticky; few fine soft reddish brown Fe Mn stains; HCl negative; [SamplePK011/6 @ 180-190 cm]

Comment: Continued below 195 cm by auger. For next metre, no sand or boulders were found. Texture continued as clay and silty clay loam; some sand seems below 290 cm. The textural heterogeneity is inherited from the alluvial deposition, and is greater than in the upper terrace soils. 0-26 cm probably aeolian deposit.

SPAL analytical results for BSS **Profile PK011** **Survey area: Bathpalathang RNR-RC**

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC	Avail.	Organic C%	Total N %	C:N
			H2O	KCl	Diff	mS/cm	P ppm			
PK011/1	0-10	4358	6.2	4.9	1.3	Nd	1	2.6	0.26	10.0
/2	50-60	4359	6.7	5.8	0.9	Nd	7	0.1	Tr	nd
/3	70-80	4360	6.3	5.7	0.6	Nd	1	0.2	0.05	4.0
/4	80-90	4361	6.5	4.6	1.9	Nd	1	0.1	Tr	2.5
/5	140-150	4362	6.8	4.7	2.1	Nd	2	0.2	Tr	5.0
/6	180-190	4363	6.9	4.7	2.2	nd	13	0.2	0.08	2.5

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK011/1	2.8	0.3	0.1	0.3	3.5	Nd	12.2	Nd	29	Nd
/2	2.4	1.3	0.1	0.3	4.1	Nd	6.5	Nd	63	Nd
/3	2.9	1.8	0.2	0.3	5.2	Nd	8.2	Nd	64	Nd
/4	2.1	1.2	0.2	0.3	3.8	Nd	5.2	Nd	73	Nd
/5	4.6	2.3	0.4	0.4	7.7	Nd	10.0	Nd	77	Nd
/6	8.0	3.0	0.2	0.5	11.7	nd	15.3	nd	77	nd

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK011/1	Nd	nd	Nd	Nd	Nd	38.4	14.4	26.2	40.6	21.0	L
/2	Nd	Nd	Nd	Nd	Nd	76.5	3.3	6.8	10.1	13.4	SL
/3	Nd	Nd	Nd	Nd	Nd	46.1	13.6	19.2	32.8	21.1	L
/4	Nd	Nd	Nd	Nd	Nd	59.4	12.7	14.7	27.4	13.1	SL
/5	Nd	Nd	Nd	Nd	Nd	40.3	10.8	17.8	28.6	31.1	CL
/6	nd	Nd	nd	Nd	nd	33.4	9.8	19.4	29.2	37.5	CL

APPENDIX C – Soil Correlation

APPC .1 Soil classification and correlation in Bhutan

Table 5.3 in the main report summarises the correlations of the Bathpalathang soil classes with the international soil classifications. This appendix discusses the reasoning behind the correlations assigned. This is necessary because BSSP is still at an early stage of its operations and the soil correlations need to be worked out. Some of them will undoubtedly be revised in the future, when we learn more about Bhutan's soils.

The international systems suffer from several problems. The worst is that there are two of them. It is to the discredit of the international pedological community that they have not agreed to a single system. Proponents of the two main systems – the USDA and FAO – feel that the other has too many defects to be acceptable. Nonetheless, either system would be improved more quickly if it was accepted by all and was the sole focus of attention.

The Soil Taxonomy (Soil Survey Staff 1975) was originally developed to meet the needs of soil survey in the continental United States. It has been extended (Soil Survey Staff 1992) since then, but it is still stronger on temperate than on tropical soils. It is detailed and comprehensive. The FAO (1974 and 1988) system is more globally oriented, and is less detailed, but still quite comprehensive. It has an advantage that it uses more traditional and comprehensible soil names.

Nepal has used the Soil Taxonomy, but previous consultants in Bhutan have preferred the FAO system. At this stage it is not necessary for Bhutan to choose between them. It is intended that, at present, BSSP will use local soil classes and names within Bhutan, and will correlate them against both of the international systems.

APPC .2 General criteria

Before considering individual soils, there are some general environmental considerations for the Bathpalathang site as a whole that need to be determined for the application of Soil Taxonomy.

APPC 2.1 Soil moisture regimes

This is necessary for the definition of suborders or great groups. In the absence of soil moisture data, soil moisture regimes are normally approximated from rainfall totals and distribution. Bathpalathang has an ustic climate, which is defined as having more 90 consecutive dry days per year and having a summer rainfall distribution. All of the soils at Bathpalathang have ustic soil moisture regimes except for the poorly drained, and some of the imperfectly drained, soils. These have an aquic moisture regime, which refers to soils that are permanently wet due to their topographic position. Some of the imperfectly drained soils may have udic moisture regimes, which are transitional between ustic and aquic, and have less than 90 consecutive dry days per year.

APPC 2.2 Soil temperature regimes

This is a criterion for classification at family level in Soil Taxonomy. In the absence of soil temperature data, atmospheric temperatures are used. Bathpalathang has a mesic temperature regime,

with an annual mean between 8^0 C and 15^0 C and a summer – winter difference between monthly means greater than 5^0 C.

APPC 2.3 Mineralogy classes

This is another family criterion in Soil Taxonomy. Although muscovite is a visible component in many soils at Bathpalathang, mica contents are less than 40 % of the combined sand and gravel fractions. The soils therefore do not qualify for the micaceous mineralogy class, and have to be classified as mixed.

APPC 2.4 Particle size class

This varies with stone content and fine earth texture, and is therefore different for the different soil classes at Bathpalathang.

APPC .3 Correlation of Bathpalathang soils

APPC 3.1 Shallow hill soils

Most of these soils appear to be residual and quite deeply weathered. Their subsoils have slightly higher clay contents than the topsoil but clayskins are not common. These soils fit well into the Inceptisols of Soil Taxonomy or the Cambisols of FAO. Most of the dark topsoils are shallow (< 18 cm) so that the profiles qualify for the suborder of Ochrepts. The soil moisture regime puts them into the Ustochrept great group, with subdivision into the lithic (for the very shallow hill soils), dystric (for most of the rest, as their base saturations are less than 50%) or typic (all others) subgroups. In the FAO Soil Map of the World, these soils mostly qualify as Dystric Cambisols, with a few qualifying as Humic Cambisols.

APPC 3.2 Deep hill soils

These soils consist of layered deposits of weathered alluvial and colluvial material. In Soil Taxonomy, the degree of weathering has priority over the layering in keying out, so that most of these soils probably qualify as Dystric or Typic Ustochrepts. A few of these soils have high contents of unweathered minerals, and therefore qualify as Typic Ustorthents. In the FAO system, the layering and youth of the deposits key out before the degree of weathering, and many of these soils qualify as Regosols, rather than Cambisols.

APPC 3.3 Terrace soils

Despite their similar origins, the differences in age and pedological development appear to qualify the soils of the three terraces for three different taxa at the highest level in both of the international systems. The soils of the 10 m terrace (Tl) are little developed and qualify for the Entisols (Fluvent) in ST and Fluvisols in FAO. The apparently impeded drainage puts them into the Aquic Ustifluvents (ST). The absence of a Gleyic subgroup in the Fluvisols (FAO) puts them into the Dystric Fluvisols. The soils of the 40 m terrace (class Tm) still show considerable layering inherited from the alluvial deposition but have enough weathering and profile development to qualify as Inceptisols in Soil Taxonomy. The alluvial origin, limited organic matter contents, and the soil moisture regime make them Fluventic Ustochrepts. In the FAO system, the layering may keep them in the Dystric Fluvisols

but the weathering and development of soil structures and cutans may qualify some of them as Dystric Cambisols.

Most of the soils of the 70 m terrace (class Tu) have sufficient weathering, structural and cutan development and an incipient manganese pan to qualify as Typic Haplustults in ST. The less developed soils are probably Fluventic Ustochrepts, similar to the soils on the 40 m terrace. In the FAO system, the more developed soils are Haplic Acrisols, and the less developed are Dystric Cambisols.

The soils of the riser connecting slopes (class Rx) are poorly developed and qualify as Typic Ustifluvents or Lithic Ustorthents.

APPC 3.4 Imperfectly drained soils

The impeded drainage is the main classification criterion in these soils. In Soil Taxonomy, most of the hillside imperfectly drained soils (Hi) are considered to be Aquepts. The less weathered imperfectly drained soils of the landslip site probably qualify as Aquents. Because both the landslip and hillslope soils are kept wet for long periods by shallow subsurface throughflow, the drainage of their upper layers tends to be worse than in the lower subsoils. The soils therefore qualify as Epiaquents rather than groundwater–fed Endoaquents. This distinction is not made in the FAO system, and these soils qualify as Mollic (high organic matter and base saturation greater than 50%) or Dystric Gleysols.

APPC 3.5 Poorly drained soils

These soils are probably wet all year, and qualify as Aquepts or Aquents in Soil Taxonomy and Gleysols in FAO. Some of them have low decomposition rates and have accumulated mucky topsoils with high organic matter. However none appear to be organic or deep enough to quality as Histosols. As these soils are wet throughout the profile, they qualify for the Endo – rather than Epi – groups in the Aquept and Aquent suborders of Soil Taxonomy. Although insufficient for the Histosols, the organic matter contents are high enough in some of these soils for them to qualify as humic or mollic subgroups or subunits in both systems.