(2) タクライ川：集水面積　169 k㎡

表4－3　タクライ川河川状況

日平均流量　　Unit：㎥／sec

	1 月	2 月	3 月	4 月	5 月	11月	12月
1回目	2.16	2.35	2.16	2.15	4.63	7.00	2.71
2回目	2.80	2.16	2.16	2.65	4.35	6.22	2.00
3回目	2.60	3.60	2.40	2.80	5.65	4.64	1.45
平　均	2.52	2.71	2.24	2.53	4.88	5.95	2.05

※6月～10月は洪水で測定不能

4－3　対象地の水文地質

4－3－1　水理地質

(1) ゲラフ

マオ川とタクライ川の水力で扇状地を幾重にも重ねたような地形となっている。河岸段丘の発達で三つの段丘面から成る。

1) 高位段丘面：標高280～400 mの山麓急傾斜面で、地表面は玉石を混入する砂礫層が主体で保水性が不良である。オレンジの果樹園や畑地が多く未開地もある。
トルバリでは典型的な扇頂部となっている。

2) 中位段丘面：標高230 m～280 mの緩傾斜面で、土壌は小石を混入する砂質土である。そのほとんどが稲作を行っており、灌漑施設もあり農業の中心的存在となっている。
調査対象地のカツセ、ビスタダラやタクライ・ゲラフ扇央部が位置する。

3) 低位段丘面：標高190 m～230 mの平坦面で、ゲラフの市街地となっている。河床近くは砂地で畑作が行われているが、他は良質な稲作地となっている。

調査対象地域では、低ヒマラヤ帯のプンツォリン層が後背山地を形成している地質構造は複向斜をなしているが、マオ川流域では激しい断層、クラック等が見られる。また、ゲラフイリゲーションエリアから北の後背山地を望むと東西方向へ幾重にも滑り面が見られるが、それらはトリバリの西側山地及びタクライ川東側の山地にはいずれも連続しない。

おそらく、主境界衝上断層は今の後背山地南斜面より5～7 km南方を東西方向に走っているはずである。衝上によるナップ現象で、南へせり上がったものが、ある東西方向からの圧力で寸断され、流出欠如したことが考えられる。

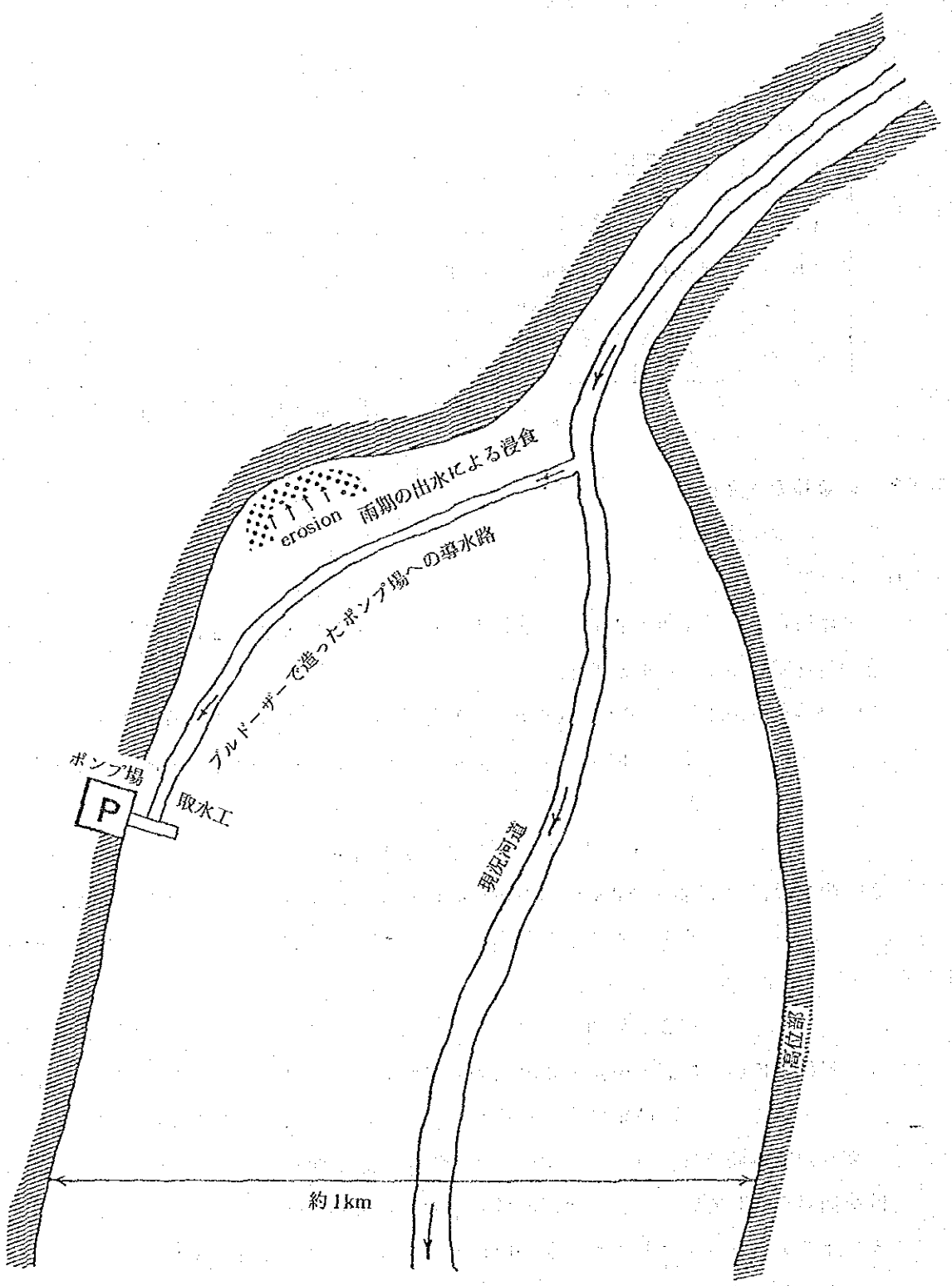


図４－８　マオ川の現況イメージ〔乾期の踏査に基づく〕

ナップが事実ならば、ゲラフ扇状地の地下にはモラッセ堆積物のシワリーク層が潜存するはずである。

ゲラフの地下地質は、次の三つが考えられる。

1) ナップのプンツォリン層は、流出欠如してインドプレートの基盤岩に洪積～沖積の堆積物である玉石、砂礫層を直接覆う。

2) ナップのプンツォリン層は流出欠如するが、基盤は既にシワリーク層に覆れており、礫岩、砂岩泥岩が存在する。

3) ナップのプンツォリン層が流出せず扇状地の下に潜存して、不透水性基盤をなしている。

1) 及び 2) であれば、透水性の高い扇状地堆積物及び段丘堆積物であるため、地下水開発は可能である。

(2) サルバン

サルバン川の中流域には3段の台地面が見られるが、このうち高－中位台地面はプンツォリン層（千枚岩）のナップにより形成されたもので、低位だけが河岸段丘をつくっている。

ただし、河床にはプンツォリン層の露頭が認められ、自由地下水の開発可能性はない。

4－4 農 業

4－4－1 概 況

就業人口のうち87.2％が農業従事人口である。国土面積は、九州をひと回り大きくした程度の46,500㎢で、このうち71％が森林に覆れており、わずか9％の356,000haが農耕地である。主な穀物は米、メイズ、小麦、大麦、そば、ミレットであり、このほか換金作物としてオレンヂ、じゃがいも、りんご、チリー、しょうがなどの他野菜が挙げられる。

米とメイズの耕作面積等は次のとおりである。なお詳細は表4－5に記す。

表4－4 米とメイズの耕作面積

1984年

	耕作面積	生産高
米	30,600 ha	65,000 t
メイズ	58,500 ha	87,300 t

畜産に関して言えば、86年の推定で34万頭の牛、3.6万頭のヤク、4.4万頭の羊、21.1万頭の家禽及び8.9万頭の豚がいる。

表４－５　Crop Area and Production for Each Crop, 1981 and 1984

	Crop Area ('000 hectares)			Crop Producton ('000 tonnes)		
	1981	1984	Target 1987	1981	1984	Target 1987
Cereals						
Paddy	28.0	30.6	37.0	57.4	65.0	84.5
Wheat／Barley	12.0	14.4	16.6	13.3	16.0	22.5
Maize	56.8	58.5	52.5	80.7	87.3	85.1
Buck wheat／millets	15.5	20.6	15.0	12.3	16.8	12.7
Total	112.3	124.1	121.1	163.7	185.1	204.8
Other Crops						
Pulses	4.0	3.0	5.3	2.4	2.6	3.8
Mustard	2.9	5.0	5.5	1.9	3.5	3.9
Potato	3.7	4.2	5.1	24.9	32.6	50.0
Chillies／vegetables	3.1	1.7	3.6	12.2	5.3	15.1
Oranges	6.2	7.8	8.0	25.6	38.7	53.1
Apples	1.5	1.6	1.9	3.3	3.5	8.8
Cardamom	5.9	8.8	6.6	2.8	3.0	4.1

Note : Figures are based on estimates made by District, block and village officials. Target 1987 refers to targets for the Fifth Plan.

Source : Surveys undertaken by Agriculture Department in 1981 and 1984.

ブータンの農業問題は、①土地生産性が低く、穀物については生産高が少ない。したがって米を中心としてインドからの輸入に頼らざるをえない。②山国であるため耕作可能地に限りがある。したがって渓谷やなだらかな尾根、そしてインド国境の扇状地に耕地を求めざるをえない。また、１戸当りの面積も小さい（１家族当り 1.2 ～ 1.6 ha）。③道路などのインフラが整備されておらず、流通上の問題がある。④多くの耕地が天水に依存し、灌漑面積が少ない。⑤南部では雨期の多雨のために、土壌流亡や施設の流失などの問題がある。

４－４－２　灌漑地の状況

地域別に土地利用を表４－６にみると、耕地面積が一番多いのは南西部のサムチ県の27.3千haで、次がゲラフ県で19.7千haであり、同国の大規模な耕地は南部にあり、南部扇状地が同国の穀倉地帯である。

表４－７は県別の灌漑プロジェクトの面積を示している（1986年３月までのプロジェクト完了面積と思われる）。それによるとサムチ、ゲラフ、サンドルプジュンカーという南

部県にプロジェクトが集中していることがわかる。

4－4－3　ゲラフ地区の作付体系

Lift Irrigation 地区（Area Development 地区）の主要作付体系は図4－9に示すとおりである。雨期作の米作を主体に乾期に、pattern Ⅰでは菜類と小麦、Ⅱでは、小麦の次に豆類、乾期に水がかりのよい所ではⅢのように、米の二期作プラス乾期一毛作を入れている。

表4－6　Land Under Agricultural Use by Dzongkhag, 1984
('000 hectares)

Dzongkhag	Wet Land	Dry Land	Tsheri Pangshing	Kitchen Garden	Orchard & Plantation	Total Area
Ha	0.1	1.5	0.3	—	0.3	2.2
Paro	2.1	2.5	0.2	—	0.2	5.0
Samchi	6.1	13.6	1.9	0.3	5.5	27.3
Thimphu	1.8	1.2	0.3	0.1	1.1	4.4
Chirang	3.0	7.8	0.1	0.1	3.8	14.8
Dagana	0.7	2.6	0.2	—	0.1	3.6
Gasa	0.1	0.3	—	—	—	0.4
Punakha	1.5	0.2	—	—	0.1	1.8
Wangdiphodrang	1.8	0.9	0.1	—	0.1	2.9
Bumthang	—	2.6	0.6	—	0.1	3.4
Gaylegphug	4.1	9.4	0.7	0.1	5.4	19.7
Shemgang	0.9	1.4	0.8	—	0.4	3.6
Tongsa	0.7	1.2	0.4	—	0.2	2.4
Lhuntshi	1.2	1.6	0.7	0.1	—	3.5
Mongar	0.5	2.9	0.9	0.1	—	4.4
Pemagatsel	0.1	1.8	0.7	0.1	—	2.7
Samdrupjongkhar	1.8	4.2	2.8	0.2	0.5	9.5
Tashigang	3.2	10.1	1.2	0.2	0.1	14.3
BHUTAN	29.7	65.6	11.8	1.3	18.0	126.5

Note : These figures conflict with those given in Table 5.2. The figures in this table are based on estimates made by District, block and village officials, while the figures in Table 5.2 were based on remote sensing methods.

Source : Department of Agriculture.

表 4 － 7　Irrigattion Schemes Completed During Year Ending March 1986 by Dzongkhag

	New construction			Renovation			Bank Protection	
	No of schemes	Length of channel (km)	Command area (hectares)	No of schemes	Length of channel (km)	Command area (hectares)	No of schemes	Length of embankment (km)
Ha	6	4.3	81.0	5	4.0	48.2	3	44.0
Paro	1	1.9	100.0	26	42.6	1,836.6	25	3.8
Samchi	9	22.6	641.3	15	43.0	1,573.7	13	13.5
Thimphu	10	31.7	904.9	23	54.7	1,318.7	—	—
Chirang	10	22.7	571.7	5	13.4	206.5	2	1.0
Dagana	7	20.3	396.8	4	16.3	388.7	—	—
Gaza	2	2.9	50.6	5	7.8	79.4	—	—
Punakha	3	10.5	102.0	25	72.2	2,355.6	2	0.2
Wangdiphodrang	2	10.1	283.4	15	18.4	1,040.0	—	—
Bumthang	2	4.3	40.5	—	—	—	3	2.5
Gaylegphug	10	24.0	1,217.4	8	19.5	1,012.1	15	15.6
Sheingang	2	6.4	182.2	7	16.8	400.4	1	1.0
Tongsa	6	11.1	244.9	7	9.2	230.8	—	—
Lhuntshi	10	44.4	659.9	12	38.6	598.0	—	—
Mongar	5	21.4	789.1	6	8.4	478.5	—	—
Pemagatsel	4	10.1	206.9	—	—	—	—	—
Samdrupjongkhar	11	35.3	1,799.6	5	16.3	607.3	5	4.2
Tashigang	10	65.0	1,513.8	6	13.5	317.4	3	2.0
BHUTAN	110	348.9	9,786.0	174	394.8	12,491.9	72	87.8

Source : Department of Agriculture.

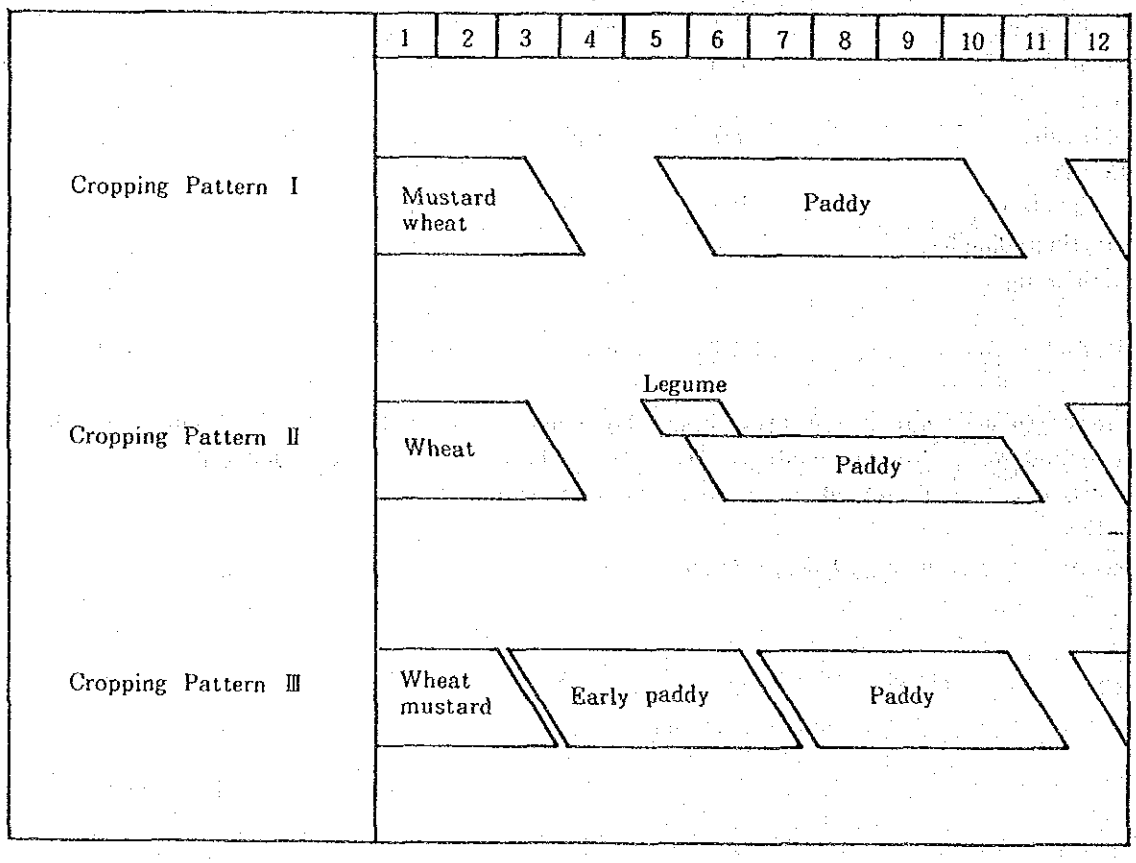


図 4 － 9　Cropping Pattern (Area Development)

第5章　本格調査の内容

5－1　調査の基本方針

(1) 背　景

ブータン国は、北は中国チベットに接し、7,000m級の山がそびえ立ち、東西南三方はインドに接し、南部は200mまで下がっている山国である。国土面積は46,500㎢で、日本の九州よりひと回り大きく、人口は120万人程度である。耕地は国土の3%を占め、耕地面積は少なく、穀物収量（米、メイズ、小麦など）も少ないので（米でha当り2.5トン程度）、穀物自給は達成していない。耕地は、谷合いの沢沿いや比較的平らな尾根を段々畑に切り拓いている。したがって、インド国境に接する扇状地は、当国においては貴重な土地資源と言える。ゲラフ地区には、現在、代表的なもので次の二つの灌漑プロジェクトが実施されている。

ゲラフ県は、耕地面積の少ない同国の中で、サムチ県に次いで農地の多い県である。

内陸国が故に、食糧自給は安全政策上重要であり、かつ輸入代替としても重要である。一方、80年代初めから始まったゲラフ地区の灌漑プロジェクトが当初の目標に達していない状況である。

一方、ゲラフ地区は、年間5,000㎜以上も降雨量がある多雨地帯である。それが雨期の4カ月に集中しているので、灌漑施設の維持管理上の問題がある。

例えば、取水口への堆砂の問題、用水路の流亡、地滑り等災害が多い。また、表流水は季節変動が激しく、水量が安定的に確保できない。

表5－1　灌漑プロジェクト

諸　元	Gaylegphug Lift Irrigation Project	Taklai Irrigation Project
計画面積	Stage Ⅰ　713ha Stage Ⅱ　865ha 計　1,578ha	Upper canal　675ha Lower canal　550ha Syplon　220ha 計　1,445ha
実際の灌漑面積	Stage Ⅰ　385ha	Lower canal　500ha 主に雨期のみ
灌漑方式	Mao川からポンプ　2台 (560lps)	Taklai川からの重力灌漑
援助機関	インド政府	UNDP／FAO UNCDF
開始時期	1982年	1983年

したがって、地下水開発で、ポンプに対するコマンド・エリアを小規模にすれば、上記の矛盾は解決できるとしている。

しかし、本プロジェクト地区は扇状地の扇頂に位置しており、生活用水、農業用水確保のための地下水開発には困難な点も多い。

流域全体を地下水開発を含み水資源開発の観点からとらえ、次に記述するような本プロジェクトの基本方針を提案する。

(2) 目　的

ブータン国南部ゲラフ地区における地下水を中心とした水資源開発の基本計画を策定することを目的とする。

本件調査では生活用水と農業用水を主たる対象とし、地下水のみにとらわれず、1河川水、2地下水、3その他、天水、溜め池等、4これらの組み合わせを水源としてゲラフ地区の水資源開発に係る基本計画を策定する。また、調査を通じて気象（雨量など）、水文（河川水位、流量など）、地下水（地下水位など）の観測体制の樹立を図り、将来のデーターベース作成の基礎づくりを行う。

このような方針に基づき、調査の結果として提言が行われる取水設備については、実験施設の設置、運用による実証試験を実施する。

(3) 基本的な取り組み

第2章に記載されているように、首都ティンプーにおける協議、及びゲラフにおける現地踏査の結果をまとめて、事前調査団が決定した事項は以下のとおり。

1) 調査対象地区

ゲラフ県（約400 k㎡）を調査対象とする。

計画対象は同県南部平野部及び周辺山岳部（約220k㎡）とする。

2) 調査の取り組み

地下水を中心とする水資源開発の可能性調査を実施し、その結果に基づき対象地域の水資源開発のマスタープランを策定する。

3) 水文観測体制の確立

本件調査に係る必要性のみならず、将来のゲラフの開発に備えるため資料整備を目的として気象・水文・地下水観測体制（データーベースを含む）の基礎体制を確立する。

4) 水資源利用目的

生活用水と農業用水を目的とする。現在、農村部の生活用水は河川水の導入によって賄われているが、飲料水が原因と考えられる疾病が多く見られ、乳幼児の死亡率も非常に高い。また、対象地域での将来的な水需要の増加が見込まれている現状から、特に衛生面、水質面からの検討を行うと同時に、地下水利用の可能性を検討する。

また農業用水については、先方は水源として地下水を想定しているが、地下水を利用する場合、次の点に注意する必要がある。

1　井戸及びポンプ設置の設備費と耐用年数

2　電力または燃料費等ポンプの運転経費

3　水中ポンプ等設備の維持管理

4　水源維持にともなう共同管理体制及び受益者負担

農業用水については地下水に限らず表流水、伏流水の利用も検討する。

5) 実験施設の設置

調査の結果として提言が行われる施設設備については、実験施設の設置運用による実証試験を行う。

1　先方に対し調査のOutputの具現化の一例を示すことができ、効果的な技術移転が可能となる。

2　調査－計画－立案－実施に至るプロセス全体を示すことにより、いわゆるソフト的技術移転を行うことができる。

3　既存資料が不足している対象地区において、実施段階に至る前に小規模の実験施設を設定することにより、確実な実施に結びつけることができる。

6) 水文観測体制の確立

本件調査に係る必要性のみならず、将来のゲラフの開発に備えるため資料整備を目的として気象・水文・地下水観測体制（データーベースを含む）の基礎体制を確立する。

これらのことを踏まえて、本調査を実施する。

(4) 調査対象事項

1) 気　象

気象観測については、現況の雨量データから推察する限りにおいて、年較差、地域特性の相違（空間的分布）が顕著であると判断される。本件調査では、最低1水文サイクルにわたり降雨観測を行うことが望まれる。特に山地部の雨量を知ることが必要である。また雨量以外の気象要素、蒸発量、気温等についても観測を行う。

これらの観測を通じ、対象領域全体の水収支解析、河川水の利用計画立案に必要な流出過程の推定を行う。

2) 河　川

河川水については、まず、日本国内と極端に異なる河川状況を把握し、基本的な水位観測を通じ、流量の推定を行う。また、堆砂についても観測を行い、導水対象地区の特性、河道、河床の状況を十分に反映した取水地点の選定を行うことが必要である。現段階では上流部（平野部への出口、扇頂部）での取水、透水管による河床からの取水などが考えら

れる。

3) 地下水

計画対象地域内の地区ブロックで他水源（表流水、天水など）と比較して、地下水のフィージビリティを確認する。

また、本件調査では、調査ボーリングを行い、観測井に仕上げ、地下水の観測を行う。

現段階では、水質上の観点から農業用水としての利用に先立ち、生活用水としての利用が有利であると考えられる。河川近傍の伏流水の活用などを検討すべきであろう。

4) その他の水源

上述の河川からの直接の導水、地下水からの取水のほかに、天水を貯留する、あるいは河川水、地下水を一時貯留する溜池の可能性の検討をはじめ、その他の水源の可能性を検討する。

5－2 調査項目及び内容

(1) 調査項目

実施調査の内容は下記のように考えられる。

〔現地調査〕

1) 既存資料の収集・整理・分析
2) 地形・地質調査
3) 測量
4) 水文観測（機器設置を含む）
5) 河川現況調査
6) データーベースの作成および入力
7) 物理探査（電気探査）
8) ボーリング・揚水試験
9) 水質試験
10) 地下水位観測
11) 給水調査
12) 利水調査
13) 実験施設の設計・施工
14) 堆砂調査
15) 実験施設のモニタリング

〔国内解析〕

1) 社会・経済分析

2) 気象解析

3) 水収支解析

4) 流出解析

5) 水文地質解析

6) 生活用水分析

7) 農業利水分析

8) 地区別、水源別開発可能量算定

9) 開発基本計画

(2) 調査内容

〔現地調査〕

1) 既存資料の収集・整理・分析

調査の目的を効果的に達成するために必要な資料として地形、地質、水理地質、水文、気象、水源、給水システムに関する文書・図面、利水、都市計画、開発計画、農業関連、観測データ等を収集し、整理する。

地図：s＝1：50,000の地形図があるが、これらはSurvey of Bhutan が一括管理しており、入手には農業局長からの公文書が必要である。また、地形図の国外持ち出しは禁止されている。

航空写真：s＝1：30,000の写真があるが、入手には地形図同様の手続きが必要である。

2) 地形地質踏査

調査対象地域は約400k㎡を有するが、この地域について地形区分図、地質図、地質断面図、土地利用図等を作成する。スケールは1：50,000とする。

地質図：s＝1：500,000の地質図があるほか、Geological Survey of Bhutanには種種の地質資料がある。ただし、水理地質資料については多くを期待できないものと考えられる。

3) 測量

調査対象地域の開発が有望な地域に簡易測量でs＝1：10,000の地形図を作成し、ボーリング位置、電気探査の位置等をプロットする。

4) 水文観測

1 水位観測

対象地域内の河川について水位観測を実施する。本観測データは取水計画、水収支解析、水資源開発のデーターベースの基礎として重要項目である。

河川水位観測はブータン電力局が実施しており、既存の観測施設のうち調査地域内にはマオ川観測点があったが、既に撤去されている。

2　流量観測

対象地域内の河川につき、最低、雨期、乾期各１回ずつ流量観測を実施する。また、対象地域が扇状地であることから山岳部から平野部への移行による浸透（伏流）機構との関連を見るうえで各河川につき縦断方向に観測点を設け、流量の変化を調べ、浸透、周辺地下水との関連を把握する。

3　雨量

降雨量の空間的分布が卓越していることから、地域代表性、面積雨量の把握という観点から最低１水文サイクルにわたり雨量観測を行う。特に、河川流出解析、地下水の入力要素となる山岳部の雨量観測も実施する。

4　蒸発量

水収支解析上、また、実験施設の候補として考えられる溜め池の運営上必要となる蒸発量の観測を行う。

5　その他の観測

気温、湿度、風向、風速等について、現況の観測データを検討し、必要に応じ補足調査を行う。

5）河川現況調査

表流水の取水の可能性を検討するため、河道状況につき調査を実施する。特に周辺の地形を十分考慮する。我が国の河川と著しく異なり、護岸等が全くなされていない現状を踏まえて、雨期、乾期による河床、河道の変遷状況を過去にさかのぼって既存資料、洪水痕跡、聞き込み等により調査する。

6）データーベースの作成および入力

ＪＩＣＡ貸与のパソコンを利用し、既存資料、水文観測及び今回の各種調査の結果等の入力を調査終了まで継続して行い、データーベースを作成する。

7）電気探査

地下地質構造を把握するために電気探査を実施し、その結果を比抵抗断面図、分布図にまとめる。なお、探査深度は100～200mとする。

電気探査地点は暫定的に以下のとおりとする。

・カッセ、ビスタドラ、ラライ：　５０地点
・タクライ、ノルブリン　　４０地点
・ゲラフ、マオ川右岸　　５０地点
・トリバリ　　１００地点
・サルバン　　３０地点

8) ボーリング調査

観測体制の樹立、水理地質の確認のため調査ボーリングを実施する。ボーリング地点、仕様は地質調査、電気探査等の結果を踏まえ、決定すべきであるが、事前調査結果に基づき暫定的に以下のとおり計画する。

(1) 調査地区及び数量

調査地区名	数　量	備　考
カッセ、ビスタダラ、ラライ：	2孔、 50m、120m	地区境界部
タクライ、ノルブリン　：	1孔、120m	マオ川左岸
ゲラフ、マオ川右岸　：	2孔、120m、120m	Lift Irrig.Proj.
トリバリ　：	3孔、 50m、50m、120m	
サルバン　：	2孔、 50m、50m	サルバン川右岸
	10孔、延べ850m	

なお、選定されたボーリング地点は図5－1のとおりである。

(2) 調査ボーリングの仕様

・掘削口径　：150～245㎜（5－7／8"～9－5／8"）
　ただし、地質状況に応じては100㎜を最小径とする。

・ケーシング径：100㎜

・孔内検層　：比抵抗、自然電位を実施
　結果はさく井柱状図として整理する。

・井戸仕上げ　：揚水が清浄になるまで継続する。このため、間断水等の手段を適宜実施することとする。

(3) 揚水試験

・段階揚水試験：揚水方法　3段階×3時間／段階
　回復測定　6～10時間

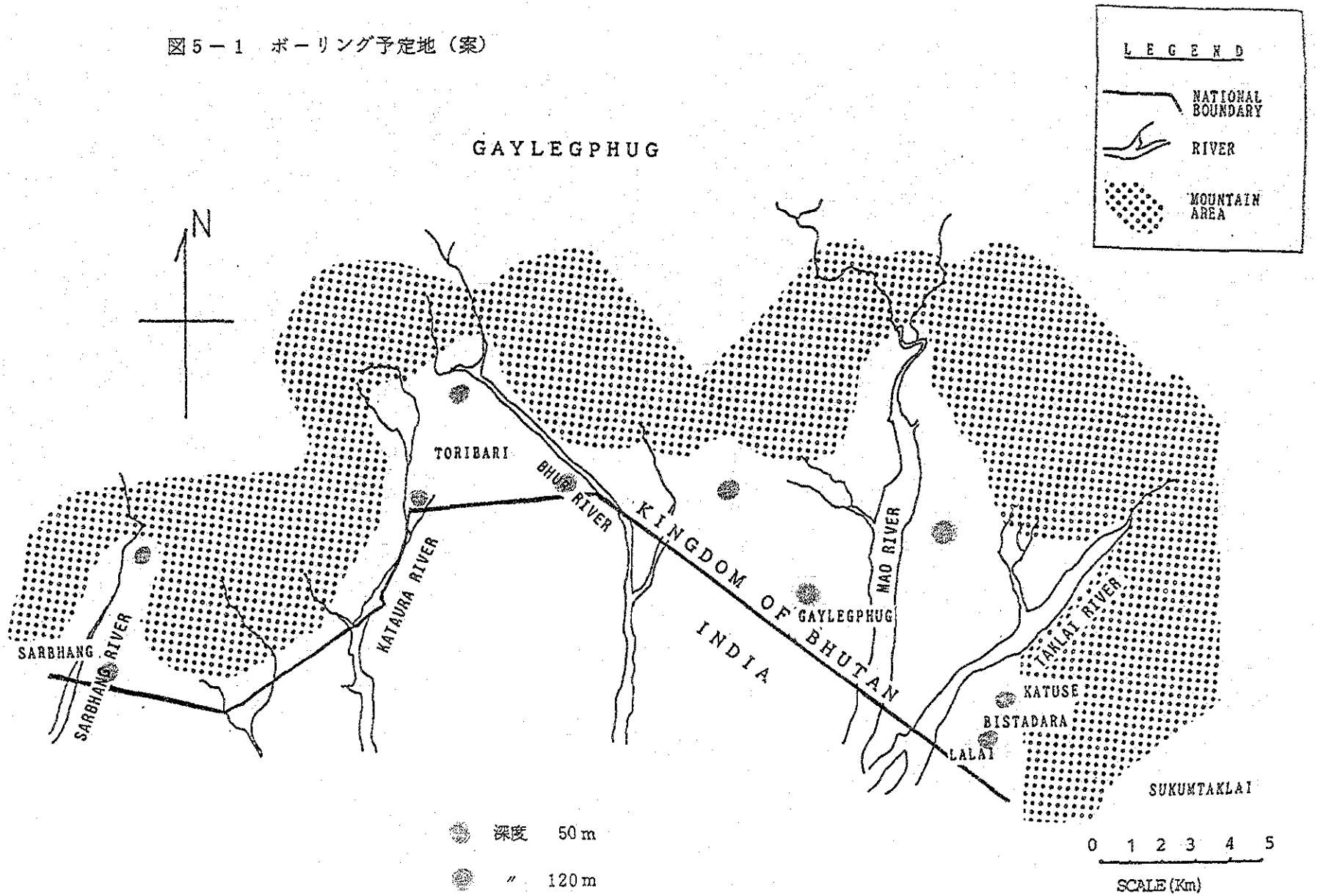
・連続揚水試験：揚水方法　24時間
　回復測定　8～15時間

なお、本試験と段階揚水試験との間には少なくとも48時間以上開けることとする。

9) 水質試験

水源の利用価値を判断・検討するための基礎資料を得るために水質試験を実施する。上記の試掘井については、連続揚水試験後に採水して、表流水、湧水に関しては生活用水の水源として利用している箇所および地下水との相関性が認められる地域を中心に、一般項目および水道基準の主要項目について水質分析を行う。分析には事業団より簡易水質分析器を貸与する。

図５－１　ボーリング予定地（案）



ボーリング業者委嘱分

10) 地下水位観測

試掘井の代表的井戸について事業団が貸与する自記水位計を設置し、地下水位変動の長期観測を行う。他の井戸については事業団が貸与する簡易井戸水位計台を用いて継続的に定期観測を行う。

11) 給水調査

対象地域内にある市街地および村落での既存の給水施設の現状及び水需要、問題点を把握する。特に衛生面に重点を置き、また乾期、雨期の相違にも十分留意のうえ調査する。ゲラフでは将来的に国際空港やニュータウン建設等が予定されているため、それらの開発計画についても調査を行う。

12) 利水調査

現況の農業利水の概況を調査する。例えば作物収穫、作付体系、農民収入、既往のプロジェクトの実態を調べ、またパロなどの試験場の結果を参考に農業用水量を把握する。また、農業省の開発計画についても十分な検討を行い、将来的な動向も把握する。

13) 実験施設の選定・設計

本件調査で提案する地域水資源開発に基づく各地区ごとの最適給水施設の選定に先駆け、地下水、伏流水、表流水に基づく施設を各々1例ずつ実験施設として選出する。事前調査結果に基づき暫定的に想定される施設は下記のとおりである。

1. 地下水……試験井の成功井をレベル2（高架槽、共同栓）として設置
2. 伏流水……浅井戸揚水による既設水路への導水
3. 表流水……取水工の新設による既設水路への導水

代替案として溜池の造成等も検討する。

上記で選定した3例の実験施設が提案される施設設置地点の実地測量を実施し、設計・積算を行う。

14) 堆砂調査

本件調査において、河川からの取水計画を検討する場合、堆砂が大きな問題となるため、流送土砂量調査、1出水ごとの堆砂量調査、上流山岳部の踏査等を通じ、堆砂に関する定性的、定量的な調査を行う。

15) 実験施設のモニタリング

実験施設の施工完了後、雨期・乾期における施設の有効性を確認するためモニタリングを実施する。

5－3　調査実施体制

日本側調査団要員計画

(1)　団長・総括

調査全般にわたり企画、調整、運営の全責任を持ち、本件開発調査の総括を行う。水資源開発全般についての知識があり、農業土木、河川工学、地下水探査、さく井等を含んだ地域総合開発を策定する能力が必要とされる。

(2)　地下水開発・水文地質

地下水による水資源開発のための水文地質調査および解析を担当する。物理探査、削井、揚水試験、水質分析、表流水、地下水観測等の各作業を各担当と共に企画し、ブータン側を指導しながら実施する。それらの各調査結果を総合して水理地質図、断面図等の水資源評価の基礎資料を作成し、水資源開発ポテンシャルの算定を行う。また、給水・利水計画、測量、施設設計・積算、地域経済担当等と共同で、実験施設の選定・施工を含む本調査地区の水資源開発計画をとりまとめる。

(3)　水文・水質

気象観測、水文観測、流出解析、水質分析を担当する。

気象・水文観測機器を設置し観測体制を確立する。その観測結果を踏まえ対象地域の水収支を判定し、開発可能量を算定する。また流出解析を行い給水・利水計画に解析結果を反映させる。水源の水質分析を行うため化学、生物の知識を有することが望まれる。

(4)　給水計画

既存生活用水施設などの調査を行い、実験施設の選定・施工を含む給水計画の策定を行う。給配水計画および建設に経験のある設計技師が望ましい。

(5)　利水計画

農業セクターにかかる調査全般を担当する。灌漑計画および取水工、導水工に関する構造物の知識を必要とする。

(6)　物理探査

電気探査を担当し、ブータン側に機器の操作方法、探査方法、解析手法を技術指導する。また、各種探査結果について解析・評価を実施し、水文地質担当へ資料を提供する。物理探査のハード、ソフト両面に詳しい地球物理技師が望ましい。

(7)　削井

揚水井の掘削計画を立案し、ブータン側のカウンターパートを指導して、掘削の管理を行う。また、掘削終了後の孔内検層、揚水試験も併せて担当し、ブータン側に試験方法、解析・評価方法を技術指導する。

(8) 施設設計・積算／試験施工

施設設計・積算、施工計画を策定する。取水工・導水工、生活用水供給施設などを検討する。

また、施設の建設にあたってはカウンターパートと協力し、雇い上げた作業員の指導・監督を行う。

(9) 測量

簡易測量で調査対象地域の s ＝ 1 ： 10,000 の地形図を作成する。

実験施設の地形測量を実施する。

(10) 地域経済／プロジェクト評価

5－4 調査実施に必要な機材

機材名	数量	仕　様
1. 自記水位計	1	水圧式長期自記水位計 検出器：器種 0 ～ 5 m、精度 0.5 % 電源　DC 12 V 自記水位計：精度　± 1 cm 記録　2 ペン式 電源　DC　3 V 記録　1 カ月以上
2. 水位計用スタッフ（10 m）	3	幅 15 cm　厚 1.0 mm　鋼板
3. 自記雨量計	6	検出方法：転倒ます型 受水口径：200 mm 精度：20 mm以下の時　± 0.5 mm以内 20 mm以上の時　± 3 %　以内 記録期間：3 カ月
4. 井戸水位計	8	測定範囲：0 ～ 10 m 精度　：± 0.5 % 記録方式：1 ペン式 適用井戸径：100 mm
5. 携帯用水位計	2	測定範囲：　100 m 巻取　：　手動式 テープ：スチロンテープ

	機材名	数量	仕　　様
6.	流速計	2	三映式流速計
			測定方法：コード／パイプ併用
			適用範囲：低速、高速用受信器
			表示方式：デジタル表示
7.	同上補助用品	1式	浮子（昼、夜用）各50
			水深用ロープ（30 m、5 kg）　2本
			ストップウォッチ　2個
8.	測量機器		
	トランシット	1	測角方式：両読、最小単位　20"
			望遠鏡　：45 mm、30×、f＝1.3 m
			気泡感度：円形　10′／2 mm
			平盤　60"／2 mm
	レベル	1	望遠鏡　：40 mm、30×、f＝40 cm
			気泡感度：10′／2 mm
			自動補正範囲：　±16′
	光波測距儀	1	測距範囲：1,800、2,500、3,400 m
			精度　　：±（5 mm＋5ppm）m.s.e.
			視準望遠鏡：8倍、視界2
	平板	1	アリダート、測針器、替スケール等1式
			測板規格：　大
9.	同上補助用品	1式	スタッフ　3 m　3段　6本
			ポール　20本
			巻き尺　50 m　4本
			鋼巻き尺　50 m　2本
10.	電気探査機器	1式	垂直探査装置
11.	ボーリング機材補充部品	1式	掘削ツールス
			保護ケーシング
			調泥剤
			井戸ケーシング、スクリーン
			エヤーリフト・ポンプ
			揚水試験機材

12.	採水機	1	採水量：2 ℓ以上 最大深度：10 m 任意深度で採水可能な機構を有する
13.	簡易水質分析器	1台	標準試薬別途一式を含む
14.	車両	4	ワゴン車3　ピックアップ1
15.	コピーマシーン	1式	
16.	パソコン	2式	
17.	発電機（ 30KVA ）	1	

5－5　調査実施上の留意点

(1)　要請の背景と取り組み

先方の要請は、農業開発を目的として農業用水についてのものであるが、まず対象地域全体についての水資源の状況を明らかにし、調査対象地区内の地域別（ブロック別に）に、種種の水源の適切な取水法、導水法、貯留法を勘案のうえ、開発可能量を算定するものとする。

(2)　気候特性

対象地域は、インド洋からのモンスーンの影響を受け、年間降雨量は2,000～5,000㎜以上にも達する。一方、雨期、乾期の相違も著しく、ゲラフの雨期の1カ月間に東京の年間降雨量（約1,500㎜）相当分がもたらされるのに対し、乾期には東京の降雨量を下回っている。

(3)　河川状況

このような気象特性に加えて、基本的なインフラ、特に河川管理の立ち遅れが顕著であり、水資源計画策定上の大きな制約要因となっていることは否めない。河道は不安定であり、雨期の出水のたびに大きく変動、蛇行し、かつ大量の流送土砂による堆砂が発生している状況である。

(4)　表流水の取水・導水

そのため、取水工の設置、維持管理は極めて困難であり、現地で実施されているインド政府援助によるポンプ揚水灌漑計画（Lift Irrigation Programme）は取水工の維持、土砂によるポンプの損傷、導水部の堆砂などの問題が生じている。

(5)　現地アクセス上の留意点

ブータン唯一の国際空港パロへは、デリーまたはカルカッタからそれぞれ週1便のブータン国際航空が飛んでいるのみであり、在インドブータン大使館でビザ取得の後のパロ入りの日程に注意が必要である。パロから首都のティンプーへは問題がないが、ティンプーから調査対象地域であるゲラフへのアプローチには十分な注意が必要である。特に雨期の場合はインド領の通行確保のための手続きを完了しておくことが無難である。

(6) 現地における宿泊設備等

現地ゲラフには、長期宿泊可能なホテルがあり問題はないが、事前の確認が必要である。ホテルにおける食事は不可能であり、自炊する準備が必要と思われる。ゲラフ市内に中華料理風のレストランが1軒あるが、長期の滞在には十分とは言えない。乾期は比較的乾燥していて過ごし易い。雨期は、南北に横切る数本の川が増水して東西方向の通行が不可能となる。インド領域の通行確保の手続きを完了しておく必要がある。

(7) 調査に必要な労務者の確保

ブータンは労務者の確保が困難である。基本的には先方政府の責任であるが、人口が少ないにもかかわらずネパール、インド等の労務者の入国に対して厳しい制限を設けており、その事情を理解したうえでの交渉が望まれる。これを反映して賃金も高い可能性があり、また外国人の使用については先方政府との十分な打合せが必要である。

(8) ボーリング班の調達

調査のためのボーリングは、2班編成の必要があると想定している。1班は、現在パロに保管されているＪＩＣＡ供与の機材を使用することとなるが、他の1班は請負工事として施工する必要がある。現在ネパールの合弁企業との協力が現実的であるが、ネパール業者のブータンにおける労働については厳しい制限がある。農業局長との会談においては、数人程度のネパール人技術者がＪＩＣＡのチームとして入国するのは問題はないであろう、との発言があったが、特に議事録での確認は行っていない。このようなケースについては、農業局と十分打ち合わせる必要がある。

(9) 実験施設の設置

実施計画の中に含まれる実験設備計画は、予備調査の段階を経て決定されることになるが、現在のところ、地下水揚水による既設灌漑水路への導水を想定している。場所、規模等については本格調査団により決定されるが、ゲラフ地区の主たる灌漑用水の水源にはインドの技術協力と関係したものがあり、これらが現状では十分機能していないので、そのかかわり合いについて注意する必要がある。また、実験施設の機材準備の時間が少ないと思われるので、調査開始の早い時期から、その計画について考慮しておく必要がある。

(10) 河川取水の問題点

本計画の全体のトーンが地下水に重点を置いたものになっているが、これは先方の要請書の内容を考慮したもので、現実には河川水の取水の手段が有効となる場面が十分想定される。平野部に出てからの河川の状況は、取水設備の構築を非常に困難なものとしており、従来の失敗もこの点に起因している。今回の計画では、できるだけ維持管理が容易な案を提案する必要があり、事前調査団は、水路延長が長くなっても上流部の岩盤露出部分から取水することが賢明であろうと判断した。この見解を含めて幅広い検討が望まれる。ただし、大規

模ダム計画は、インドとの協定上、インドと協議の対象となるので注意が必要である。

(11) 農業開発との関連

対象地域の中には、既開発の農業地域ばかりでなく、今後の農業開発を期待すべき地域が含まれている。本調査は、農業開発計画を策定することが目的ではなく、あくまでも農業及び生活用水確保のための水源調査及びその供給設備計画の策定であり、その点を明確に区別して、必要が生じた場合は農業開発計画策定の提言をなすにとどめる。

(12) 地形測量

本件調査では下記の3通りの地形測量を実施する。

1) 既存5万分の1の地形図を補完するための1万分の1の地形図作成

2) F/Sレベルの構造物設計のための数箇所の局部的な実測地形図作成

3) 主要河川に対する水面形解析等を想定した縦横断測量

1) の1万分の1の地形図作成は、水文地質マクロ解析、地域全体概略計画策定および調査工事の位置の確認を目的とするものであり、事前調査団は次のような手順を想定している。

a. 既存5万分の1の地形図を機械的に1万分の1に拡大した図面を基礎とし、現地踏査（地形の確認、河川の変化状況の吟味、道路・水路・家屋等の地物の変化、土地利用状況の確認等）、既存航空写真の立体視による地形の確認を実施し、また物理探査・ボーリング・実験施設の位置も考慮に入れて、修正の必要のある地域を特定する。

b. 修正の必要がある地域について必要な簡易測量、例えばレベル測量による主要点の標高の確認、ハンドレベルによる補完、基準点間の位置確認作業（簡単なトラバース、三角測量または部分的な平板測量等）を実施して等高線および地物の修正、或いは等高線の線形の詳細化を拡大地図上で行う。

c. 修正された拡大地形図について、等高線等の線の太さの修正、美観の見地からの間曲線の挿入、地物の記入等を行って再度トレースして、作成方法および使用目的を明確に記述して完成品とする。

一般に地形図の作成において重要なことは、ある目的のために作成された地形図がその精度を無視して多目的に使用される危険がある点であり、今回のように簡易化された作業で作成された地形図については、その作成方法を図面上に注記しておくことが重要である。

附　　屬　　資　　料

附属資料1. 要 請 書

PROPOSAL FOR INVESTIGATION

ON

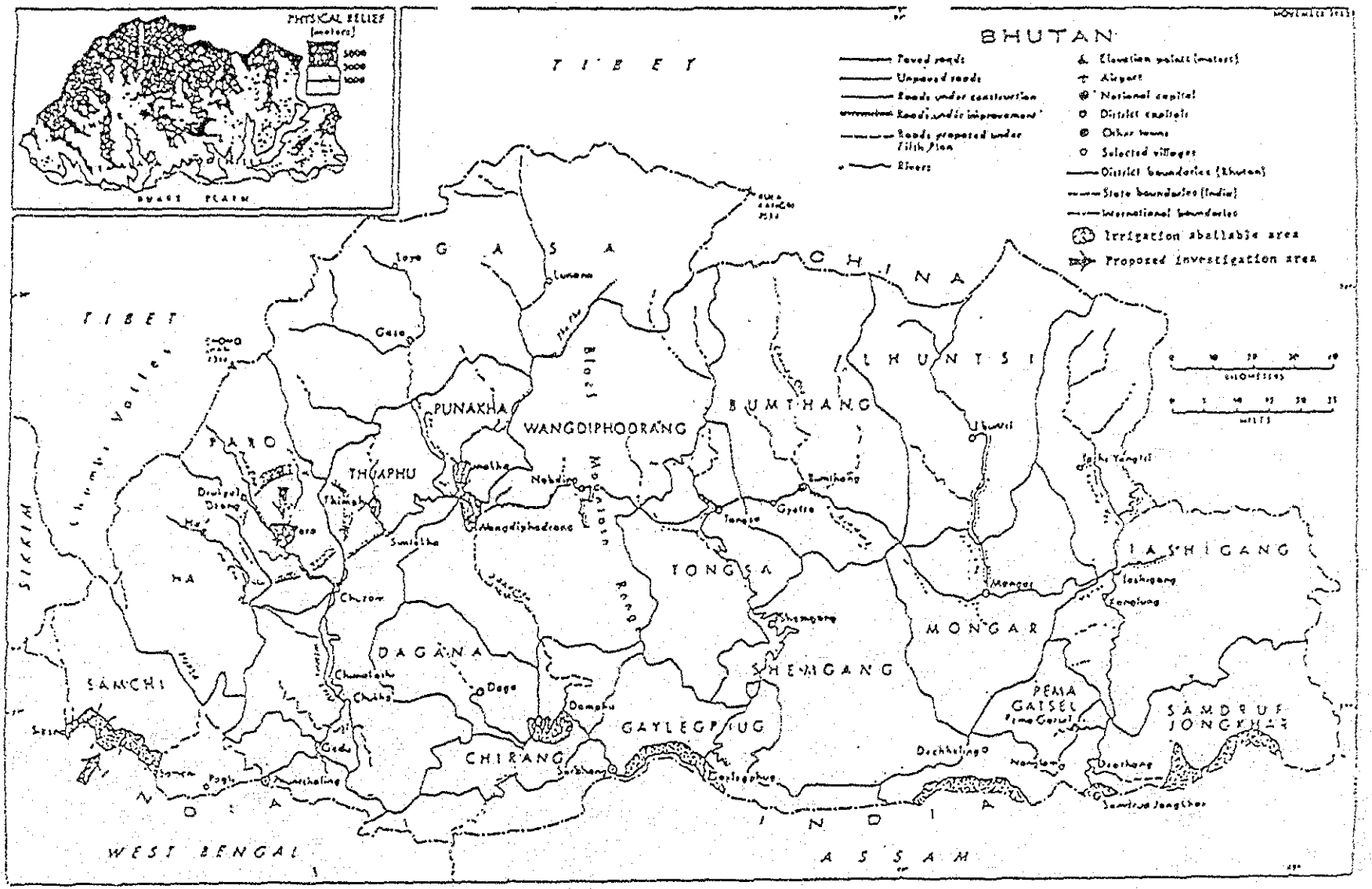
GROUNDWATER IRRIGATION PROJECT

1988

Department of Agriculture

MINISTRY OF AGRICULTURE & FORESTRY

ROYAL GOVERNMENT OF BHUTAN


BHUTAN
PHYSICAL RELIEF (meters)
DUARS PLAIN
TIBET
INDIA
CHINA
SIKKIM
WEST BENGAL
ASSAM
Paved roads
Unpaved roads
Roads under construction
Roads under improvement
Roads proposed under Fifth Plan
Rivers
Elevation points (meters)
Airport
National capital
District capitals
Other towns
Selected villages
District boundaries (Bhutan)
State boundaries (India)
International boundaries
Irrigation available area
Proposed investigation area
KILOMETERS
MILES
GASA
PUNAKHA
WANGDIPHODRANG
BUMTHANG
LHUNTSI
PARO
THIMPHU
HA
TONGSA
LA'SHIGANG
MONGAR
DAGANA
SHEMGANG
SAMCHI
GAYLEGPHUG
CHIRANG
PEMA GAISEL
SAMDRUP JONGKHAR
Punakha
Wangdiphodrang
Bumthang
Lhuntsi
Paro
Thimphu
Tongsa
Mongar
Shemgang
Dagana
Samchi
Gaylegphug
Chirang
Pema Gaisel
Samdrup Jongkhar

I. BACKGROUND INFORMATION

1. Introduction

The major objectives of the Sixth Five-Year Development Plan of the Royal Government of Bhutan (RGOB) are:

i) the improvement of living conditions in the nation;

ii) the establishment of national self-reliance; and

iii) the preservation and promotion of the country's rich cultural heritage and its values and institutions.

In order to achieve these objectives, the Royal Government will continue to give very high priority to the development of the agricultural sector. Agriculture is the mainstay of the Bhutanese economy, directly or indirectly engaging 90% of the population.

The country's configuration is one of high mountain ranges. As such, the amount of available agricultural land is highly limited. Agricultural development strategy should therefore emphasize the more efficient use of available land through more judicious application of other non-land inputs.

As a part of this strategy, Government plans to develop the use of ground water for irrigation. However, there is no previous experience in Bhutan with full-scale development of ground water for either agricultural or domestic use.

The Royal Government hence wishes to make a request to the Government of Japan for technical assistance in groundwater development.

2. General Geographic Conditions

Bhutan is a land-locked surrounded by the Tibet Region of China to the North and North-West and by India to the East, South and South-West. It has a total area of 46,500 sq.km. Most of the country lies within the Himalayan ranges. The mountainous character of the country means that flat land is limited to a few relatively broad river valleys in the mid-country and some expanses of plain areas (the Duars) in the South.

Three East-West geographical zones are usually distinguishable. The southern foothills rise steeply from about 200 m to 1,500 m, and extend about 20 km into Bhutan; this zone is subtropic in nature. From the foothills to the north, the hills of the inner Himalayas rise more gradually. This region contains the broader river valleys of Punakha-Wangdi, Paro, Thimphu, Bumthang and Tashigang, the economic and cultural heartland of Bhutan. The high Himalaya zone consists mainly of high alpine mountain ranges. Thus the climate is very varied, ranging from hot and subtropical conditions in the south to perpetual ice and snow in the high Himalayas.

The total population of Bhutan is about 1.2 million people, and growing at about 2.6 per cent per annum. The population density is only about 26 people per square kilometer. Most of the population is dispersed in small rural villages situated in the ravine plains.

3. Present Agricultural Conditions

Bhutan is a typically agricultural country in which 90% of the people are engaged in agriculture or agriculture related activities. Agriculture contributed about 44% of GNP in 1984. Thus general economic development will have to rely greatly on the development of the agricultural sector.

Subsistence is a main feature of Bhutanese agriculture. But even this is strongly influenced by topographic circumstances. The amount of cultivable land available to a farm household is only about 0.7 ha, and GDP per capita for people in agriculture is only about US $ 79 as opposed to US $ 140 for the whole nation.

Only 2.7% of the total land area, ie. 126,000 hactres is agricultural land. (Table 1) The majority of the land is occupied by forested or snowcapped mountains and peaks. There is thus only a limited capability to extensively expand the amount of land available for cultivation.

TABLE I

Area of cultivable land by region

Region	Area (ha)
Western	16,733 (13%)
Central	9,399 (7%)
South-central	18,353 (15%)
Southern	56,527 (45%)
Eastern	25,473 (20%)
Total :-	126,485 ha

In Gaylegphug, for example, paddy yields on irrigated land have been tripled since the early 1980s, and are four times as high as yields on unirrigated land. (Table 2)

TABLE II

Comparative Yield Statement on Paddy in Gaylegphug

Year	Average Yield by rain water	Average Yield by Irrigated water
1982/83	415 kg/ha	679 kg/ha
1983/84	531 kg/ha	1,751 kg/ha
1984/85	467 kg/ha	1,976 kg/ha
1985/86	576 kg/ha	2,307 kg/ha

In the Fifth Five Year Plan (1981-86), the irrigation facilities that were completed drew water from river sources. These new structures brought an additional 8% of the total farm land under irrigation.

In the southern border zone, the average length of water courses is 3.6 km, with an average command area of 30.6 ha per km. In the ravine plains of the inner Himalayas, the average water course length is only 1.9 km, but has a command area of 41 ha per km. This may be considered to be efficient in comparison to studies from other parts of the world.

The major crops of Bhutan are paddy and maize. The two crops, respectively, occupy 30% and 54% of the permanently cropped land. Wheat (16,000 tonnes) crop and potatoes (32,000 tonnes), buck-wheat/millet (16,800 tonnes) and oil seeds are important crops. Pulses, fruits, vegetables, cardamoms are also cultivated on a smaller scale.

The main paddy producing areas are in the south adjacent to the border with India (in Gaylegphug, Samchi, and Samdrup-jongkhar Dzongkhags), and in the small open river plains of Paro, Thimphu, Wangdi, Punakha and Chirang. Typically, paddy is a single annual crop; it is only traditionally double cropped in parts of the irrigated areas of Gaylegphug.

In most cases, wheat is cultivated as the second crop after paddy and maize. Buckwheat and millet are mainly cultivated in the mountain zones. Self-sufficiency is yet to be achieved in the main food stuffs. The country imports about 25,000 tonnes of grains annually.

4. Irrigation

As stated before, there is little capability to extensively expand the amount of cultivable land. Increased output, therefore, may be obtained mainly through using improved inputs and growing two or three crops a year on the same land. Irrigation is almost always an imperative for the later proposition, and to be able to use inputs more efficiently.

The construction in Bhutan of irrigation projects that involve full scale water courses commenced in 1980. Results so far have been very encouraging.

TABLE III

Irrigation Schemes completed during the Fifth Plan

Region	No. of Schemes (No.)	Length of Canal (Km.)	Area (Ha)
S/Jongkhar	10	43.1	1,435
Gaylegphug	14	41.3	1,359
Samchi	18	66.1	1,791
(Sub-Total)	(42)	(150.5)	(4,585)
Tashigang	12	33.8	1,948
Chirang	8	27.3	433
Paro	7	0.6	149
Thimphu	14	22.6	767
W/Phodrang	3	0.5	183
(Sub-Total)	(44)	(84.8)	(3,480)
Other (10-Zone)	45	180.3	2,048
(Grand Total)	(131)	(415.60)	(10,113)

5. Surface Water Irrigation

The main advantage of surface water irrigation is that water courses are technically easy to construct. But it has the following disadvantages.

i) Since the water is taken directly from the river, channels are frequently damaged by swift currents, mud flows, and landslides.

ii) When parts of the channels gets damaged, down stream-irrigated areas are adversely affected.

iii) Because of the large volume of mud in the river, during the rainy season, sand sendimation creates problems in intake facilities and farm land.

iv) In large scale irrigation projects, operating costs become high because high capacity pumps have to be used.

v) In the dry season medium and small rivers are often unuseable as they dry up.

6. Ground Water or Well Irrigation

In Bhutan, surface water course irrigation covers only about 20% of the total farm land area. There is little scope for expanding the amount of available farmland. In order to increase productivity on available land the Sixth Five Year Plan proposes to expand and improve irrigation facilities. The Fifth Plan concentrated on building surface water irrigation facilities. The disadvantages of these facilities were pointed out above.

Steady supplies of good quality irrigation can alternatively be supplied from ground water. The merits of groundwater or well irrigation are as follows:

i) A steady flow of good quality water can be maintained throughout the year;

ii) Irrigation facilities can be constructed at the center of the targeted area, which can cover relatively compact areas of up to 15-20 ha. This reduces the rate of water loss (leakage) at the time of delivery, and makes maintenance easy.

3. Japanese and Bhutanese Government Contributions

In conducting the survey, the Government of Japan will provide engineers and necessary equipment and materials. For its part the RGOB shall provide office space and necessary local labour. The Royal Government shall provide national counterparts who will be trained in groundwater management technology.

4. Components of the Survey

The survey will consist of the following hydrogeological components:

i) Surface reconnaissance: approximately 30 sq.km.

ii) Electric resistivity testing of soils; about 60 sites (200m deep).

iii) Test boring: 5 sites (maximum depth 150 m).

iv) Water quantity and quality survey: 5 sites.

v) Simple survey: 1 site.

In addition to the above hydrogeological survey, there will be a socio-economic appraisal of the feasibility of ground-water irrigation in the study areas.

5. Survey Perod and Follow-up

The conduct of the survey including the production of a final report will take 12 months. If the results of the survey show that it is hydrogeologically and economically feasible to develop groundwater irrigation in the study, a full-scale development programme will be immediately initiated.

iii) Although construction costs are high, operating costs are low and only for electricity.

iv) It is possible to provide supplementary irrigation efficiently.

While these merits are considerable, there has been little survey work conducted to establish the existence of groundwater sources. Thus, it is proposed that any investigation in groundwater irrigation in Bhutan would have to start at this point.

II. GROUNDWATER DEVELOPMENT SURVEY PROJECT

1. Objective

The objective of this project is to study the possibility of using groundwater for future irrigation development. This will be achieved through a hydrogeological survey of some selected areas of Bhutan to determine the economic feasibility groundwater irrigation. The project will develop appropriate survey methods, as well as train Bhutanese engineers in fields of groundwater development.

2. Study Areas

Surveys will be conducted in Samchi and Paro Dzongkhags. Samchi will be representative of the Southern plains area, and a 20 sq.km will be surveyed in that Dzongkhag. Paro will be representative of the ravine plain areas of the inner Himalayan zone, and a 10 sq.km will be covered in that Dzongkhag.

6. Executing Agency

The survey is expected to be implemented through grant assistance from the Japanese Government for the provision of technical assistance, equipment and materials. However, the implementation agency for the project will be the Department of Agriculture, Ministry of Agriculture, RGOB.

7. Equipment and Materials

The following are the major equipment and materials required for the survey:

i)	Geophysical prospecting equipment:		2 sets
ii)	Drilling equipment with accessories for a test well	:	1 lot
iii)	Casing and well screen	:	for 5 wells
iv)	Testing equipment:		
	- Pumping test unit	:	2 units
	- Logging equipment	:	1 unit
	- Water quality analysis kit	:	1 unit
v)	Observation equipment:		
	- Water level measuring instrument	:	3 sets
	- Water flow meter	:	3 sets
vi)	Vehicles for Transportation:		
	- Truck with crane	:	2 units
	- Station wagon/pick up	:	4 units
	- Water tank lorry	:	1 unit.

Appendix-1

Report of Feasibility Study

of

Groundwater Development

in

Gaylegphug Area

Kingdom of Bhutan

December, 1986

INTRODUCTION

A preliminary survey of the possibility of groundwater development was conducted in Gaylegphug in 1926. It consisted only of a field reconnaissance survey and electric resistivity testing of the soil. Given the very limited scope of this preliminary survey, more accurate surveys and designs are required for project implementation.

1. General Condition in Gaylegphug

Gaylegphug Dzongkhag is situated around the centre of the southern border plains regions. It is about 1,530 sq.km. in size and shares about 150 km of border with India. It has a population of 111,283.(1985) which is about 10% of the total population of Bhutan. The population density of Gaylegphug is about 72.7 persons per sq.km, which is about three times the national average.

Gaylegphug town is the third largest urban concentration of people in Bhutan after Thimphu and Phuntsholing. The town has a customs checkpoint, and is a key traffic point in Central Bhutan.

There is about 197 sq.km of farm land in Gaylegphug Dzongkhag, the second largest parcel after Samchi. There is also a small amount additional land that could be converted into farmland.

2. Summary of Topography and Geology

In the hinterland of the Gaylegphug plain is the Mahabarato range of the lower Himalayas which rises to a peak of

2000 m. The Mao, Thaklai and Bhur Rivers flow out of this mountain range and form a fan-like configuration in the plain below:-

Topographical and geological formations are poor in the east-west direction, but favorable in the south-north direction. Terrace development is intensive and south-north in nature. Three stages of terrace faces are recognisable (Figure 1).

i) Upper level terrace face:

This is on the steep slope of the mountain foot in the 280-400 m altitude range. Sub-surface soil is of sand-gravel formation containing bolders. There is farm land and also undeveloped land. In Leopani this land is used for orange orchards.

ii) Middle level terrace face:

This is on the moderate slope of the mountain foot in the 230-280 m altitude range. The soil is sandy, and the land mostly used for paddy. This level is suitable for irrigation and is the core of agricultural production.

iii) Lower level terrace face:

This land is on the flat river bank in the 190-230 m altitude range, and includes urban Gaylegphug. The river bed has sandy soils. Some land is used for dry field crops while some suitable for paddy cultivation.

The Mao River is arborescent and has a catchment area of 619 sq.km. It has a maximum flow rate of 240 cubic meters per second and a minimum flow rate of 17 cubic meters per second.

The Taklai and Bhur Rivers have respective catchment areas of 169 sq.km. and 60 sq.km. They become slow flowing streams in the dry season.

The hinterland of the study area is in the main Himalayan tetonic zone. The geological structure of the lower Himalayan zone is moderate with synclinorim structure and forms a double-inclined structure. The lithofacies is weak metamorphic to non-metamorphic sedimentary rock, consisting of sandstone, shale-clay slate stone and red-purple colored quartzite and lime-stone. The samalik formation of the sub-Himalayan zone is not seen in the study area, but is believed to be hidden at the lower part of the flood plain. The terrace deposits at the top of the fan-like configuration are bolder-sand-gravel in formation with mixtures of large stones. They sandwich silt. The largest bolders are at the center of the fan. The river bed is mostly made up of sand formations with some gravel.

3. Hydrogeological Summary

It is presumed that the deposits at the top of the fan are highly permeable, and therefore that region would have a deep groundwater level. Thus a total of nine electric resistivity tests were carried out in this region to ascertain whether or not wet zones and base-ments exist.

There are no deep wells in the study area or else where in Bhutan. As such, there is no other data with which to compare data from this study. But judging from the results of this study, there is a possibility of obtain-ing groundwater from 150-200 below the surface.

The potential for groundwater development is best at the lower and middle level terrace faces, where water replenishment by the Mao River is best. But even at the higher level terrace face, if replinishment is good no problems are foreseen. But if the hinterland is narrow development may be difficult.

The existence of a good layer ofgroundwater has been confirmed. It is now desirable to implement as early as possible, boring tests to study possibilities of development.

4. Rainfall

Rainfall in Gayleghug, 1985 is stated as fallowa;

Table-1 Rainfall (1984) in Gayleghug

Month	Temperature Max.(C°)	Min.	Evaporation for 24 hrs(mm)	Rainfall (mm)	No. of Rainy day
Jan.	23.27	15.66	23.2	23.2	4 days
Feb.	21.96	17.57	24.7	59.8	11 days
Mar.	26.84	22.15	37.4	62.4	11 days
Apr.	28.58	24.82	39.2	87.2	14 days
May.	28.61	24.98	41.3	512.5	17 days
Jun.	28.83	26.30	27.1	1,135.5	24 days
Jul.	29.08	24.52	19.4	1,681.2	29 days
Aug.	30.40	26:24	25.7	690.4	25 days
Sep.	29.92	24.18	15.3	912.2	25 days
Oct.	30.40	28.82	30.0	80.6	7 days
Nov.	28.70	22.12	29.1	82.0	6 days
Dec.	25.68	17.29	21.7	61.4	6 days
Total			(Ave.)27.8	5,388.4	179 days

附属資料2. SCOPE OF WORK

SCOPE OF WORK
FOR
THE STUDY
ON
GROUNDWATER DEVELOPMENT

IN
SOUTHERN PART
OF
THE KINGDOM OF BHUTAN

AGREED UPON BETWEEN
MINISTRY OF AGRICULTURE
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

THIMPUH, NOVEMBER 28, 1989

DASHO KHANDU WANCHUK
SECRETARY
DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE
ROYAL GOVERNMENT OF BHUTAN

MR.HAYAO ADACHI
TEAM LEADER
PRELIMINARY SURVEY TEAM
JAPAN INTERNATIONAL
COOPERATION AGENCY

I. INTRODUCTION

In response to the request of the Royal Government of Bhutan, the Government of Japan has decided to conduct a study on groundwater development project in south area of Bhutan (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, The Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation of the Government of Japan, will undertake the Study in close cooperation with the authorities concerned of the Royal Government of Bhutan.

The present document sets forth the scope of work with regard to the Study.

II. OBJECTIVE OF THE STUDY

The objective of the Study is to conduct a study on water resources potential with an emphasis on groundwater project in Gaylegphug District of Bhutan.

III. STUDY AREA

The study will cover the area of Gaylegphung District.

IV. SCOPE OF THE STUDY

The Study shall include followings;

PART A: DATA COLLECTION AND REVIEW

1) national and regional socio-economy
2) topography and geology
3) hydrology and meteorology
4) hydrogeology
5) population and economic activities in the area
6) previous study results
7) miscellaneous

PART B: FIELD SURVEY

1) topographic and geological reconnaissance
2) meteorological and hydrological investigations
3) topographic survey
4) survey on cross sections and profiles of rivers
5) electrical prospectings
6) drilling survey and pumping tests
7) design, installation and operation of experimental facilities

PART C: STUDY AND ANALYSIS

1) hydrological balance

2) aquifer conditions

3) groundwater flow and recharge

4) water quality

5) water demand

PART D: FORMULATION AND EVALUATION OF WATER RESOURCES POTENTIAL

1) formulation of water resources development plan

a) rivers

b) ponds and tanks

c) groundwater

2) project evaluation

a) social and environmental impact

b) project evaluation

V. STUDY SCHEDULE

The Study, in principle, shall be carried out in accordance with the tentative schedule shown in the attached sheet.

VI. REPORTS

JICA shall prepare and submit the following reports in English to the Royal Government of Bhutan.

(1) Inception Report (IC/R)

Twenty (20) copies at the commencement of the work in Bhutan

(2) Progress Report(1) (P/R1)

Twenty(20) copies within eight(8) months after the commencement of the Study

(3) Interim Report (IT/R)

Twenty(20) copies within thirteen (13) months after the commencement of the Study

(4) Progress Report(2) (P/R2)

Twenty(20) copies within nineteen(19) months after the commencement of the Study

(5) Draft Final Report (DF/R)

Twenty(20) copies within twenty-seven(27) months after the commencement of the Study

The Royal Government of Bhutan shall submit their comments within thirty(30) days after receipt of the Draft Final Report.

(6) Final Report (F/R)

Thirty(30) copies within sixty(60) days after the receipt of the comments on the Draft Final Report

VII. UNDERTAKINGS OF THE ROYAL GOVERNMENT OF BHUTAN

1. To facilitate smooth conduct of the Study, the Royal Government of Bhutan shall take necessary measures;

(1) to secure the safety of the Japanese study team,

(2) to permit the members of the Japanese study team to enter, leave and sojourn in Bhutan for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees,

(3) to exempt the members of the Japanese study team from taxes, duties, fees and other charges on equipment, machinery and other materials brought into Bhutan for the conduct of the Study,

(4) to exempt the members of the Japanese study team from income tax and other charges of any kind imposed on or in connection with any emolument or allowance paid to the members of the Japanese study team for their services in connection with the implementation of the Study,

(5) to provide necessary facilities to the Japanese study team for remittance as well as utilization of the funds introduced into Bhutan from Japan in connection with the implementation of the Study,

(6) to secure permission for entry into private properties or restricted areas for the conduct of the Study,

(7) to secure permission for the Japanese study

team to take data and documents (including photographs) related to the Study out of Bhutan to Japan and

(8) to provide medical services as needed. Its expenses will be chargeable on the members of the Japanese study team.

2. The Royal Government of Bhutan shall bear claims, if any arises against members of the Japanese study team resulting from, occuring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the members of the Japanese study team.

3. Ministry of Agriculture , the Royal Government of Bhutan (hereinafter referred to as "MOA") shall act as a counterpart agency to the Japanese study team and also coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4. MOA shall, at its own expense, provide the Japanese study team with the following, in cooperation with other relevant organizations;

(1) available data and information related to the

study,

(2) counterpart personnel,

(3) suitable office spaces with necessary equipment in the study areas, and Thimphu,

(4) credential or identification cards and

(5) vehicles with drivers and fuels

VIII. UNDERTAKINGS OF JICA

For the implementation of the Study, JICA shall take the following measures;

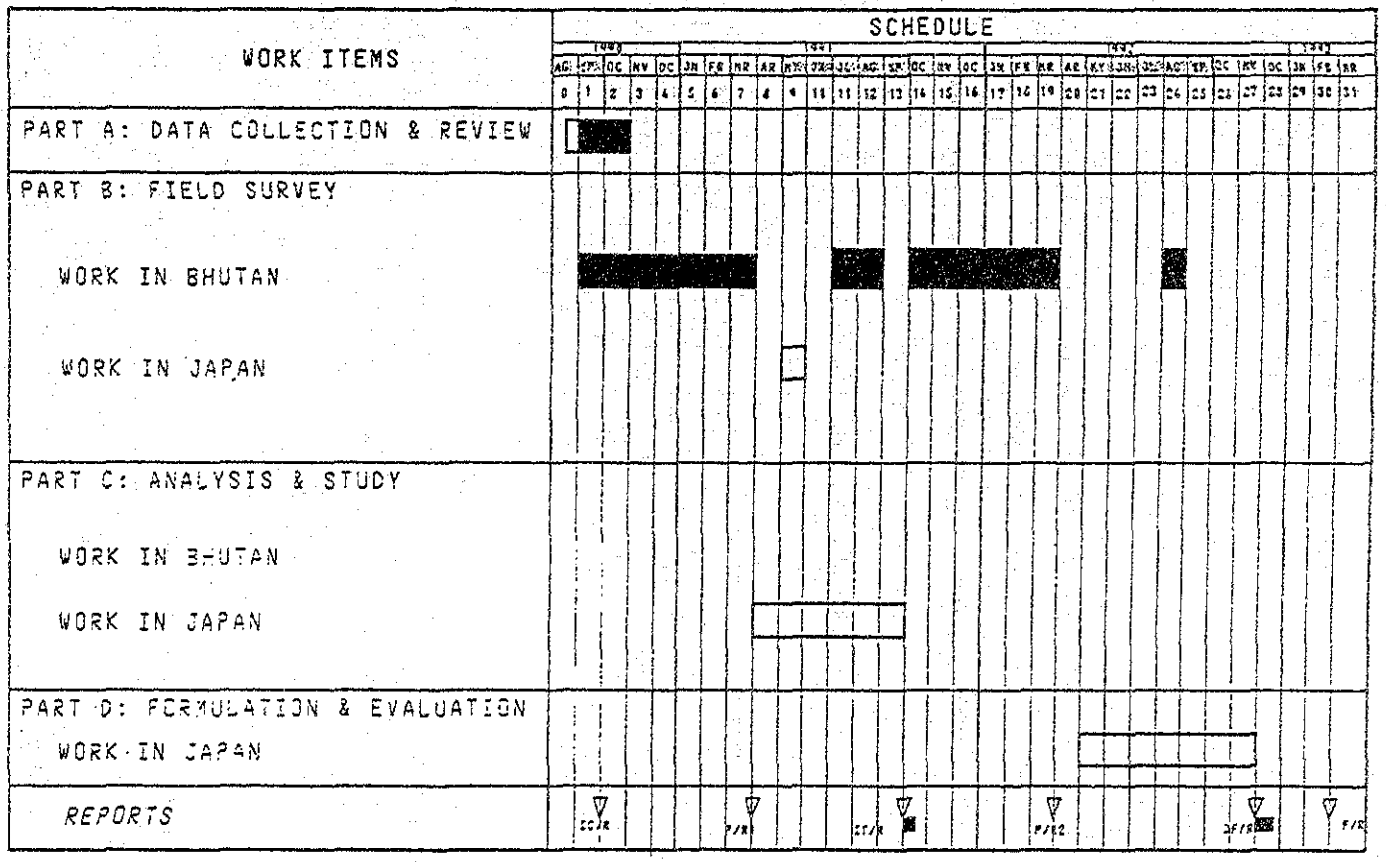
(1) to dispatch, at its own expense, Japanese study team to Bhutan and

(2) to pursue technology transfer to the Bhutanese counterpart personnel in the course of the Study.

IX. CONSULTATION

JICA and MOA shall consult with each other in respect of any matter that may arise from or in connection with the Study.

APPENDIX I TENTATIVE STUDY SCHEDULE



MINUTES OF MEETING
FOR
GROUNDWATER DEVELOPMENT PROJECT
IN
SOUTHERN PART
OF
THE KINGDOM OF BHUTAN

MINUTES OF MEETING
FOR
GROUNDWATER DEVELOPMENT PROJECT
IN
SOUTHERN PART
OF
THE KINGDOM OF BHUTAN

The Preliminary Study Team was organized by the Japan International Cooperation Agency (JICA) and dispatched to Bhutan from November 16 to December 1, 1989. The JICA team had a series of discussions with the Department of Agriculture (DOA) and conducted a site survey of Gaylegphug District and relevant facilities.

The followings are results of the discussions and understood by JICA and DOA, in connection with the Scope of Work signed between JICA and DOA on November 28, 1989.

1. *Objective Area*

With reference to Article III of the Scope of Work, both parties agreed to carry out the Study on water resources potential for the Gaylegphug District and on the project master plan of water supplies for Sarbhang, Toribari, Lift Irrigation Project area, Norbuling, Thewar Irrigation Project area, Katuse, Bistadara and Lalai as shown in the attachment.

2. *Study Schedule*

With reference to Appendix 1, Tentative Study Schedule, both parties agreed to conduct the Study in accordance with the detail of the study schedule as attached herewith. It is, however, noted that minor modification may be proposed by the JICA study team.

3. *Relevant Organization*

Both parties confirmed that this water development project could involve other water usages such as new-town water supply and drinking water for local people. It is, therefore, agreed that DOA should make necessary arrangements for discussing these with other sectors using water.

4. *Local Labourers*

DOA agreed to provide necessary labourers for the following works : installation of meteo-hydrological gauging stations and observation, ground survey, electrical prospectings, drilling and pumping tests and installation/observation for the experimental facilities.

5. *Vehicles*

JICA requested DOA to provide necessary numbers of vehicles for the Study. DOA explained the situation and proposed to provide one (1) truck when necessity arises and drivers and fuel for all the vehicles.

6. *Equipment*

DOA requested JICA to provide equipment and materials such as vehicles, hydrological observation equipment, ground survey equipment, electrical prospecting equipment, accessories and materials for drilling, office appliances and necessary materials for the experimental facilities. The JICA team stated that the DOA's requests would be conveyed to JICA head office to make budgetary arrangement for the above.

7. *Experimental Work*

With reference to item (7) of PART B in Article IV, DOA agreed to JICA's proposal of adopting the experimental works in order to ensure the water supply programs to be established in the Study. Therefore, DOA agreed to secure the land acquisition for the works.

8. *Technology Transfer*

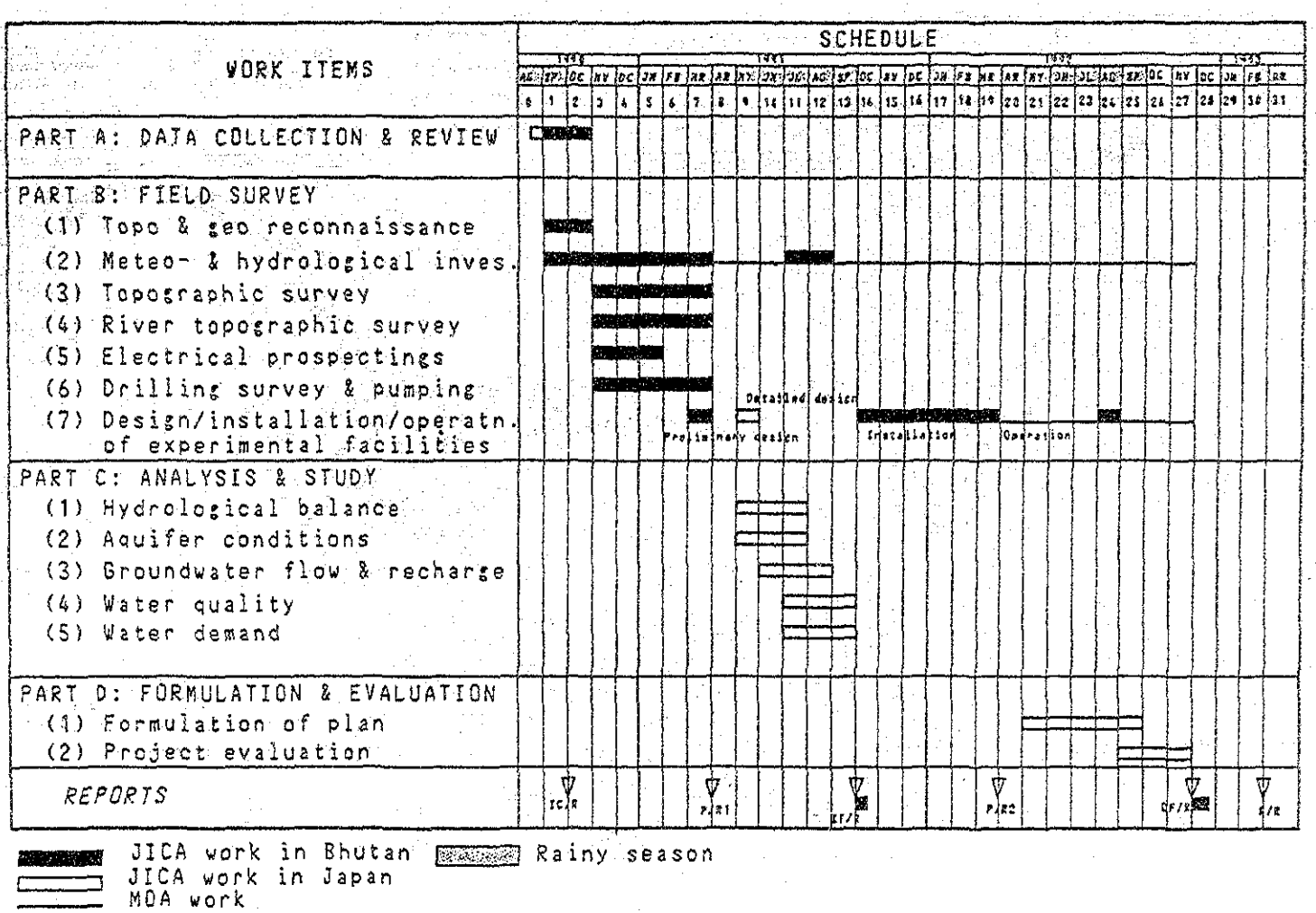
DOA pointed out in connection with undertaking of JICA especially with technology transfer for the counterpart personnel training program in Japan to be implemented. The JICA team stated that the DOA's requests would be conveyed to JICA head office.

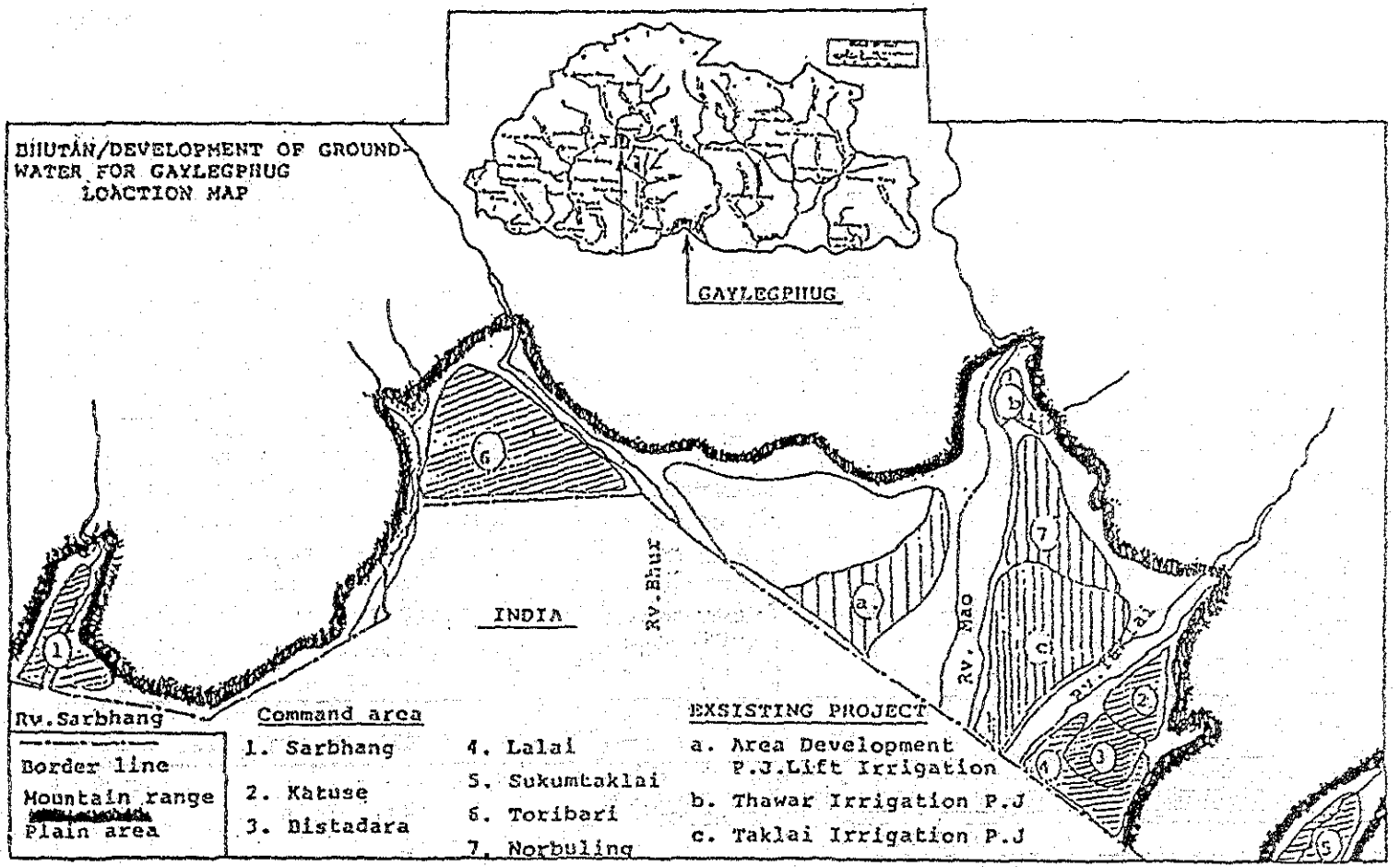
Thimphu, November 28, 1989

KHANDU WANGCHUK
DIRECTOR GENERAL
DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE
ROYAL GOVERNMENT OF BHUTAN

HAYAO ADACHI
LEADER OF
PRELIMINARY STUDY TEAM
JAPAN INTERNATIONAL
COOPERATION

APPENDIX I TENTATIVE STUDY SCHEDULE




BHUTAN/DEVELOPMENT OF GROUND-
WATER FOR GAYLEGPHUG
LOACTION MAP
GAYLEGPHUG
INDIA
Rv.Bhur
Rv. Mao
Rv.Sarbhang
Command area
1. Sarbhang
2. Katuse
3. Bistadara
4. Lalai
5. Sukumtaklai
6. Toribari
7. Norbuling
EXSISTING PROJECT
a. Area Development P.J.Lift Irrigation
b. Thawar Irrigation P.J
c. Taklai Irrigation P.J
Border line
Mountain range
Plain area

図－Ⅱ　調査対象地区図

附属資料4. 収集資料リスト

LIST OF COLLECTING DATA

1. TOPOGRAPHIC MAPS

1) Assam & Bhutan (No.78-1/5) 1 : 50,000 Copy
2) Assam & Bhutan (No.78-1/9) 1 : 50,000 Copy
3) GEOLOGICAL AND MINERAL MAP OF BHUTAN; Geological Survey of Bhutan

2. DAILY RAINFALL

1) Gaylegphug Manual recorder (1978/83 Elevation 375m)
2) Gaylegphug Manual recorder (1971/83 Elevation 327m)
3) Taklai (1987/88 Project-office)

3. DAILY DISCHARGE OF RIVER

1) Mao river at Lodai,Gaylegphug (1976/82 Elevation 266m)
2) Mao river at Lodai,Gaylegphug (1978/82 Elevation 326m)
3) Taklai river at In-take (1987/88)

4. ABOUT AREA DEVELOPMENT PROJECT IN GAYLEGPHUG

1) Outline of Lift Irrigation Scheme
2) Monthly running-hours report from Jan'87 to March'89
3) Electricity charges of Lift Irrigation Scheme
4) Result of Paddy demonstration 1985
5) Comparative yield statment of Paddy
6) Command area in Acres
7) Report of The expert team on Lift Irrigation Scheme

5. ABOUT TAKLAI IRRIGATION PROJECT

1) Outline of Taklai Irrigation Project
2) Agronomy Report by Food and Agriculatural Organisation

6. GEOLOGY & HYDROGEOLOGY

1) Himalayan Geology Seminar (1976-79) New-Delhi
2) Himalayan Geology Seminar (1976-82) New-Delhi
3) Groundwater Potential of The Kingdom of Bhutan 1982
4) Geological and Mineral Map of Bhutan 1:500,000 Copy
5) GEOTECHNICAL SURVEY AND DESIGN TRANING MANUAL FOR HILL IRRIGATION SCHEMES IN BHUTAN(EC)

7 FEEDER ROAD MANUAL; Volume

1) Hydrology
2) Irrigation design Manual
3) Feeder Road Manual

8. ABOUT AGRICULTURE & OTHERS

1) Report on Agriculture and Irrigation Planning Project
2) Final Document on Gaylegphug Integrated Area Development project
3) Statistical Yearbook of Bhutan 1987
4) Statistical Year Book of bhutan, 1988; Centaral Statistical Office
5) Statistical bulletin Agronomic Survey, 19988 and 1989 (draft); Central Statistical Office
6) Manpower development and Training Project(Asian Development Bank)
7) TECHNICAL ASSISTANCE PROGRAMME; Geotechnical Field manual for Irrigation Engineers and Technicians, June 1988

附属資料5. 面談者リスト

1. 在外公館/JICA事務所

1)	在インド日本大使館一等書記官	西 郷 正 道
2)	在インドJICA事務所所長	倉 林 太 郎
3)	在ブータンJOCA事務所所長	佐々木 憲 一
4)	JICA派遣専門家(農業園芸)	西 岡 京 治

2. ROYAL GOVERNMENT OF BHUTAN

1) Planning Commission
   1. Deputy Minister : Dasho. C. Dorji
   2. Director : Mr. Yeshey Zimba

2) Ministry of Agriculture
   1. Secretary : Dasho. Leki Dorji
   2. Deputy Director : Mr. Kimley Dorji

3) Department of Agriculture
   1. Sectretary : Dasho. Kandu Wangchuk
   2. Director General : Mr. Tshering Dorji
   3. Joint Director : Mr.Thubten Norbu.
   4. Personnel Officer : Mr. Sonam Peljore
   5. M&E Officer : Mr. Birendra Dhakal
   6. Procurement Officer : Mr. Pewa Tashi
   7. Section Officer : Mr. S. B. Tamang
   8. Project Manager. of Taklai : Mr. R. B. Subba

4) Zonal Administrator : Dasho Kinzan Dorji

5) Department of Geology and Mines,
   Joint Director : Mr. Sonam Angley

6) Department of Power,
   Officiating Divisional Engineer : Mr. D. B. Chettri

7) Central Statistical Office
   Chief Statistical & Natiohal Project Manager
   : Mr. Chewang Rinzin

8) Departmert of Works and Housing
   1. Deputy Executive Engineer : Mr. Gchharam Dulal
   2. Planning Officer : Meghraj Adhikari

附属資料6. 資材・機材単価表

価　格　調　書

Unit：Nu＝IRs＝¥8.6

No	種　目	仕様サイズ	価格		備　考
			Thimphu	Gaylegphug	
1	人件費				
1－1	プロジェクトマネージャー		3,500／月	3,500／月	
1－2	マネージャー		3,000／月	3,000／月	
1－3	監督		2,000／月	2,000／月	
1－4	シビルエンジニア		1,800／月	1,500／月	
1－5	メカニカルエンジニア		1,800／月	1,500／月	
1－6	ドライバー	重機	2,000／月	1,700／月	
1－7	ドライバー	トラック・カー	1,500／月	1,300／月	
1－8	スキールレバー		40／日	30／日	
1－9	アンスキールレバー		30／日	20／日	
1－10	ハウスキーパー及びウォッチマン		30／日	20／日	
2	宿泊代				
2－1	高級ホテル	三星シングルルーム	300~400／日	Non	
2－2	普通ホテル	三星シングルルーム	100~200／日	50~60／日	
3	レンタルハウス				
3－1	レンタルハウス	3ベッドルーム、キッチン&ダイニング	2,500~4,500／月	－	
3－2	レンタルハウス	2ベッドルーム、キッチン&ダイニング	－	1,000~2,500／月	
4	車輌チャーター代				
4－1	ステーション・ワゴン	ランドクルーザー 4WD－87型	4.9／km	Non	含燃料、運転手
4－2	ピックアップ	ダブルキャップ 4WD－87型	4.9／km	Non	〃　〃
4－3	ジープ（タクシー）	場所指定－ネゴベース	8／km	6／km	タクシー
4－4	トラック	8 ton 車－Tata インド製	800／時	700／時	
4－5	ブルドーザー	キャタピラ	3,000／時	3,000／時	
4－6	クレーン		Non	Non	

価　格　調　書

No	種　目	価　格	
5	燃料、オイル	(Gaylegphug)	
5－1	ガソリン	9.0／ℓ	
5－2	軽油	4.0／ℓ	
5－3	灯油	5.0／ℓ	
5－4	ギャーオイル	20.0／ℓ	"B"Grade
5－5	ブレーキオイル	85.0／ℓ	〃
5－6	グリース	27.0／ℓ	〃
6	電気代	0.4／unit	unit：KWH
7	L.P Gas	90／シリンダー	シリンダー保証金 3,000.－
8	工事材料・工具		(Gaylegphug)
8－1	セメント	58／袋	1袋－50kg
8－2	砂	200／トラック	4.5m³、10km以内
8－3	砕石	88／m³	
8－4	レンガ	0.85／pc	
8－5	鉄筋	6.5／kg	インド
8－6	木材	48／f3	
8－7	スコップ	45／pc	インド
8－8	ツルハシ	40／pc	〃
8－9	ハンマー	25／pc	〃 1kg
9	食料品		(Thimphu)
9－1	タマネギ	6／kg	
9－2	キャベツ	3／kg	
9－3	カリフラワー	4／kg	
9－4	ジャガイモ	3／kg	
9－5	ナス	5／kg	

No	種　目	価　格	
9－6	エンドーマメ	12／kg	
9－7	トウガラシ	10／kg	
9－8	サツマイモ	4／kg	
9－9	ダイコン	4／kg	
9－10	サヤエンドー	6／kg	
9－11	ナガネギ	1／束	30㎜束
9－12	トマト	4／kg	
9－13	セリ	1／束	20㎜束
9－14	アスパラガス7／束		40㎜束
9－15	サトウキビ	5／本	1本1.2m
9－16	ナッパ	1／束	60㎜束
9－17	ニンニク	20／kg	
9－18	ショーガ	16／kg	
9－19	ウリ	3／pc	1pc－300g
9－20	白米(上)	9／kg	
9－21	〃 (下)	4.5／kg	
9－22	赤米	8／kg	
9－23	砂糖	6~8／kg	
9－24	塩	2／kg	
9－25	小麦粉	4.5／kg	
9－26	鶏肉	40／kg	Gaylegphug 25－30／kg
9－27	牛肉	14／kg	9／kg
9－28	豚肉	27／kg	23／kg
9－29	マトン	45／kg	35／kg
9－30	ヤク肉	25／kg	
9－31	生魚(養魚)	60／kg	
9－32	ビール	10／本	インドGolden Eagle
9－32	ミネラルウォーター	9／本	〃
9－33	サラダオイル(ひまわり油)	40／kg	Lipton India
9－34	タマゴ	1~1.5／pc	

価　格　調　書

No	種　　目	価　　格		
10	日用雑貨			
10－1	トイレットペーパー	13／pc	インド製	
10－2	ロウソク	10／pc	〃（大）	
10－3	マッチ	0.5／pc	〃（小）	
10－4	洗剤	7／box	〃 Surt 200g	
10－5	石ケン	7／pc	"A"Grade	
11	Hotel SONAM RABPHL	Gaylegphug	Thimphu Hotel JUMOLHARI	
	レストランメニュー	価　　格		価 格
1	Coffee	3.0		6.0
2	Tea	2.0		6.0
3	Orange juice	5.0		11.0
4	Soda	3.0		6.00
5	Beer（India）	14.0		17.0
6	Sandwich	8－10		6－25
7	Potato tinger chip	5.0		8.0
8	Vegetable Soups	5.0		11.0
9	Chicken Soups	8.0		14.0
10	Omlete	5.0		11.0
11	Fried Egg	5.0		9.0
12	Boiled Egg	2.0		4.0
13	Fish Fried	13.0		26.0
14	Mutton Curry	12.0		24.0
15	Chicken Curry	13.0		24.0
16	Chicken Chilli	17.0		26.0
17	Fried Rice	8－18		11－18
18	Rice	3.0		8.0
19	Chowmin（焼ソバ）	12－15		18－20

附屬資料 7.

GROUND WATER POTENTIAL OF THE KINGDOM OF BHUTAN

(Fact Finding Mission)

Prepared by the consultant:-

Dr.CHANDRA H.SHARMA,
Executive Director,
Water & Energy commission,
NEPAL

For:-
SOUTH ASIA CO-OPERATIVE ENVIRONMENT PROGRAMME
P.O.Box 1970,
COLOMBO,
SRI LANKA,
1982.

CONTENTS

SURFACE WATER

From the rainfall data it is possible to say that about 11..mm is the average rainfall and most of the rainfall goes as a surface run off (76%) whereas, about 5% retained in snow and rest 19% percolates as ground water (see river hydrographs). The low and high flow difference is not much ie 10 to 16 times unlike the other himalayan river, where it is in the order of 100 to 500 times.

River gauging was done for a limited period and also in the few rivers which does not provide good picture. However Bhutan posses the river gauge data of some of the major rivers (table..8.....) from 1956 on ward which if converted into discharge will be a major asset in water resources planning for hydropower, irrigation and other development. Even if the cross section and discharge are not available, it will possible to utilise the above data by making one or two years observations at the same sites from where the data were collected and correlating the staff gauge height with the discharge. However a rough estimate of discharge can be made from the data of rivers of other regions.

Though discharge of a river at any point is related to cross sectional area and average velocity but it can be correlated withstaff guage to reduce the frequency of observation and computation of cross section and velocity. Whereas in the absence of any data of velocity and cross section the guage height data becomes less useful and in such case whatever is estimated may have ± 50%. However it is possible to correlate with similar environmental himalayan rivers data which is given below.

The relationship is averageas shown below in the table and may be tested in case of Bhutanese river of which guage height is given in attached table no.8.8.Fig 5

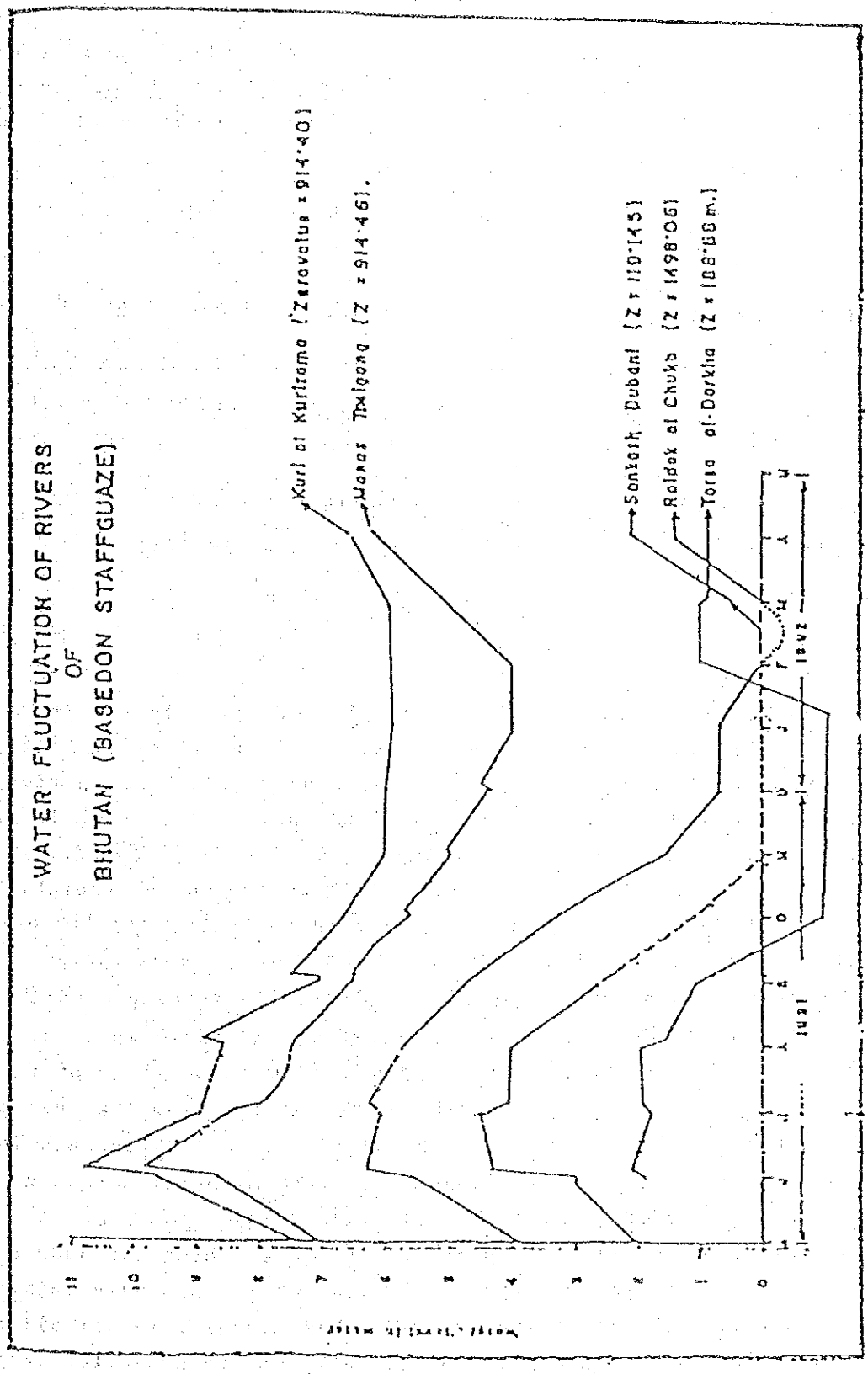
STAFF GAUGING OF RIVERS OF BHUTAN

Table 8

	Torsa	Kurlat	Raidak	Sankosh	Dankosh	Tongsa	Manas	Chamkarchu
	Dorekha	Kurizamu	Chukha	Dubani	Wangdipho	Mangdechhu	Tashigang	Bumtang
Zero Value M				1901				
mtr	100.65	914.40	1490.26	492.0	119.145	557.15	914.40	-
Jun	0.7-1.9	7.35-9.7	3.70-5.55	2.0-3.0	1.20-4.10	6.6-7.02	7.05-8.65	-
Jul	2.05-1.8	10.74-8.93	6.35-6.10	4.35-4.50	4.10-3.40	7.99-8.17	9.05-8.59	-
Aug	1.85-2.0	8.9-8.66	6.25-5.70	4.10-4.00	3.5-2.1	7.90-7.50	8.1-7.60	
Sep	1.5-1.05	8.93-6.75	5.65-4.75	3.90-2.60	2.3-1.2	7.46-6.96	7.55-6.55	
Oct	1.05-0.7	7.6-6.75	4.60-3.30	X	1.30-0.43	6.94-6.37	6.55-5.6	
Nov	m-.7	6.65-6.1	3.30-1.50	1-0	0.43-0.31	6.36-6.06	5.65-5.0	
Dec	m-.70	6.1-6.04	1.50-0.7	X	0.31-0.25	6.06-5.92	5-4.45	4.72-4.60
			19	02				
Jan	m-0.70	6.04-5.99	0.7-0.7	0-0	0.24-0.21	5.92-5.01	4.5-4.15	4.70-4.60
Feb	m-0.70	5.99-5.94	0.71-0.15	0-0	0.21-0.19	X	4.15-4.10	4.61-4.60
Mar	1-1	5.94-6.06	X	0-0.50	0.19-0.20	5.01-6.81	4.15-5.25	4.61-4.61
Apr	0.95-0.7	6.06-6.6	0.15-1.45	X	0.21-0.15	5.99-6.15	5.30-6.35	4.63-4.66

* M means minus below: Zero
* all readings are in meters.

FIG. 5


WATER FLUCTUATION OF RIVERS
OF
BHUTAN (BASEDON STAFFGUAZE)
Kuri ol Kurtsma (Z = 914·40)
Manas Thalpong (Z = 914·46).
Sankosh Dubani (Z = 110·145)
Raidak ol Chukb (Z = 1498·061)
Torsa ol-Dorkha (Z = 108·150 m.)
1981
1982

Rivers	Max v m/s	Min v m/s	G.H.max m	G.H. min m	Discharge m^3/sec max	Discharge m^3/sec min
a.Kernali	3.41	0.52	4.09	0.85	1648	94.82
b.Bagmati						
at Chobar	2.90	0.41	10.12	1.63	504	00.297
c.Sunkoshi						
at Khurkot	3.57	0.46	6.89	1.12	2786	84.23
d.Tamur	4.16	0.46	5.04	2.17	16.42	54.06
			26.14	6.03	6780	233.9

1. Maximum discharge per meter gauge height = 260m^3/s.
2. Minimum " " " " " = 38m^3/s.

Water and Power Potential:-

It appears that Bhutan's net contribution of water to the Brahmputra system will be 0.8(run off coefecient) x1.15(annual precipitation) to the river system which means annual discharge of Bhutan river will be $47000 \times 10^6 \times 1.15 \times 0.8 = 43240$ million cubic meter which is compatible to total run off as given by Dr.K.L.Rao(.1979.*.....) to Sankosh 17270 million and Manas 32000 to the point of Brahmputra. In his data a large part of India is also included. (See fig 6,7,&8) (*Dr.K.L.Rao-India's Water Wealth P 257 Orient Longmen Ltd.)

According to Bhim Subba Executive engineer electricity Department, the low flow of Manas is 200 cu mec,Sankosh is 50 to 75 cumec and Chukha is 28 cumec.As low flow and high flow is 16 times difference the average will be approximetly 5 times of low flow.That means 1000 cumec for the river Manas and 375 for Sankosh and 140 Raidak.The total may be 1515 cumec.If other rivers are also taken into account and the total average discharge of 1717x.8=1373 cumec may be possible.This is really comparable with Nepal which has 5000 cumec with nearly 3 times area that of Bhutan. Bhutan has more rainfall in the foot hill region whereas,Nepal has higher rainfall all over midland.The above discharge theoritically can be converted in to electric energy $\frac{1373 \times 3333 \times 9.81}{2} = 22446$mw

FIG.6.

FLOW DIAGRAM OF THE BRAHMAPUTRA RIVER IN INDIA AND BANGLADESH

NOT TO SCALE

AVERAGE ANNUAL VOLUME IN MILLION Cu.M

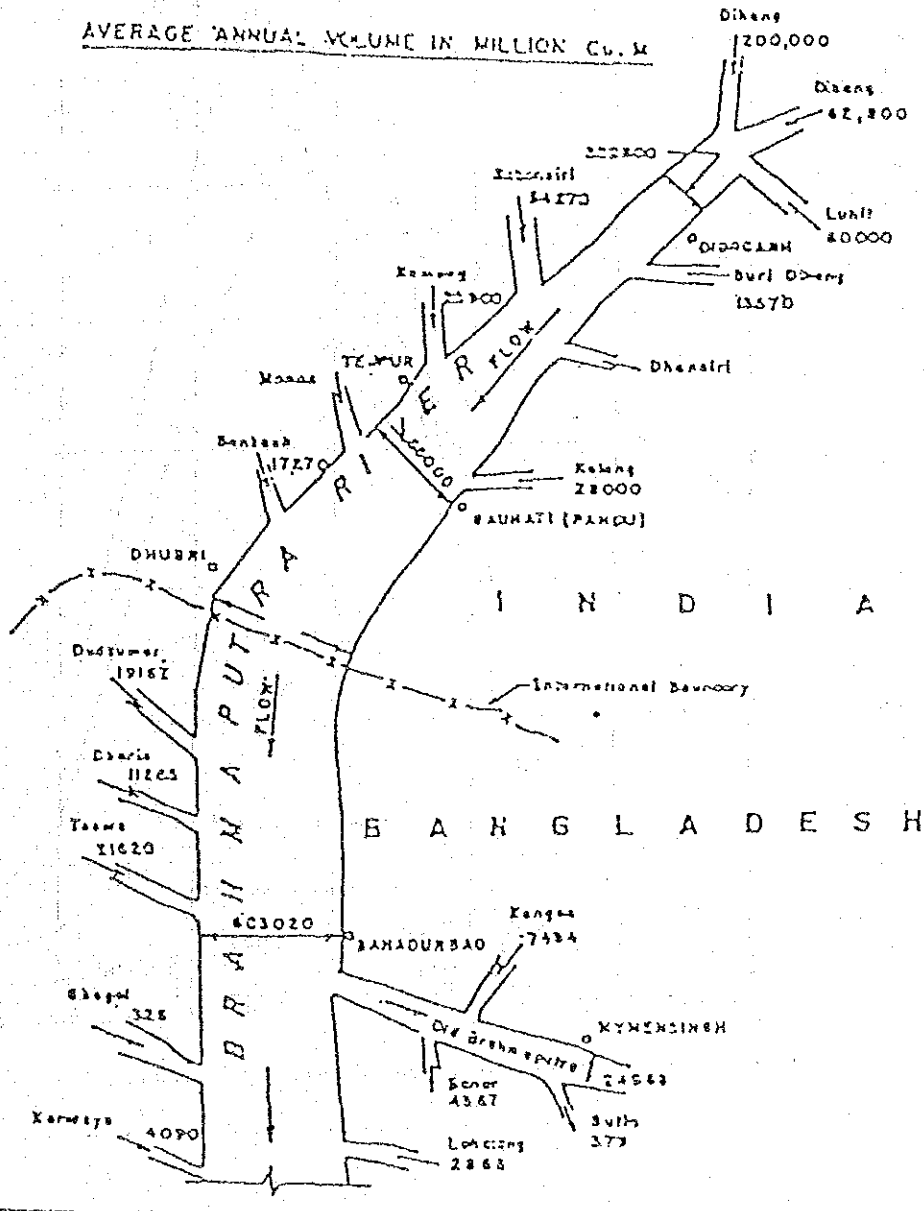
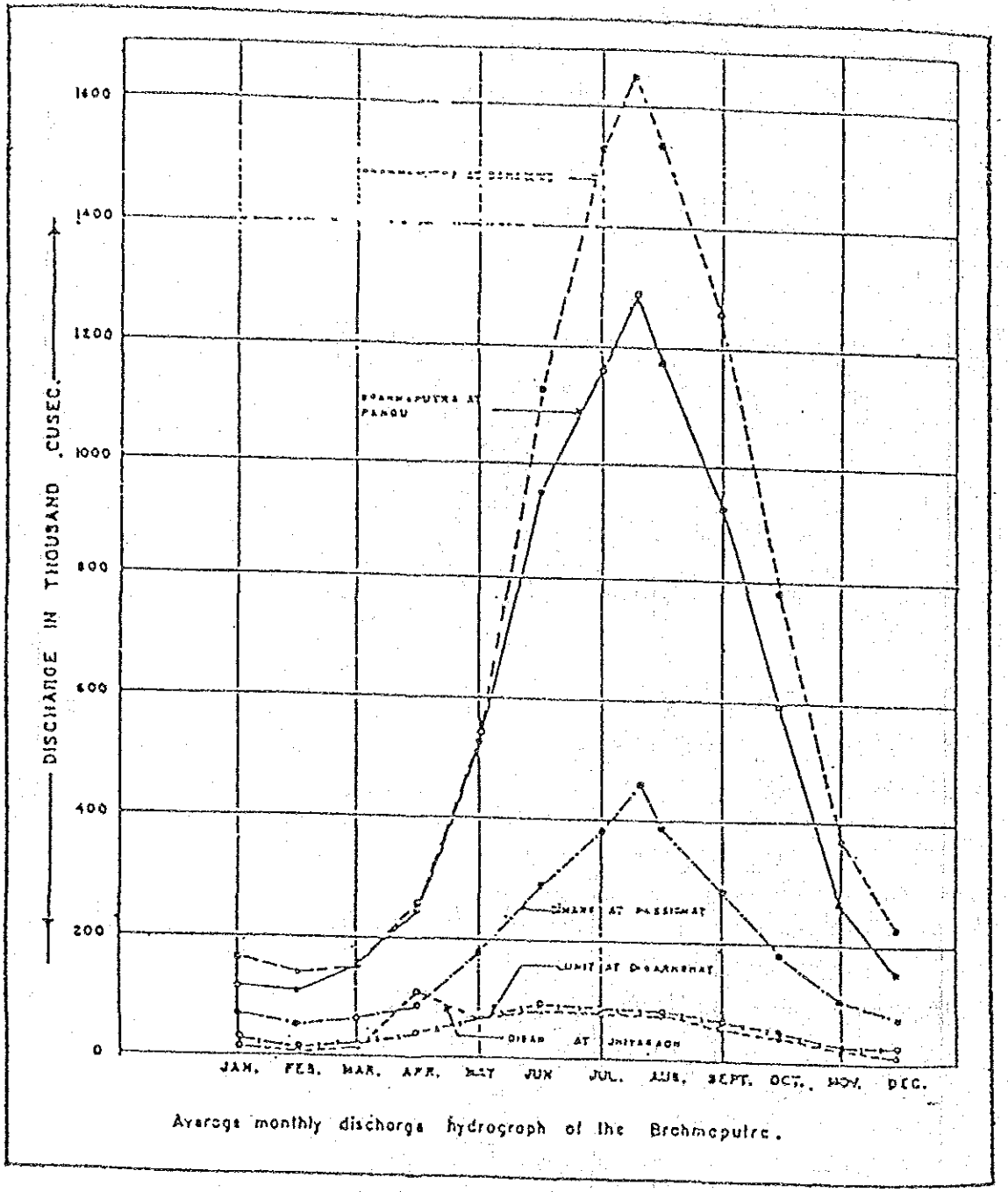
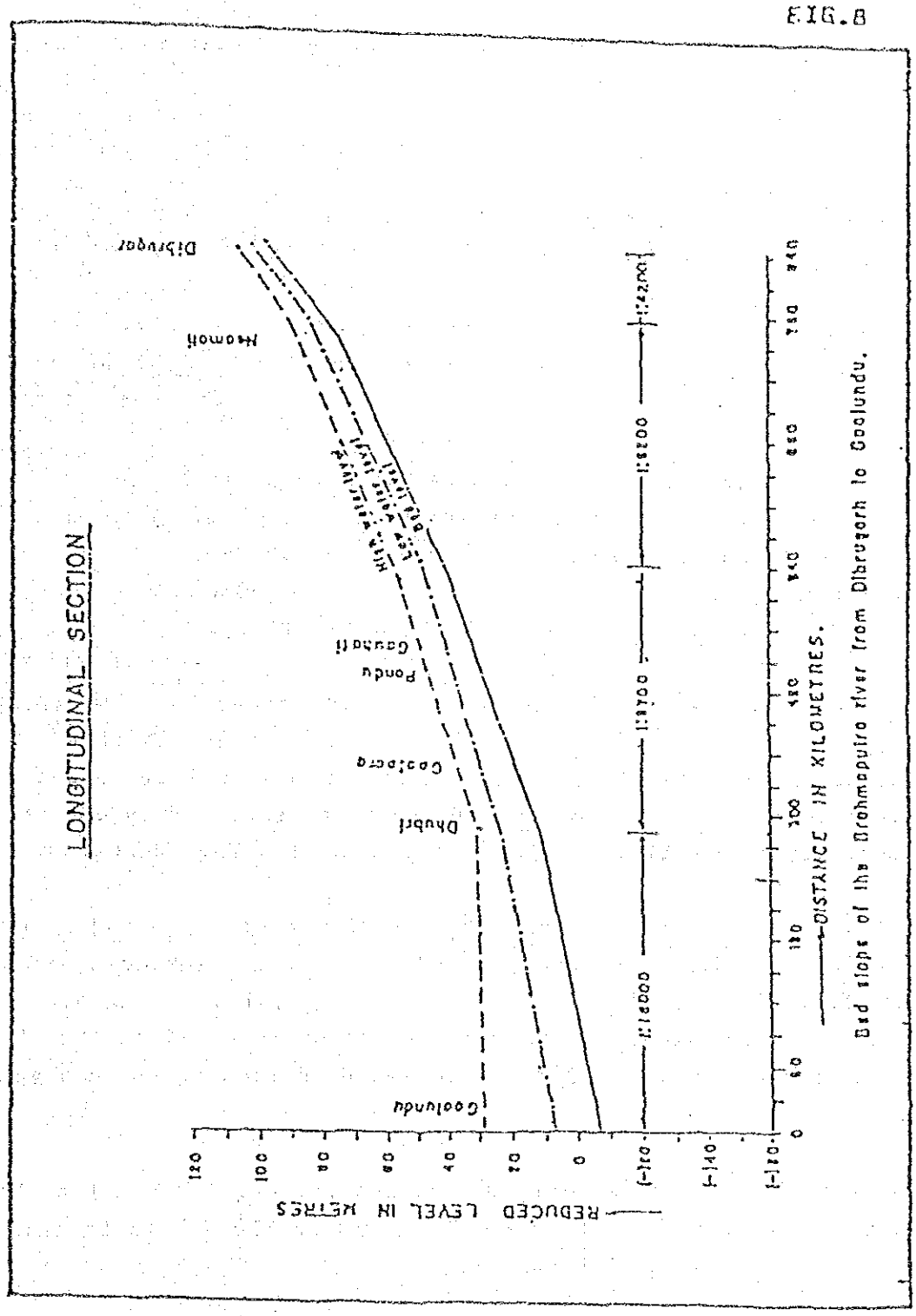


FIG.7



Average monthly discharge hydrograph of the Brahmaputra.

FIG.8


LONGITUDINAL SECTION
Dibrugar
Mamoth
Gauhati
Pandu
Goalpara
Dhubri
Goolundu
REDUCED LEVEL IN METRES
DISTANCE IN KILOMETRES.
Bed slope of the Brahmaputra river from Dibrugarh to Goolundu.

On the basis of elevation and porbable discharge the figures appear to be as follows:-

Zone	$\frac{Q}{3}$	H	G	Energy
1. 400mm	144/sc	3355	9.8	4.7×10^6 kw
2. 800mm	228	2745	" "	7.75×10^6 "
3.1500mm	332	1525	" "	5.00×10^6 "
4.2500mm	297	915	" "	2.07×10^6 "
5.3750mm	225	305	" "	0.07×10^6 "
				20.9×10^6=21000mw.

The above theoritical energy can be broken down as below:-

a. Basin energy inclusive of surface flow = 21000mw.
b. Energy of concentrated river courses = 14000mw.
c. Technically feasible 43% of a = 6020mw.
d. Continous energy 14% of a = 2000mw.

From the above analysis it can be said that commercially feasible energy of Bhutan lies near about 4000mw,which comes 20% of total theoritical potential (21,000mw). As Bhutan will not be able to consume this large block of hydropower in foreseeable future,it is possible to export to neighbouring countries for economic benefit.

The nature of rivers are streight and valleys are deep and narrow which is suitable for runoff type of river schemes.As gradient is sharp ie 3000 meters in 200km ie 25 meter drop per km the area is not suitable for reservior schemes.Due to sharp gradient the river has volocity 0.6m sec to 3 meter/sec at different times in a year (see fig..11...)

Reservior area is limited only at the out let part in the foot hill region where rivers are flat and have wide valleys.This is true in case of the Manas and the Sankosh.

Rivers Systems of Bhutan:-

Rivers systems of Bhutan are important not only for water resources but also they have developed wide valleys in the head regions which have helped to flourish the Bhutanese culture and civilization. The important river valleys are Thimpu, Paro, Punakha, He, Bhumthang, Teshigang etc.

The main river system of Bhutan are following(from east to west):-

1. Nyera Amari
2. Dhansiri river
3. Manas or Gong Ri
4. Mao or Ale river
5. Sankosh or Tshangchu
6. Raidak or Wangchu
7. Amochu or Torsa river
8. Jiti river

INVENTORY OF RIVERS BASED UPON 1:250,000 scale Mao

From East to West:-

Primary		Secondary and teritary	
1. Nyera Amari river	90km.	a. Dish Lal Nadi	20km
		b. Richhong Ri (Chenle Ri)	30km(Ri or Chu means river)
		c. no name	12km
Total length	90km		62km.
2. Dhansiri river	55km	a. Jumri(Chumchu)	22km
3. Manas or Gongri	110km	b. Kuri or Uri	12 "
		c. Gamrichu	50 "
		d. Kulong or Teshiga -yang chechu	60km
		i. Wohmung chu	28 "
		ii. Kurichu	75 "
		e. Bigger chu(Behlungchu)	38km
		f. Tongsa(Mogden chu)	150"
		i. Bhumthang river (Murchhangu chu)	60km
		ii. Burgong chu	38km
		iii. Ranji gang chu	20km
		iv. Langte (Nechu)	45km

Subdivisions of 3E1 Bhumthang:-

a. Teng chu 42km
b. Chamkhar (Chamokha chu) 32km
Total 74km

Subdivisions of 3E18

a. Mela chu 20km
b. Chakoe chu 20km
Total 40km

Total 110, 360, 292, 129.

4. Hao (Ale river22km)
   a. no name 12km
   b. Gokechu (Gong khola) 20km
   c. Tirkhola 16km
   Total 22km — Total 50km

5. Between Hao & Manas
6. Sankosh(Tshangchu) 105km.
   a. Dagnachu 50km
      i. no name 15km.
   b. Changchu Khola 20km
   c. Burichu 33km.
      i. Larechu 20km.
   d. Hochu 40km
      i. no name 10km.
   e. Sheongchu 45km
   f. Phochu 97km.
      i. no name 22km (N-E of Phobijika)
      ii. no name(W of Lunana) 35km
      iii. no name(E of Lunana) 15km
   g. Punakha(Mochu)65km.
      i. no name(E of Nora) 12km
      ii. no name(W of Gasa) 22km
      iii. no name(S of Gasa) 17km

P= 105km — S=350 — T= 173

Raidak river (Wangchu)	125km.	a. Pipingchu	32km.	i. no name	22km (Shari)
				ii. no name	17km(S of Drugeldzor
		b. Ha Chu	55km.		
		c. Parochu	70km.	i. no name	17km.
		d. Thimpu Chu	37km		
		e. no name	22km (south of Thimpu)		
	125km.		166km		34km.
Amochu(Torsa river)	85km.	a. no name	35km (near Dungna)		
		b. no name	25km (" ")		
	85km		60km		

iti river 18km.
no name(near Kopche) 15km.

Grand total length:-

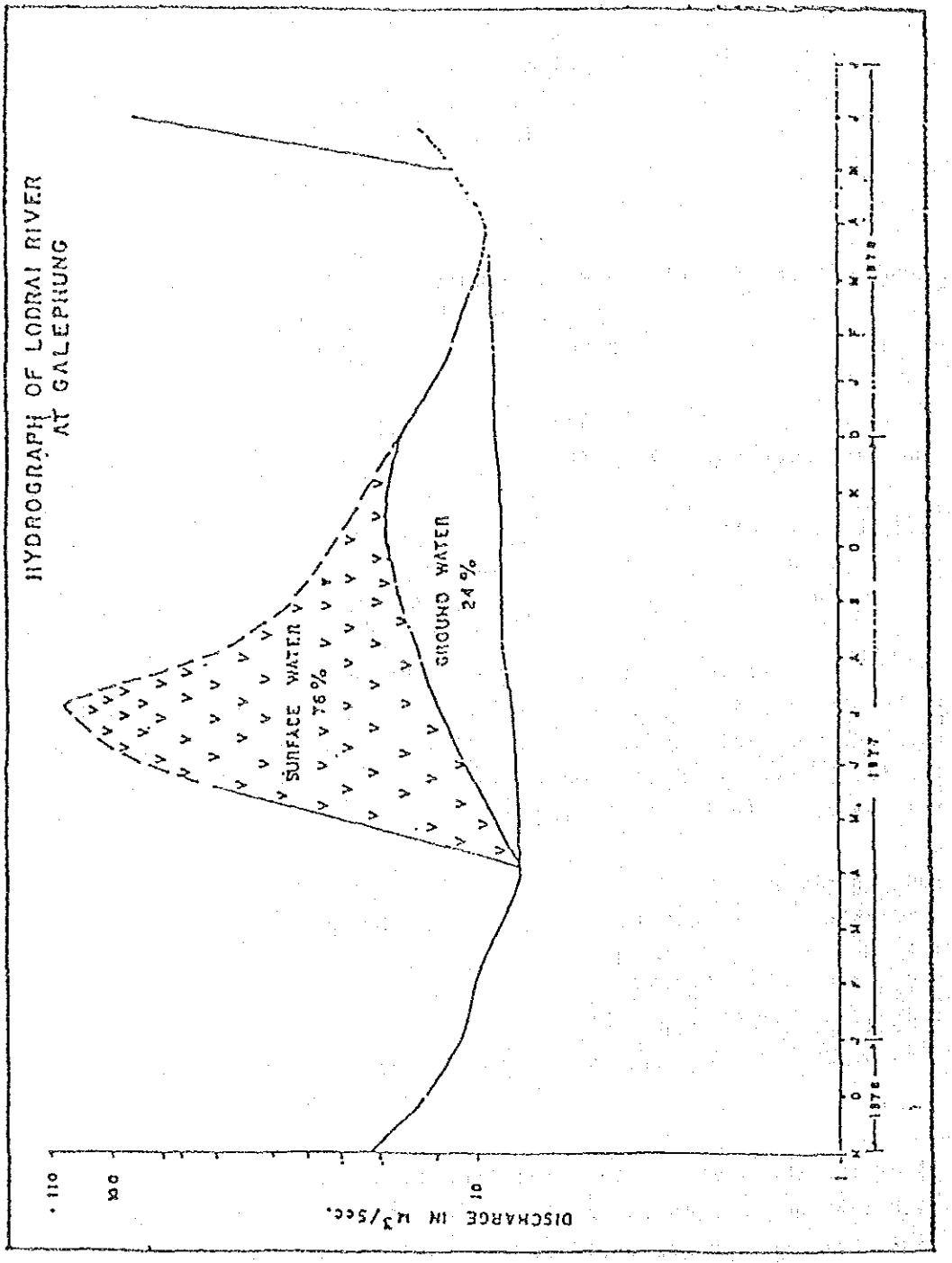
Primary	Secondary
654km.	998km.

The above figure indicates that the 72,80 sq.,km.,is covered by per sq.,length of primery river if secondary is included it comes to 2,60 sq.,km.,.This indicates that the topography is hard and density of primary river is 0.0138 which is less as compared to rivers of Nepal,as shown in the following table:-

Snow fed river		Non snow fed river	
1. Sunkosh	0.0165	1. Kankai	0.066
2. Arun	0.0150	2. Kamala	0.054
3. Tamur	0.0335	3. Bagmati	0.045
4. Kaligandaki	0.0260	4. Babai	0.058
5. Karnali	0.016227	5. Jimruk	0.075
		6. West Rapti	0.0395

Out of the above rivers the most important are the Manas,the Sunkosh the Raidak and the Amochu or Torsa.Only the Torsa river rises in the Tibet whereas rest originate in the southern part of Himalayas of Bhutan.Except the Manas and the Sankosh all the rivers flow towards south east of Bhutanese territory whereas,the Manas and the Sunkosh'

FIG.9


HYDROGRAPH OF LODRAI RIVER
AT GALEPHUNG
SURFACE WATER
76%
GROUND WATER
24%
DISCHARGE IN M³/Sec.

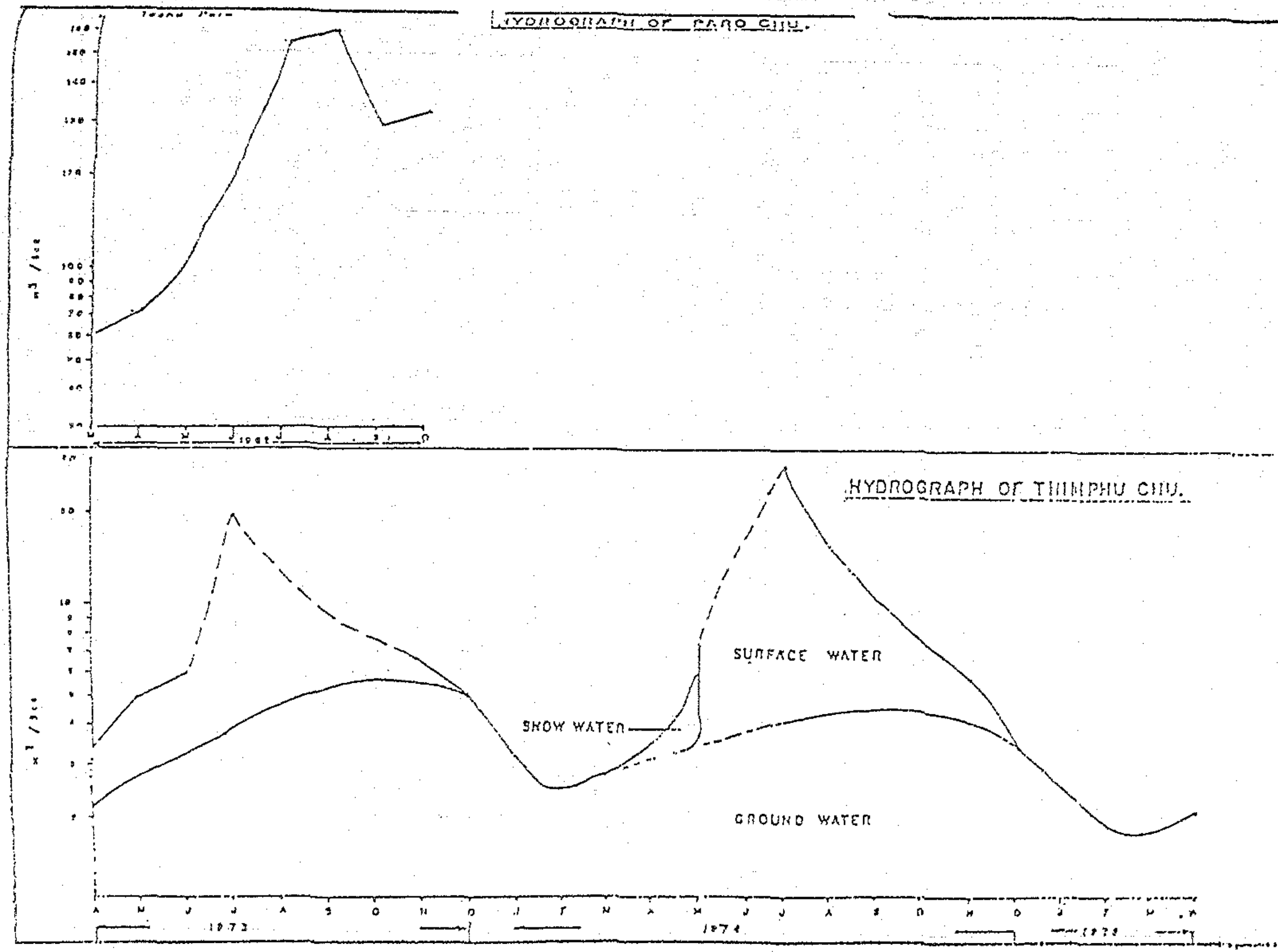
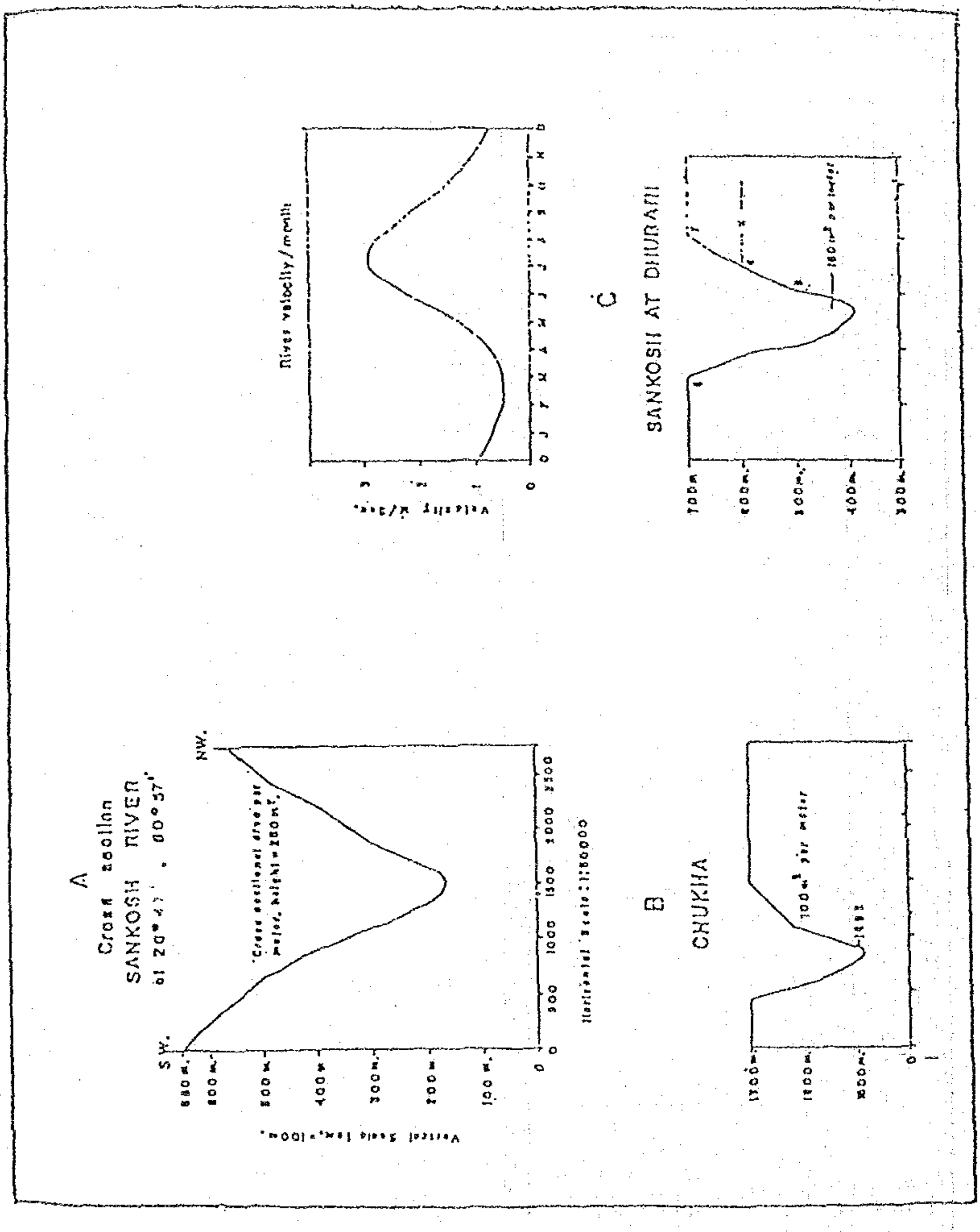

HYDROGRAPH OF PARO CHU.
HYDROGRAPH OF THIMPHU CHU.
SURFACE WATER
SNOW WATER
GROUND WATER
1973
1974

FIG. 10

FIG.11



flows towards the south west. The catchment areas of rivers are cover with the forest and hard rock with the result, the sediment transport and erosion are limited The hydrograph of the Brahmputra indicates the ratio of low to high flow in neerly 10 times at Pandu (upper reaches) and 12 times at Bahadurbed (lower reaches). Like wise rivers of Bhutan will behave in similar fashion as that of the Brahmputra.

This characteristics is seen in the rivers of Bhutan which have low and high flow ratio 16 to 30 times and this helps much in the water resources development without reservior system.

These rivers also recharge the ground water equifers in the foot hill region and are also fed by ground water system in the hills. It is observed that from the nature of river hydrograph contribution to the low flow by ground water is more significant as compared to snow melt. However, the rain fall being spread all over the year has also helped much in reducing the rigorasity of the rivers, ie flood in rainy season and low flow in the summer. If immediate rain fell part is deducted the ground water contribution becomes smaller to the river.

These rivers have developed terraces in the foot hill regions wherees, in the mountains except in upper reeches the river terraces are very few. There appears two old river terrace at Paro and at Thimpu and the river terraces are sloping towards the river. The discharge and other characteristic of some of the rivers are given in table at the end (Annexe) and represented in Hydrograph Fig 9 to 11.

Utilisation:-

At present Bhutan is importing electricity for the southern belt from adjoining part of India. However Bhutan has also developed many mini and micro hydro plants.

1. Power:-
2. Mini Hydro plant:-

Gita com	1.25 Mw.
Thimpu	0.36 "
Paro	0.40 "
Wangdiphodrang	0.30 "
Tashigang	0.75 "
Mongar	0.39 "
	3.45 "

On the top of the above generation, nearly 1315.5x10^6 kwh is purchased annually from India.

b. Major plant:-

A big hydroelectric at Chukka is on its way to completion. In th first phase the capacity is 4x84mw=336mw operating under a head of 466m. A 40 meter high gravity type diversion dam and head race tunnel of 6.5km long and 4.9m diameter, surge shaft 12m dia and two presure shafts of each 3m diameter will generate power in under ground power station. The estimated cost is about US$ 187 to 250 million.

2. Irrigation:-

In irrigation sector much had been done particularly in the hill and lift irrigation system.

The following is a list of irrigation coverage in different districts. The cost of lift irrigation is becoming expensive as cost of electricity is about 60 paise per unit.

	District	Total command area	
1.	Thimpu	5045 acres hill area	
2.	Paro	414	
3.	Haa	100	
4.	Punakha	491	
5.	Wangdi Phodrang	2247	
6.	Gasa	nil	
7.	Tongsa	122	
8.	Bhumthang	nil	
9.	Shemgang	404	
10.	Daga	393	
11.	Tashigang	5460	
12.	Pema Gyel shel	133	
13.	Mongar	500	
14.	Luntshi	1245.5	
15.	Phunsoling	4745	southern zone
16.	Galephung	7320	lift irrigation
17.	Chirang	203	
18.	Samdrup Jonkar	1540	
		31370.5 acres.	

In the above hill irrigation schemes, generelly the idle length of canal is at present 6 to 7 km and may be 10 to 12 km in future schemes. One lift irrigation is seen in Galephung area.

The details are as follows:-

1. No of intakes 3 (Two are operating)
2. No of pumps 2 (one will be added)
3. Capacity 20 cusec
4. Lift 17 meter
5. Length of main canal 6.85km.
6. Length of distributaries 21km.
7. Capacity 20 cusec up to 2.5 and 25 cusec beyond
8. Command area 2000 acres
9. Requirement of water 20 cusec

In the second stage the lift will be about 121 meter.

3. Drinking Water:-

For centuries people lived either near the river or walked several kilometers to fetch the water. Now many areas are under piped supply tapping surface water. Piped drinking water is supplied in most of the district head quarters of Bhutan. Samdrup Jonkar has a well and lift arrangement to supply water. Except limited area there appears to be no problem of drinking water.

By 1980, 150 units of rural and 25 in the urban water supply schemes were completed and now nearly 48 schemes are in progress in the rural parts of Bhutan.

GROUND WATER

The hard and impervious rocks of the hills are not suitable for percolation and storage of ground water except in the weak and faulted zones which help as a secondary porosity to preserve the ground water.Most of the springs from where the water is now supplied either for irrigation or drinking water,are located in the fractured zones.A systematic survey of such weak zones with springs will help Bhutan not only in the selection and identification of cheap drinking water projects but also for drilling in hard rock to tap the most of the spring water.In valleys like Thimpu and Paro nearly 16m gravel deposits are found in the mid part valley.At present the surface water and springs are found to be sufficient in hills not to warrant the ground water development.

In plain area the drinking water is a problem at Pagli,Samdrup Jonkar and Phunsoling where water is supplied for two times a day.It becomes acute during the summer when most of the rivers dry up. In irrigation sector,during Feburary and March. the small supply from contour canals also,dries up and this creates problem for 2nd.,crop even though sometimes there are scattered showers of rain.For third crop there is always a problem.

To have assurred round the year irrigation as well as to supply drinking and indudtrial water,Bhutan Govt.,has shown interest in the search and the development of the ground water.

The ground water is a part of hydrologic cycle and influenced by the rock system.It is necessary to analyse each of parameters like rain fall,surface water,rock and terrain.

The following are the conclusions derived from the study of various physical parameters, discussed in earlier chapters.

Bhutan has ample rain fall and the rain fall is spread practically round the year hence additional water requirment will be little to meet the evapotranspiration need,which varies from place to place but can be estimated 1 meter in total.The total rain fall figure varies from 1600 to 5441mm,which if refined in course of time will give a better picture.To be on safer side the available rain fall is assumed to be above 1152mm and may be around 3000mm per annum in specific places.

Rocksin the hills are unfavourable for ground water storage except in valleys where at present there is sufficient water which if required can be lifted up.

As Bhutan is covered nearly 70% of land surface by various types of forest,she is fortunate to have very few land slides as compared to other part of Himalayas,but rivers are becoming wild and rivers training in Pero and other places are now essential.As hard rocks covers most of the area in hills the agriculture is done only in the valleys.In areas where soft rock has been found,people have cultivated and irrigated by contour canal and in few years time they have lost their entire field due to slides.(This feature is seen near the bridge at Sarbhang).

Toooqraphic analysis:-

Bhutan has limited plain and more slopy area at the foot hill, suitable for irrigation and agriculture development,consequently the requirament of the ground water will be small.

From topographic maps the following areas are found to be reasonably sloping for agriculture development and from general analysis suitable for ground water investigation and development.

	Name of the area	Size of the area	Elevation	Name of near by river
1.	Nainital	1.5x3km	(gradient) 400-500,1:5	Chung Patan Perenial
2.	Chengmari	1x2.5km	320-440(1:11)	Diana perenial
3.	Samchi	4x4.4	300-460 (1:3)	Chamarchi river (perenial)
4.	Gokti (near cement Factory)	1x0.5	280-320 (1:25)	Suktinadi (seasonal)
5.	Pagli	2.C5	340-400(1:33)	Pagli nadi(seasona

In the north of the area a highly dense and steep topography is observed whereas, the southern area which falls in India has more smoother contours. Near by peaks in the north have elevation 632m, 1018m, 1120m, 879m, 962m, respectively. (see Fig. 12).

Topography analysis indicates that better prospects exists in Pagli Khati and Samchi area and unfavourable in Changmari and Nainital.

FS

1. Phunsoling	1x0.7	200-240(1:25)	Dute Khola& Torsa perenial.
2. Kali Khola	2x1.5	420-440(1:50)	Kali Khola
		440-700(1:4)	perenial

Very steep topography and flat area are found in the north and south respectively. The terrace is 6 to 16km high from the river bed at Phunsoling whereas, at Kali khola terrace level is 45m elevation on the average.

The nearest peak at Kali khola is 1019m. In Phunsoling area ground water potential exists in lower part at Indo-Bhutan border.

D

1. Samatung	3x0,7	300-320 (1:25)	Tungkhola
		320-360 (1:10)	Perenial
2. Kewal Tar	1.5x1.5	300-400 (1:15)	Shistikhola pernial

D/13

Area between Dysa nadi to Gobar kund nadi	14x2	200-300 (1:20)	Gobar kund area
		280-360 (1:25)	Dysanadi area

In this area the symptom of recharge is seen as the river goes under ground from a reasonable distance. In Gobar kund area the terrace is 50m., above the river bed whereas, it is 6 to 8m., above river bed, at the Dysanadi area. Though this area is under the forest, it may be cleared in future if more agriculture land is needed, as it has better potential for ground water.

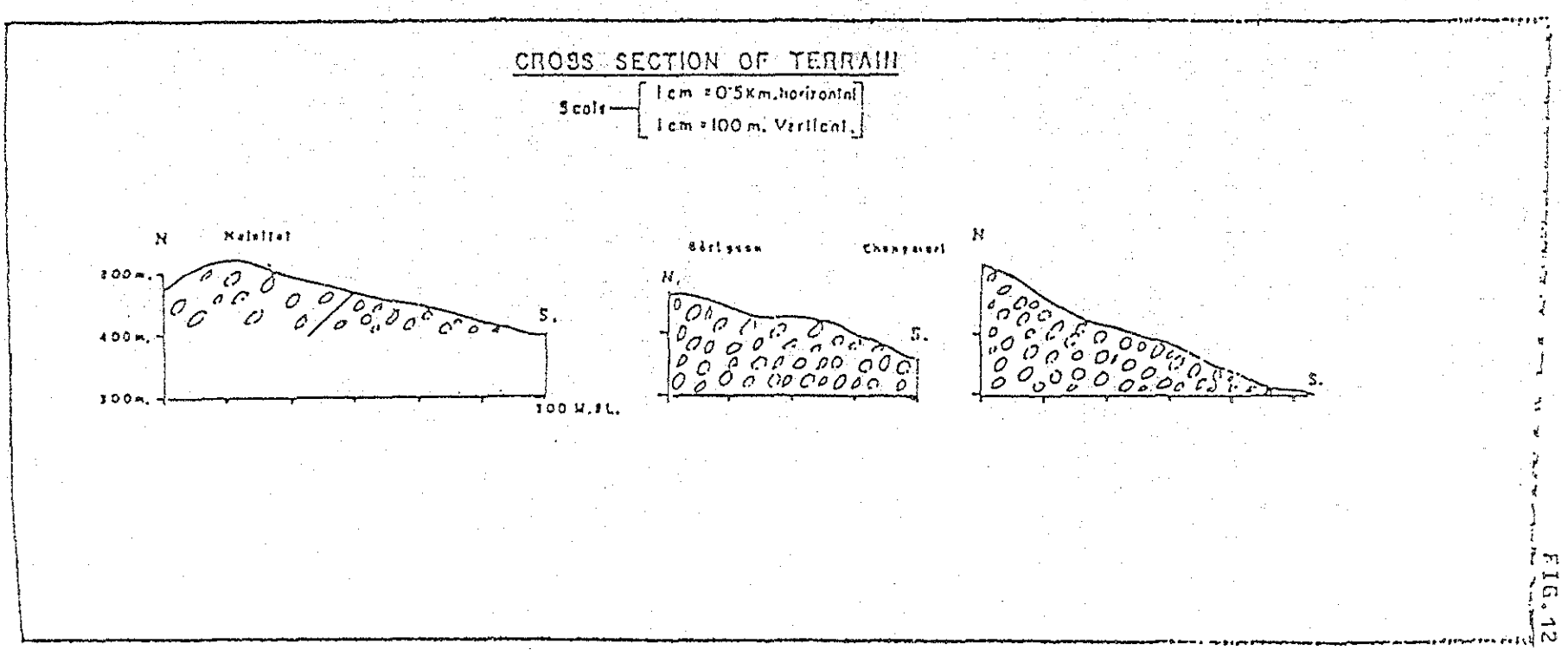

CROSS SECTION OF TERRAIN
Scale
1 cm = 0·5 Km. horizontal
1 cm = 100 m. Vertical
N
Kalaltat
500 m.
400 m.
300 m.
S.
100 M.S.L.
N.
S.
N
S.

FIG. 12

j. The Manas river is 200 to 300m.,wide at the out let part in Bhutan. There is a terrace 1.5x1km.,which has elevation from 180 to 200m. This area may be good for lift irrigation

Map 78/I

i. Charphuli to Suti Nadi 7x2km.,100-200 (1:2)

South east of the area in the Indian territory three spring line lakes were observed.They are Kohal Suri bil ,Chanmari bil and Dhel dhela bil.The Rabang nadi gains water and Charphuli nadi loses water indicating ground water recherge.The river bed is 12 meter below the land surface.North of.Charphuli area the terrain is steep and the elevation renges from 967 to 1082m.In the south flat land and dense forest area (with broad leaved tree and 3 meter high elephant grass) are found.

78N/5

Only the western part has some flat area of 300 to 400m.,elevation, where the river gains and loses water indicating ground water system working in that area.The northern part has relatively flat conrours and elevation is 1066 meter.

76N/9

Samdrup Jonkar has flat terrace and the elevation varies 180 to 200m.The available area is 0.5x1.5m.Development site for the ground water appears in the central part of the area.In the north hills have bad land topographic feature like Siwalik rocks in other parts of himalayas.The rivers are perenial and lose and gain water.

The course of Barnadi has terrace all along for distance of 9km., on either side.The terrace lies at 6 to 12 meter above the river bed and the elevation of terrace is 180 to 220m.,on the average.

Kalapara flat area 0.5x1km 200 to 240m.

1. In this area, it is found that the river loses water in India. The southern part in India has a flat land with forest and tall grasses.

2. Between the Chamrang Nadi and th Kalapani Nadi a comparatively flat area of 260-380m., elevation is seen. This size of the area is 3x1km., and gradient is 1:12. The Chamrang nadi loses water in India.

3. Some flat area of 340 to 360 elevation are found at Khirkhria near the Kampajuli nadi. Near by river loses water just above the terrace and gains water down below, indicating that ground water recharge and discharge are occurring.

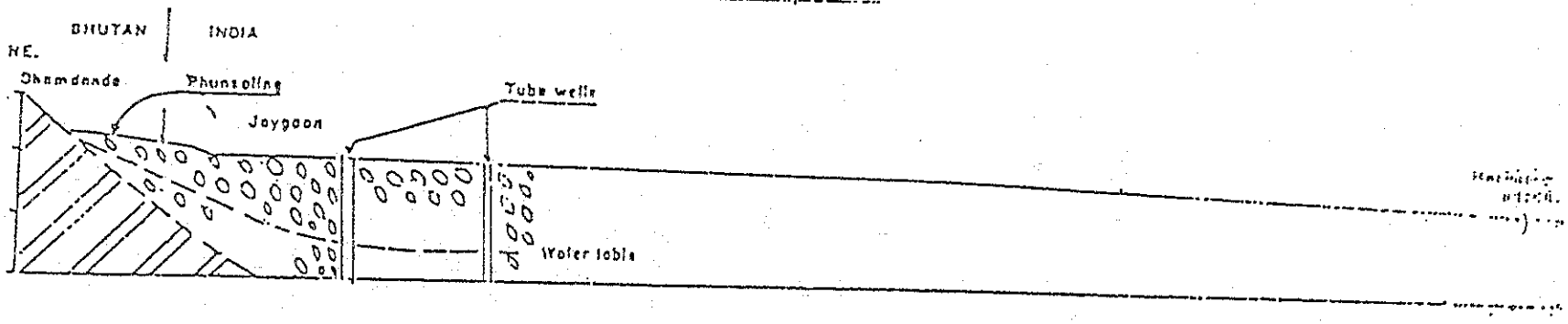
4. Conclusions:-

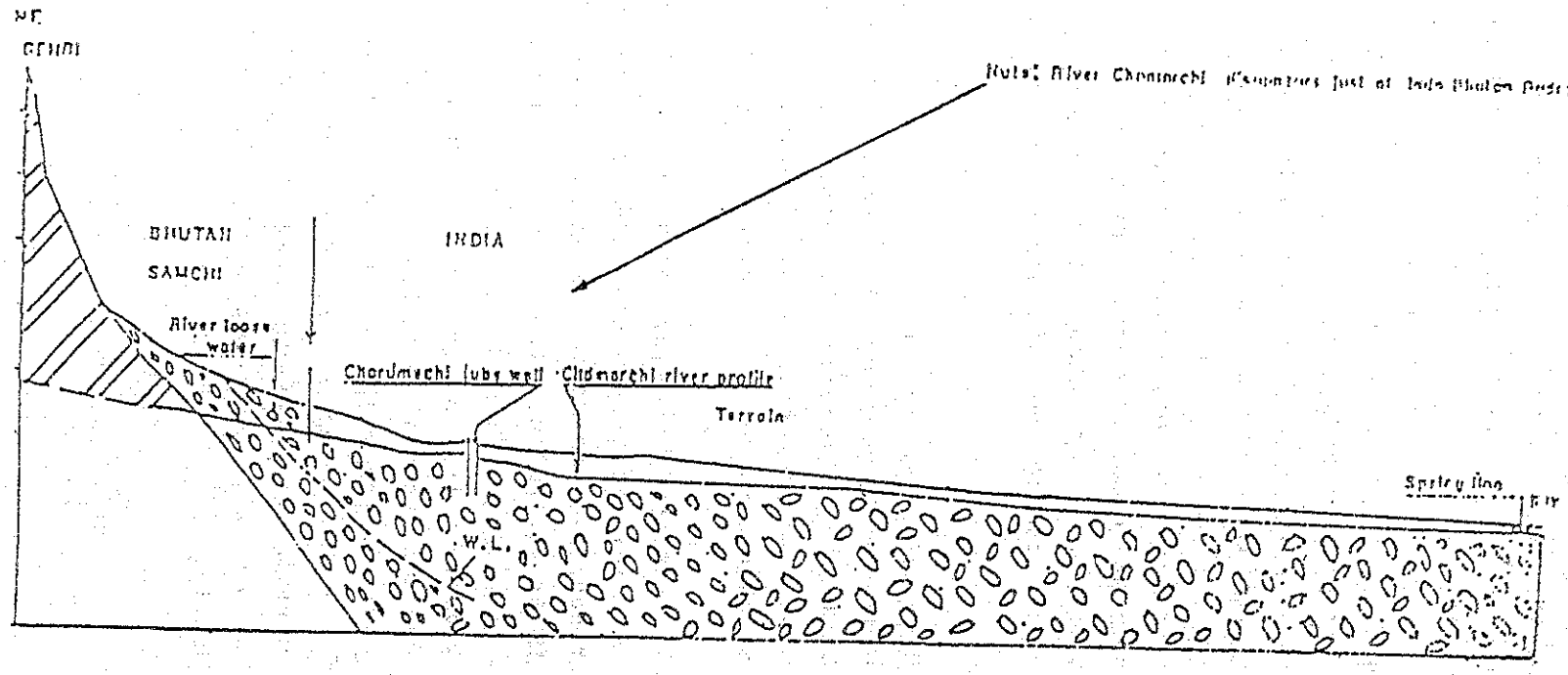
1. From the above study it is seen that the south eastern part of Bhutan has comparatively better chance for ground water development than the west. However limited areas in the west also can be developed under the ground water.

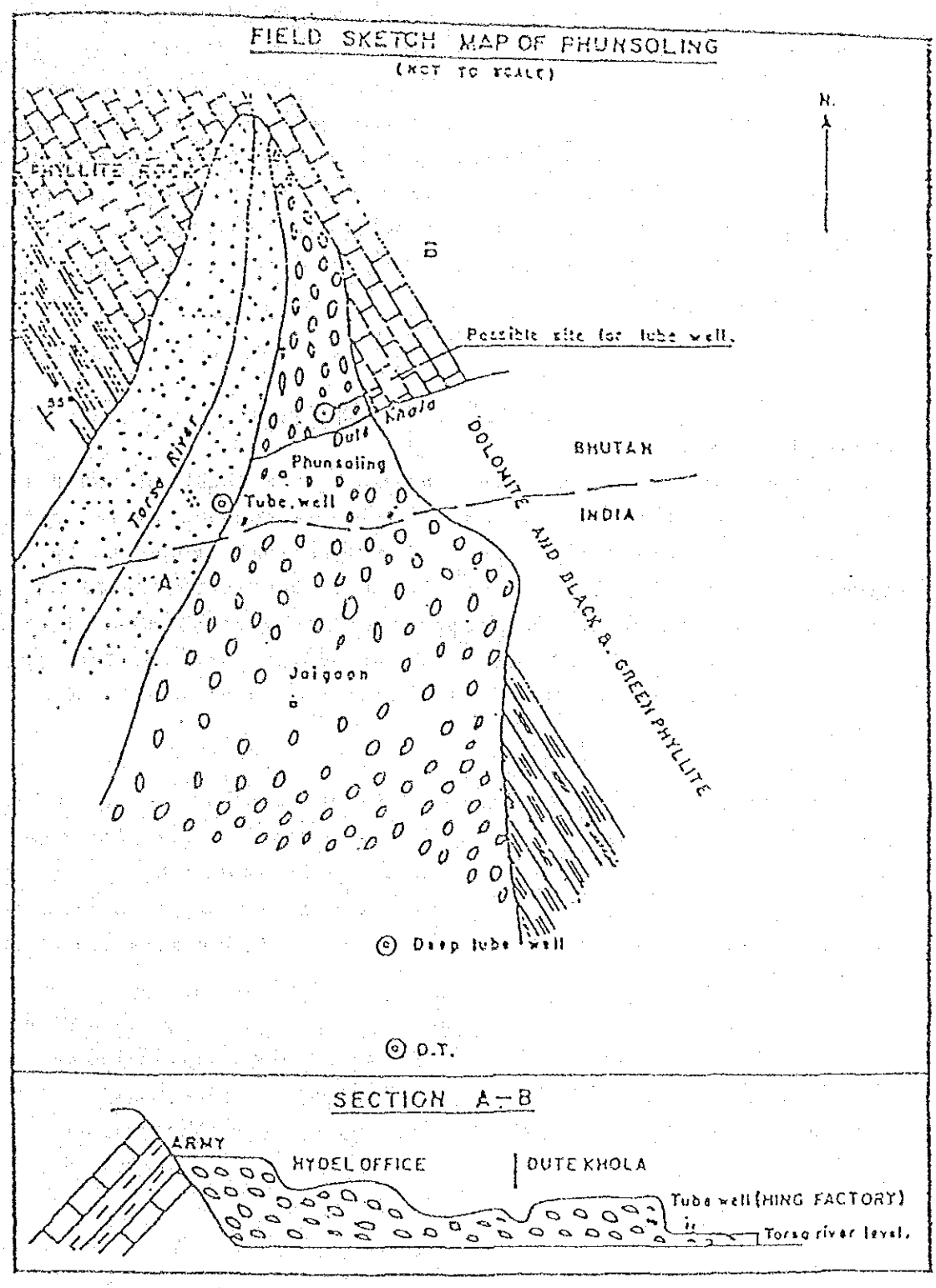
2. In this study some of the forest area has been included, as Bhutan has limited agriculture land, the area under forest where water resources seems to be adequate may be converted in the future in to agriculture land.

3. Surface water and ground water needs to be augumented for the conjunctive use, in order to balance the slide problem as well as to increase the command area in the low flow season of the river when water is required utmost for agriculture and domestic uses. In mucnicipaluse also ground water can be pumped directly without any treatment which will finally help in financial savings.

TYPICAL SECTION






FIELD SKETCH MAP OF PHUNSOLING
(NOT TO SCALE)
N.
PHYLLITE ROCK
B
Possible site for tube well.
Khola
Dute
Phunsoling
Tube well
Torsa River
DOLOMITE
BHUTAN
INDIA
A
Jaigaon
AND BLACK & GREEN PHYLLITE
Deep tube well
D.T.
SECTION A-B
ARMY
HYDEL OFFICE
DUTE KHOLA
Tube well (HING FACTORY)
Torsa river level.

Regional geological picture indicates that the alluvium deposit at the northern flank of the Brahmaputra river will be order of 250 meters minimum as the rivers like the Raidak the Sankosh and the Manas have respectively 40m,30m,70m,60m, elevation from M.S.L. at the junctions of the Brahmputra.If a trough fault like in the Gangetic plain is proved in that case the thickness of alluvium will be several 1000 meters.Hydrograph of the Brahmputra river impress that the contribution by the ground water is reasonably high and will spread.

FIELD OBSERVATIONS

Phunsoling Area:-

Geomorphologically the area is a notch inside the hill and hill go far south of Bhutan to India making a delta shape area in Bhutan. Phunsoling area has three levels of old terraces above the present river bed.From present river bed level of the Torsa,the first terrace is 3 meter high and second terrace is about 10 meter high where the office of Chukha hydel department is located.The upper most terrace where Army office is located is also nearly 10m., above the second.

The terrace consists of boulder gravel and sand in unsorted form and work as a recharge zone.Hing factory made 1m diameter dug well upto 11m depth in the river bed and is supplying the water to the factory.There is no dug well even in the Jaygaon area of India.Nargam Cinema hall area appears to be ideal site for first test well in Phunsoling.

The sketch map of Phunsoling is given in the fig..11.&.14On investigation it is found that West Bengal Govt.,has recently drilled one tube well south of Jayagaon and another is in progress.

The details are as follows:-

Test tube well:-

Total depth drilled	282' by precussion method.
Size of the well	10"163'
Size " " "	6"119'
Screan zone	165'
Water level	150'

Strata log:-

0-60'	Boulders
60-160	clay sand etc.

2nd. tube well is located nearly 1km., south of the first well

Strata:-

0-3	top soil etc
30-90	heavy boulder
90-102	coarse sand with clay
102-120	clay with coarse sand
120-140	coarse sand and clay
140-156	coarse sand with gravel
156-160	Yellow sticky clay (marker horizon)
160-175	coarse and medium to fine sand
175-180	yellow sticky clay
180-240	coarse sand
240-	drilling in progress
	water level 140 feet.
	Duration of drilling 2 to 3 months for a tube well.

On the basis of above data, it can be said that the gravel deposit in Phunsoling extends to greater depth and appears to be faulted block which may provide good aquifers. The depth of water table may be little bit lower than India ie 150 feet. With in a depth of 250 feet three groups of aquifers (one phreatic, two confined may be found.

:. Ghumaune area:-

In Ghumaune area the terrain slowly raises and finally on the top of the hill, a forest area is found. The soil is red coly epparently weatherd, phyllite. In the Ghumaune area several dug wells are found. They are located at the following places

:. Forest department.
:. Lakshman Chetri well.
). Lower terrace.
. At India near Bhutan boarder.

The dug well of the Forest department is located in a gully an is nearly 3 feet in diameter. The water level was at 30' below the surface in July 1982. The well is 75 feet deep and is said to dry up in the summer.

Nearly 30 feet below, in the same line practically at the gully Mr. Lakshman Chetri dug a 10 feet diameter well and depth was 70 feet and water table is nearly 5 feet below the surface and this well does not dry in the summer.

In the same line practically 100 meter (330 feet) below a dug well is found near Indo-Bhutan boarder on the east of the road which is also 3 feet in diameter and depth is unknown and remins as it is in summer ie water table is nearly at the surf

Follow ng the same slope coming to Indian territory, a dug well of 3 feet diameter and 32 feet deep is found where the water level stands at 20 feet and in summer it reaches to 28 feet ie 8 feet fluctuation. While digging they found gravel and boulders. It appears thet the same aquifer which is sloping wit the terrace is found in that area and like wise there may be deep aquifer.

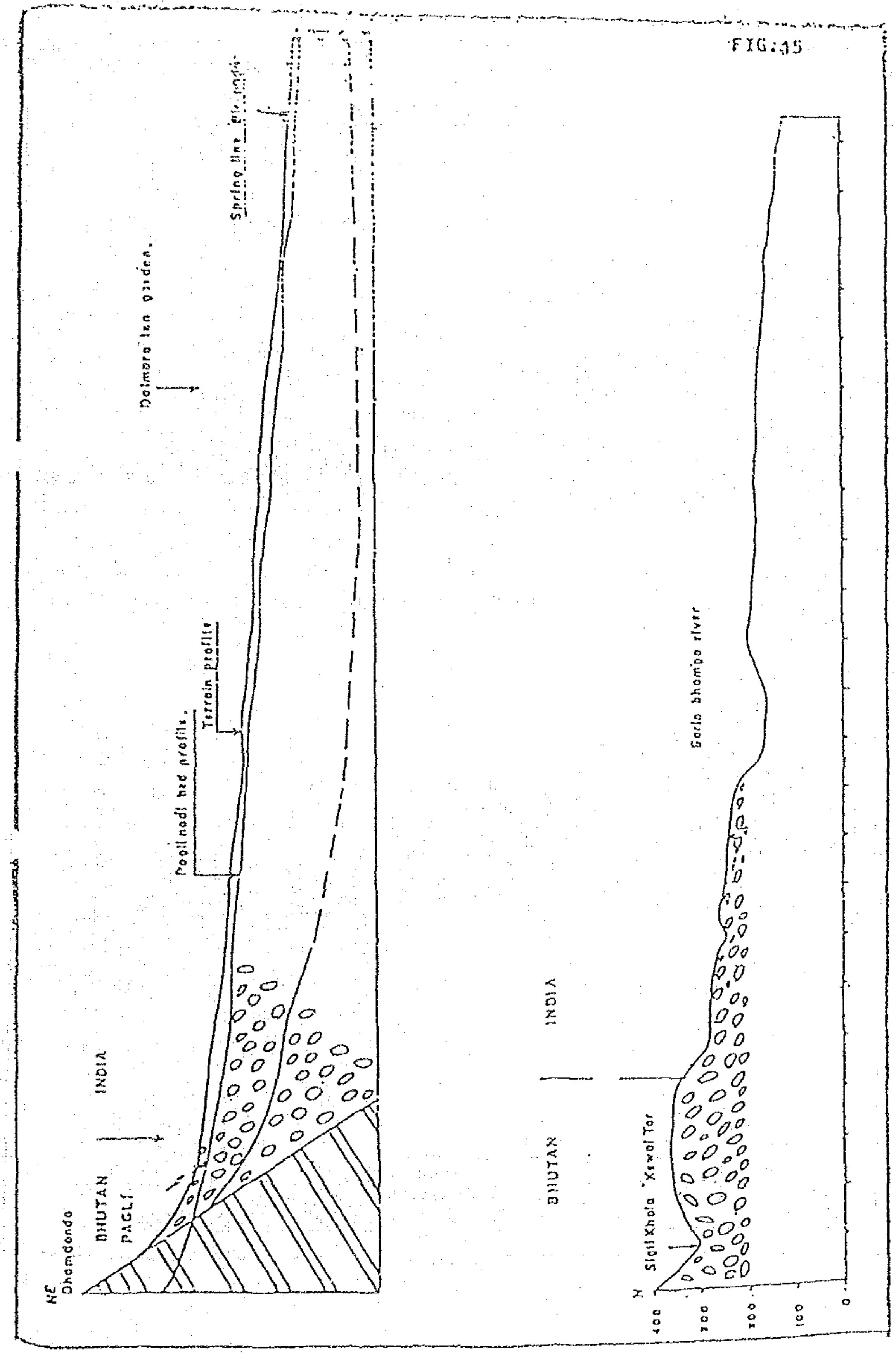
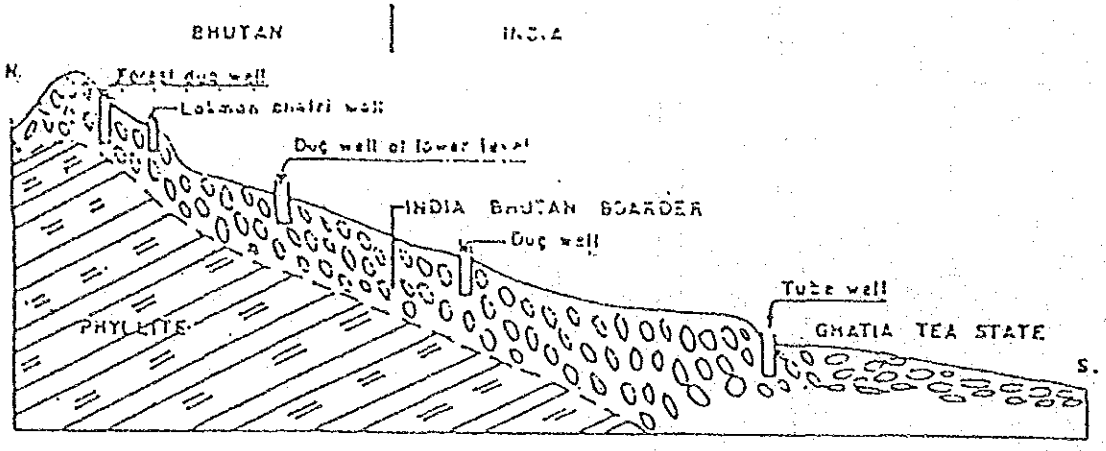

NE
Dhamdonda
BHUTAN
PAGLI
INDIA
Pagli nadi bed profile.
Terrain profile
BHUTAN
INDIA
N
400
300
200
100
0

FIG. 15

FIG. 16

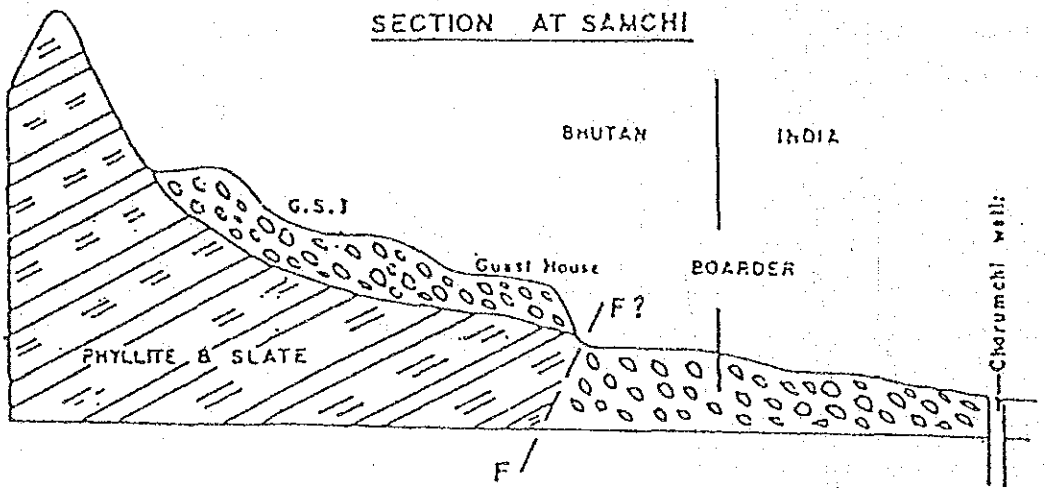
A

SECTION AT GHUMAUNE



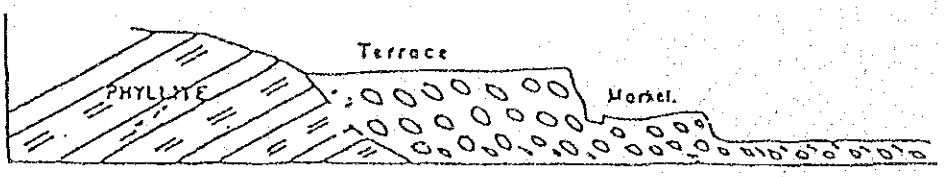
B

SECTION AT SAMCHI



C

SARBANG AREA



C. Samchi area

In Samchi area there are four levels terraces

1. Bhutan boarder zone
2. Market
3. Guest house
4. Geological survey of India compound

In Samchi for the drinking water piped water supply comes from a stream in the north and they do not have problem of drinking water.The terraces are covered with 10 feet layer of boulders and below it lies the basement rock of phyllite.Irrigation is being done by means of contour canel in the lower terrace of Bhutan boarder zone.The agriculture farm of 15 hectars located in the lower zone does not have sufficient water and a tube well can be drilled for them.The well will encounter boulder and sand horizons.Two kms., south of Bhutan boarder at Charmuchi a well was drilled by West Bengal Govt.,and the available details of the wells are as follows

Size of the well	10"x6"
Drilling depth	350'
Water level	265'
Depression	5' after 5000Gpm.
Sp.yield	1000G per foot

They have installed a 36 BHP motor and it is said it took six months to the contractor to drill that well.

D. Pendent Cement Factory Area:-

Pendent cement factory(Bhutan Govt.,undertaking) is located at the foot part of the hill in the east of Samchi.There most of the rivers are dry and water is tapped from the hill.In this area one deep well can be tested.(see fig. 15 & 16)

f. To Pagli:-

Between Pendent cement factory and Pagli village, most of the rivers are dry and topography of the area is smooth.Rivers are aggrading and guide bunds to protect Pagli are now found to be buried in the river bed.Water is supplied from stream in hills through pipe.There a tube well can be drilled but the problem is river aggradation which if not controlled will cover the entire agriculture land with boulder within few years.Engineering and geological solutions have to be found to control the rivers. At Bir Pada (India) which is nearly 15km south the spring line has been noted.

f. Galephung area:-

Compared to other foot hill part of Bhutan,Galephung have smooth topography and wide terrace.The terrace consists of boulder and gravel.No well has been drilled in this area.At present for town and some of villages and also for Sarbhang water is supplied from the hills.For irrigation a lift irrigation from the river Lodrai is developed to command 2000 acres with water duty 20 cusec.The capacity of pumps is 20x2=40 cusec which in the low flow season is unable to meet the demand.

Near Galephung in India territory people tried to dig a well and they went upto a depth of 50' and finally they had abandoned due to financial problem and boulder.Nearly 10km south of Bhutan boarder a dug well is found at the check post of Deosiri in India. The well is 3 feet in diameter and water table was 20 feet from surface (August 1982).From the above observation it is possible to drill several wells in Galephung area and water table may be order of 180 feet (estimated).

G. Sarbhang and Chiramg area:-

Five kilo,meter east of Sarbang near Akhaw a spring well constructed by Dantak while constructing the road was located.It is said that the well never dries up.

Sarbhang valley consist of pebble and boulders of slates and phyllite.The requirement of drinking water for the population terrace in the eastern part of Sarbhang,is met by the piped on the water.The rock dip 40° due north near the bridge.Sarbhang has enough water from Sarbhang river as well as from its tributary to meet the agriculture need.The mein problem is of slides and aggradation of the river.

Between Sarbhang and Dampu (Chirang valley) lies a hill which consists of lead grey phyllite at the base and then a thick well bedded and possibly repeated white quartzite which has produced several interesting high head water falls by the side of road on the way to Chirang.On the top lies micaceous schist and gneiss which are found to weather into red clay. At Damphu,water is supplied by piped water supply.For the future requirement a tube well can be drilled in the fractured zone.

H. Samdrup Jonkar:-

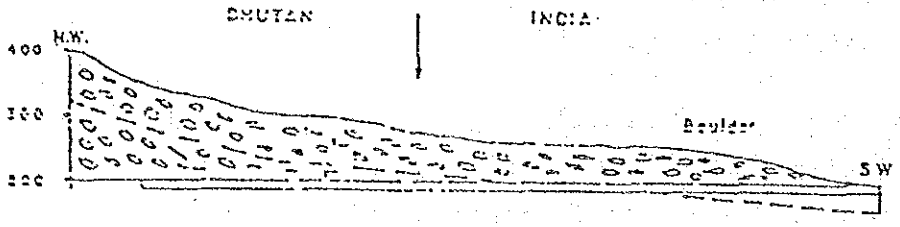
The area rises sharply and very limited area lies in Bhutan.For the drinking the piped water is supplied in some of the parts where as a large well 10 feet diameter is constructed in the river bed from where the water is lifted for the town, There are terraces in the area.The dug wells are found at the following places

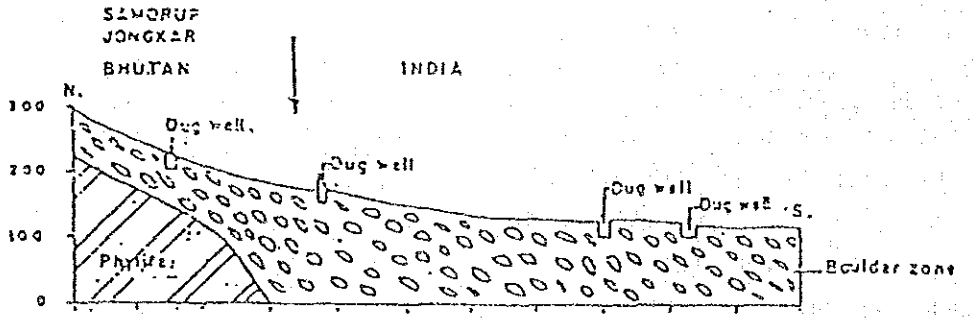
1. Market area (Ratanlal well 1960)
2. Kunfen Mills area
3. Hospital

In the area two dug wells are found one at the check post of Bhutan and other in India near Bhutan boarder.The water table is near to the surface and the well is nearly 2 meter deep and never dries up.It is located in the spring line as most of the rocks at the base are in sand stone and the shale dipping north.

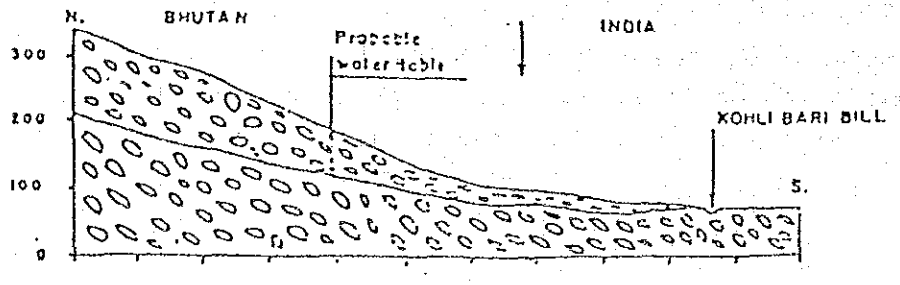
FIG. 17

SECTION WEST OF GOSAR KUNDANDI





EAST OF GARUCHANADI



In Indian boarder they have tapped the well at drainage point and the water table is near to the surface.

At Kunfen mill the gravel is found abutting the Siwalik rock.A small well of 30 feet deep was dug where the water level was found at 5 feet below the ground and it is said that it does not dry up in the summer months.

The hospital building is located on the Siwalik clay formation and a well was dug which started intercepting the sewage of septic tank and later on it was abandoned.

In south of Samdrup Jonkar,in India numerous dug wells are observed. As Siwalik dips north below the upper terrace sediment,well in Siwalik sand stone may bear ground water.(see fig: 17)

Over all Analysis:-

A critical analysis of the available data of surface water ic the hydrograph of the Lodrai river and water level fluctuation data of all the major rivers,lead to conclude that about 19 to 23 of the total river flow is contributed by the ground water system.The total flow is 58385 million^3,the ground water share will be 11717 million m^3.If converted in to daily discharge it will be order of 372 cumec.

In practice about 50% of the above can be tapped from a series of tube wells.However,this will lead to the depletion of base flow of the rivers,but at the same time there will be reduction in high flow by recharging of the reservior.

In the mountainous part,besides th using of the streams,ic ground water also can be tapped to augument the surface water in order to meet the domestic and agriculture needs.As ground water has uniform quality and temperature round the year,this will help not only in water supply but also in industry where uniform temperature and quality can be an asset.

Hore over Bhutan has numerous hot springs scattered in the northern zone.They need to be investigated fully for their commerical uses as well as for tourist industry.The geothermal energy can be used in room heating as well as in other energy replacement sectors, which could be exploited to Bhutan's benefit.

The aquifers in hill region consists of fractured dolomite quartizite and other faulted zones which provide enough secondary porosity for ground water percolation and retention.In selected area such zones can be tapped to meet the local demand of ground water.Fortunately, Bhutan has built roads all over the regions and have developed electricity in most of the districts it will not be difficult to ake the drilling rig and install pumps in those places.

In mountain valleys like Thimpu,Wangdiphodrang and Paro,the lift irrigation and tapping of mountain streams may meet the present demand of water,however for the future it will be advisable to have inventories of all the streams and ground water potentials of different regions.

Exploitations of the ground water in mountains of Bhutan may have the following benefits:-

Temperature moderation in colder places.
Industries where chemically treated water is not advisable ike beer and other processing units
When supply line is too long and expensive.

At present the Royal Government of Bhutan is interested to know the ground water resources of southern foot hill region,particularly. This also supports the view of consultant who feels that it is easier to start from the south and gradually cover the mountainous area in leter phases when Bhutanese nationals are competent to carry out the developmental work by themselves.

The southern Bhutan has anple rain fall and geology of foot hill and terrace indicates that at least 25 to 50% of the rain fall percolates down as a recharge to aquifer which comes out as a spring in far south in the Indian territory.

The fluctuation of water table at Ghumaone and Samorup Jonkar indicate suceptibility of aquifer system to react with the condition.Wells drilled in the adjoining parts of India indicate that theterrace material goes below the surface for several hundered feet,suggesting a faulted zone on the northern flank of Brahmputra velley which may be similar to Indo gangetic plain where thethickness of alluvium deposits amount to not less than 5000 feet at several places.If this is also proved by:series of drill holes, a new concept will come for development of ground water of Bhutan.Along with geological test holes,geophysical and pump testing of wells will definitely add new data and ideas for further development.Finally addition of data will help in better planning of the resources.The permeable nature of boulder and gravel at the foot hill region suggests that this area adjacent to the foot hill is a recharge zone for phreatic as well as semiconfined aquifer system of the northern plain of the Brahmputra river.This assumption is further reinforced by other evidence.

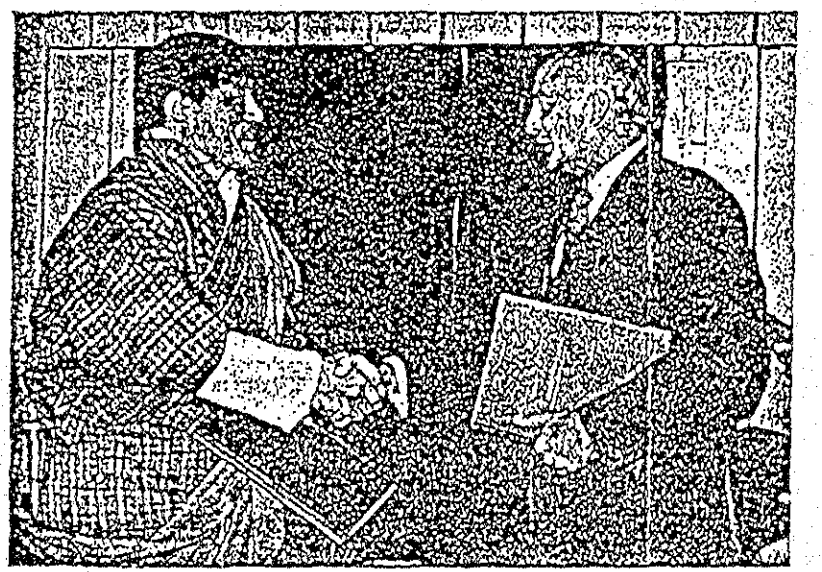
Firstly this is an area of high rain fall,secondly the available water level in the dug wells and resulting pattern suggest flow from thim formation out ward.Thirdly the fluctuation of water level in the dug well indicates at least more efficient recharge there than further down in India.The foot hill boulder and gravel grade into other finer sediment further south.

These all features indicate that transmissivity may be order of 1000,00 to 4000,00 gp d/per foot in this region which is comparable to Bhabhar zone of Nepal.

This area can only be drilled by percussion machine and it may take 2 to 3 months to complete a well.As there is enough recharge the water quality will be good.

Kuensel Aug. 5. 89

Agricultural development for Geylegphug



An agreement reached : Dasho C. Dorji with Mr. N. Dayal

Bhutan and India sighed a Nu. 51.576 million agreement for the Geylegphug Integrated Area Development Project.

The project, to be started in 1989-90 for a five-year period, will emphasise on agricultural development with an allocation of Nu. 41.164 million. The balance of Nu. 10.406 million will be spent on the development of livestock and poultry.

The project is aimed at increasing food production, the income, and the living standard of the people.

About 2558 acres of land will be brought under irrigation, apart from improving existing irrigational channels which cover about 2700 acres.

The Bhur Agricultural Research Station will be developed and upgraded to a regional station with better extension training programmes and seed multiplication. A pig and poultry breeding center will be set up at Sarbhang.

Since one of the major problems faced by the farmers is a shortage of money to buy agricultural inputs, the project will include an agricultural credit system.

Some of the other activities of the project are soil and land resource assessment, soil conservation, manure and compost sheds, development of manpower and agricultural extension facilities, establishment of a statistical cum information unit, and horticultural development.

Five consultants will come to Bhutan through the project to advise on areas like soil conservation, water management, and crops like sugar cane, rice, and oil seed.

In animal husbandry, the main objectives are to achieve self-sufficiency in milk and milk products, and to raise the per capita income of the farmer through improved livestock and increased production.

The agreement was signed on Thursday in Thimphu by the Indian Ambassador to Bhutan, Mr. Narashwar Dayal, and the Deputy Minister for Planning, Dasho C. Dorji.

"Since cooperation was established between the two countries more than a quarter century ago," said Dasho C. Dorji, "Bhutan's economy has been transformed from a subsistence farming into a modern one. The past five years have been most gratifying, as many of the joint Indo-Bhutan projects like the east west highway have been completed."

"India stands committed to be a partner in Bhutan's development process, and this agreement is a part of that commitment," said Mr. Dayal who is at the tail end of his term in Bhutan.

According to Dasho Khandu Wangchuck, Director General in the Department of Agriculture, it has been the royal government's strategy in the Sixth Plan to identify and establish development projects. Geylegphug was chosen since it was suitable, because of existing infrastructure like the road network and the ability of the population to adapt to change.

A different experience

For Richard Snellen, the new project officer for the local office of the World Food Programme, Bhutan is a big change from his last station in Sudan. He calls it a "unique opportunity".

Caught in the middle of a civil war, Juba, where Snellen was stationed, was besieged for two years. With different factions stopping the food supplies, 250,000 people died of starvation, said Sneller.

UNICEF and WFP set up the "Operation Lifeline South Sudan" and delivered more than 60,000 tonnes of food by June this year.

Meanwhile for Bhutan, said Snellen, the buffer stock of 1,750 metric tonnes of cereal - 300 mt of sugar and 100 mt of oil - is on its way. This stock will be kept to tide over any interruption in the supply of essential goods into the country.

A WFP sub office will soon be set up in Phuntsholing to help FCE distribute food.

The WFP also plans to combine the school feeding project and the health project. Supplies for the dairy plant, scheduled to be commissioned by November, was also well under way, he said.