のリストを要請したところ以下のような回答を得た。

表５－５　資機材リスト

機材名	仕　様	数量
Bulldozer	21 t with ripper	4
	32 t with ripper	1
Motor Scraper	16 m^3	1
Shovel	0.4 m^3	3
	0.7 m^3	2
Toractor Shoval	1.2 m^3	2
	1.5 m^3	1
Track Crane	35 t	1
Motor Grader	3.1 m	1
Road Roller	10 t	1
Vibration Roller	4 t	2
	7 t	1
Compressor	50 ps	2
	80 ps	1
Diezel Generator	75 KWA	5
Vehicle	4WD Large	1
	4WD Small	2

出典）質問表回答

上記機材リストには道路建設工事に使用されるであろう機材や、分流構造物の維持管理には必要度が低いと思われる機材が含まれており、しかも数量が非常に多くなっているが、国内解析の時点で、上記リストは、車両を除き日本政府に正式に提出されたものとは別のＰＣ－１（おそらく原稿とおもわれるが確認できず）に記載された、建設工事に必要とされる機材リストそのものであることが判明した。当方の意図した質問の内容が先方に理解されていなかったようで、結果的にパキスタン側が本無償資金協力で調達を希望している資機材についての確かな情報を得ることはできなかった。

ただし、分流構造物の維持管理のための機材は、ほとんどが上記リスト内機材の中から選定されるものと考えられる。

また、流域保全計画に必要と考えられる機材については、ＦＡＯのコンセプトペーパーに示された、以下に示す内容以上の検討は現在行われていない。

＜ＦＡＯコンセプトレターに示されている無償資金協力で調達を期待する機材＞

建設機械、水平井戸掘削機、４ＷＤピックアップ（４台）、コンピュータシステム（４台）、ノートブックコンピュータ（２台）、複写機、ファックス、タイプライター、ポータブルビデオシステム、35mmカメラ（４台）、スライド映写機、一般事務機器、気象観測機器、空調機、発電機

現在のところ、パキスタン側は流域保全計画に必要となるであろう資機材についてはほとんど関心を示していないことから、基本設計調査にあたっては、パキスタン側、ＦＡＯ双方の機材計画を調整し、最終的なリストの作成を行うことが必要であろう。

5-5.事業実施計画

現在、基本設計調査が８月の末から９月にかけて予定されており、順調に作業が進めば、年内閣議、年明けＥ／Ｎ締結が考えられる。その後、コンサルタント選定、詳細設計、業者選定を経て工事開始が可能となるのは、早くても来年度初旬となろう。しかしながら、現地はその直後から雨期に入ることが予想されるため、当初は仮設工事、道路工事しか行うことができず、本格的な工事に掛かれるのは雨期の明ける１０月以降となる模様である。

現在、パキスタン側が想定している規模の洪水分流構造物建設工事のみであるなら、着工年度（来年度）内完成も十分可能と考えられる。工事内容はそれほど複雑でなく、基本的に現地業者で十分対応可能なものである。また、サイトは４カ所に分かれているが、Ｄ.Ｇカーン地区内には工事に対応できる技術を有した業者が数十社有り、能力の有るサブコントラクターを得ることはそれほど困難ではないとのことであるため、工期はある程度短期間に抑えられるものと考えられる。

しかしながら、現在明らかでない流域保全計画の内容によっては、長期の工事期間が必要となり、２年に渡る工事期間を計画しなければならない可能性も生じる。また、ＦＡＯ専門家の派遣時期との調整も必要になってくる。

現在ＦＡＯがカシュミール地域で行っている協力はあくまでソフト先行型であり、現地に入った専門家が試行錯誤しながら必要な施設、機材を整備してゆく方法で計画が実行されている。そのため、ＦＡＯの専門家は、施設機材の整備に関わるほとんどを、計画の初期段階に決定してしまう日本の無償資金協力との協調に多少違和感を感じるようである。

本調査時にはＦＡＯの専門家に対しても日本の無償資金協力制度、特に単年度主義であるため、援助決定後短期間ですべての業務を終了させなければならないことを説明し、日本の無償資金協力スケジュールを考慮に入れた流域保全計画の立案を要望しておいた。しかしながら、双方の協力手法の違いから、今後、計画が具体化するにつれ、日本の無償資金協力のスケジュールと合致しない内容が含まれる可能性も十分考えられる。

たとえば、デモンストレーション保全区域、デモンストレーション農場の選定などは、ＦＡＯ専門家が社会経済的調査（約６ヶ月を予定）を終えた後に行うのが理想的である。しかしながら、ＦＡＯの専門家を選定するだけで、普通早くて数カ月から１年は必要となるため、実際の無償工事においては、ＦＡＯ専門家の調査結果を待つ余裕はほとんど無いものと考えられる。

基本設計では、可能な限りＦＡＯの考える流域保全計画に合わせて無償資金協力の実施時期を調整する必要があろうが、内容によってはそれらを変更したり削除することも考慮に入れる必要があろう。

5-6.環境に対する影響

本調査対象地域であるミタワンヒルトレント地区は、パンジャブ州のほぼ中央に位置し、地域の西方を走るスレイマン山脈と、多くのヒルトレントが流下する山麓沖積平原と、沖積扇状平野とに大きく分けられる。

気候は乾燥気候帯に属し、夏季には最高気温が45'cに達する事もあり、生活環境は良いとは言えず、小集落が所々に点在し、人口密度も約210人/平方マイルである。

本計画では、ミタワンヒルトレント地区の流域保全を大きな柱としており、計画地域内上流域の植生を改善することが目的とされている。また、下流域では農作物等に多大な被害をもたらしている洪水を制御し、可能な限り作物栽培に活用しようとするものである。

プロジェクト開発のための道路が建設されれば、車馬の往来が可能になり、農産物を含めた物資の移動、物流が盛んになり、流域保全により地表水の流出が減少され地下水が涵養されるようになれば、住民の飲料水ほか生活用水が確保される事にもなり、生活環境も向上し、荒れ地に緑が戻り、荒廃した山々に木々が芽吹けば５年後、１０年後の農業への期待も大きく膨らみ、安心して農業開発に従事できるようになる。

5-7.事業便益と自立発展

ＰＣ－１では、洪水分流構造物は２５年発生率での洪水に対して十分耐えられる構造で設計されており、洪水被害解消による便益は、２５年間に起こりうる可能性の洪水被害額の総計を年平均したものを年間の便益としている。計算ではこの洪水被害解消による便益が全体の便益の約７５％を占め、現場では本計画は洪水防除計画と認識されている。

いっぽう、農産物の便益は、２５年間に起こりうる可能性の全ての洪水量を農業用水として活用した場合の農産物生産便益から、過去の実績を基にして計算した、洪水分流構造物が無い場合の２５年間の農業生産便益を差し引いたものの年平均を年間の便益としている。実際の計算では、分流構造物が無い場合は６年発生率の洪水までなら制御可能で、農業生産は増え続けるが、それ以上は洪水の被害が大きくなるため生産高は急激に低下し、８年発生率以上の大きな洪水が来ると収穫が皆無になると想定している。

基本的には便益計算方法はこれで妥当と考えられるが、農業生産の便益は過大な評価になっているものと考えられる。なぜなら、本計画は毎年流量が大きく変化する洪水を分流構造物で制御し、洪水流を水利権を持つ地域に優先的に分散させることで農業生産に活用しようとするものであり、毎年の水供給量を根本的に安定させ計画的な灌漑を行おうとするものではない。そのため、下流域においては、発生時期、規模が予知できない洪水に依存した不安定な農業を営む現状に根本的な変化はなく、計画的な営農を行うことは不可能なままである。以上から、農家は経験上安全性を考慮した作付けを継続し、決して冒険は行わない可能性が強い。たとえば、いくら洪水の制御が可能になったとしても、利用でき

る安定した水量が見込めない以上、農家が２５年発生率の大洪水を当てにして作付けを拡大することは現実には考えられない。以上から、洪水の灌漑への利用による農産物増産効果はある程度は認められるものの、ＰＣ－１の計算ほど大きな便益とはならないことが予想される。

また、、ヒルトレントからの洪水の被害は、パチャッドに対するものよりも、D.Gカーン灌漑運河、及びその灌漑地域の農作物に対するもののほうが大きいため、厳密に計画地域の線引きを行えば、計画地域内より計画地域外に及ぼす便益のほうが大きい結果となる。しかしながら、計画では、運河及びそれによって灌漑が行われている地域を、開発の対象地域からは除外しているものの、現場では同じミタワンヒルトレント流域に位置する、それら地域全てをほぼ一体の地域として認識しているものであり、そのことによって計画そのものの便益が変化するものでもない。

4-2-3.でも述べたように、洪水で生じる水量を全て農業用水として活用するには、ヒルトレントの流域保全対策によって土砂生産量を低減し、その後、貯水ダム等の建設によって計画的な灌漑を可能とするしかない。本計画は、ある程度の灌漑効果は認められるものの、総合的・計画的な灌漑を可能とする前提条件を整備するための計画、すなわち、「洪水制御と流域保全のための計画」と位置づけられるものと考える。

第６章　結論と提言

6-1.結論

6-1-1.無償資金協力としての妥当性

(1)改善を要する問題点

本計画地域では洪水流を利用した農業が行われているが、以下の問題があり早急な対応が必要と考えられる。

1)乾期はほとんどが不毛地帯であり、運河灌漑地域との較差が歴然としている。

2)雨期といえども、計画的、安定的な営農が困難である。

3)洪水は程度いかんでは、下流域（運河灌漑地域の農地、市街地）へも、少なからず被害を与えている。

(2)ダム建設について

安定した営農のためには、究極的には、上流部に灌漑や洪水調節のためのダムを建設することがベストの手法であると思われるが、当地域は流出土砂が多いことからダム建設は経済的でない。

(3)洪水流制御、流域保全の妥当性

現実的には、まづ洪水流を分流堤で制御し、長期的には上流域の植生の回復等により洪水、土砂流出を制御し、貯水ダムの建設により計画的な灌漑を可能とすることが以下の理由により妥当と考えられる。

1)洪水流の流況の改善により、下流域の灌漑施設等に対し維持管理上有効である。

2)上流域の土壌侵食防止、植生の回復による環境保全、農地の造成に寄与する。

3)堆砂生成量の低減による貯水ダム建設の経済性の向上が期待できる。

(4)無償資金協力案件としての妥当性

計画の便益の大半は、下流構造物による洪水抑制によって生ずるものであり、その必要性は理解できる。また、それらは長期的な開発戦略上も妥当性の高い施設であることは明かである。しかしながら、ミタワンヒルトレントにおける洪水の発生はかなり不定期であり、毎年ある程度の被害を計画対象地域にもたらしているのではない。そのため、構造物が完成後数年間以上その十分な効果を発揮する機会がない可能性も強い。

洪水防御のような防災を目的とした無償資金協力は、その実施によって、ある一定以上の社会経済的便益が毎年確実に生じる前提に立って、計画実施が決定されるものである。

以上から、洪水分流構造物に関しては、制度上無償案件として馴染まない可能性が強いものと考える。基本設計の実施にあたっては、要請のあった各構造物の機能をそれぞれ再度検討し、協力範囲の一部見直しも必要となるものと考える。

6-1-2.今後のスケジュール

パキスタン国政府は6月中にＦＡＯへ本件技術協力の正式要請を行う事を確約したが、ＦＡＯはこれに協力し、正式要請書のコピーをＪＩＣＡに送付することを約束した。

また、パキスタン側は7月末までに、流域保全計画の具体的内容をＦＡＯと協議し策定の上、ＪＩＣＡへ提出することを確約した。

6-2.提言

6-2-1.計画内容

(1)流域保全

1)ＦＡＯの協力は、単に植栽技術のみでなく、自営管理組織の設立運営、過放牧の抑制（輪番放牧の実施）など住民対策も含めた地域開発を目指しており、わが国のこれまでの技術協力とは視点が異なる。
そのため、基本設計調査においては、わが国の長期的対応方針を明確にする必要がある。

2)無償資金協力によって上流域に造成する施設等は、ＦＡＯへのものでなく、パキスタン国政府に対するものであり、パキスタン国政府がＦＡＯの協力にあたってそれらの使用を許可するものであるとの認識を、関係者の間で明確にする。

3)実験圃場及び施設、低砂防ダム群、ベチベル草等高線植栽等の細部計画は、パキスタン側の流域保全に対する管轄部署との連携のもとに企画・立案しなければならない。また、このことはメインテナンス上からも重要なことである。

(2)下流域構造物

1)各構造物（洪水分流堰、導水堰、道路等）のベンチマークの確認、平面・縦横断の測量は不可欠である。

2)各構造物の構造・規模の決定にあたっては、現地の流況、自然条件を熟知している現地技術者の意見を十分に反映しながら、入念な調査を実施しなければならない。
また、既存のパキスタン国の基準を考慮すべきである。

3)かんがい整備水準は低く、定量的な事業便益は高くないことが予想される。従って、現地の実状にかなった現実的なかんがい施設の意義を十分に認識した評価とならざるを得ない。

(3)実施体制

本計画の事業内容は、単なる施設の建設による洪水対策ではなく、流域保全も含まれており、複数の機関からの幅広い分野の協力が不可欠と考える。特に流域保全は、いままでのパキスタン国では一般的でないアプローチであり、詳細な実施運営体制、予算人員配置計画等の確認が必要である。

6-2-2.基本設計調査

(1)調査の時期

基本設計調査の時期は８月後半と予定されているが、その時期は現地が雨期の最中であり、洪水発生の危険もあることから、もう少し調査時期を遅らせてはとの提言がパキスタン側より行われた。現地の気象データによると、７月～９月が雨期となっており、年間降雨量の約６０％がこの時期に集中していることから、可能ならば調査時期をもう少し遅らせることが妥当と考える。

(2)団員構成と調査期間

現地作業量の目処については、以下の点を考慮する必要がある。

1)計画対象地域が広く分散していること

2)道路事情が劣悪で移動に時間を要すること

3)流域保全計画に対するＦＡＯとの意見調整が必要であること

以上を勘案すると、以下の団員構成が望ましいものと考える。

	現地調査	国内解析	報告書説明
a.業務主任（農業開発、かんがい計画）	３０日間	３０日間	１４日間
b.測量	３０日間	１５日間	－
c.施設設計	３０日間	３０日間	１４日間
d.流域保全、堤防設備	３０日間	３０日間	－
e.道路設計	３０日間	３０日間	－
f.積算	－	３０日間	－

(3)測量業務

測量業務は外注にするほうが合理的と思われるが、その場合必要な測量は下記のとおりである。

1)ミタワン洪水分流堰
2)バティィワラ導水路堰
3)チョティナラ洪水分流堰
4)ナンガールナラ配水路
　}・・・・・平面測量、縦横断測量

5)チョティナラ・シャヒサワール道路（４０km）
6)工事用道路（１２km）
　}・・・・・縦横断測量

7)ベチベル草植栽・・・・・・・・・・・平面測量

8)実験圃場、施設・・・・・・・・・・・平面測量

(4)テストピット

分流堰、導水堰等の基盤地盤は、施設構造の設計に先行し、テストピットによる試掘調査を実施する必要がある。

２ｍ Ｘ ２ｍ Ｘ ２ｍ程度のものを全体で概ね５０カ所必要と思われる。

(5)携行資機材

計画対象地域は地形図も十分なものが無いこと、分流堰・導入堰等の計画地点４カ所が広範囲に分散していること、道路の延長も長距離であること、上流域の植栽対象地域の概定が困難であること、などの理由から、グローバルポジショニングシステムが３台程度携行資機材として必要であると思われる。

(6)ＦＡＯ専門家の現地調査への参加

本計画の大きな部分を占める流域保全計画は、ＦＡＯの技術協力を前提として実施されるものであり、ＦＡＯのイニシアティブのもと計画の具体的内容が立案されるものと考えられる。そのため、基本設計調査時の打ち合わせにおいても、パキスタン側関係者のみならず、ＦＡＯ専門家の意見の聴取が非常に重要になる。可能なら、パキスタン国政府関係者、ＦＡＯ専門家、日本調査団の３者合同で現地調査を実施し、無償資金協力の対応を協議することが、その後の本計画のスムースな実施に役立つものと考える。

(7)ＦＡＯ流域保全計画地域の見学

流域保全計画に付いて本格的な協議を開始する前に、現在ＦＡＯが実施している流域保全計画地域の見学を提言したい。ＦＡＯのコンセプトペーパーを読む限り、本計画における流域保全計画の内容の多くは、現在のＦＡＯ実施地域でも実施されているものである。見学の実施は、計画の具体的な理解を深め、その後の実りある協議に役立つものと考える。

(8)ＮＥＳＰＡＫ社の協力

本計画のフィージビリティー調査は、現地コンサルタントNational Engineering Services Pakistan (PVT) Limited（ＮＥＳＰＡＫ）によって実施され、ＰＣ－１もＮＥＳＰＡＫの協力を得て作成されている。以上から、本計画に関わる詳細な情報は現地政府関係者よりむしろＮＥＳＰＡＫで保有している場合もあり、本調査においてもいくつかの情報について協力を得た。担当者によれば、必要とあれば基本設計調査団への協力もいとわないとのことである。

6-2-3.その他

本計画の和文名は”灌漑開発計画”とされているが、便益の大半は洪水防御によるものであり、”灌漑”と名付けるような、計画的で安定した水の供給は、現段階では全く期待されていない。パキスタン国政府からの要請書にある計画名は"Hill Torrent Pilot Project"となっており、本計画が、灌漑を主体とした計画ではないことを如実に示している。

従って、英文の名称はそのままで、和文名を計画内容に合わせて変更することを検討する必要があるものと考える。

添付資料

1．調査日程

2．団員構成

3．面談者リスト

4．協議議事録（ミニッツ）コピー

5．ＦＡＯとのメモランダム

6．ＦＡＯコンセプトペーパー

7．収集資料リスト

添付資料－1

調査日程

No.	月／日	曜日	行程・調査内容
1	5/17	月	東京→イスラマバード（ＰＫ－７５３）。
2	5/18	火	ＪＩＣＡ事務所打ち合わせ。日本大使館表敬。大蔵経済省表敬。水利電力省表敬。
3	5/19	水	ＦＡＯ表敬。全国洪水対策委員会表敬。合同会議（全国洪水対策委員会、パンジャブ州灌漑電力部、ＦＡＯ）
4	5/20	木	イスラマバード→ムルタン（ＰＫ－３８５）、ムルタン→Ｄ．Ｇ．カーン。パンジャブ州灌漑電力部Ｄ．Ｇ．カーン地区事務所と協議。
5	5/21	金	サイト踏査。Ｄ．Ｇ．カーン→ムルタン。
6	5/22	土	ムルタン→イスラマバード（ＰＫ－３８６）。
7	5/23	日	全国洪水対策委員会、パンジャブ州灌漑電力部と協議。
8	5/24	月	日本大使館経過報告、団内打ち合わせ。
9	5/25	火	協議議事録（ミニッツ）内容協議、サイン（水利電力省、全国洪水対策委員会、パンジャブ州灌漑電力部出席）。ＪＩＣＡ事務所報告。
10	5/26	水	大蔵経済省報告。ＦＡＯと協議、メモランダム交換。農業省でＦＡＯ技術協力要請手続き確認。 イスラマバード→カラチ（ＰＫ－３１９）にて田村団長、黒川団員帰国。
11	5/27	木	イスラマバード→ムルタン（ＰＫ－３８５）、ムルタン→Ｄ．Ｇ．カーン。サイト踏査。
12	5/28	金	サイト踏査。パンジャブ州灌漑電力部Ｄ．Ｇ．カーン地区事務所と協議。 田村団長、黒川団員日本着。
13	5/29	土	パンジャブ州灌漑電力部Ｄ．Ｇ．カーン地区事務所と協議。 Ｄ．Ｇ．カーン→ムルタン、ムルタン→ラホール（ＰＫ－３８８）。
14	5/30	日	パンジャブ州灌漑電力部表敬及び協議。NESPAK（本計画Ｆ／Ｓを行った現地コンサルタント）と協議。
15	5/31	月	パンジャブ州計画開発部表敬、打ち合わせ。資料収集。
16	6/1	火	ラホール→イスラマバード（ＰＫ－３１２）。
17	6/2	水	ＦＡＯ実施"Suketar Watershed Management Project"見学。
18	6/3	木	資料整理
19	6/4	金	〃
20	6/5	土	ＪＩＣＡ事務所報告。
21	6/6	日	イスラマバード→東京（ＰＫ－７５２）

添付資料－2

団員構成

氏　名	担　当	所　属
田村　蓁	総括／農業開発計画	農林水産省東北農政局土地改良技術事務所所長
黒川　清登	無償資金協力	ＪＩＣＡ無償資金協力調査部基本設計調査第1課
榊山　今日児	灌漑施設計画	財団法人　日本国際協力システム
吉野　治伸	農村開発計画	財団法人　日本国際協力システム

添付資料－3

面談者リスト

1. パキスタン国関係者

(1)Munistry of Finance and Econoic Affairs

Mr.Shahid Humayun	Deputy Secretary, Economic Affairs Division

(2)Ministry of Water & Power

Mr.Syed Shahid Hussain	Additional Secretary(Water)
Dr.Asif H. Kazi	Chairman, Federal Flood Commission
Mr.I.B. Shaikh	Chief Engineer, Federal Flood Commission
Mr.Tariq Masud	Senior Engineer, Federal Flood Commissionm
Mr.Fazlur Rahman Siddiqui	- ditto -

(3)Ministry of Food, Agriculture and Cooperatives

Mr.A W Qazi	Additional Secretary(International Cooperation)

(4)Irrigation & Power Department, Government of Punjab

Mr.Khalid Mahmood	Secretary
Mr.Riaz Ahmad Khan	Chief Engineer(Multan Zone)
Mr.Qazi Anwar Ali	Deputy Securetary(Development)
Mr.Muhammad Ilyas	Superintending Engineer(D.G. Khan)
Mr.Muhammad Ramzan Bhatti	Executive Engineer, Jamupur Division(D.G.Khan)
Mr.Saif Ullah	Sub Division Officer, Jamupur Division(D.G.Khan)
Mr.Karamat Ali	Director, Land Reclamation
Mr.Zia Ullah Azmat	Divisional Forest Officer(Multan)

(5)Planning & Development Department, Government of Punjab

Mr.Malik Ahmad Khan	Chief(Water & Power)

(6)National Engineering Services Pakistan(PVT) Limited(NESPAK)

Mr.Abdul Ghani Randhawa	Principal Agronomist

2. ＦＡＯイスラマバード事務所

Mr. H. A. Ismat-Hakim	Reprasentative
Dr. Reinhard Breitbart	Programme Officer
Dr. Neil Martin	Chief Technical Advisor

3. 在パキスタン日本国大使館

赤沢　正人	公使
安部　忠宏	参事官
田野井　雅彦	一等書記官

4. ＪＩＣＡイスラマバード事務所

御手洗　章弘	所長
新垣　和成	次長
Mr. Kaoru Iwasaki	所員
Mr. Hitoshi Takahashi	派遣員
Mr. Mahmood A. Jilani	Chief Programme Officer

添付資料－4

Minutes of Discussions
Preliminary Study on
Mithawan Hill Torrent Pilot Project
in Punjab
in The Islamic Republic of Pakistan.

In response to the request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a Preliminary Study on Mithawan Hill Torrent Pilot Project (hereinafter referred to as " the Project") and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Islamic Republic of Pakistan a study team, which is headed by Mr.Shin TAMURA, Director, Land Improvement Engineering Service Center, Tohoku Agricultural Administration Office, Ministry of Agriculture,Forestry and Fisheries, Government of Japan from May 17 to June 6, 1993.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Pakistan and conducted a field survey.

As a result of the discussions and field survey ,both parties have confirmed the main items described on the attached sheets. On the condition that the Government of Japan approves the implementation of Basic Design Study on the Project, JICA will prepare the study, including dispatchment of a survey team.

Islamabad ,May 25 ,1993

Mr.Shin TAMURA
Leader,
Preliminary Study Team,
JICA

Mr.Khalid Mahmood
Secretary
Irrigation and Power Department,
Government of the Punjab

← 関係機関)の承認を得た上
EADから最終的にサインする

Mr.Farhat Hussain
Joint Secretary,
Economic Affairs Division,
Ministry of Finance and Economic Affairs,
Government of the Islamic Republic of Pakistan

1. Objective

The objective of the Project is to construct dispersion structures and watershed management facilities to control and utilize flood water for irrigation purposes in Mithawan area in Punjab.

2. Project site

The sites of the Project are located at Mithawan Hill Torrent in Punjab.
The location map of the sites is shown in ANNEX-I.

3. Executing agency

(1)The responsible authority is the Ministry of Water and Power, Government of Pakistan.
(2)The executing agency is the Irrigation and Power Department, Government of the Punjab.

4. Items requested by the Pakistan side

After discussions with Preliminary Study Team, the following items were requested by the Pakistan side:
(1)Engineering Works.
  1)Main Dispersion structure(Mithawan)
  2)Second Dispersion structure(Bhattiwala Bund).
  3)Dispersion structure(Choti Nullah).
  4)Improving Distribution system(Nangar Nullah).
(2)Watershed Management.

(3)Rehabilitaion Works.
  1)Rehabilitation of Road(Choti Bala - Sakhi Sawar,40Km long)
  2)Temporary Road to site.(12 Km long)

However,the final components of the Project will be decided after further studies.

5. Major Points of Discussions.

(1)The Pakistan side will prepare an official request for technical cooperation concerning watershed management and submit it to FAO not later than June 1993.

(2)The Pakistan side will prepare and submit a detailed plan of watershed management,necessary for further studies, to JICA in cooperation with FAO by the end of July 1993.

(3)Major undertakings and necessary measures to be taken by the Pakistan side are described in ANNEX-II.

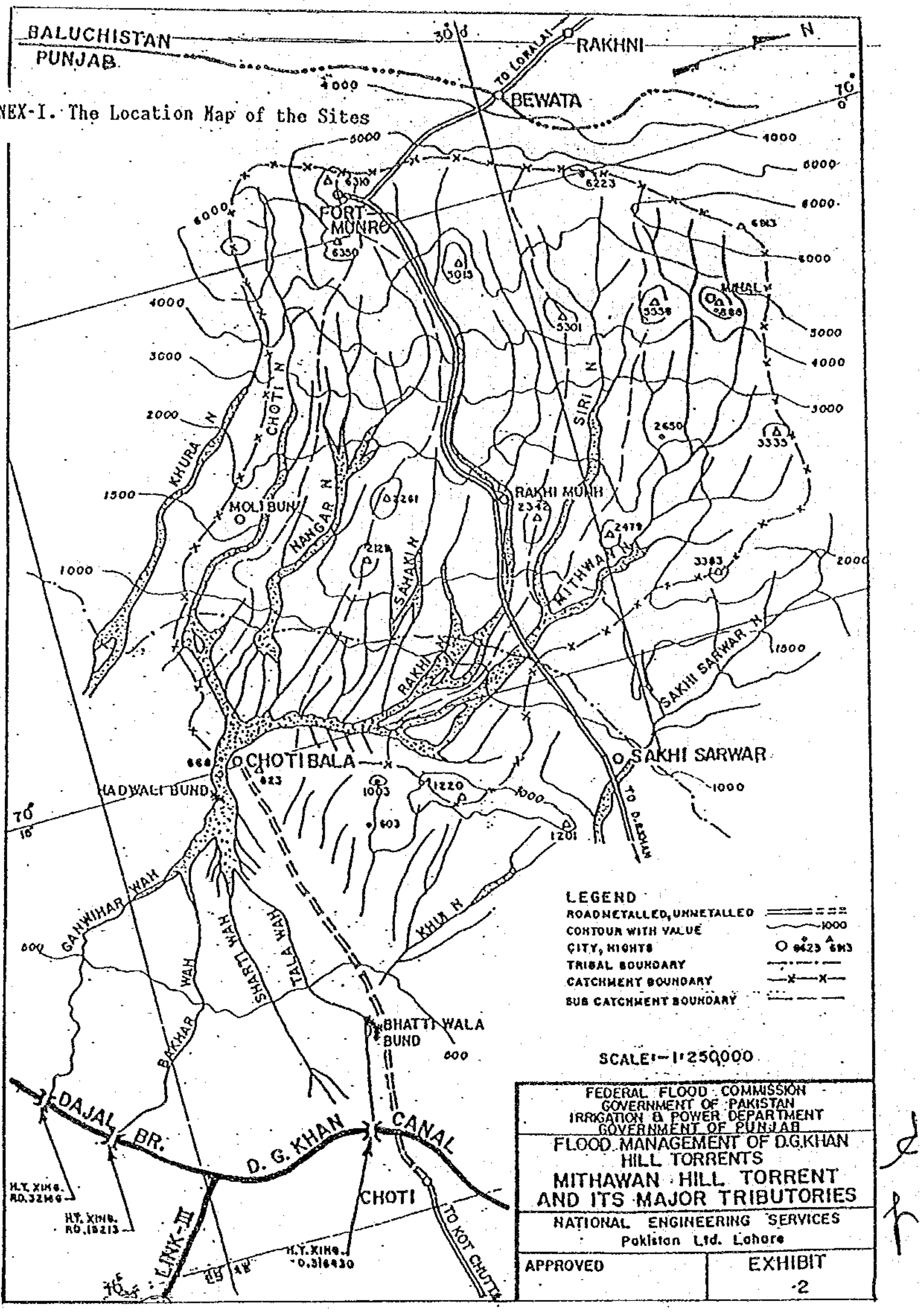
6. Japan's Grant Aid System .

(1)Pakistan side has understood the system of Japan's Grant Aid explained by the team.
(2)Pakistan side will take the necessary measures described in ANNEX-II for smooth implementation of the Project, on condition that the Grant Aid Assistance by the Gvernment of Japan is extended to the Project.

7. Schedule of the Study

If the Project is found feasible as a result of the Preliminary Study, JICA will send Basic Design Study Team around August 1993.

ANNEX-I. The Location Map of the Sites



ANNEX-II.

Major undertakings and necessary measures to be taken by the Pakistan side.

Items to be taken by the Pakistan side,

(1)To provide data and information necessary for the Project.

(2)To secure land for the sites of the Project.

(3)To clear the sites free from all obstructions prior to commencement of the construction.

(4)To bear the commissions to the Japanese foreign exchange bank for the banking services based upon the banking arrangement.

(5)To exempt taxes and take necessary measures for customs clearance of the material and equipment brought for the Project at the port of disembarkation in Pakistan.

(6)To accord Japanese nationals whose services may be required in connection with supply of the products and services under the verified contracts, such facilities as may be necessary for their entry into Pakistan and stay therein for the performance of their work.

(7)To assign the necessary staff for operation and maintenance of the facilities constructed and equipment purchased under the Grant Aid.

(8)To maintain and use properly and effectively the facilities constructed and equipment purchased under the Grant Aid.

(9)To bear all the expenses other than those to be borne by the Grant Aid in connection with the Project.

添付資料－5

MEMORANDUM

A meeting was held between Dr. Niels L. MARTIN, FAO Pakistan, and Mr. Shin TAMURA, JICA Preliminary Study Team for the Mithawan Hill Torrent Pilot Project on the 19th and 26th May 1993 in Islamabad.

The purpose of this memorandum is to record the results of discussions on the tentative areas and procedures of cooperation between JICA and FAO in this project.

Main points of the discussion are as follows:

1. Dr. Niels L. MARTIN will revise the concept paper on *Mithawan Hill Torrent Pilot Project* reflecting the realistic budget for FAO/Japan Trust Fund agreed in principle to be provided to FAO Headquarters for Technical Assistance in this project. The Technical Assistance of FAO, therefore, will be implemented on condition that the budget would be allocated from FAO/Japan Trust Fund.

2. Dr. Niels L. MARTIN has requested the Punjab Government Representative to facilitate submission of a formal letter of request to FAO from the Government of Punjab. He will follow up on this matter to see that it is carried out and a copy of the letter will be provided to JICA.

3. Dr. Niels L. MARTIN requested the JICA preliminary study team to convey to the Government of Japan the following requests for Japanese Grant Aid for supporting FAO Technical Assistance to the watershed management program in *Mithawan Hill Torrent Pilot Project*:

(1) Construction of a Project Office and Rest House with necessary garages, workshops, laboratories, meteorological station etc. with requisite electrical supply facilities, telephone communications, etc.

(2) Vehicles for use of FAO and government staff working on watershed management activities.

(3) Establishment of an experimental farm and demonstration watershed, including necessary earthwork, labor, equipment, buildings and/or other facilities to be determined in the Basic Design phase of project preparation.

(4) Construction of conservation structures as deemed necessary including check dams, silt trap dams, torrent control structures, etc.

(5) Provision of labor for the establishment of conservation plantings of grasses and shrubs such as the proposed planting of *Saccharum munja* hedges along contours of erosive slopes, planting of shrubs and trees for conservation and fodder/fuelwood as appropriate, and other vegetative soil erosion control measures.

(6) Provision of equipment, labor and other tangible inputs in water development and conservation structures and facilities such as the construction of ponds for water harvesting for small-scale irrigation, livestock water supplies, fish production, etc.; and the drilling of horizontal wells or other appropriate development of seeps and springs within the pilot project area.

4. The Preliminary Study Team stated:

(1) Japanese Grant Aid will be extended in the form of financial assistance which makes available the funds for facilities construction, establishment of demonstration farm and watershed area, and procuring equipment necessary for implementing the Project. Other costs necessary for implementation of the watershed management program such as operation and maintenance, office operation and supplies,etc. will not be covered by Japanese Grant Aid.

(2) Facilities and equipment including vehicles necessary for the Project will be decided at the Basic design Stage. FAO Technical Assistance staff will carry out the watershed management program by use of these facilities and equipment under the consent of Government of the Punjab.

(3) For smooth execution for the Basic Design Study, the team requested Government of the Punjab to prepare and submit a detailed plan for a watershed management program by the end of July 1993. The team requested Dr. Niels L. MARTIN to cooperate with the Government of the Punjab for compiling the detailed program.

After further studies, the final components of the project will be decided at the Basic Design stage. *This memorandum is not intended to be and must not be taken as the basis for any obligation on the part of either JICA or FAO.*

Mr. Shin TAMURA
Leader,
Preliminary Study Team, JICA

Dr. Niels L. MARTIN
Chief Technical Adviser
FAO Pakistan

C: Mr. H.A. Ismet-Hakim, FAOR, FAO/Islamabad
Mr. A. Chikhaoui, FODO, FAO/Rome
Mr. M. Tanoi, First Secretary, Embassy of Japan, Islamabad
Mr. A. Mitarai, Resident Representative, JICA, Islamabad

MITHAWAN WATERSHED MANAGEMENT PROJECT

THE AREA

The watershed of the Mithawan Torrent is part of the complex of the Sulaiman Range that drains into the Pachad Plains, adjacent to the Indus River in western Punjab (see maps, Appendix 1.). The watershed covers approximately 68,000 hectares. elevation ranges from 250 meters above sea level to over 2,000 meters. Parent material is of sedimentary and alluvial origins with geological strata reaching the near-vertical in the hilly parts of the area.

Some of the limestone and indurate layers of sandstone are of limited permeability, resulting in the retention of groundwater in natural subterranean reservoirs behind these vertical layers. Seeps and springs emerge where the water over-tops the impermeable strata or emerges through weak points.

The area is semi-arid with about 300-350 millimeters annual average precipitation. About 60% of the precipitation falls during the monsoon period of July to September. Many rainfall occurrences are high intensity-short duration, resulting in high percentages of runoff with the consequence of common flash floods. The area is highly eroded as a result of overuse by livestock, the aridity and the nature of the rainfall.

Natural vegetation includes trees and shrubs of *Ziziphus numularia, Z. jujuba, Prosopis spicigens, P. juliflora, Acacia spp., Salvadora oleoides,* and *Tamarix articulata.* Grasses include *Cynodon dactylon, Cenchrus ciliaris, Lasiurus sindicus,* and *Saccharum munja.* Grasses are generally very heavily grazed and shrubs are extremely heavily browsed, resulting in compact hedging. small drainage ways are more heavily vegetated than are areas without extra water accumulation. The vegetation is present in enough density to allow good increase in plant size and vigor and for reproduction with good management of livestock.

The population of the area occurs in small villages or family units where water is available for human and livestock use. There are a few areas where perennial surface flow of water allows the development of limited agriculture. In other areas earthen and stone structures have been erected to capture surface flows of runoff from precipitation to grow crops. Crops grown in the area include wheat in the winter season and sorghum or millet in the summer. Fruit trees including dates, pomegranates, and guava are grown on a limited scale as are a few vegetables.

Land ownership is vested in the tribal leaders with verbal and traditional ownership rights given to individuals for cultivated land. Village units have rights for grazing in areas adjacent to the villages. Water rights to perennial water and flood waters from the torrents are clearly established.

NEED FOR PROJECT INPUTS

The nature of the area results not only in heavy erosion losses on site but also extensive down-stream damage to irrigated croplands by sedimentation and physical damage to irrigation structures by the flood waters. The watershed management project will complement the downstream works to be constructed by the Irrigation Department/JICA to enhance the use of flash-floodwater for irrigation and to eliminate the damage caused to the irrigation works by the floods.

According to estimates in preliminary studies, flood volume per unit time will be reduced by 20% by the implementation of watershed management alone. This will greatly reduce pressures on the downstream structures to be built by the JICA funded project and will make maintenance less expensive.

Upstream benefits will include improved soil stability and increasing productivity of the area by reversing the trend of accelerated soil loss. Vegetation cover will be enhanced with the resulting improvement in livestock forage production and increased amounts of fuelwood for local use and for sale. water resources will be developed for better distribution of livestock, more reliable sources of water for the human population and for increased production of agricultural crops. This, and other peripheral benefits will result in a higher and sustainable standard of living for the inhabitants of the watershed area.

PILOT AREA

It is recommended that the project activities begin in a concentrated area for initial testing of activities and to demonstrate the effectiveness of interventions. In a field visit and in collaboration with the study team, it was determined that the Dholi area would be the most suitable site from which to begin project implementation for the following reasons:

- Central location
- Reasonable accessibility
- Concentrated population
- Water available for:
  - Nursery
  - Office and rest house/residence
  - Construction
- Many landscape types occurring in the watershed are present

PROJECT CONCEPT

Time span. Watershed management requires not only a long period of time for the biological and physical improvements required but also for changes in attitudes for the local people. Total development must be approached over a period of many years. For this reason a long-term view should be taken with development phased as explained below. The proposed project should include two phases with follow-up being considered for the subsequent phases.

Currently planned project

Phase 1. Six months--Mobilization period.

Phase 2. Five years--Major implementation period.

Future follow-on project

Phase 3. Five years--Phase-in of local community organization (CO) to operate project and to maintain project works.

Phase 4. Five years--Phase out of donor funding and increase in independent funding by CO.

Mithawan

Phase 1. Mobilization

The mobilization phase should include the following activities:

Placement of project staff
Socio-economic study of project area to include:
- Demography
- Tribal structure
- Land tenure
- Economic base
- Traditional organization of communities
- Feasibility of CO development

Planning of demonstration area:
- Resource mapping
- Conservation plan

Range management in demonstration area:
- Farmers' meetings
- Study tour for farmers
- Develop concept of grazing association
- Grazing management plan

During this period the JICA Contractor would establish with Japan Grant Aid the following:
- Field Office
- Rest House/Residence
- Meteorological station

The primary objective of the mobilization phase would be to obtain an understanding of the social structure and the economics of the project area for the involvement of the local people in the implementation of the project and eventual organization of a viable Community Organization, and to get the project set up and operable. The conservation and range planning and developments would only be preparatory activities with most actual work being done during the second phase.

Phase 2. Project Development

Objectives of this phase would be to:

- Establish a viable resource development program to begin the rehabilitation of the vegetation, soil and water resources of the Mithawan Watershed.
- Establish viable grazing associations in at least half of the villages of the project area for the organized, managed grazing of half of the area within the watershed.
- Establish a Community Organization (CO) within the Mithawan Watershed (this may be exclusively within the watershed or may extend outside its boundaries, depending upon the social structure of the area) that will be trained to maintain systems and structures developed by the project.

Project Activities:

Conservation. The major cause of the flash-flood problems down-stream in the torrents of the sulaiman Range is the deterioration of the soil and vegetation in the uplands. Unrestricted grazing and other uses have contributed to the drastic decrease of the ground cover and the erosion of the soil. Measures must be taken to reverse the trend.

Traditionally, soil conservation in Pakistan has meant the establishment of checkdams and gully plugs. These measures can be effective in arresting the development of gully erosion but do nothing in stopping sheet erosion. When checkdams fill with sediment, the eroded soil continues to pass over these structures and contributes to the sediment load in the streams. Vegetation cover in the drainage channels and on the land is essential to reversal of erosion, resulting in soil building instead of degradation.

To provide the necessary vegetation cover, grazing management must be implemented on the area (see Range Management section, below). In

CONCEPT PAPER
MITHAWAN WATERSHED MANAGEMENT PROJECT

NIELS L. MARTIN
FAO
PAKISTAN

addition, contour hedges of *Saccharum munja,* a native grass of the area, will be planted initially in minor drainage channels, and then on the contour across the slopes. This will provide a vegetative barrier against sediment loss and will trap the sediment on the land, developing mini-terraces. *Vetiver* spp., a grass being used for this in many parts of the world, will also be tested in this function. *Vetiver* will also be tested as a conservation tool on terraces and field boundaries on farm land where it has the advantage of minimal spread into adjacent areas from where it is planted.

Small earthen dams will be constructed as silt traps in the drainage channels of the tributaries to trap water and sediment before it reaches the major torrents of the watershed. Project bulldozers will construct the dams with the people using the land contributing to the work by planting vegetation on the structures and doing necessary stone masonry for spillways, etc.

Other dams will be constructed to harvest runoff water for use for livestock, human use, fish farming, and small scale irrigation. In many cases these will be constructed in conjunction with silt trap dams, with the silt trap built up-stream to relieve the water of most of its sediment load and then collecting the water in the pond.

Where the water supply in a pond is reliable enough to provide a year-round supply, small-scale irrigation can be set up for orchard production using drip irrigation or other efficient irrigation methods. Hand watering or trickle irrigation can also be used for vegetable gardening. Fish-farming can be done where water supply is adequate.

Silt trap ponds can also be used for agriculture when the water soaks into the soil, leaving enough residual moisture after surface water is gone, to support a crop of grain or vegetables as is the traditional practice in the area.

<u>Range Management</u>. The key to range management is the active and willing participation of the livestock owners and herders. A grazing association must be organized under the auspices of the community organization that will help the graziers in working together to manage the rangelands.

Mithawan

Members of the association will be taught concepts of range management and will participate in the decision making process regarding how it will be implemented on their grazing lands. They must gain the understanding that it is forage they are producing on the land and that the livestock are the means of making the forage useable by man.

Grazing management will first be implemented on the lands of the pilot area at Dholi and then will extend to other areas. Likely management will include a simple rotation system that will allow each area to be rested in alternate years during the monsoon growing season. For example, half of a given area will be rested during July, August and September of the first year and then the other half will be rested during the monsoon season of the second year. Details of the grazing systems will be developed as project personnel gain familiarity with the resources and have a chance to test it.

The core principle of range management, however, will be the natural recovery of existing vegetation. Very little artificial revegetation should be needed except for the conservation planting outlined above.

Water spreading on rangelands will also be developed in areas where this practice is feasible and where it will not take away water from flood irrigated croplands.

Other feed resources will be developed by assisting the local people to enhance their irrigated forages. Now most irrigated fodder is food grains cut before maturity and fed to livestock. Legumes and fodder grasses will be introduced to the landowners to test their acceptability for irrigated forage production. Fodder trees will also be considered for use in irrigated areas as well as in areas of water accumulation such as in silt trap dams or water spreading areas.

Livestock water resources will be developed in cooperation with the grazing associations as part of overall range management development. some of the ponds will be developed specifically for livestock so the animals will have easily accessible water in their grazing areas. Horizontal well drilling in appropriate locations (see Appendix 2.) will be used for livestock water development as well as for human use.

As a supplement to the range management program, assistance will also be given to the grazing associations in breed improvement. Selection and marketing procedures will be taught and improved herd sires may be purchased by the associations to upgrade the quality of their livestock.

Extension and training. As population involvement is the key to the success of the proposed project, extension activities will be a vital component of it. Extension staff must be closely involved with all project activities and all other project staff must be aware of and intimately involved with the extension program. The group promoters will work especially closely with the grazing associations to ensure that all members understand the concepts behind range management and understand how to work together for the common good through the association.

Field trips will be taken to areas where range management has been effectively implemented by village and grazier groups and training courses will be developed in range management. Other courses will be organized in group organization and management for the officers of the associations.

Other Activities. Other activities will be considered that will enhance the living standards of the people within the watershed. These may include cottage industries, fish farming, bee keeping, orchard production, etc.

Wildlife will also benefit from the activities of the project as vegetation improves and water is developed. The Community Organization may also want to consider how to best control exploitation of the wildlife to benefit their communities. This may include controlling hunting to build populations to the point where hunting becomes a good management tool and then sell hunting rights and hire out guide service to hunters. There may also be grants the community could get through the CO for wildlife preservation.

Project Organization

The project should have the Forestry Wing of the Punjab Irrigation and Power Department as the counterpart agency. Local department involvement should, inasmuch as possible, be limited to advisory services, allowing the development of the local population to the fullest extent possible to provide their own support.

The JICA contractors will provide all equipment, buildings and conservation structures as well as establishing the demonstration farm and demonstration sub-watershed.

FAO Forestry Department will provide technical adviser(s) and support staff to the project. The following personnel are suggested for the project:

<u>FAO Staff</u>

International Staff
- CTA/Watershed Management Adviser
- APO, Range Management
- APO, Extension-community Development
- International consultants

National Staff
- National Senior Adviser/Extension Specialist
- National Socio-economist (.5 yr.)
- 3 Male Village Group Promoters
- 3 Female Village Group Promoters
- National consultants

Support Staff
- Administrative Assistant
- Clerk/Messenger
- 2 Drivers

Mithawan

Forestry Wing Counterpart Staff

Professional Staff
- DFO Extension
- Male Sub-DFO Extension
- Female Sub-DFO Extension
- Sub-DFO Range Management

Support Staff as required

Equipment (Provided under FAO/Japan Trust Fund)
- 2 4x4 double cab pickups
- 1 10 passenger 4x4 Utility vehicle
- Nursery equipment
- Field equipment for participation of local people
- Misc. equipment not covered by JICA grant

Equipment (Provided to the project for watershed work Under JICA Grant)
- Heavy equipment as needed for construction, seconded from downstream JICA project
- Horizontal well drilling rig
- 4 4x4 double cab pickups
- 4 Station office computer system
- 2 Notebook computers
- Copy machine
- Fax machine
- Typewriter
- Complete portable video system (camera, TV/VCR, portable generator, etc.)
- 4 35mm cameras
- Slide projector system
- Overhead projector
- Misc. office equipment
- Meteorological equipment
- Air conditioners
- Back-up generator system

Subsequent Phases.

Staffing, equipment needs, operation and maintenance costs, funding sources etc. for Phases 3 and 4 will be determined near the completion of Phase 2. A Mid-Term Evaluation should be conducted at the end of year three of Phase 2 to determine what absorptive rate can be expected by the Community Organization and thereby determine how much international staffing is required, financial inputs necessary, etc. for the next phases.

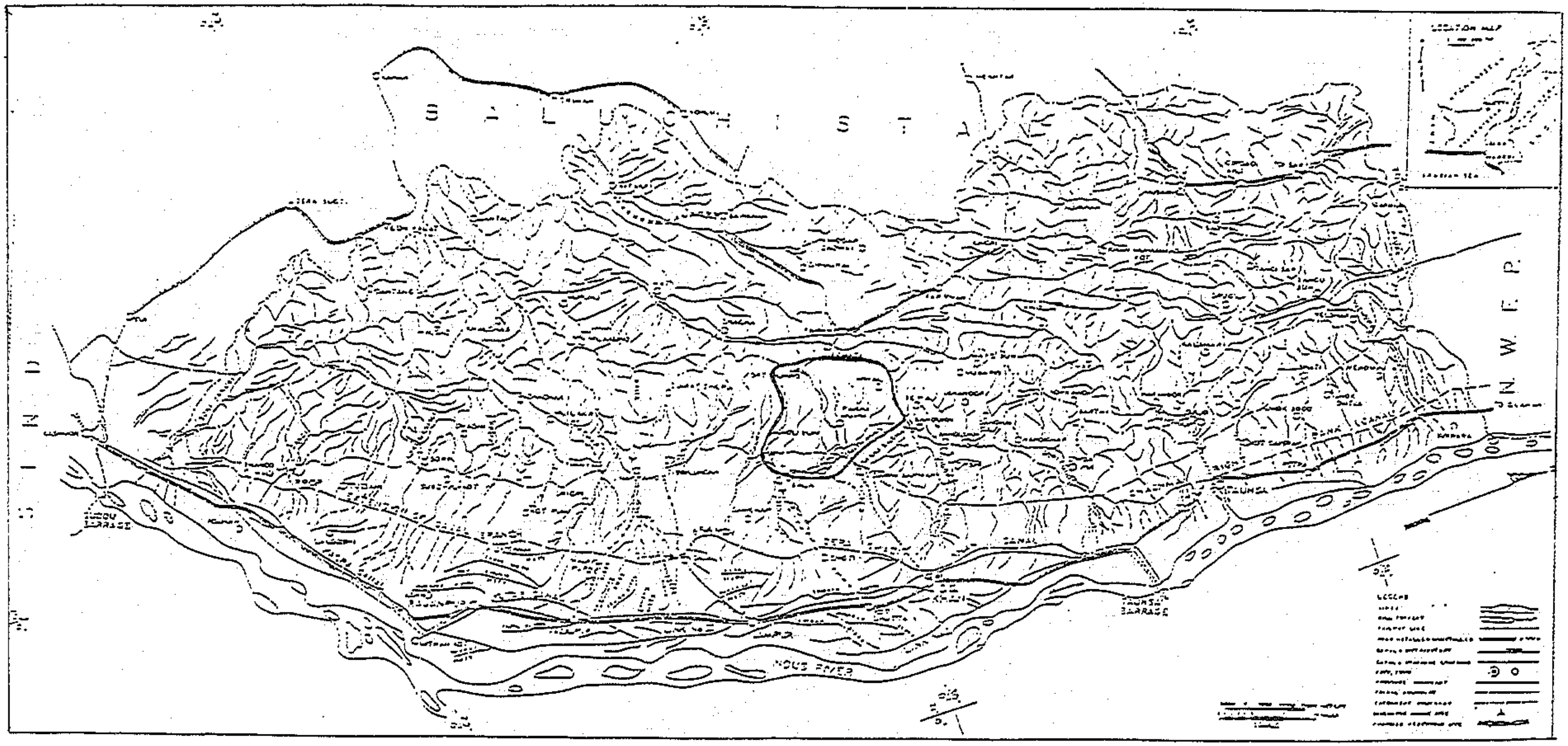
MITHAWAN BUDGET

	Total	Total M/M	M/M	Costs 1993	M/M	Costs 1994	M/M	Costs 1995	M/M	Costs 1996	M/M	Costs 1997	M/M	Costs 1998
CTA	$722,500	63	3	$32,500	12	$130,000	12	$140,000	12	$140,000	12	$140,000	12	$140,000
APO Wtrshd	no cost to project	60	0		12		12		12		12		12	
APO Extension	no cost to project	60	0		12		12		12		12		12	
Consultants	$270,000	18	2	$30,000	4	$60,000	3	$45,000	3	$45,000	3	$45,000	3	$45,000
Ntl. Adviser	$92,250	63	3	$4,050	12	$16,200	12	$18,000	12	$18,000	12	$18,000	12	$18,000
Ntl. Soc/Econ	$11,000		3	$5,500	3	$5,500								
Ntl. Consult	$18,900		0		4	$5,400	4	$5,400	2	$2,700	2	$2,700	2	$2,700
Grp.Prom. (6)	$108,000		0		72	$21,600	72	$21,600	72	$21,600	72	$21,600	72	$21,600
Admn Asst	$44,100	63	3	$2,100	12	$8,400	12	$8,400	12	$8,400	12	$8,400	12	$8,400
Msgr/Clerk	$31,500	63	3	$1,500	12	$6,000	12	$6,000	12	$6,000	12	$6,000	12	$6,000
Driver 1	$31,500	63	3	$1,500	12	$6,000	12	$6,000	12	$6,000	12	$6,000	12	$6,000
Driver 2	$31,500	63	3	$1,500	12	$6,000	12	$6,000	12	$6,000	12	$6,000	12	$6,000
Duty Travel	$32,000			$2,000		$6,000		$6,000		$6,000		$6,000		$6,000
Training	$35,000	0		$10,000		$5,000		$8,000		$2,000		$5,000		$5,000
Equipment	$98,000	0		$53,000		$8,000		$10,000		$4,000		$15,000		$8,000
Op.& Maint.	$38,500	0		$3,000		$5,500		$7,000		$7,000		$8,000		$8,000
Sundry	$59,000	0		$3,000		$10,000		$12,000		$10,000		$12,000		$12,000
Mission Costs	$17,000	0								$17,000				
Reporting	$7,000	0												$7,000
TOTAL	$1,647,750	516	23	$149,650	179	$299,600	175	$299,400	173	$299,700	173	$299,700	173	$299,700

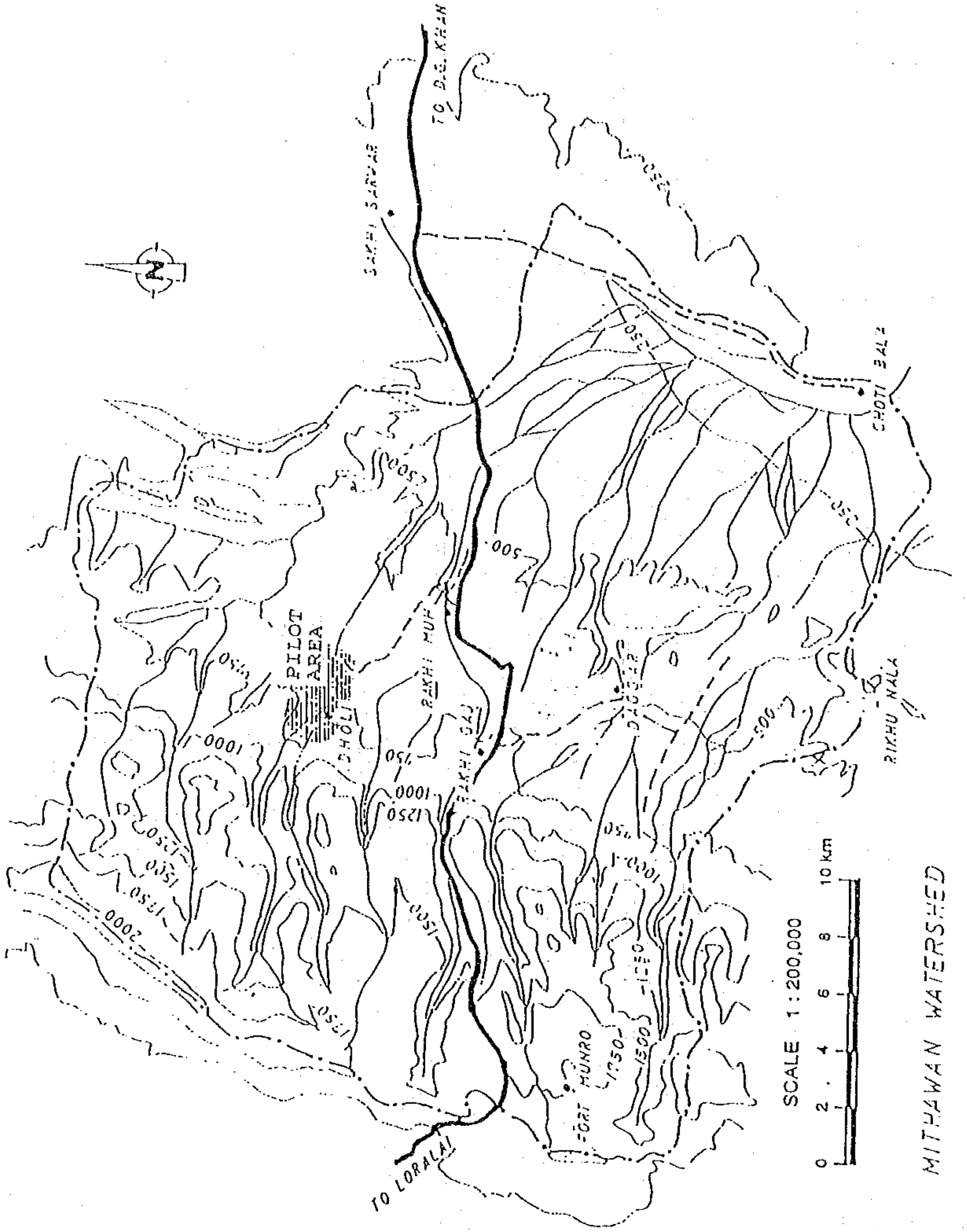
The two Associate Professional Officers (APOs) will be requested through FAO headquarters but their actual posting depends upon establishment of APO positions by participating governments.

APPENDIX 1

MAPS



LOCATION OF MITHAWAN HILL TORRENT


TO D.G. KHAN
SAKHI SARWAR
CHOTI BALA
PILOT AREA
BHOLI
RAKHI MUH
RAKHI GAJ
RAKHU NALA
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TO LORALAI
SCALE 1:200,000
0 2 4 6 8 10 km
MITHAWAN WATERSHED

APPENDIX 2

HORIZONTAL WELL INFORMATION

Reprinted from *Journal of Range Management*
Vol. 26, No. 4, July 1973, p 253-256

'Horizontal' Wells

W. T. WELCHERT AND BARRY N. FREEMAN

Highlight: *Forty-five horizontal wells were constructed on the San Carlos Apache Indian Reservation during 1967-69. This paper describes site selection, drilling equipment, and the construction process and lists the advantages of the horizontal well system over more conventional systems.*

Adequate water supplies, located for best utilization of range resources, are essential to good range management. A rancher doesn't need a large water yield in most areas. A single watering site can serve one to three sections of rangeland. In Arizona, the typical beef cattle stocking rate varies from four to ten animal units per section. At 12 to 15 gallons per animal-day, the maximum potential use per watering site is less than 500 gallons per day (gpd).

A yield of 0.25 gallons per minute (gpm) may serve a single watering site. A lesser flow may be utilized with the addition of tank storage designed to accumulate water to match the anticipated demand for the grazing season. Even spring sites that flow for only a few weeks in the year may prove useful with adequate storage.

A yield of 3 to 10 gallons per minute (4,000 to 14,000 gpd) may be extended to a dozen or more water sites through pipe distribution systems. One-inch pipe distribution systems of 10 miles or more are in use on a number of Arizona ranches.

Providing stock water at a suitable location and reasonable cost has always been a problem for the stockman. "Dirt tanks" (stock ponds) are relatively inexpensive, but reliability depends upon soil factors and rainfall. Runoff aprons and catchment basins are expensive, require some maintenance, and are dependent upon regular precipitation. Conventional wells are reliable but expensive, and associated pumping equipment may require considerable maintenance.

Properly developed springs approach the ideal range water supply specifications, but are often wasteful of water. Spring development is an ancient art. When a water seep or other evidence of a potential spring is located, it is either dug or blasted to expose the aquifer. The results are erratic and include the risk of permanently destroying a natural barrier which may be serving as a dam for the underground reservoir. The flow, once established, is almost impossible to control and may result in rapid depletion of the stored water. The horizontal well virtually eliminates the disadvantages of conventional spring development techniques. Each of these methods has a place in providing range water supplies and will continue to play a role.

The authors are extension agricultural engineer and extension range management specialist, University of Arizona, Tucson.

This contribution was approved for publication as Journal Paper No. 1979 by the Agricultural Extension Service, University of Arizona, Tucson.

The authors gratefully acknowledge the cooperation of the drilling contractors, Albert W. Smith of Crestline, California, and his son Errol Smith of Globe, Arizona, and of Gunter Frode, retired, head stockman for the San Carlos Apache Tribal Council.

Fig. 1. *A completed horizontal well on the San Carlos Apache Reservation test yields over 50 gpm.*

Origin and Development of Horizontal Wells

Horizontal wells are a recent addition to the range water development picture. They have a tremendous potential in areas having favorable geological formations. Fortunately, such areas include a substantial portion of the better rangeland in Arizona and the mountain states.

A horizontal well is simply a horizontally-cased well in a water-bearing formation (Fig. 1). A "horizontal" boring rig (Fig. 2) is used to drill a hole and install pipe into a mountain or hillside at a slight downward slope to tap impounded groundwater.

Although miners, road builders, plumbers, electrical contractors, and geologists have developed equipment and techniques for horizontal boring, little attention has been given to adapting these techniques to water supply development. The equipment used to construct horizontal wells is also used to construct horizontal drains for control of landslides in

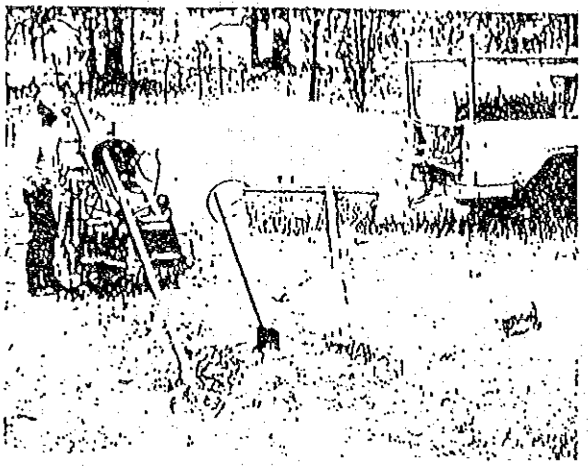

Fig. 2. *Horizontal well drilling equipment should be as light and portable as practical for use in rough range country. Note that water is recirculated through a rotary wet-boring drill stem. The heart of the rig is a pipe chuck which turns at about 100 rpm and is powered by a 10 hp gas engine.*

California. Hellesoe (1941) reported that the first installation of horizontal drains was made on the Cuesta Grade in 1939. In 1948, Stanton (1948) reported on the Hydrauger Method of installing horizontal drains on 53 landslide areas of the California highway system. Tripp (1963) credited Eric A. Anderson of Petaluma, Calif., with successful horizontal well drilling in the early 1950's. Root (1955) reported on the progress of horizontal drill equipment development. These reports indicate that equipment development was stimulated by drillers competing for highway drainage contracts and that the practice of horizontal well drilling evolved as a natural extension of earlier experience in constructing horizontal drains. It is also probable that a number of early innovators from both arts have contributed to the evolution of the equipment and drilling techniques. To date, the most effective equipment has been designed, built, and rebuilt by the drilling contractors.

The driller-cooperator on the San Carlos Apache Reservation has demonstrated three different "generations" of equipment while developing about 50 producing wells during the period from 1967 to 1969.

Site Selection

Potential sites are located by evidence of a water seep, presence of water-loving plants, or observation and analysis of geologic formations. Generally, a site will show geological evidence of either a natural dike or a "contact" type of spring.

The dike formation (Fig. 3) is a geologically tilted impervious formation, such as rock, which forms a natural barrier to an aquifer; in essence, a natural dam for an underground water storage reservoir. Water may not be visible, or it may seep through cracks in the dike or over the top of the barrier. The objective in horizontal well development of a dike formation is to drill through the barrier somewhere below the seep and tap the storage water.

The contact type (Fig. 4), consisting of a perched water table above an impervious material, is more difficult to recognize. Water seeps out at a point near the outcropping impervious layer. The line of seepage can frequently be located by observing the presence of water-loving plants. Drilling below the seepage will often fail to increase the yield because the entry may be into the impervious layer.

Drilling Equipment and Process

A rotary method of drilling is used with recirculating water to remove the drill cuttings. Standard lengths of 1½ inch nominal diameter extra strength steel pipe are used as the drill stem. The drill bit is a standard pipe coupling with tungsten-carbide blanks welded into notches in the leading edge (Fig. 5) which bores a hole with a diameter about ½ inch larger than the coupling. The drill bit must be small enough to clear the inside of a standard two-inch casing. The drill stem is clamped in a chuck and rotated at about 100 rpm as the chuck and stem are moved forward on a carriage. The equipment must be rugged and, equally important, light and portable for transport to sites in rugged terrain.

Drilling is started at a likely site with a minimum downward slope of ½-inch per foot. Water, pumped through the rotating drill stem, washes the cuttings back through the annular clearance between the hole and the stem. A portable gasoline engine-driven pump with at least 3 gallons per minute capacity at 120 pounds per square inch provides water return velocity of 1.0 to 1.5 feet per second necessary to cool the bit and to remove the cuttings. A continuous flow of return water is essential to prevent binding of the drill stem in the hole. Return flow is directed to a holding pond for settling and reuse. A readily available source of 100 to 300 gallons of water per day is necessary.

The drilling rate usually varies from 3 to 9 inches per minute through heavy clay, decomposed granite, or soft rock. In extremely hard rock, the rate may be less than 1 inch per minute. When this occurs, the carbide bit is replaced with a commercial diamond drill bit.

When the drilling produces evidence of a water supply, the exposed lengths of drill stem are removed, leaving just enough stem to serve as a guide for a two-inch casing. This stem is then equipped with a drill stem plug and pickup guide (Fig. 6) which serves to keep recirculating water out of the drill stem during placement of the casing. The tapered end of the plug also serves as a guide for recoupling to the drill stem for removal after the casing is set.

Cementing in the Casing

The two inch casing, equipped with a carbide-tipped coupling, is used to ream the hole around the drill stem guide until contact is made with the impervious layer. Drilling is stopped when the exposed end of the casing provides a convenient location for an outlet tee connection. A section of pipe and a standard coupling is attached to the pickup guide, and the 1½-inch drill stem is removed from the casing.

Another hole is then drilled immediately alongside the casing, penetrating several feet to form a control path for

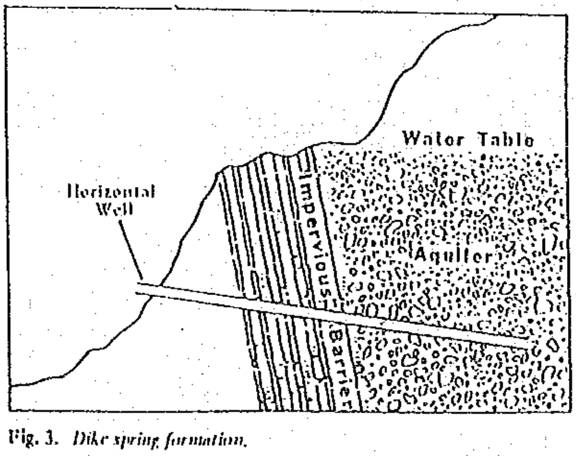

Fig. 3. *Dike spring formation.*

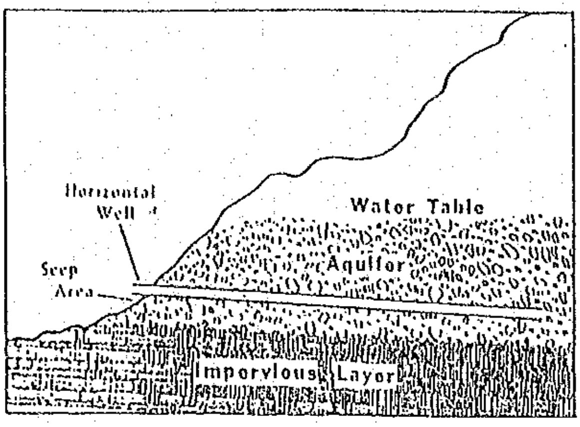

Fig. 4. *Contact type of spring formation.*

cementing the casing in place. A cement slurry pressure tank, containing about two sacks of plastic cement slurry mixed to a consistency of heavy cream is then connected, so that water pressure from the pump forces the slurry into the annular void and soil surrounding the casing. The drill stem is sealed at the ground by packing paper around the stem. Pumping is stopped when the cement begins to show in the casing return flow. The drill stem is then removed and the slurry is allowed to set, usually overnight.

The next morning, the drill stem is reinserted inside the casing and drilling continued until a satisfactory yield is established or until the practical limit of the drilling has been reached. The drill stem is then replaced with 1¼-inch perforated pipe, usually the full length of the hole or at least through the principal water-bearing strata, to keep the hole open.

Plumbing

The plumbing for the system is simple, consisting of a gate valve, vacuum relief valve, and fittings, all attached to a tee at the end of the casing. Normally, a bibb faucet is added to provide drinking water for both the ranchers and hunters. If the relief valve is subject to fouling from dirt or debris, a riser is included. With the well at a downward slope into the aquifer, the tee and air relief valve are at the high point in the system and the vacuum relief valve prevents the formation of a vacuum in the casing when flow rate exceeds water yield from the formation. If the vacuum were permitted to exist, fine grained materials would be sucked from the water bearing strata into the system.

The elevation of the water in the aquifer above the outlet provides a head of water, making this a completely automatic water system. From the tee, the necessary distribution pipe is connected to the float controlled watering sites.

Drilling Results

A serviceable water supply was obtained at 45 of the 53 locations where development was attempted on the San Carlos Apache Indian Reservation. It should be pointed out that success is a measure of both the driller's skill in site selection and the geological character of the area. Success was defined as a yield of 0.25 or more gallons per minute. Flow measurements were made after the plumbing of the well was completed, at which time the well normally had been running for a day or more. Yield estimates varied from 0.25 to 60 gallons per minute, and most were in the 3 to 10 gpm range.

Because every area has unique problems, drilling success and cost of development will vary considerably. Drilling distance at San Carlos varied from 41 to 270 feet and averaged 123 feet per producing well. Neither the shortest hole at 41 feet nor the longest at 270 feet were the least or most expensive site. The well record at the Blue Spring site shows a total development time of only 12 hours for a 101-foot hole, while at Johnny Spring, 52.5 hours were required to complete a 90-foot well. Development time averaged 32.3 hours per producing well.

The well construction costs averaged $500 per producing well, including $50 for plumbing supplies. This cost includes the dry holes and time spent on site preparation and road building, but does not include pipe distribution and water tank systems.

Advantages

The horizontal well system has a number of advantages over other range water supply systems:

1) When compared with conventional springs, water loss is minimized since the flow can be controlled by float valve or completely shut off when not required.

2) The system provides a sanitary water supply. Normally, spring water supplies are of good quality and purity as they emerge from the ground. However, contamination in a spring area is common and difficult to control. With the horizontal well, the possibility of contamination at this point is virtually eliminated.

3) The cost of the horizontal well will normally be substantially less than other water supply systems. The construction cost is moderate; maintenance cost is low and the operational cost is insignificant.

4) The chances of developing a successful water supply with a horizontal well are greatly improved over conventional spring development methods. Several of the better yielding wells in the San Carlos area were developed where there was no evidence of a spring or water seep.

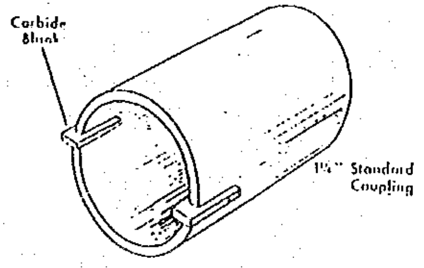

Fig. 5. *Drill bit.*

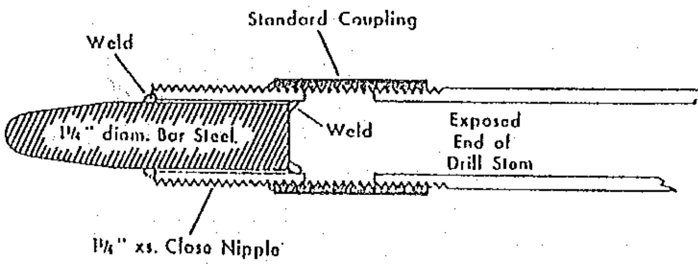

Fig. 6. *Drill stem plug and pickup guide.*

Arizona ranchers are enthusiastic about the potential application of horizontal well drilling in remote and rough country.

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"One hundred and twenty-three feet long!"

The horizontal well as a new method of range water development.

*by W. T. Welchert & Barry N. Freeman**

Recently overheard, the following conversation between two local ranchers — "Reub, how *long* is yer new well an' what did it cost yuh?" "Lemme see now, th' Coyote Well is a-hundred-twenty-three feet *long* an' it cost near $500.00 complete, thet is 'cepting th' water trough an' float valve!"

Well now, whoever heard of a well being *long* and a complete one costing only $500.00? Until recently not many in the range livestock business in Arizona had! But now with the introduction of "horizontal well" drilling, we have a revolution in stock water development in Arizona and potentially throughout the West!

Providing stock water where desired at a price one can afford to pay, has always been a problem for the stockman! Dirt tanks (stock ponds) are relatively inexpensive, but their reliability depends upon soil factors and rainfall. Trick tanks (runoff aprons and catchment basins) are expensive, require some maintenance and are dependent upon precipitation. Conventional wells are reliable and efficient, but they are expensive and require considerable maintenance. Springs properly developed, come close to filling our "wanted" prescription, though they are often inefficient conservers of water. Each of these systems has its place in providing needed water for livestock, and they shall continue to play a role.

With the introduction of horizontal wells into the range water picture, we have possibly the most exciting range water development system to occur in the last 50 years! Consider these pluses — they are relatively inexpensive, efficient, reliable, sanitary and maintenance-free! Add to such merits the fact that this system permits us to tap relatively small, trapped water supplies that go undeveloped in conventional vertical well drilling (because of location and small supply), and we have a highly desirable water development method!

In the simplest sense, a horizontal well is a "cased spring," and once developed it requires no power system to pump and dispense the water. Because the water is cased in a "closed system" from the point of origin to the point of use, it is more sanitary than other range water systems.

Site Selection

It must be pointed out that "horizontal wells" cannot be drilled just anywhere — site selection is most important! Fortunately, the potential for such water development includes a substantial portion of the better rangeland areas in Arizona and the western states. Proper site selection using such indicators as old springs, seeps, the presence of water-loving plants and geologic formations is the key to reliable horizontal well development.

The recognition of the two basic kinds of trapped water (spring types) is most important in determining where to drill. The "dike" formation is a geologically tilted dam of an impervious nature (rock or clay), which forms a natural barrier to an underground water supply. In such an instance, the well driller drills through the impervious layer and cases the hole into this layer to tap the water supply. The "contact" type is in essence a "perched" water table sitting on top of an impervious layer. To tap this supply the driller goes above the impervious layer with the drill-hole, exposing additional controlled seepage area which is then cased. To date in Arizona, successful wells have been brought in by this drilling process in such formations as granite, decomposed granite, malapais, sandstone, clay, etc.

Drilling Process and Equipment

The process of development involves a small rotary wet-boring drill stem rig, a drill water supply, a recirculating water pump, tube steel casing, and a few simple plumbing supplies.

When a site is selected, drilling begins horizontally into the site. Water is pumped through the rotating drill stem (one and one-quarter inch extra-strength steel) washing the cuttings back on the outside of the drill stem. The drill bit is a coupling with tungsten carbide tips. This type bit is adequate for cutting most strata. However, when very hard, dense material such as hard granite is encountered, a diamond bit must be used. With evidence

**Extension Agricultural Engineer and Range Management Specialist, respectively, Cooperative Extension Service.*

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College of Agriculture, University of Arizona, Tucson, November-December, 1969

evidence of the return flow of the cement in the casing; it is then allowed to set overnight. The next day the drill stem is inserted in the casing and drilling continues until a satisfactory yield is produced or until a practical drilling limit has been reached. The drill stem is then replaced with one and one-quarter inch perforated pipe through the principal water bearing strata to shore the hole.

Plumbing

A plumbing "T" is then attached to the two- inch casing protruding from the site. The "T" consists of a shut-off valve, a vacuum air relief check valve and a reducer. To this "T" the water distribution system is then attached, and you have a completed water system. By attaching an upright extension to the vacuum air relief valve, it is protected from being fouled with dirt or debris. With such an extension in place, the entire exterior of the well can be earth covered to prevent freezing. Normally a hose bibb faucet is provided in the cap end of the casing for drinking water convenience to the rancher and hunters.

Arizona Innovation

In Arizona the innovator and authority for this system of water development is A. W. "Bud" Smith of Crestline, California. Smith is locally known as "Horizontal." He and his son Errol have 14 years of drilling experience on more than one-thousand locations, including a number of specialized drainage systems. Their Arizona experience includes wells in the Patagonia, Seligman, Flagstaff, Globe and San Carlos areas. The largest single development area has been on the San Carlos Apache Indian Reservation, where the Smith's have developed over 45 producing horizontal wells. The data reported here is based on this experience compiled during 1967-69.

Results of Well Log Data

The drilling results on the San Carlos have been nothing less than spectacular! The analysis of well logs from 53 locations on the Reservation are summarized in the table above.

The total development cost for 45 producing well installations including the plumbing "T" average $500.00 per site. This cost includes the dry holes and frequently includes 30% or more time spent on site preparation and road building. Today these costs would be slightly higher.

Because every area has its unique problems, both drilling success and cost of development can be expected to vary a great deal. A wide variation in development costs due to location and formation is demonstrated in the figures above. Neither the shortest at 41 feet, nor the longest hole at 270 feet was the least nor most expensive site. The well log on Blue Spring shows a total development time of only 12 hours for a 101' hole, while Johnny Spring required 52.5 hours to complete a 90' well.

As noted in the yield data, production was usually in terms of three to ten gallons per minute, with a range of yield from one quart to sixty gallons per minute. Although one quart per minute seems a meager flow, this can be considered to represent a successful well under this system of development. Running continuously, it is sufficient to supply water for 20-25 head of cattle based on

Success	45	1,183.0	5,518	184
Failures	8	265.5	1,540	none
TOTAL	53	1,448.5	7,058	184

Success Ratio: 45/53 85%

Yield: varied from 1 quart to 60 gpm - 3 to 10 gpm for most sites.

Drill Distance: varied from 41 to 270' -- average 122.6' per producing well

Development Time: averaged 32.2 hrs./producing well
least (101' at Blue Springs) -- 12 hrs.
most (90' at Johnny Springs) -- 52.5 hrs.

Development Costs: averaged $382.62 per location
averaged $450.65 per producing well
casing and plumbing materials were furnished by the owner at an average cost slightly less than $50.00 per producing well.

a cow consumptive use of 15 gallons per day. A single watering site will permit the utilization of 3 to 5 sections of grazing land otherwise unavailable because of distance from water.

System Advantages

The horizontal well spring development system has a number of advantages over other water supply systems available to the rancher.

1. Water loss is nil since flow can be controlled by a float valve or completely shut off when pasture is not in use.

2. Maintenance is low for the life of the water supply. The only working parts are a float valve, a check valve, and a shut-off valve. Providing drinking water for hunters may even discourage vandalism of equipment in the pasture.

3. The cost of a horizontal well will usually be substantially less than any other water supply except the natural spring.

4. The chances of developing a successful water supply with a horizontal well is greatly improved over conventional spring development. A number of excellent yields have been developed where little or no spring site evidence was available.

5. The system provides an excellent sanitary water supply. Normally spring water supplies are of excellent quality and purity as they emerge from the ground. However, contamination in the spring development area is common and difficult to control. With the "cased" spring the possibility of contamination at this point is virtually eliminated. This system is ideal for domestic water supplies in remote areas.

This system of providing stock water has proven itself in Arizona and its potential has yet to be fully developed! Because of the mobility of the equipment and the ability of the system to take advantage of meager water storage the process has great merit on most range livestock operations in the West for developing stock water!

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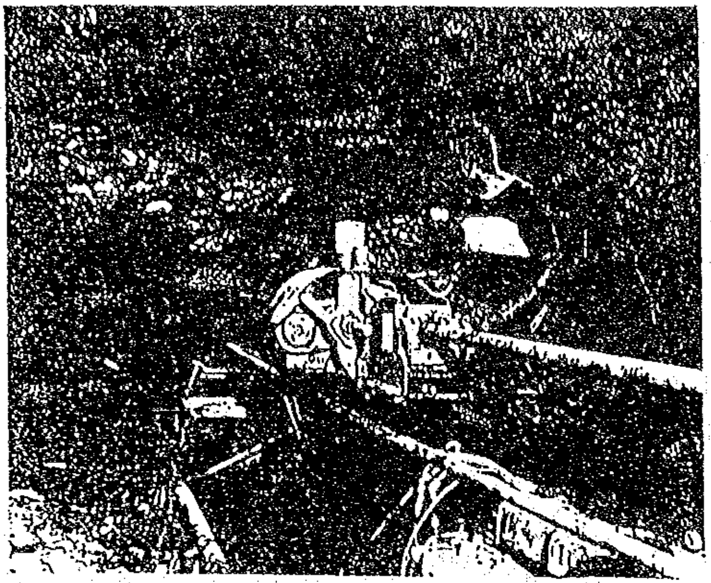

Figure 1. Development of "horizontal well" springs in Arizona has been pioneered by A. W. "Bud" Smith and his son Errol. Errol is shown above. While the exact origin of this drilling technique is unknown, the Smiths have dramatically demonstrated the value of this system to the Arizona range livestock industry. During the past three years they have successfully developed 45 of 53 locations on the San Carlos Indian Reservation at an average cost of about $500. per site.

Figure 2. A horizontal well is a "cased" sp
drilling process involves a rotary, wet-boring
a cement slurry pressure tank, a drill water
well is purposely drilled on a ½ inch per foo
in the casing.

Figure 4. A completed horizontal well involves a 2 inch steel casing set in concrete to an impervious layer and a plumbing "T." The "T" includes a shut-off valve, a pipe reducer for connection to the distribution system and a vacuum air relief valve. This spring on the San Carlos Indian Reservation test-yielded more than 50 gpm.

Figure 5. A hose bib installed at the casing '
and hunters. Except for the errors of man,
over the spring water storage supply and neat
use. The cased spring provides excellent sani

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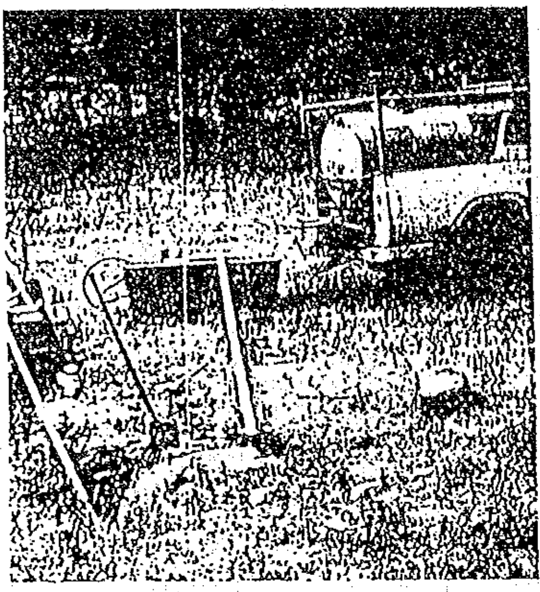

l well is a "cased" spring with complete plumbing controls. The
s a rotary, wet-boring drill stem, a small recirculating water pump,
re tank, a drill water supply, plumbing tools and supplies. The
l on a ½ inch per foot downward slope to avoid vacuum problems

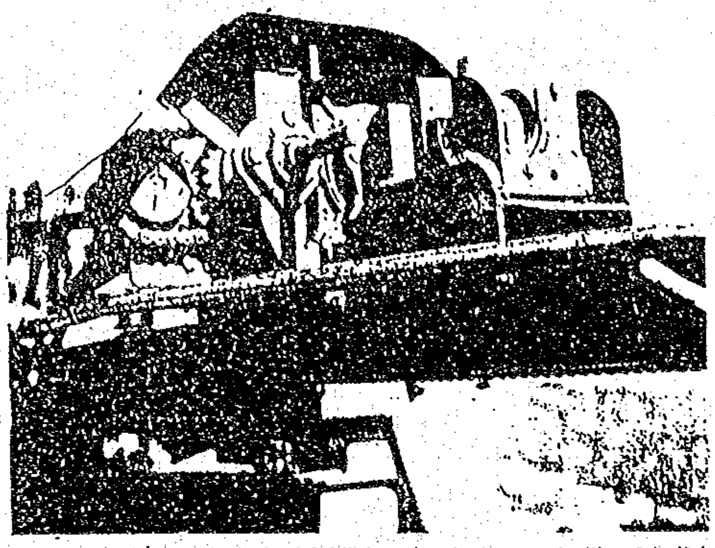

Figure 3. The heart of the horizontal drill is a pipe chuck powered with a 5 to 10 h
gas engine. The transmission and drive mechanism turns the chuck at about 100 rp
The chuck slides on a carriage frame. For drilling in rough range country, this equipme
should be as light and portable as practical.

nstalled at the casing "T" cap provides drinking water for ranchers
for the errors of man, this spring system provides complete control
storage supply and nearly all of the water can be classed as beneficial
provides excellent sanitation control.

Figure 6. Two sacks of plastic cement are used to set the casing in place. A water pu
is used to force the cement slurry out of a 20 gallon tank. A heavy duty hose runs
the slurry through the drill stem to a hole beside the casing until the cement begins
show in the casing return flow.

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