INTRODUCTION AND SUMMARY

It is difficult to subdivide interrrelated agricultural production systems in barani areas. At the same time, it is not possible to present everything at once. To assist in explaining the options and possibilities, barani agricultural development has been separated into water rainfed agriculture resource development, treated in the present volume, and development, which will be treated in Volume Four. Water resources projects, presented in this volume, call for large water development initiatives: major irrigation systems, such as dams and water conveyance structures; flood control in hill torrents; and tubewell schemes, covering hundreds of thousands of acres. Development of water resources is productive, however, only…

[4:01 pm, 11/02/2025] Naeem Khan: Two possibilities were available for presentation of the material collected on Barani development: it could be presented by subject or by zone. In the Water Resources Development volume information is presented in both ways. The first five chapters contain information for the barani areas as a whole, and the modes of water development employed are investigated. In Chapter Six the analysis for each of the zones is presented, and solutions regarding their water development are proposed. The zones are, in fact, significantly different, especially since the physiography and rainfall patterns make each zone unique within the planning area. There are no overarching water projects or programs that embrace all the zones. In the final chapters, the report synthesizes the analysis, the implications of water development for the barani zones during the next 20 years is discussed, and a five. year Action Program is presented. Each initiative is analyzed to determine how the project will fulfill the objectives of the Master Plan. Development Project, is carried through consideration by the Asian Development Bank. a One project, the Riverain preassessment feasibility study for

Individual barani zones are addressed more specifically in Chapter Six, where each zonal analysis is presented according to following plan:

* Existing resources and conditions, providing basic information on the zone and its resource base soils, land use, water development trends, and special issues in water development;

* Opportunities for water development, divided into groundwater and surface water development;

* Costs of proposed initiatives, divided into capital investment, operations, maintenance, and replacement costs;

* Evaluation of alternatives; and Recommendations of the Master Plan.

Each level of analysis, beginning with the Master Plan and moving through the zonal assessments to specific projects, is more specific and directed at lower-level opportunities. In the Riverain Development Project a highly specific investigation of barani conditions and a groundwater development strategy for the Riverain area for boosting agricultural production are presented. Even though its focus is on water development, the project includes agricultural extension services and on-farm water management in an effort to support improved agricultural practices.

More specifically, investment possibilities for development of water resources in the barani areas are presented and costed. Proposed initiatives to harness the diverse water resources of the tract vary from the large, structural dams on the Potwar Plateau to small tubewells scattered across the Riverain and Siwalik zones.

Details of the proposed initiatives and the settings that determine their shape d timing are described, zone by zone, in Chapter Six, where it is shown that the ect of newly developed water on agricultural output in the barani zones will be atest in the Riverain Zone and on oitable water the Potwar Plateau. These areas have sources, acceptable soils and topography, tolerable climatic "itions, and access to markets, agricultural inputs, and technology.

Of less importance, but still significant, is water resource development in the Siwalik Zone, an area that enjoys relatively high rainfall and good soils. attention to conservation needs and shifting of already well established agriculture With toward high-value crops, the area justifies investment to exploit deep sources of groundwater and development of newly recoverable lands along the Ravi River.

More limited results from near-term development of water resources are anticipated in the Salt Range, except for groundwater and several small targets of opportunity, because of soil and water salinity, and in the Thai Zone, because of sandy soils and shifting sand dunes. Dera Ghazi Khan (D.G. Khan) has a different water regime, and water development there is primarily for flood control, with a hill torrent project proposed to create an irrigation system.

Water development is initially considered zone by zone in the context of a full development framework. Investment schedules are then formulated with a 20-year perspective and for a 5-year Action Program, still on a zonal basis. Realism is introduced into the process by combining zonal potentials and testing them against two possible levels of availability of investment funds Rs 80 million and Rs 160 million (1987 price levels) annually.

The investment schedules so derived (see Tables IX-1 [low] and IX-2 [high]) present a graph of a proposed program of:

Low-cost divisible projects with potential for high early returns that mobilize substantial private resources (tubewells);

Initial or pilot projects that will facilitate evaluation of large programs (irrigation from a link canal on the Potwar Plateau); and

Investigation and study programs to define difficult and possibly costly future developments.

If investment is restricted to the low-level investment projection, Rs 80 million per year, 12 projects could be completed in five years. Nine are for development of groundwater and a spring, one is for a hill torrent, and two are for basin irrigation with surface water.

Irrigation water can be provided on a controlled basis to about 240,000 acres, and occasional flood irrigation will be provided to a large tract of land on the piedmont slopes of D.G. Khan.

Projects proposed for the high-level investment projection (Table IX-2) do not differ in nature and objectives from those of the low-level projection. Four more groundwater projects can be constructed on the Potwar Plateau, and an additional project can be introduced for the Kaha Hill Torrent in D.G. Khan. Investigations of potential projects in the Salt Range and Thal zones will be intensified with the intent to bring one or more surface-water irrigation projects forward.

To ensure the feasibility of some of these initiatives for the long term, new policies will need to be adopted, and organizational, administrative, and legislative actions will be required. The fostering of widespread further development of smal tubewells, for example, will require institutional mobilization of private resources on a large scale; while planning for the construction of sizable reservoir projects in the distant future will require early adoption of land-use control measures to ensure the future availability of an economic site.

A review of the organizations in water resource development whose involvement is critical to a high level of success in the proposed projects appears in Appendix A of this volume.

CHAPTER TWO

PHYSIOGRAPHY AND HYDROLOGY

The occurrence of streams, stream flow, and groundwater is largely determined by physiographic features that divide the barani ares into distinct geographic sones, with water regimes that are unique to each. Exhibit II-1. while following chapter. the water regimes Physiographic features are shown in of the several zones will be described in the

The lands of the barani area can be grouped into five broad physiographic categories:

- Mountains;
- Piedmont;
- River flood plains;
- Dissected uplands; and
- Desert.

INTERZONAL RELATIONSHIPS

Three mountain ranges. Siwalik, Salt, and Sulaiman generate flood flows that have formed and are still reworking piedmont areas. The D.G. Khan or Sulaiman alluvial fans and piedmont soils are being reworked most actively by 13 large streams (hill torrents), while the Siwalik piedmont is subjected only to local flooding from 3 large streams (nullahs). Nullahs that flow from the Salt Range onto the piedmont are flashy and damaging, but they are comparatively small in watershed areas and flood discharges. Thus, the lands of three of the seven barani zones--the Salt Range, the Siwalik, and D.G. Khan are predominantly piedmont.

All of the piedmont zones are bordered by Zone 6 (the Riverain). The riverain lands are flood plains that are alluvium deposited by the larger rivers of the Punjab, in some areas underlain by or intermixed with alluvial deposits laid down by earlier rivers and possibly soils aeolian in origin. Although the reworking of soils and lands of the Riverain Zone takes place during the annual flood season, this process has been significantly diminished along the Ravi River by the diversion of water by India and along the Jhelum, Chenab, and Indus rivers by the operations of the Mangla, Sallal, and Tarbela reservoirs.

The Potwar is largely an extensive dissected upland plateau bordered on the north and east by the Himalayan foothills, on the south by the Salt Range, and on the west by the deeply incised Indus River. The Murree hill tract, by virtue of its elevation and the heavy rainfall there, dominates the plateau to the north and provides much of the run-off that crosses the plateau in the Haro and Soan rivers.

The Thal lies almost entirely in a desert, some 75 percent of which is covered by sand dunes. There are no important streams in the zone.

PHYSIOGRAPHY OF ZONES: CHARACTERISTICS AND SOILS

Each of the broad physiographic categories described above has its own characteristic land forms and soils, which will be described in more detail, zone by zone, in Chapter Six.

CHAPTER THREE

WATER RESOURCES

The water resources of the barani tract comprise rainfall, streamflow, and groundwater.

RAINFALL AND EFFECTIVE PRECIPITATION

Rainfall, directly on the land and collected naturally in running over the land, is at present the primary source of moisture for nurturing agriculture range, livestock, forests in the barani area. crops, have been constructed and private tubewells have been installed. In certain areas, however, small dams

Effective precipitation, or that amount of the rainfall available to crops, is a variable percentage of total rainfall and for any given event. irrigation requirements where tubewells and reservoir canal systems are proposed Determination of requires an estimate of effective precipitation. Exhibit III-1 shows that rainfall varies from 4 inches at the southern end of the Thal and Sulaiman zones to more than 30 inches in the Siwalik and northeastern Potwar zones. Table III-1 shows total annual and seasonal precipitation and estimated levels of effective precipitation for several points in the barani area.

Rainfall, its occurrence, and its use, as related to production systems for rainfed agriculture, will be described further in Volume Four of this report.

Streamflow

The largest streams that flow through or border the barani area are the Indus, Jhelum, and Chenab rivers. and which are perennial Rivers that rise in and flow through the barani areas that is, those with significant non-monsoon or winter season flows rise in the Potwar Zone.

Streamflow patterns are also shown in Exhibit III-1. Seasonal and annual flows of perennial streams of the Potwar Zone are given in Table III-2.

Floods affect the barani tract in three important respects. Floods of the Indus, Jhelum, and Chenab rivers determine the areal extent and timing of potential cultivation in the Riverain Zone. Floods of nullahs and torrents, as well as being sources of water for flood (sailaba) irrigation and groundwater recharge, are highly destructive communities. to established irrigated areas, public works infrastructure, and Where measured records are inadequate, statistical and synthetically derived flood levels are used to determine the capacities of the specific structures. Flood flows relevant to analyses of proposed initiatives are given in Table III-3.

Groundwater

Groundwater is the only widely exploitable source of water in the Siwalik Z There is essentially no groundwater in the piedmont barns and areas quantities restricted but very important locally in the Salt Range and the Potwar. the Thal Zone limitations of groundwater development are related more to the depth complexities of developing fresh water that overlies saline water than to availability In mucho

Characteristics of groundwater and the several aquifers have been investigates and are described in a series of seven reports prepared by the water Development Authority (WAPDA) between 1972 and 1983, as follows:

* "Ouantitative Estimates of Different Quality Ground Water in Thal Doab," by 1972). 116, (Lahore: WASID,

* "Geology and Groundwater Resourcefydrology Groundwater Investigation Circle, Hydrology Division (Lahore: 1976).

* "Hydrogeology of Hazro Area, Potwar, Groundwater Hydrology Project (Lahore: WAPDA, February 1979).

* "Hydrogeology Data of Dera Ghazi Khan District," Vol. I, Basic Data Rele No. 4, (Lahore: Directorate General of Hydrogeology, WAPDA, June 1981).

L. A. Khan, K. M. Ashraf, and M. Ismail, "Hydrogeologic Investigations in Haro River Basin, Potwar Plateau, Punjab Province." GWIP Report No. 36 (Lahore: Directorate General of Hydrogeology. WAPDA, April 1981).

"Hydrogeologic Investigation in Soan Basin, Potwar Plateau, Punjab Province, L.A. Khan, M. Is Ismail, GWIP Report No. 3, (Lahore: Directorate General of Hydrogeology, WAPDA, August 1982).

"Hydrogeologic Investigations in Eastern Drainage Basin, Potwar Platesu, Punjab Province, by M. Ismail, GWI Report No. 43, (Lahore: Directorate General of Hydrogeology, WAPDA, December 1983).

IDENTIFIED GROUNDWATER RESOURCES OF THE BARANI AREA

Potwar

Three fairly extensive areas and four areas of limited extent are shown in Exhibit III-2 to have high-yielding aquifers that could be exploited by tubewells. The principal areas are the Chach Plain, the Hasan Abdal-Taxila area, and the area around Rawalpindi and Islamabad. Smaller, but significant, are the tracts at Pindi Gheb, along the left bank of the Soan River, along the Soan-Kanshi River topographic divide at Gujar Khan, and in a small circular area at Talagang. There are, in addition, extensive areas of sandstone aquifers that yield water from dug wells, 100 feet deep although the average depth is less than 50 feet quantities adequate for domestic supply or to irrigate one to two acres.

The classification of these aquifers for exploitation and areal extent is shown in Exhibit III-2 (Haro River Basin in Punjab) and Exhibit III-3 (Soan River Basin).

Characteristics of the tubewell-capable aquifers and the quality of the water of these and other barani zones are summarized in Table III-4. WAPDA investigators concluded that the aquifers of the Potwar could support development of tubewells with capacities of 0.5 to 1.5 cubic feet per second (cfs). Tubewells would be situated in sands and gravels of unconsolidated alluvium. The transmissivities range from 12,000 to 417,000 gallons per day per foot (gpd/ft). The quality of the water is quite good for irrigation, with concentrations of total dissolved solids (TDS) of 150 to 800 parts per million (ppm). Piezometric water depths range from water at the surface in the Hazro area to water at 90 feet in some lands at higher elevations.

Salt Range

Exclusive of riverain lands. three sizable there are The lands areas totaling about 300 square miles of the Salt Range Zone where tubewells can be developed. lie along and above Jhelum Town. Table III-4 shows the aquifer to have 218.000 gpd/ft. Groundwater is four to 65 feet deep and has TDS concentrations of less than 500 ppm. Tubewells can be developed transmissivities ranging from 9,600 to with specific capacities of about 24 gpm per foot of drawdown.

Siwallk

Some 77 percent of the Siwalik Zone between the Chenab and Ravi rivers (1,711) square miles) has aquiferous conditions favorable for the development of tubewells Water table conditions prevail across most of the area with depths to water table varying from 8 to 30 feet. Transmissivities vary from 41.000 to 112.000 gpd/f1 enjoys the higher, more favorable specific capacities. Deeper waters are generally north of Sialkot, where turbine pumps would have to be installed to develop groundwater instead of the cheaper, more common centrifugal pumps.

Thal

The Greater Thal Area, as defined for possible development whic surface water irrigation, is nearly coincident with the barani zone of the Thwhichhich lies outside irrigation, isisting canal commands (Exhibit III-4). The zones, which isuunderlain by aquifer, extends over some 3,050 square miles. quality of the groduitwaterds poof (greater than 1,500 ppm TDS) throughout two-thirds of the grou area (Exhibit III-4).

Exhibit III-4 shows a more favorable situation along exploration profile Z-Z (400-Fexhibiepth with TDS less than 1,000 ppm) between Driver and the Lowe This is (400-fog dep thesuit of water migration from the Indus River ande, the Lower Thal Canal. Profile G-G', which crosses the center of the barani zone, is inconclusive, although hopeful, concerning water quality. The water table is deep throughout much of the zone and thus cannot be exploited easily by centrifugal pump.

D. G. Khan

Exhibit III-5 shows that groundwater of usable quality (less than 1,100 ppm TDS) in the D.G. Khan area is exploitable by tubewell only in the canal command (nonbarani) and riverain areas. The pachad, or piedmont, lands are underlain at depth by water with salinity concentrations of 1,100 to 3,000 ppm or more, The piedmont areas also have poor aquifers, although shallow, open wells have been developed across most of the piedmont area. The riverain aquifers of D.G. Khan are described as part of the Riverain Zone.

Riverain

This zone extends as a ribbon of land on both sides of the Indus, Thelum. Chenab, and Panjnad rivers. The aquifer is in sand, water tables are high, and the potential for tubewell development is excellent; it has specific capacities of 67 to 150 gpm/ft. There are areas where saline water migrates from adjacent piedmont areas and makes development undesirable. These areas are along the right bank of the Indus River, looking downstream, between Rajanpur and Fazilpur in the D.I. Khan-Taunsa reach, and along the right bank of the Jhelum River Rasul Barrage to Khushab. In other areas, the water is of excellent quality -- generally less than 400 ppm TDS.

CHAPTER FOUR

MODES OF WATER DEVELOPMENT

Initiatives to develop water will be presented hereafter in Chaptering water ecological zone. To avoid repetition, selected modes or methods of mobilizing ille resources for agriculture will be developed in their basic generic form. They will be inclused in zonal plans only with respect to their differences, to determine applicable costs, benefits, and effects.

There are four potential barani water systems:

Tubewells;

Connecting reservoirs;

Gabion dams; and

Transfer of water between zones.

TUBEWELLS

Tubewells are wells developed by setting pipe casing and a screen or slotted pipe into a vertical bore hole that penetrates a groundwater aquifer. Prime movers are located on the land surface, and pumps may be centrifugal for wells in which the pumping head is less than one atmosphere of pressure. Turbine pumps with bowls set in the well, below drawdown level, are generally used in Pakistan where water tables or piezometric surfaces are deep. Submersible pumps are not in wide use for pumping deeper waters.

Traditionally, each private owner or a government agency has constructed a tubewell as a fixed installation with all components bore screen, pump, motor, and ancillary facilities housed at the site. In East Punjab and increasingly in Pakistan pumps and motors are being moved among several bores. This is being done in the Siwalik by landowners who have several small plots of land. In instances where farmers cannot place fixed installations in flood areas, for example the removable pump is used as an appropriate solution.

Mobile Tubewells

This mode of water development is designed to help farmers who have been unable in the past to install tubewells where the water table is shallow and the groundwater is of good quality. A farmer would be required to invest less than half the cost of a full tubewell if the government or a private entrepreneur arranged to pump water on a given, but flexible, schedule using a mobile prime mover and pump.

The proposed delivery of water and the proposed staffing of the entrepreneur operation is summarized below:

- The farmer installs casing, screen, and couplings for a tubewell of specified standard capacity.
- The private entrepreneur has a fleet of farm tractors wagons, water and fuel barrels, and several small diesel motors and pumps per wagon.
- If the objective cropping pattern during the rabi season occupies one and the one half to two times the areas of area of kharif crops, then pumping will approximately balance in rabi and kharif seasons.

- In an area of low rainfall and coarse soils, irrigations may be required as frequently as weekly during the kharif season. The Rabi watering will be less frequent and may be of less depth.
- Round-the-clock operation with daily moves requiries Round the clock pump to operate 161 apro deliver one-hour inches, if it i6 acre. moves will permit one is of one efs capacity, or 80 inches, if it is of one half cfs capacity.
- If each farm has a bore and the farm is small, there will be many more bores than pumps.
- A Punjab Land Utilization Authority (PLUA) or On-Farm Water Management type of organization and operation can assist the private entrepreneur to develop a tripartite agreement among himself, the farmer, (OFWM) and an agricultural development bank to handle water charges through the bank.

CONNECTING RESERVOIRS

It is possible on the Potwar Plateau to connect existing and planned reservoirs, which have small catchment areas, to streams with larger flows to achieve greater regulation of streamflow and, in turn, more extensive irrigation. The systems would be connected only where the reservoirs command substantial areas of good agricultural land. They would be designed to connect only small and intermediate or large reservoirs. Minidams and those small dams with small reservoirs of approximately 400 acre-feet (0.5 mcm) would not be included unless they provided a convenient crossing of a stream or hydraulic control at the head of an irrigation system.

Existing Situation

Historically, small dams have been built to serve small areas of irrigation (70 to 2,000 acres). These small areas have not been brought under cultivation for the following reasons, a reported by the Barani Commission in 1975, Punjab Economic Research Institute (PERI) in 1984, and the ADB in 1985:

- Low acceptance of irrigation by farmers because they are accustomed to barani farming:
- Dams situated far from cultivable land;
- Incomplete construction of water channels, or none, to and on the farm;
- Higher unit cost of inputs;
- Lack of extension support;
- Need for farmers to associate for joint work; and
- Lower run-off to reservoirs than was anticipated in the design.

An Asian Bank Project, which came out of the Bank's 1985 study, is now under way.2 Twelve new dams and irrigation systems will be built after socioeconomic studies and efforts to organize farmers have been made.

Remedial works will be undertaken at nine existing sites. It is the opinion of the Master Plan Study Team that it will be difficult to sustain the appropriate levels of inputs and extension services for the isolated small areas of the small dams, even if the systems are well set up. From this point of view it is proposed that areas to be irrigated be connected and expanded so that they will be large enough to command the attention necessary for commercialized irrigated agriculture.

Connection of Reservoirs

Shown schematically in Exhibit IV-1 are illustrated systems and the expected magnitude of increases in area that should result from connection of reservoirs. It is shown that small reservoirs, which generally irrigate only a few hundred acres or less, by drawing flow from reservoirs or sizable streams that are higher in elevation can serve much larger areas. The larger areas will, in fact, serve as magnets. Extension time can profitably be introduced, operations will be large enough to attract credit, and two-way market flow will occur through supply of inputs and as a point to market produce. so, output will be of such volume that small Also, agro-industries can be established. Such a mode of development is divisible for purposes of implementation. The channels and reservoirs can be developed as resources become available. It is possible to develop the smaller reservoirs first, as has already occurred, then to connect them.

Connecting reservoirs would increase the size of the irrigated area 5 to 100 times, depending on the extent of the irrigated land before the connection took place. Additional water will be made available as a result of the following:

- Kharif-season spills of medium-to-large reservoirs can be conveyed to smaller reservoirs that are not likely to fill that is, advantage will be taken of excess storage capacity.
- Kharif-season spills of large reservoirs can be passed through smaller reservoirs to irrigate kharif crops without the use of storage.
- Full reservoirs will be available to irrigate rabi crops.

An important advantage of developing storage for agricultural use on the Potwar Plateau over irrigation of the Indus Plain is the availability of ample effective precipitation and the consequently much lower irrigation requirement. In fact, the Potwar irrigation requirement is only one-half to two-thirds of the requirement on the Indus Plain.

GABION DAMS

The piedmont areas of the barani tract have formed as outwash from streams that experience flashy floods of short but intense duration. These streams are generally nonperennial and thus do not warrant construction of traditional water conservation structures large monolithic concrete or fill dams to store water for later use. Even when such structures might be appropriate, their utility is not feasible because of the high sediment loads of the streams and the consequent rapid depletion of reservoir capacities.

Monolithic concrete diversion structures, low weirs, and head gates have been constructed. In many instances they have been outflanked, have eroded, and have cracked, and repairs would be costly or are not feasible.

The Punjab Irrigation Department has evolved a structural mode that is flexible and readily repairable at reasonable cost. This is a weir made of gabions. rock bound in steel wire bags. The gabions are stacked and anchored. Abutments of sloped compacted soil, faced with gabions and rip-rap -- loose dumped rock. Advantages of gabion structures are:

- If a section of a weir has been undermined by scour, the resultant structural sag can easily be releveled by the addition of gabions on top.
- It is also possible to increase the level of the weir, to extend guide walls, or to reinforce abutments by the addition of gabions on top.
- Downstream aprons can be created or repaired by the simple ad addition of gabions
- Gabions can be put together by unskilled labor at the site of the work. No large plant is required.

TRANSFER OF WATER BETWEEN ZONES

This mode of development relates to the captured in other which runs to waste from the Potwar Zone for beneficial be used as a use ase and in canal-irrigated areas. or trading system, should plateau to gain in the Such development also could als diverted from water be phic advantage topographic and western lands of the Potwar Plateau. of the Tabela irrigation Reservoir command across the middle and western lands of the Potwar Plateau.

From the national point of view the rivers of the Potwar have been regarded as parking place for huge quantities -- 9 to 12 million acre-feet [MAF] – of Indus River flood water for release of downstream to irrigation systems of the Indus Plain. In 1964 and 1966 Associated Consulting Engineers prepared basin reports for development of the Haro and Soan rivers. These two rivers were considered independent systems, and although some sizable projects were proposed for the tributaries of the Soan River, the idea of an integrated plateau irrigation system was not adopted in that study.

Should a national view of the water resources of the plateau be adopted, it would be possible to capture almost the entire annual flow of the Soan River 1.5 MAF -- at Dhok Pathan or Dhok Abakki for use downstream. Because there are no sizable tracts of land suitable for irrigation in the Soan Valley, downstream from Dhok Pathan, most of the water would be released during the low-flow season and could serve one or more of the following purposes:

- Offset diversions from the Tarbela Reservoir, should integrated non-lood-season link operations ever be deemed beneficial to the country;
- Provide additional extended to Jalalpur, should there be opportunity for economic development of the Salt Range Zone; duty of water for
- Provide additional flows to canal commands of the Punjab, Sind, NWFP, and Baluchistan;
- Provide a reservoir for future pumped-storage hydroelectric operations is conjunction with a Kalabagh Reservoir,
- Provide a dam that could be raised should it some day become imperative to link a Tarbela Reservoir channel storage. with depleted storage to 9.0 MAF of off channel storage.

CHAPTER FIVE

CRITERIA FOR SELECTION OF WATER RESOURCE DEVELOPMENT PROJECTS

Principles and criteria related to water-based agricultural development will be defined below. Clearly specified principles and criteria for those projects with water development components were articulated to refine objectives further, to assist in establishing limits for formulation of interventions, and to measure and compare alternative interventions. A consistent set of principles has been applied in developing programs in which plans are presented and evaluated. Any water resources development project considered for the barani zones should be measured against these criteria.

The principles and criteria are related to four regional objectives for barani development productivity, sustainability, equity, conservation that were used to guide the preparation of the Master Plan.

Principle 1. Projects and programs amenable to quantification will be compared on a consistent economic basis. To put this principle into practice, the following criteria should be applied:

- Productivity. Only interventions with favorable estimated economic returns will be included in the Action and Perspective plans.
- Productivity and Sustainability. Public funding will be used to activate private development, or subsidies that are complementary private funds will be identified. required to draw out

Principle 2. One ranking of interventions will be made according to their expected mobilization of productive private investment. To put this principle into practice, the following criteria should be applied:

- Sustainability. Projects and programs will be designed to stimulate the use of private investment in preference to public funding.
- Sustainability. Projects will be designed, first, to mobilize any personal funds that may be available and, second, to assist financing through commercial financial institutions. Only in a situation in which the beneficiaries of a project or program are unable to command credit financing, or in which a catalytic effort is required, will it be assumed that the government will intervene directly with full project financing.

Principle 3. Only major infrastructure will be fully financed, operated, and maintained by the government. The costs of facilities that contribute to broader regional or national goals will not be fully charged to their beneficiaries or to the immediate area and sector benefited. The criteria for putting this guiding principle into practice are the following:

- Equity and Sustainability. damage Facilities to supply water and control Nood roads, canals, irrigated areas, and towns, s well as for hill torrents of D.G. Khan, will not be fully charged to the are to infrastructure suc such as that receives irrigation.
- Equity and Sustainability. Road construction improvements should be regarded as public that complements irrigation works infrastructure and, purpose of determining the financial and economic for the viability of projects Certain road should not be charged to the beneficiaries of the project. should, however, be an integral part of a project and should be financed through specific project funding.

Principle 4. Groundwater will be extensively exploited, while the feasibleffects on adjacent and downstream users should be minimized. zed the following criteria should be will be used to recharge groundwater reserves. observed: st

- Sustainability and Conservation. Groundwater will be developed in accordance with the economic and financial criteria listed above, without resort to depletion of aquifers.
- Conservation. Riverain groundwater development will be organized and implemented to minimize reduction of dry-season river regeneration.

Principle 5. Water development projects will extend from the headworks to the completion of on-farm conveyances and the delivery of the technology and inputs required to exploit new irrigation capacity. The following criteria will be observed:

- Productivity and Sustainability. Project interventions will specifically include consideration of farm-level requirements and costs that will be amenable to project monitoring, to ensure that private actions that will actually produce the benefits needed to justify the project are forthcoming.
- Productivity. Projects will include some portion of the farm-level costs in the public investment budget when there is reason to believe that rapid private actions will not be forthcoming to respond to irrigation opportunities. Twenty-five percent of the total farm-level costs added to the engineering structure budget will be used until better estimates are available from feasibility studies.

Principle 6. Surface water will be developed in the short term with a view to its long-term potential. Run-off from monsoon rains will be controlled and, where possible, channeled to productive uses. putting this principle into effect: The following guidelines can be used in putting this principle into effect:

- Conservation. Each individual surface-water development, reservoir, or conveyance will be evaluated for its potential integration into a system designed to develop and exploit the available surface-water resources fully.
- Equity. Stored water on the plateau will be released downstream to compensate for Indus and Jhelum river withdrawals to gain topographic advantage.
- Conservation. Run-off water will be controlled to prevent erosion and will be used, whenever it is feasible and cost-effective, to increase crop and range production.

Principle 7. Sustainability and Productivity. The designs of capital facilities and equipment such as tubewells for irrigation will make use of the principles of intermediate technology and will foster ready adoption by individuals and farmer groups. Most components will be manufactured in Pakistan, with easy-to-replace parts from ready supplies in the market. Designs will minimize operating costs.

Principles 8. Municipal and industrial (M&I) use water has priority over agricultural use. The following criteria should guide decision making regarding development initiatives:

- Conservation. Municipal and industrial water users have a responsibility to restore water quality, at least partially, after use. crucial This stems from the fact that most M&I users degrade water, but do not consume it. The water used is returned to the hydrologic system and impairs the functioning and subsequent quality of that system.
- Sustainability. M&I users have a responsibility to use and conserve the water resource efficiently.

CHAPTER SIX

DEVELOPMENT OPPORTUNITIES FOR WATER RESOURCES IN THE BARANI ZONES

There are no overarching water projects or programs that embrace all the zones. As noted, the physiography and rainfall patterns make each zone unique within the planning area. Thus, descriptions and details of potential initiatives are presented, and comparisons among alternative initiatives are made by zone. Some initiatives to be realized fully will have to be developed, however, in the larger framework of the Indus Basin system.

Water supply, floods in D.G. Khan, Indus River water for the Thal, groundwater in the Riverain and Siwalik zones, and some groundwater and streamflows in the Potwar and Salt Range are primary determinants of the mode of development to be selected for each zone. In this chapter we shall look in some detail at issues to be faced in determining the appropriate use of the water, soil, and land resources.

THE POTWAR

Existing Resources and Conditions

The Potwar Plateau is dissected by a series of streams that flow east to west the Haro, Resh, and Soan and southeasterly the Kanshi, Bunha, and Kahan. The 6,400-square-mile area is bounded by the Salt Range to the south and the Himalayas to the east. The Indus River borders the north and west and the Jhelum River flows below the ridge to the east, as illustrated in Exhibit i.

The rainfall varies across the plan from 10 inches in the drier west to 35 inches in the more humid eastern region. The relief is a gently undulating plain with deeply incised river valleys. Erosion is widespread in the area, particularly on the areas of loess.

All of the Attock and Rawalpindi districts, except for the Murree hills, are included in the Potwar Zone. About 75 percent of Chakwal District, 15 percent of Jhelum District, and 20 percent of Mianwali District are also included.

The zone is a large, gently undulating plain dissected by an intricate drainage system of gullies and rivers considerably below the level of nearby land. About 60 percent of the Potwar land surface has eroded into gullies; the rest is gently sloping tableland. Most of the gully formation is the result of geologic erosion, although the process has been intensified during recent times by the activities of man and his animals. Vertical slopes are common throughout the gully area. The ridge and trough uplands land form is found only in the Potwar Zone. Elevations range from about 700 feet along the Indus River to about 3,000 feet in the hills north of Islamabad.

The plateau is divided by physiography and geology into subareas. For descriptive purposes and convenience of describing planning units, 12 subareas are outlined in Exhibit VI-1.

Three rivers of the area the Soan, Haro, and Kanshi yield most of the surface water available, in excess of 2.0 MAF per year. The Soan River is so deeply incised that potential reservoirs on the main stream do not command the land.

There are two important aquifers on the plateau, as defined in Chapter Two. One of sand and gravel is limited in extent but is important for tubewell development in the following areas: Rawalpindi/Islamabad, Hasan Abdal, the Chach Plain, the Upper (Fateh Jang) Sil River, along Wadala Kas, and near the ridge between the Soan and Kanshi rivers (see Chapter Three). The Directorate General of Hydrology, WAPDA, estimates that tubewells that yield 0.5 to 1.0 cfs can be successfully installed in these areas.

The second aquifer is sandstone. Its transmissivity is low and it is most suitable for dug wells that can be pumped by small centrifugal pumps with yields of 50 to 100 gpm, and the quality of the water is generally good for irrigation. TDS range from 300 to 800 ppm.

Soils

The potential for cultivating land of the Potwar Plateau has been expressed both through classification of soils (Exhibit VI-2) and delineation of the area according to a land-capability classification.

Most of the agricultural soils have developed from materials transported by wind and water loess, old alluvial deposits, mountain outwash, and recent stream valley deposits. Some soils have been formed in situ from the underlying rocks, which consist mainly of shale and sandstone. The soils are predominantly of medium texture, with a high proportion of clayey soils. Most of the soils are deep, except for those developed in situ.

Twenty-six soil associations, nine complexes, and one undifferentiated group are recognized in the zone. The largest single unit is the Rajar complex, which occurs in dissected loess plains and is described as silt loams with no structure. constitutes about 8 percent of the total zone. It Other significant units are the Balkassar association and complex developed in weathered rock plains and in ridge and trough uplands. They constitute a total of about 10 percent of the zone. About 5 percent of the zone has Guliana and Missa associations from loess plains.

There are miscellaneous areas that constitute 50 percent of the zone. Such lands are rough broken land, rough mountainous land, gully land, hilly gravelly land, riverbeds, and urban land.

Lands with potential for irrigated agricultural development are delineated in Exhibit VI-3. These lands are an aggregate of land capability classes I, II, and III of the Soil Survey of Pakistan. They are:

Class I Very good (loamy) irrigated crop land;

Class II -- Good (predominantly clayey) irrigated crop land;

Class II Good (clayey) irrigable land; and

Class III- Moderate (saline) irrigated or irrigable crop land.

Land Use

Use of the lands of the Potwar is dictated by topography and water supply. Urban and industrial development and its spread over large areas is centered along the Taxila to Rawalpindi-Islamabad axis. It is here that rainfall is highest and here that groundwater was first developed in large quantity. This development is significant for future construction of reservoirs and water conveyance facilities, especially if large tracts of the irrigable land are to be irrigated.

There is also urban development on a smaller scale in the Attock area. Population density and use of the ravine areas of the Soan Valley system are sparse. Development of major reservoirs there would thus not be impeded.

Agricultural development throughout the west and southwest, stretching from the Talagang Bedrock Plain to the Chitta Range, is limited by some of the lowest rainfall on the plateau. 10 to 15 inches and limited availability of water from dug wells. It does not appear that water development will be restricted by land use.

Water Development Trends

Water development in the Potwar has not been focused or integrated. What little development there is irrigates less than 10 percent of the potentially cultivable lands and supplies municipal and industrial water to industries at Wah and Taxila and to Rawalpindi and Islamabad. There are more dug wells than tubewells, but even dug wells number only in the hundreds. Dug wells irrigate small patches of an acre or less if they are used for irrigation at all.

Previous development of the large Potwar rivers, with the notable exception of Khanpur Dam on the Haro River, has been by isolated dams that can support only small areas of irrigation so far an uneconomic proposition. In addition, Rawal Lake, on the Kurang River, a small tributary of the soon if the the impounded area. Most of its storage is now used to supply water to Rawalpindi, Simly Dam on the headwaters of the Soan River of Rawal Lake, provides water to Islamabad.

The result of this piecemeal development of the water resources has been a considerable lack of interest in new investment possibilities because of the lack of promise of large scale returns that could compete with canal irrigation or tubewell projects of the Indus Plain. Now is the time for a new look. One of the most economic uses of water in the country's future may be in the Potwars Plateau. Here two feet of water can produce what five or six feet of water do on the Indus Plain.

Special Issues

Three special issues must be addressed if the Potwar Zone is to be developed within the long-term framework proposed in this plan. These issues deal with the allocation and reuse of water for municipal and industrial (M&I) purposes, the Indus waters dispute, and the need to zone areas so that they can be maintained in open-space use until they are needed for water development.

- Allocations of Water for Municipal and Industrial Use

Growth of population and industrialization is proceeding rapidly in urban areas across the country. The Potwar Zone is no exception. A large tract of land has been plotted for expansion of the capital area, and the Rawalpindi, Wah, and Taxila areas are growing rapidly. These areas will need some 131 million gallons per day (MGD), or 175,000 acre-feet of new water annually, by the year 2000, according to estimates presented to the Planning and Development Division, Government of Pakistan. This water is to be drawn from the Khanpur Dam on the Haro River.

In addition, there is approximately 100,000 acre-feet of water available that flows through the reservoir annually, which is still allocated to the development of irrigation. Since Khanpur Dam is in place and diversion tunnels and channels that carry water to the vicinity of Taxila exist, it is important to use directly for irrigation all the available water until it is needed for M&I purposes.

- Reuse of M&I Water

In addition to the Khanpur allocation, Islamabad and Rawalpindi now have production capacity of 95 MGD 49.6 and 45.2 MGD, respectively. Fifty MGD, or just over half this water, is derived from tubewells and the remainder from Rawal Dam -- Rawalpindi, 21 MGD, Islamabad, 2 MGD. Simly Dam, with a potential for 834 million cubic meters, now provides some 21 MGD to Islamabad.3

Much of the collected sewage or return flows from these municipal supplies is sent untreated into tributaries of the Soan River. These tributaries are already polluted unpleasant and unusable. If these waste streams are increased several fold, the pollution will affect the Soan River all the way to the Indus River.

Essential to efficient use of water resources is the collection and treatment --at least to the primary level of the sewage water for reuse on agricultural lands of the Potwar.

- Indus Waters Dispute

The Indus waters dispute has been in progress for the better part of the past century. Much progress in water development has been achieved in spite of the dispute. Yet each proposed project in the Indus Basin is altered to accommodate different views of the competing provinces, or the project is deferred or rejected outright. As Pakistan approaches full use of the water resource for irrigation and as increasing amounts of Indus waters are diverted to Karachi and other municipalities for M&I use, the luxury of deferring resolution of the dispute will no longer be an option. The dispute must be resolved or the equivalent of electric power load shedding -- that is, severe restriction of traditional established water use will occur.

Since there is to be rapid growth of M&I water use on the plateau and since the Potwar area is riparian to the Indus and Jhelum rivers, plateau needs must be taken into account. This implies a right to eventual withdrawal of water from Tarbela Reservoir for use on the plateau, either directly for M&I use or as replacement for M&I use.

- The Need for Open Space Zoning

Development of reservoirs and canals on the plateau should take place within the framework plan, across areas in the path of urbanization and other developments. A careful survey needs to be undertaken immediately, and lands that would be in reservoirs should be zoned to ensure that area developments are essentially open space. In addition to urban uses, new highway, railroad, and airport locations should be checked against such an open space plan.

There will be a need to compensate owners for uses forgone. This could be accomplished by the funding of land-purchase options, tax holidays as applicable, or other incentives.

- Opportunities for Water Development

to Initiatives for water development are driven by the relative location and elevation of water and cultivable land. It is this relationship that led conceptualization of the high-level and low-level link canal systems, which are shown planimetrically in Exhibit VI-3 and schematically in Exhibit VI-4.

These two linked systems of reservoirs are conceived in accordance with the development mode entitled Connection of Reservoirs. The relative elevations of some 50 existing and proposed reservoirs were associated with topographic contours of the plateau and the location of lands with irrigable soils. Of the more than 500,000 plateau and gable lands identified, 373,000 acres lie within the boundaries of the two link-canal systems. For purpose of conceptualization and costing, it has been assumed that all these lands are commandable. It is anticipated, however, that a large share of these lands will not, in fact, be commandable because of the extreme changes in slope and contour within short distances. Actual delineation of a project can be accomplished only after detailed topographic and soil surveys have been made.

Groundwater of the zone is not available in copious quantity except at a few restricted locations. There are, however, important potentials in some locations, such as on the Chach Plain near Attock. For these and for other locations described inch Chapter Three, groundwater developments by tubewell were integrated into the linked systems. The groundwater developments should be carried out separately, as rapidly as possible.

Water development potentials, outside the commands of the linked systems, are extremely limited in the quarter of the plateau that lies south of the Soan River and west of Chakwal. This is primarily because of the high elevation of good agricultural lands, the poorly developed natural surface water system, and the generally low-yielding sandstone aquifer that exists in much of the area.

Groundwater Development

Areas with Potential for Tubewell Development

Tubewell-capable aquifers extend over about 400 square miles of the Potwar Zone. Their locations and their probable productive capacity within the limits of identified agricultural tracts are given in Table VI-1.

Considering that the most extensive aquifer 100 square miles the one in the Rawalpindi-Islamabad area, is already heavily exploited for M&I water, there remain for irrigation development aquifers that extend over 300 square miles of the Potwar Zone. As shown in Table VI-1, it may be possible to produce 93,000 acre-feet of irrigation water annually.

Area Dependent on Rainfall and Dug Wells

There is extensive but not high-flow potential for development of open dug wells with water lifted by pumps in most of the cultivable plateau lands that are not proposed for service from the connected reservoir systems or from individual small to medium-size reservoirs. The aquifer is generally sandstone with low transmissivity. Dug wells 60 feet deep could yield 50 to 100 gallons per minute (gpm), not an Such wells are suitable for drinking-attractive prospect for large-scale irrigation. There is potential for development of 0.5 to 1.0-efs water supply, however. tubewells in a limited area at Talagang, but there are no large tracts of cultivable land for development lying northeast of Talagang town, where the sand-and-gravel quifer rexistvelopwater under artesian pressure exists at Dhurnal, but again there are no cultivable lands in the vicinity of the potential tubewell development.

Potential Water Developments, Other Areas

It is recommended that groundwater tests be conducted across the 100,000 acres of cultivable land in the extreme southwest of the plateau, which lies on the southern and western limits of the Talagang Bedrock Plain. No hydrogeologic reports were located for this area, but there is obviously some potential, since there are a number of good-sized springs in the area.

There are several identified springs in the area with reported flows of one to four cfs. These warrant a carefully executed project to capture and convey the flows to cultivable lands before the flows become saline. This is dealt with under the proposals for integrated development of barani lands in Chakwal and adjacent areas.

Surface Water Development

As shown in Exhibit VI-3, existing and proposed reservoirs of the northern two-thirds of the Potwar lands can be connected into four main water-service units:

A. Chach Plain Sarwala Loop area around Attock, 40,000 acres (Exhibit VI-5);

B. Jandal Plain Canal System, 122,600 acres (Exhibit VI-6);

C. Eastern Khaur Plain system, 75,700 acres (Exhibit VI-7); and

D. Gujar Khan Plain area, 103,800 acres (Exhibit VI-8).

Additionally, there is scope for servicing agricultural areas along the link canal systems, which total 31,000 acres.

The high-level system begins at Khanpur Dam on the Haro River. A tunnel and pressure conduit eight miles long would carry water to a junction point near Goira Village (elevation 1,860 feet).5 The junction commands the four irrigation systems and can supply water to the Wah and Taxila industrial complexes and for the municipal and industrial needs of the capital area and Rawalpindi. Water would have to be pumped to some higher locations in the capital area. The westward link to Taxila and Wah leads directly into the Low-Level Link Canal, which serves the reservoirs and canals of agricultural lands in units A, B, and C. The High-Level Link Canal would be routed through the capital area to Bhaun Dam (elevation 1,780 feet) on the headwaters of the Kanshi River.

The Low-Level Link Canal is also commanded by the existing Left-Bank Canal from Khanpur and by the Tarbela Reservoir (elevation 1,550 feet). It would thus be possible to store now-wasted flood waters of the Indus River in the reservoirs of the Potwar Plateau.

Water Balance of Link Canal Systems

Preliminary judgment is that a fair balance can be achieved between the available surface water and groundwater and the need for a supply of irrigation to 373,000 cultivable acres of the plateau. The principal exception is the land across the high Talagang Bedrock Plain between the back side of the Salt Range and the eastern watershed of the Soan River Basin. These are the barani lands now cultivated around and southwest of Chakwal plus those in the far southwest of the plateau.

The connected system is shown schematically in Exhibit VI-4; groundwater potentials are shown in Exhibits VI-9 and VI-10; and gross water balances are shown in Table VI-2 for the High-Level Link Canal system and in Table VI-3 for the Low-Level Link Canal system. In accounting for the available groundwater and dams as proposed earlier, it should be noted that, with full use of the Haro River flow at Khanpur, the entire M&I and unit D (Gujar Khan) irrigation can be met.

If the demands of all four irrigation units A, B, C, and D commanded by the link canal and for M&I water in the year 2000 are to be fully met, it will probably be necessary to add most or all of the storage and operations shown in Table VI-4 to the two linked systems.

This amount of storage exceeds the shortfall of 330,000 acre-feet suggested in Table VI-3 by 170,000 acre-feet, or the equivalent of either the Papin or Sanjwal reservoir plus part of the storage increases planned for smaller reservoirs on the plateau. Building of the two storage structures would compensate, however, for the inevitable losses that will occur in operation of the system. The Papin and Sanjwal dams may cost Rs 1,300 million at 1987 prices.

The initiative proposed should be the subject of more intensive investigation in the future.

Surface Water Soan Valley, Left Bank

With the exception of an 11,000-acre tract of cultivable land lying along the Dharab Tributary, there are no sizable blocks of good agricultural land along the left bank of the Soan River downstream of Wadala Kas. These lands are commanded by Dhok Sial Dam 12,000 acre-feet of storage at an elevation of 1,572 and lower areas are possibly commanded by Dharabi Dam 20,000 acre-feet of storage at an elevation of 1,345 feet. It may well be unnecessary to build more than Dhok Sial Dam to serve the 11,000 acres, depending on the flow of the Dharab River during the kharif season. Building only Dhok Sial Dam is likely to be the most economic option, since Dharabi Dam will require a sizable spillway (Exhibit VI-11).

Headwaters of the Bunha River, Potwar Zone

Three dams have been developed in the headwaters of the Bunha River near Chakwal. They are the Khokhar Zer Reservoir 3,300 acre-feet at an elevation of 1,921 feet above mean sea level; Surlah 1,900 acre-feet at an elevation of 1,921 feet; and Dhok Tahlian 1,950 acre-feet at an elevation of 1,984 feet. There are some 20,000 acres of cultivable lands in the vicinity, but they appear to lie on higher ground. If run-off fills these reservoirs each year, it may be desirable to lift water to the good lands and irrigate perhaps 3,000 to 4,000 acres intensively. Rehabilitation and improvements to the Surlah and Khokhar Zer projects are part of the ADB program now in progress (Exhibit VI-11). The only recommendation of this plan, therefore, is that pumping be evaluated as part of that program.

Costs

Capital investment, operation and maintenance, and replacement costs were estimated for proposed project works and investigations.

Capital Costs

Capital costs were estimated for elements of a project unit. They were then aggregated into unit and system totals. System and unit costs were regrouped to determine costs of alternative development projections.

Estimated capital costs of the water development potentials across the Potwar Zone and the western or back slope of the Salt Range area are summarized: (1) in Table VI-5 for the High-Level Link Canal system, (2) in Table VI-6 for the Low-Level Link Canal system, (3) in Table VI-7 for the land-preparation cost, and (4) in Table VI-8 for the small dam and isolated groundwater and spring developments.

Components of the High-Level Link Canal system and the Gujar Khan irrigation unit are shown in Exhibit VI-8. A high-pressure tunnel is required to carry 770 cfs of water from Khanpur Dam and deliver it at Golra village at an elevation of about 1,900 feet. Thus, supply will serve both irrigation Unit D and the M&I needs of the Capital Development Authority (CDA) in the year 2,000. The Golra hydraulic junction must command Bhaun Reservoir at normal pool level, which is 1,780 feet above mean sea level. This link canal would traverse about 25 miles eastward along the 1,900- to 1,800-foot contours. The alignment chosen for the tunnel is the approximate route, but with slightly different elevations from the alternate alignment proposed by National Engineering Services of Pakistan (NESPAK) in their 1980 study of water supply for the CDA. NESPAK costs were increased 25 percent over their unit cost for an 8.5-foot high-pressure tunnel, with horseshoe section, to account for the larger design flow. Costs were, in turn, augmented by 60 percent to account for price increases, and 25 percent was added for engineering, contingency, and interest during construction. The total estimated cost is Rs 700 million. Of this, Rs 200 million would be chargeable to water supply to the CDA, and the remainder should be charged to the irrigation system for unit D. The cost of the tunnel would be about Rs 5,000 per acre. Cost of the 25-mile conveyance, Gorla to Bhaun Dam, would be Rs 75 million.

Evaluation of Alternatives

There are two alternatives for development of water resources for agriculture on the plateau in the long term. The first is to continue with development of small dam developments with high unit costs that will probably never realize their potential, to continue with three localized groundwater developments, and to be satisfied with rainfed agriculture throughout most of the area. The second alternative is to develop, project by project, an integrated irrigation system of linked reservoirs that will serve 373,000 acres of cultivable land across the northern three-quarters of the Potwar Plateau. Developments over the remainder of the land would be site-specific. In fact, of the approximately 150,000 acres of cultivable land in the Potwar and Salt Range lands on the plateau not commanded by the linked reservoir system, it is likely that no more than half can be served by surface and groundwater irrigation. The first alternative is the business-as-usual approach to development of water resources in the Potwar. It has failed to keep barani agriculture of the Potwar on a path of acceptable growth. It is within the second that viable paths to development of part or all of the 373,000 cultivable acres have been formulated.

Alternatives were therefore framed as follows:

- Develop the High-Level Link Canal (HLLC) system and only that part of the Low-Level Link Canal (LLLC) system that can be served from local reservoirs, Rawalpindi M&I return flow, and groundwater, without a connection to the Tarbela Reservoir (185,000 acres).
- Develop the LLLC system using all flow of the Haro River at Khanpur Reservoir that is in excess of the M&I requirements of the CDA, Rawalpindi, Wah, and Taxila; return flows from CDA and Rawalpindi carried to the low-level system (150,000 acres).
- Develop both link canal systems and divert flood flows from the Tarbela Reservoir to serve some 90 days of kharif-season watering in the LLLC system; store flood waters in any unfilled reservoirs of the low-level system (270,000 acres).
- Develop the full 373,000 cultivable acres to be served by both link canal systems, using 130,000 acre-feet of Tarbela water, outside a 90-day flood-diversion period. These withdrawals would be compensated for by releases from reservoir developments on the Soan River, the Haro River, or both.

- Develop the full 373,000 cultivable acres by building Sanjwal Reservoir on the Haro River to supply 50,000 acre-feet of water to irrigate Unit A (near Attock), and incorporate 60,000 to 80,000 acre-feet of additional storage at or above an elevation of 1,470 feet into the LLLC system for storage of Tarbela flood water.

Initiatives for the development of groundwater and the southerly quarter of the plateau are the same for each of the five alternatives.

Components and initiatives that are a part of each alternative are summarized in Table VI-10.

Alternative A merits consideration, because it could be the catalyst for construction of a tunnel to serve Islamabad with Haro River water at an elevation that will avoid much future pumping of water to serve that city. Unless considerably more than Rs 200 million of tunnel cost is assigned to the M&I water component; irrigation costs are 30 percent higher in Unit D, however, than in other parts of the plateau.

Also, it must be confirmed that M&I return flows can be captured and treated at high enough elevations to discharge into the HLLC. The construction of a canal across the capital area could be aesthetically pleasing. A 100-to-200-foot land corridor would have to be reserved fairly soon. In summary, careful investigation, some detailing of designs, and costing must be carried out if this alternative is to be more fully evaluated.

Alternative B has the advantage that it can be built unit by unit, progressing from areas near the existing conveyance points from Khanpur Dam at Taxila. Yield of the reservoir is already dedicated to irrigation as well as to future M&I use. The cost of initial developments will be comparatively low slightly less than Rs 6,000 per acre for canals and structures and Rs 10,000 per acre for watercourse and on-farm work.

Alternative C is attractive in that water from the Indus River flood season would be diverted into the LLLC by a simple cut of the ridge between the Tarbela pool and a right bank tributary of the Haro River. The same unit-by-unit development could be carried out as planned for Alternative B. The timing of development will require preliminary studies and considerations identified for Alternative A.

Alternative D is the most favorable full-development alternative. It would require major decisions regarding direct diversion and use of water of the Indus River and the full development of reservoirs on the Soan River for integration into the national storage system.

Alternative E avoids the necessity of using non-flood-season water from the Tarbela reservoir by building storage on the Haro River to serve Unit A, the Chach Plain, directly and to augment the flow of the Indus River.

Shown in Table VI-11 is an evaluation and comparison of the five alternatives. The preferred alternative based on each of the criteria is highlighted in the table. Fundamental to each alternative is the allocation of M&I demand for CDA, Rawalpindi, and the Wah and Taxila industrial complexes in the year 2000. Return flows are assumed to be available from Islamabad and from Rawalpindi. If conveyance facilities are built, M&I waters of the Khanpur Reservoir can be used for irrigation until required by the users. During that time new storage and diversions can be brought into the system to replace the water increments as they are appropriated for M&I use.

On the basis of costs per cropped acre and the extent to which benefits work across the plateau, it appears that Alternative B, development of 150,000 acres commanded by the Low-Level Link Canal system, should be implemented, and work toward Alternative D should be continued. Alternative Dis, in fact, a delicately balanced system that has just enough storage if it is operated perfectly. It is also assumed that water can be drawn from the Tarbela Reservoir beyond the 90-days the flood season with compensation from a Papin-sized reservoir on the Soan River.

Alternative E limits withdrawals from the Tarbela Reservoir to 90 days of flood flows and has some 80,000 acre-feet of excess storage at Sanjwal that would be released to the Indus River.

As shown under productivity in Table VI-11, considering that the cost to build reservoirs and convey water to the watercourse level varies from Rs 7,500 to Rs 10,800 per cultivable acre or Rs 5,000 to Rs 7,200 per cropped acre; even the more costly alternatives are attractive. Other factors considered in evaluating the attainment of development objectives of Table VI-11 are:

- Only 2.2 feet of water is required annually to achieve 60 percent cropping intensity in the kharif season and 90 percent in rabi. This is one-third the water required to achieve equivalent intensities in the hot, windy areas of the Indus Plain, where rainfall is low.
- The systems require almost no drainage works, although land leveling is required.
- The increment of production going from barani production levels to irrigated levels is very large. The addition to national output will be significant.
- Widespread irrigation and resultant fodder and wood production will take away the twin pressures of foraging for firewood and overgrazing by animals throughout most of the Potwar Range. The result should be natural regeneration and sharply reduced soil loss and erosion.
- Erosion will be reduced by terracing, capture of rainfall, storage of some flood flows in reservoirs, and range regeneration.
- A considerable fisheries potential will be established.
- Considerable labor, on-farm and construction, will be required for the entire Perspective Plan period of 20 years.
- Following systems building, a large potential for marketing, supply, and an agroindustry will be established.

Recommendations

It is important to look at water development potential in the plateau in terms of short-term needs and priorities, and long-term water development strategy and goals. The analysis presented earlier regarding the linked canal system pertains more to the latter, looking at the totality of water resource potential. The first priority for the Potwar is the undertaking of smaller groundwater development schemes in direct support of the efforts to boost agricultural production. Surface water development should be phased and the majority of the effort should be undertaken later on.

Regarding the linked canal system, it is recommended that an initial or pilot irrigation project of 10,000 net cultivable acres be planned and implemented as early as possible in the Taxila-Fateh Jang area. It would be served by construction of the first-stage, partial-capacity segment (Lx) of the LLLC from Taxila Junction to the area shown north of Fateh Jang on Exhibit VI-11.

The gross cultivable area is probably in excess of 20,000 acres. It is assumed, however, that because of frequent slope reversals and rapid topographic changes, it may be possible to command by gravity flow considerably less than the gross area.

The project is proposed, as shown in Table VI-12, at an estimated capital cost of Rs 165 million for canals, watercourses, and on-farm development. A detailed mapping program of topography and soils must be carried out. The cost of this program may require as much Rs 7 million. A substantial provision has also been made for layout, design, and preparation of contract documents.

Execution of this project will do much to demonstrate how large-scale development of the lands along the link systems can most readily and economically be accomplished. This program should be started as soon as possible. water is there, not being used. Khanpur

Operation and maintenance of the system may cost the Irrigation Department 0.75 percent office and transport support for a total of 1 percent, or Rs 600,000, per year. It is assumed that once put in place the watercourse systems would be maintained by the landowners.

A number of reservoirs are essential to realization of the development of linked linked systems in the long run. A careful survey needs to be undertaken immediately and lands that would be in reservoirs should be zoned perhaps in the form of options with just compensation, to ensure that land developments will be limited essentially to open use. It is recognized, for example, that the height of the Sanjwal Dam, which can be constructed, is already limited because of the development of military facilities upstream.

During the course of the investigation and study, the Indus waters dispute has continuallys been mooted as a reason for not proposing most water initiatives. It is indeed a deterrent to rational, efficient development of the resources, especially for agriculture but increasingly for M&I use. 200,000 to 225,000 acres of land can be developed by gravity flow from controllable resources of the Soan, Haro, and Kanshi rivers. Thus, the capture of flood water directly from the Indus River enters into the development of only 150,000 to 170,000 acres.

This conclusion has been reached despite the large part of the Haro River flow at Khanpur that is dedicated to M&I use. Looking downbasin to Karachi, an increasingly large portion of the Indus River flow is being diverted from irrigation to M&I use. Since the Potwar is riparian to both the Indus and Jhelum rivers, logic would suggest that the capital of the country and Rawalpindi are both entitled to diversion of the Indus River.

It bears repetition that the water resource of the Potwar exceeds the combined foreseeable demand of both irrigation and M&I use on the plateau. The only reservation is that much of the flow of the Soan River, the largest stream in the area, can be captured only at low elevations. in a national, rather than a regional context. diversions from the Tarbela Reservoir will have will have to be built on the lower Soan River. Thus, the water should be developed To achieve such a system, ultimately, to be permitted and a large reservoir

New Dams

No additional small dams should be constructed beyond those under way in the ADB-funded Small Dams Project before it is determined that streamflows are sufficient to fill the reservoir annually and that the reservoir will command an adequate area of nearby cultivable lands. An overlay of proposed dams and the land capability map show that few potentials exist beyond those included in the link canal systems of this plan and in the lower Kanshi, Bunha, and Kahan river areas. Domeli Dam on the Bunha River 6,500 acre-feet, elevation 1,168 feet and Pattian Dam on a tributary of the Kanshi River 3,200 acre-feet, elevation 1,630 feet look to be the most promising, as yet undeveloped reservoirs to the east that command cultivable lands. These reservoirs are proposed in the program for development of the Salt Range. Existing and programmed dams on the Potwar were shown in Exhibit VI-11.

Areas for Further Study

1. Study should be made of the better aquifer at Talagang if it is determined that cultivable land is nearby something that is not shown on Soil Survey of Pakistan maps or if there is a shortage of drinking water.

2. The artesian aquifer at Dhurnal should be studied after assessment of needs.

3. Groundwater investigations should be conducted along the south and western limits of the Talagang Bedrock Plain.

Rs 5 million has been budgeted for early use during the period of the Action Plan for these investigations.

Schedule of Investment

Set forth in Table VI-13 is a water project investment schedule for the Five-Year Action Planeriprogram and the total expected investment in the 20-year Verspective plan periodnenInvestments shown for the five-year Action Plan anticipate high level of investment for water resource developmen year Action Plan anticipate high-level investiment Planulhas total an average of approximately Rs 160 million per The Action Plan has been designed with a least-cost, early action program potential, shown in the alternative analyses, in view. The storage and can costs, year. potaling Rs 3,440 million, are all to be publicly financed. Thetrager cand canal costs. leveling costs of Rated 880 million will be shared between the public and private sectors. It is expected that farmers will provide capital and workul kind private public inputhare will be perly subsidies and management and extension kind an government share will be perhaps 25 percent, or Rs 1,000 million. The

RIVERAIN AREA

Existing Resources and Conditions

The Barani Commission identified the Riverain Zone as a strip of land 3 to 6 miles wide that stretches 550 miles and lies on both sides of the Jhelum, Chenab, Panjnad, and Indus rivers (Exhibit i). The lands abut the other six zones on one side only along 200 miles of their length. The remainder of the Riverain Zone lies across the river from barani lands or adjacent to canal commands. The young alluvial soils and flooding conditions that prevail across much of the riverain lands have led to a pattern of water use for agricultural development that differs considerably from that practiced both in adjacent canal commands and in the rest of the barani area. Conditions are diverse, even within the Riverain Zone.

Soils

Soils of the riverain areas generally do not have developed structure. They vary from sand in areas that flood annually to those that have six inches to two feet of stratified silty clay overlying sand. The former are called low katcha, Category II, and the latter are called high katcha and are Category I lands.

Because of stratification, rates of water intake by the silty-clay soils are quite low. The water travels laterally between the layers. Water intake by most Category I lands could be greatly improved by plowing to a depth of approximately one foot.

Leveling of any Category I lands must be done carefully, since it is easy to strip away the soil. It is best accomplished, therefore, by recognizing the general contour of the land and not attempting to establish a uniform rectangular pattern of fields. Leveling of Category II lands is not nearly so risky, since they are essentially sand.

Land Use

Because of their widespread location across several rainfall regimes, the desirability of associating the lands with other barani zones whenever it is possible, and the unique water source and land capability, the riverain lands are described, by unit, in Table VI-14. There it is shown that about 25 percent, or some 450,000 acres, of riverain area is Category II land, which generally floods during the kharif season. In fact, these lands are subject to erosion and deposition, with the result that entire mauzas may disappear, 10 similar expanses of newly formed lands nearby. Lost lands are almost always replaced by

Of the 1.3 million acres of Category I lands, nearly a third have some tubewell water supply. This development varies from some 20 percent of the lands around Panjnad and Mithankot to probably 60 percent of the lands in the Trimmu area. some Category II areas, rabi-season vegetables are grown on residual flood water. In Here, growers may come several hundred miles to cultivate the land. On the higher sands, they establish temporary but quite livable residences made of reed mats. When the crop has been harvested, they return to other areas. lands are not served by tubewells. Most Category II There are a few tubeweils with easily removed pumps, and occasionally a permanent well is fixed on high ground.

Category 1 lands are occupied by permanent farmsteads, and crops are either grown on residual moisture or are watered by the Persian wheel or tubewells. There are still areas with natural vegetation that are unoccupied.

Major roads do not serve the riverain area directly. National and provincial highways and Irrigation Department roads often parallel the rivers inland, away from the riverain zones. For the most part, riverain lands are served by katcha tracks, which originate at highways or from adjacent roads of the Irrigation Department. PM FMR, MNA, MPA, and Zilla Council Road programs are now being built toward and into riverain lands. 11

Electricity is supplied only to small areas of the riverain. For purposes of this study, it is anticipated that hardly any electric power systems will be extended to riverain lands during the next decade. This expectation arises from a forecast possible 6,000-megawatt shortfall in power-generating capacity and the long lead time required to bring new, powerful generating stations on line.

Water Development Trends

Water development for agriculture in the riverain is accomplished either through exploitation of residual soil moisture from floods or the lifting of groundwater by dug wells or tubewells. There is occasional lifting of water from channels and dug pits by centrifugal pumps driven by diesel engines or belt takeoffs from farm tractors. Some old pumps are driven by large reciprocating engines.

Throughout the past decade, the Punjab Agriculture Department has subsidized and assisted with the installation of some 27,000 tubewells in the barani, riverain, and tail areas of nonperennial canals. This program has been accomplished by 215 hand drilling units (tripod, winch, pulleys) of the Agriculture Department and 400 such units in the private sector. Some 4,000 new and replacement bores are made annually. The Agriculture Department now subsidizes the sinking of 1,100 new, one-cfs, private diesel tubewells in the Punjab annually, 12 These are advertised, and about 6,000 applications are received. Thus, there is a considerable unfulfilled demand, although nearly as many new tubewells are installed entirely with resources, from the private sector as are installed under the subsidy program.

If 2,000 new tubewells can serve 50 acres each, the area of new coverage could be as much as 100,000 acres. Data collected for D.G. Khan and Rajanpur (Table VI-15) show that about 45 percent of the subsidized tubewells have been installed in sailaba lands, which are about 12 percent of the riverain areas.

If a similar pattern exists across the riverain area, then 500 government-subsidized tubewells and a small number of nonsubsidized tubewells are being installed in the riverain area annually. They could serve as much as 50,000 acres of new land, but few of the nonsubsidized tubewells serve more than 25 acres. With present trends, it will be three to four decades before nearly full watering of riverain lands with groundwater will be accomplished.

The operating cost of pumping a tubewell for one hour varies from Rs 15 to 25 for electric and diesel pumps to Rs 35 to 50 for a tractor to drive a pump. Tubewell owners sell water to neighbors for Rs 25 to 30 per hour of pumping.13

Private tubewell operators have difficulty obtaining diesel fuel for pumping, both because the supply is limited and because of difficult road conditions.

Those who purchase water are reported to limit irrigation to three to five waterings per season. In the low-rainfall areas of the riverain, this number of irrigations is too few to achieve high crop yields. Irrigators who own their tubewells generally irrigate when they perceive the need.

Special Issues

Farmers of the riverain grapple with conditions and constraints, some of which are unique to their area and some of which are provincial or national in character. are unique that therise out of these conditions must be addressed inundhole or in par The issuusedh riverain agricultural development project based on groundwater supply is to be successful.

- Individuality

Most farmers strive to avoid working within a formal group or cooperative, especially if it is controlled by the government. They prefer to have direct control over their own facilities and inputs, with no need to cater to arbitrary requirements and demands from a number of bureaucratic constituencies.

- Land Acquisition

New lands are constantly forming along the active flood channels and new lands are becoming available for agriculture because of reduction or elimination of flooding along some channels, especially the bed of the Ravi River near Shakargarh and areas of the pre-Mangla Dam, Jhelum River flood channel. Of real concern is the possibility that outsiders, with no roots in an area, will rush in to claim lands that should properly be developed by the local populace.

- Power

Electricity is not available; diesel fuel is sometimes difficult to obtain and is certainly more costly than electricity. Combined with the higher costs associated with small holdings, this makes ownership of tubewells impossible for many farmers of the riverain area.

Opportunities in Water Development

Opportunities for development were assessed on a unit or project basis rather than asad zonwide initiative. Conditions within each of eight project bares, rather summarized Table VI-14.

Groundwater

The potential for water and agricultural development in the riverain area is very large. An estimated 920,000 acres of lands not now being irrigated could be served with groundwater at a cropping intensity of 135 percent or more on lands above annual floods and at very high rabi-season intensities on stable lands that are frequently flooded.

The Planning and Investigations Division of WAPDA has prepared plans for development of the entire barani riverain area. The planning approach was to 14 and install well-designed, high-cost public-type tubewells. electrify the area Development of the required electric system has not progressed. Thus, an alternative approach was sought for this master plan that would forgo electrification until it became available, provide cheaper wells, and mobilize private resources in lieu of large investments of public resources and a subsequent need for the public sector to administer operations.

The mobile tubewell pump mode, as described in Chapter Four, was conceived to meet the foregoing criteria.

In summary, this mode of water development is designed to help farmers who have been unable in the past to install tubewells where the water table was shallow and the groundwater was of good quality. A farmer would be required to invest less than half the cost of a full tubewell, if the government or a private entrepreneur would arrange to pump water on a given but flexible schedule, using a mobile prime mover and pump.

The proposed delivery of water and the proposed staffing of the entrepreneur operation is summarized below:

- A farmer installs well casing, screen, and couplings for a well of 1 or 0.5 cfs capacity, depending on the acreage that he holds.
- A private operator or entrepreneur has a fleet of farm tractors, wagons, water barrels, and fuel barrels and the capacity to carry several 8- and 12-horsepower (HP) diesel motors and pumps per wagon.
- If the objective cropping pattern is 90 percent rabi and 60 percent kharif crops in areas where lands do not regularly flood, then pumping will approximately balance in rabi and kharif seasons.
- In an area of low rainfall and shallow soils where water tables are high, the average watering may be 1.5 inches per week and up to nine-day intervals for some 18 weeks of each kharif season for a total irrigation depth of 27 inches. The rabi watering will be less frequent or each irrigation will be for less depth. If the supply is from a shallow water table, the rabi watering may average 18 inches. The number of visits will be fewer in areas with significant effective precipitation.

- Round-the-clock operation will deliver 24 acre inches of water in 24 hours. A 1/2-cfs pump will deliver half as much.
- There will be a one-hour allowance to move a pump between sites; an operator can move 8 per shift or 24 per wagon per day.
- Landholdings may be half flooded during the kharife seasonate with the result that 45 percent (90 percent of 50 percent) may be irrigated, whereas percent of the project area would be irrigated during the rabi season.
- A one-cfs well can serve, say, 30 acres at 90 percent cropping intensity during the rabi season in 27 hours. It can serve 30 acres at 45 percent dverage intensity during the kharif season in 13 to 20 hours. The rabi season requirement thus prevails for design. The 1/2-cfs tubewell can serve 15-acre areas in equal periods. The actual scheduling of water pumping will obviously be more complex.
- The Punjab Land Utilization Authority (PLUA) or the On-Farm Water Management Organization of the Department of Agriculture can assist the private entrepreneur to develop a tripartite agreement with the farmer and an agricultural development bank to handle water charges through the bank.

Early success can be achieved in most of the area through mobilization of the private resource with non-continuing subsidies and incentives, a requirement that recipients of capital pay it back, and the use of lightly staffed, field-oriented expediting organizations. Large public organizations should not be introduced, because too much energy is devoted to their perpetuation and not enough to production.

Surface Water

Surface water is important to the riverain area in two ways: flood flows and nearby rivers keep the aquifer recharged and water table depths generally shallow, and riverain aquifers discharge water during the low-flow season to regenerate surface flows.

Operation Potential

An advantage of tubewells is that any project or area development is divisible if dependence is not placed on construction of an electric distribution grid. Tubewell units can therefore be installed and pumped, and agricultural benefits grid accrue immediately. To ensure that a private entrepreneurial operation will function effectively and economically, it is necessary to sign up groups of individual function as buyers of the diesel pumping service.

Costs

Costs were developed in detail for a system sized to serve the entire riverain area from Vehowa in D.G. Khan to Mithankot in Rajanpur. These costs were then adjusted to reflect differences in climate, rainfall, and level of development in each of the nine riverain units.

Cost of the program for the entire riverain area, as shown in Table VI-16, would be Rs 752 million, 60 percent of which would be capital expense of the farmers for tubewells (Rs 455 million) and 12 percent would be supplied by the mobile pump operators. The public sector would need to mobilize Rs 176 million to construct farm-to-market roads and to finance an oversight agency and an additional Rs 30 million to provide incentives and subsidies. There is a need for investment incentives to total perhaps 20 percent of the costs of the farmer and the operator to ensure that the initial three to five-year build-up can be achieved rapidly.

Total costs of operation, maintenance, and replacement might amount to Rs 132 million, with Rs 62 million being for entrepreneurs, Rs 15 million for farmers, and Rs 17 million for public roads.

Capital Costs

The capital costs of developing private tubewells in the Riverain Zone are set forth in Table VI-17.

Operation, Maintenance, and Repair

The costs of operation would be proportional to those given for the mode of development, modified by the required water depth, as shown in Table VI-18. Estimated annual costs of the entrepreneur for operation of 188,000 acres -- 90 percent rabi, 45 percent kharif -- in a low-rainfall zone are Rs 100 million, as shown in Table VI-19.

Incentives should also be provided as part of the projects. These might take the form of loans at low rates of interest for the first three to five years, which would be terminated when farm and water-delivery operations had been established. They are estimated at 20 percent of project cost.

The third public cost, a strengthened organization of the PLUA or PMU type, should be funded through the project. The cost of establishing such an office is given in Table VI-19. Annual costs would depend on the size of the staff, but would perhaps be Rs 1.5 million.

Commercial terms and the organization of finance and credit flow are crucial to the success or failure of this approach to riverain water and agricultural development. Although it obviously needs to be studied at the feasibility level, the following financing procedure is presented:

1. An organization similar to PLUA, the On-Farm Management Organization of the Department of Agriculture, or PMU would need to add staff for the project. The organization would facilitate dealings between farmers and institutions much as PLUA does at present in developing wasteland. credit In addition, the organization would need to cooperate with and depend upon the private entrepreneur to deliver water and possibly make other farm deliveries.

2. An agricultural development bank -- government, semi-government, or private -- must serve as middleman between the farmer and the entrepreneur. The legal agreement could be designed to accomplish the following:

> a. Set a water rate per cropped acre with a given expected frequency.
>
> b. Specify the validation procedure to be followed and the documents is, a logbook signed by the farmer that that an entrepreneur must submit periodically to the bank to draw his prescheduled water payments.
>
> c. Specify how the farmer is to pay the bank other intervals. upon marketing crops or at
>
> d. Provide for other financing, such as for crop inputs, land leveling, and well construction.

3. It is possible that assistance to the private entrepreneur and the farmer with financing would be required during the build-up period, when farmers were being signed up, land was being leveled, wells

were being installed, and the farmer was working to achieve a high intensity of cropping. There is already a system of incentives used by PLUA. Some 90 percent of the PLUA incentives, however, are dependent on the WAPDA supply of electricity. Because a severe shortage of electric capacity and energy production is in prospect for the near-term, 5-to-10-year horizon, a rapid expansion of the efficient use of diesel pumps is mooted, as given in Table VI-17 pumped by 1,370 mobile pumps and motors. that is, 7,813 new wells to be

Total capital costs of developing a 188,000-acre area would be Rs 157 million--Rs 125 million from private funds and Rs 32 million public funds as shown in Table VI-17.

With a mobile, private operation, the total nonpublic cost of delivering an acre-inch of water would be Rs 438. An average of 18 inches of water would be provided during the rabi season and 27 inches during the kharif season. Nearly Rs 40 rovided cost would accruallation excarmer to secure credit for and to annualize replace this of the well exclusive of the pump and the motor. As noted in footnote to Table VI-17, this cost should be considerably less in areas edhere the water table is high and the recharge is good. The other cost of Rs 394, or Rs 18.8 per watering (Table VI-19), would be incurred by the operator of the private pump The operator's cost of Rs 394 was estimated at 68 percent for POL and 32 pou for equipment, labor, and compensation for risk, 16

If the farmers chose to install their own pumps and diesels individually and secure individual supplies of POL, their costs would be considerably higher. Those farmers who cannot now afford a tubewell are paying to others water charges that are twice this calculated rate for mobile pump operations. The farmers would also use considerably more personal time to conduct water-producing operations.

Further advantages might accrue through an entrepreneurial operation. Inputs proposed by the extension service could be made available at the farmgate with the same credit and delivery conditions agreed to for water delivery.

Evaluation of Alternatives

Alternatives to the development of a mobile water-pumping operation in the private sector are:

1. Public tubewell projects;
2. Ownership of his own pump or the purchase of water by each farmer; and
3. Cooperative management of tubewells.

Public tubewell projects, Alternative 1, with supporting electrical systems were formulated and their costs estimated by WAPDA for these riverain areas. These projects have not been undertaken, probably because of their high cost, a prior need for construction of an electric distribution system, and the need for total public funding with high recurrent costs.

Alternative 2, having each farmer install his own well, is the current method of development, which, while progressing, is slow.

The use of cooperatives, Alternative 3, to carry out rapid development throughout a wide area has not been undertaken so far, partly because of farmers' resistance to cooperatives and partly because of the lack of a focused, funded program.

These alternatives are not mutually exclusive, however, and it might be possible to use cooperatives, for example, locally within an entrepreneurial mobile pump operation.

Recommendations

Project

It is The preferred choice is the entrepreneurial approach, as outlined in Chapter Four and as detailed for the 188,000-acre Vehowa-Mithankot area. recommended that this type of development be undertaken simultaneously in two or more locations. This would contribute to zonal equity, and, most important, by means of a replication of the initial project the management, organization, and financing of a mobile pump operation would be given a fair test. Thus, even if one entrepreneur were unsuccessful, a model for success would probably be demonstrated by the others.

A possible high-investment-level program for riverain development, assuming that resources are not a constraint and that an extremely vigorous program would be undertaken, was given in Table VI-16. Studies are indicated during year 1, and actual implementation would begin in year 2. Such a program would achieve equity by spreading projects among barani zones and would foster rapid, productive water-based agricultural development. If investment resources were restricted, the rate of implementation would be slower; see the Low-Investment Program in Chapter Nine.

Credit

The experience of the subsidy program demonstrates that if low-cost credit or other incentives were made available and agricultural production was high, many more tubewells would be constructed than at present. The Agricultural Development Bank of Pakistan (ADBP) charges 11 percent compound interest for tubewell development, more than farmers can afford without farm outputs of high value.

Soils

Soils of the riverain lands are shallow and are not efficient for taking up water and storing moisture. Farmers of the riverain areas could therefore benefit substantially from persistent, well-informed agricultural advice from within the area. This would come, preferably, from the OFWM organization or some equivalent organization during the early years of the project.

Inputs

Government programs for the production and distribution of seed are limited to 12 percent of the demand for wheat, a larger percentage for cotton, less for gram, and essentially no output for fodder, oil seed, and sorghum. Some seed is supplied by private operators, and that supply is expected to increase. In some agricultural circles, however, the private sector suppliers of inputs are regarded with mistrust. because they expect too much profit too early.

The situation is more hopeful for fertilizer. The Fauji Foundation, the FDC, and the PADSC (gypsum) are active in supplying fertilizer. The present supply of herbicides and pesticides is largely in the private sector, and the distribution system is functioning reasonably well, although the government probably needs to monitor quality control closely. The primary input issue for farmers of the riverain lands is the general scarcity of fertilizer. This is largely because of poor communication channels between the rest of the country and the riverain areas. Implementation of road construction recommended for the projects should alleviate much of the difficulty of accessing inputs.

A feasibility study, parallel to the Master Plan, has been completed for the Riverain Development Project, which is being considered for funding by the Asian Development Bank; it contains further detail about the project.

Future Studies and Actions

The initial year of the several proposed projects should be devoted to further study. While the project is very much a business development, instead of a typical water resources construction project, it would be helpful to do detailed mapping surveys and studies in the early project areas.

During this period, the procedures for mobilizing the private sector to supply all agricultural inputs could be developed, roads could be designed, and a government coordination, advisory, and implementation group could be staffed and put into operation. This would contribute to the overall success of riverain development.

DERA GHAZI KHAN (D.G. KHAN)

Existing Resources and Conditions

The Barani Commission labeled the physiographic zones in D.G. Khan District as the Sulaiman Range and the Adjoining Plain and the Riverain Area (Exhibit i). For clarity the Sulaiman Range, the adjoining plain, and the riverain area on the right bank of the Indus River, Taunsa to Mithankot, are called the D.G. Khan Zone. The areas total some 6 million acres. Agriculture outside the canal zone along the Indus River is limited to grazing and cultivation using water diverted from hill torrents. Annual rainfall on the plain is about 4 to 8 inches. The zone is located west of the Indus River to the boundary with the Baluchistan Province. It consists of approximately half of each of the Dera Ghazi Khan and Rajanpur districts and all of the former tribal areas of the two districts. The average north-south length is about 200 miles and the average width is about 35 miles. As shown in Exhibit II-1 the Sulaiman Range of mountains comprises three ridges, which lie parallel to the Indus River, the nearest lying within 35 miles of it. Exhibit VI-13 shows the tehsils of the D.G. Khan Zone.

The eastern face of the Sulaiman Range has steep slopes and rugged topography. Elevations range from 5,000 to 11,500 feet above sea level. The piedmont plains slope eastward from the base of the hills, with elevations of about 1,000 feet, toward the Indus River, with a slope of 1 to 3 percent. Elevations along the eastern edge of the zone range from 500 feet near the Dera Ismail Khan (D. I. Khan) District border to 200 feet near Rahjan.

Soils

Approximately 55 percent of the zone consists of the Sulaiman Hills, which have little to no soil cover. In addition, about 5 percent of the zone is dune lands, gravel or stony lands, gullied lands, and torrent beds, which are also recognized as miscellaneous areas. The soils of the piedmont plains were derived chiefly from the sedimentary rocks of the Sulaiman Range. They range in texture from sand to clay, but clay and loam are the dominant soil textures. The characteristic segregation of soil particles by the movement of water along the piedmont slopes is generally absent. Instead each piedmont alluvial fan has soils of basically the same texture throughout its extent, but soil textures differ from fan to fan. Most of the soils are uniformly calcareous.

Soils of the recent piedmont plains are generally formed as sand and clays and are either stratified or massive. They are highly subject to erosion by both wind and water but receive a thin deposit of fresh alluvium with each flash flood. Some of the sandy soils have blown into mobile dunes.

Subrecent piedmont plains have deep and very deep, dominantly clay soils with weak structure and are subject to water erosion. Soils of the Old Piedmont terraces are predominantly loams and loamy sands with weak structure. Those soils that occur closer to the mountains are covered by fresh sand and gravel sediment from hill torrents.

Fourteen soil associations and two undifferentiated soil groups were recognized by the Soil Survey of Pakistan in the zone. About 10 percent of the zone has soils of the Kundi association. Other large soil units are the Asni, Katahar, Chater-Duneland, and Kallarwala associations, which cover about 20 percent of the zone. About 10 percent of the zone has soil associations that were considered agriculturally unproductive along with the miscellaneous lands listed above.

The total riverain area lying between the D.G. Khan canal command and the active flood plain of the Indus River is some 250,000 acres of high katcha, or generally cultivated land, and 50,000 acres of medium katcha, land more vulnerable to flood. A detailed study was made of the Indus riverain area between the Jinnah Barrage and the junction of the Panjnad and Indus rivers, as reported in 1976 by the Planning and Investigation Directorate of WAPDA.

In that study, it is noted that lands are generally level, with a southeasterly slope of one foot per mile. The soils are moderately coarse to coarse, with good internal drainage. The water table is at depths of 6 to 13 feet. The water is of good quality, generally 200 to 600 parts per million (ppm) total dissolved salts. Some areas with shallow groundwater are covered with dense growths of grasses and other phreatophytes.

Land Use

Three strips of land and three separate water regimes prevail between the mountains and the Indus River. Nearest the mountains are the piedmont, or pachad, lands. Below the present pachad lie canal commands that serve former pachad lands and those lands that were watered by inundation canals, and near the Indus River are the riverain lands.

1. The Pachad. Large alluvial fans, which are fed by ever-shifting streams, reach from the mountains to the river. The resultant pachad, which extends across 180 miles and embraces 575,000 cultivable acres in a gross area of 2.0 million acres, is still in an active state of change. Thirteen major streams are uncontrolled except for 10 small structures recently built by the Punjab Irrigation and Power Department. During the past 20 years, the streams have become more deeply incised. Areas flooded for cultivation have decreased concurrently as the streams have changed. As a consequence of concentration of the flow, the D.G. Khan and Dajal Branch canals are frequently damaged heavily, and flooding occurs across the irrigated command areas, which were built in the lower pachad during the 1950s and 1960s. Much of the remaining 575,000 cultivable acres of the highly productive pachad soil, formed and watered by the 13 main torrents, are uncultivated today.

2. Canal Command. The command area of the D.G. Khan canal system is not part of the defined barani tract, but it is recognized in this study, because canal lands suffer damage from floods of the hill torrents. Lands assigned to the present canal command total some 1.0 million acres. more than 600,000 gross acres with extension of the another 275,000 acres with Phase III of the Chashma will considerably reduce the cultivable pachad lands. This area will increase Dajal Branch Canal and Right Bank Canal. This Initiatives, which will be presented later, for flood relief and for irrigation of the pachad, take these expected future canal developments into account.

3. Riverain Area. Between the canal command and the Indus River lies a 300,000-acre strip of land subject to flooding by the Indus River. It is designated for this study as the Vihowa-Panjnad Riverain Area.

Water Development Trends

The traditional approach to agriculture involves the construction of earthen or rock structures (gandah) across major channels just below the gullet (darrah), where the streams emerge from the last ridge of the Sulaimans onto the pachad. Gandahs direct water into major channels (wahs), where smaller gandahs, or kamarajah rodkohis, divert water to smaller channels. Small obstructing fills (wakras and sads) are placed at several points along tertiary channels to flood laths (bunded areas) to depths of three feet.

Once a lath has been filled the channel diversion is cut and the process is repeated at the next downstream wakra. These works and operations have traditionally been under the control of sardars (chiefs). With the out-migration of labor to the D.G. Khan canal command during the 1960s and to the Gulf states during the 1970s and 1980s, the social structure has changed, and the ability of the sardars to regulate labor and water flow has diminished. The highly erosive streams have changed channels and left many areas dry, and flows in specific channels have greatly intensified, all to the detriment of agriculture in canal commands of D.G. Khan. Some 10 years ago, the Punjab Irrigation and Power Department took the view that with provision of water-level control, through construction of nonrigid (gabion) structures across the principal streams, water can again be distributed to all channels, and laborers will return. 18 This view seems to have been confirmed by subsequent events. An extensive area was cultivated from one large flood, which was diverted shortly after a new structure was built in 1978.

Rights to flood flows and to year-round water supplies were framed during 1917-1920 under provisions or the Minor Canal Act of 1905. Perennial rights total some 110 to 140 cfs and irrigate some 18,000 acres that are served by three streams -- the Sanghar, Vehowa, and Kaha. Areas are shown in Exhibit VI-14. Improvements to the diversion channels of these systems and in-area water management measures should lead to increased on-farm water supply and to cultivation of a larger perennial area.

Construction of the Chashma Right Bank Canal (CRBC) is in progress in D.I. Khan District along the right (west) bank of the Indus River. The canal has been constructed from Chashma Barrage to the vicinity of D.I. Khan city under Phase I. It is expected that Phase II construction will extend the command several miles south of D.G. Khan by 1989. Phase III work, which has been planned but is yet to be financed, designed, and constructed, will carry the canal just downstream of Taunsa Barrage to Sori Hill Torrent in D.G. Khan District. The gross area of the pachad and riverain lands of D.G. Khan that will be commanded is some 275,000 acres.

Twenty-five percent of the area was formerly served by diesel tubewells. The Punjab Land Utilization Authority (PLUA) reported in March 1986, however, that tubewells are operating considerably less than

20 percent of the time because of lack of roads and access for fuel delivery, and because of the high prices of petroleum, oil, and lubricants (POL), water costs are Rs 22 to 30 or more per hour of pumping.

Opportunities for Water Development and Related Costs

Agricultural production in each three areas – riverain, hill-torrent perennial, and pachad – can be increased through independent measures or in the case of the proposed CRBC command, the several systems can be integrated to achieve economies. Large-scale use of the hill torrents for irrigation will also benefit the DG Khan and Dajal Branch canals and their irrigated areas through reduction of flood damages.

Groundwater

Potential for groundwater development in barani the full riverain Khan is limited to the riverain area. Development of described and costed in the preceding section of this chapter. D.G. Khan will be described more fully in the following sections. riverain area w Detail of the area is

Taunsa-to-Mithankot Riverain Area

Of the 250,000 acres of cultivable, high katcha land in D.G. Khan, 50,000 acres are adjacent to the planned Phase III CRBC. As noted earlier, this area could be partially or wholly developed simultaneously with establishment of the CRBC. The introduction of roads is the least that should be jointly developed.

Development of the riverain area for agriculture, crops, and fish, with 135 percent objective annual cropping intensity and, perhaps, six 625-acre fish farms will require the following series of actions:

- Construct roads for delivery of diesel fuel to pump water, to supply crop and fish inputs, and for marketing of output. These can be dirt or brick-soled roads, built at costs of Rs 320,000 and Rs 640,000 per mile, respectively.
- Introduce mobile diesel units to pump water at a cost of Rs 19 per hour or less, which will save each well owner the cost of purchase, operation, and maintenance of a prime mover and pump.
- Induce farmers to install well screens and connections for pumping water by mobile pumps.
- Although it is planned that high early returns will be achieved with mobile diesel pumps, extend power facilities into the area as rapidly as increases in generating capacity permit.
- Assist present tubewell owners to adopt a more efficient mode of operation than they are now using.
- Organize an extension service and an efficient supply of inputs and finance.

To spur early installation of private tubewells and efficient operation, it will be necessary to involve a PLUA-type public agency for oversight and to encourage a private entrepreneurial operation to conduct pumping operations for a water charge.

Total capital costs to develop the unwatered 75 percent of 250,000 acres of riverain area will be Rs 158 million -- Rs 126 million private funding and Rs 32 million in public funds -- as shown in Table VI-19.

With a mobile, private operation, the cost of delivering water to a cropped acre will be about Rs 438. Rs 40 of this cost will accrue to the farmer to secure credit for and to annualize replacements of the well installation without the pump and motor. The other Rs 394 will be incurred by the operator of the private pump. The operator's cost of Rs 394 is 68 percent for POL and 32 percent for equipment, labor. and compensation for risk.

If the farmers chose to install their own pumps and diesels and obtain individual supplies of POL, their costs would be much greater.

In fact, PLUA has calculated that farmers with diesel pumps spend 50 percent more than the foregoing estimate for pumping by a combined operation of farmer and private entrepreneur. The farmers will also use considerably more personal time to conduct water-producing operations, and agricultural inputs could be made available at the farmgate with the same credit and delivery conditions agreed to for water delivery.

Requirements for organizing, equipping, staffing, and financing of the private entrepreneur operation, in an area of 188,000 acres, are given in the Riverain Area section of this chapter and are detailed in Table VI-19.

Surface Water

Surface-water development is confined to areas on the pachad, those watered by flood, and three small areas with perennial irrigation.

Hill Torrents

Priorities for construction of projects on the hill torrents can be grouped as follows:

<u>First Priority</u>

Mithawan, Kaha, Chachar, Kaura, Vehowa, Sanghar

<u>Second Priority</u>

Vidore, Sori Lund, Sakhi Sarwar, Zangi, Sori Shumal, Pitok, Sori Janubi

Proposed is the construction of some 13 gabion cross-channel structures on the 13 main hill torrents, along with bunds and extensive watershed works in the upper catchment of the Kaha in Baluchistan. Some watershed work is also proposed for Baluchistan catchments of the Sanghar and Vehowa hill torrents. The proposed structures are shown in Exhibit VI-11, and costs are set forth in Table VI-20 NESPAK, in its 1985 report to the Federal Flood Commission, projected a 14-year construction schedule costing Rs 538 million escalated for this study to a 1987 total price of Rs 700 million -- with full project benefits to be realized after 25 years. The resultant Internal Rate of Return (IRR) was estimated by NESPAK to be 18 percent.

Mithawan

Structural models for the Mithawan Hill Torrent were constructed and tested by the Lahore Irrigation Research Institute to assess the likelihood that the proposed structures would stand up to the hydraulic and erosive forces of the torrents. Although the results were encouraging, it had already been concluded that only through construction and observation of one full system would it be known whether the systems would perform as planned. Thus, Mithawan Hill Torrent, which had been chosen as the Pilot Project, was submitted to and assessed by a mission of the Overseas Development Administration (ODA) for possible financing. Extensive bund systems, two distributors (gabion weirs), and an escape structure were planned at a 1987 cost of Rs 77.6 million, with an IRR of 17 percent. 21 This is a high-priority project, which will not only increase agricultural benefits but, even more important, will reduce flood breaching of the Dajal and D.G. Khan canals substantially.

Kaha

Kaha is the largest and most destructive of the hill torrents; it has the second highest design peak discharge, 94,000 cfs, after Sanghar Hill Torrent, which has 123,000 cfs. Proposed for management and reduction of the flow are two sets of measures the one in the catchment between mountain ridges in Baluchistan before the water discharges through the darrah onto the pachad and the other a set of cross-channel diversion structures on the pachad (Exhibit VI-11). It is proposed that both sets of measures be undertaken early, but separately. It is proposed first that the structures proposed by NESPAK be constructed in the pachad area. Simultaneously, it is proposed that an effort be made in cooperation with the Provincial Government of Baluchistan to implement a project in the upper catchment. Total costs of construction of two dispersion structures and watershed measures in the pachad (in Punjab) will be Rs 80.7 million, and the costs of works proposed for Baluchistan will be Rs 130 million.

Chachar

Even though the 274-square-mile Chachar catchment yields a design peak discharge of only 41,600 cfs, flood water of the Chachar flows in a well-defined channel and has done extensive damage to canals and irrigated areas of the Dajal Branch canal several times recently. There is potential to spread water on some 40,000 acres. With construction of the planned structures, floods will essentially dissipate on the pachad. The works will cost approximately Rs 10.4 million for structures and Rs 6.4 million for watershed management.

Perennial on the Pachad

There are two water-related opportunities to increase intensity of cultivation and to extend irrigation in the areas of the pachad that have perennial water supplies from the Vehowa, Sanghar, and Kaha hill torrents. The first is to improve diversion channels from the takeoff point to the cultivated land. These channels can be increased in capacity to divert more flood flows during the kharif season. At the same time, it is anticipated that a concrete or brick-lined cunette in the bottom of the channels will save non-beneficial infiltration losses during the rabi season. As much as 20 percent of the low-season flows may be lost in conveyance.

The second opportunity for saving water exists within the perennial command Here there is an opportunity to implement typical on-farm water-management measures across the commands. If experience in the nearby Thal, D.G. Khan, and Dajal Branch areas is any indication, a water saving of at least seven percent can be expected.

The potential water savings, the addition of cropped acres at full water supply, the costs, and the benefits that would be the result of implementation of these two initiatives are summarized in Table VI-21.

Operation Potential

Three hill torrents lie above the proposed Phase III CRB canal- Sanghar, Vehowa, and Kaura. Design peak discharges at the darrahs are 123,000, 96,000, and 58,100 cfs, respectively. At present the flows of Vehowa and Kaura combine. The plan is to separate the flows and to divert the entire flow of Kaura and a small part of the Vehowa flow upon the pachad. Sanghar flows may be reduced 10 percent on the pachad. Residual flows will cross the CRBC, flow through the command and riverain areas, and discharge to the Indus River along their present alignments.

There has long been provision for conveying CRBC flows across the Sanghar Hill Torrent through a conduit built into a highway bridge, and it is planned that the CRBC will be made to cross the Vehowa channel similarly. These measures may not be adequate for the 25-year flood without construction of the proposed control works upstream. Even if design flows would pass the canal structures, there is still a need to reduce flows and probable damage within the new CRBC command.

The cost of upstream works should be lower than those of larger cross-canal structures and potential damages in the command area. For an investment of Rs 6.8 million, the water of the Kaura will run separately from the Vehowa and will probably be spread in its entirety on the pachad.

Rs 19.6 million will be required to divert Vehowa water from the non-hoqook (no rights to flood water irrigation) channel and to protect Buzdar Village and the irrigated area of Phase III CRBC. An alternative implementation of these measures that some unspecified future date, is to combine their construction into that of the CRBC Project. Thus, it should be possible to realize:

- Lower cost through designing smaller, combined-purpose structures; and
- Greater efficiency and economies in construction.

Similarly, drainage works and possibly irrigation works of the CRBC system will extend into and across the riverain areas. Any extension of inspection access roads and electric facilities will provide a boost to the installation and operation of private tubewells in the riverain area. Here it may be possible to realize early implementation and economies by designing and constructing the CRBC system in such a way as to take riverain development potentials into account.

Most of the development on the pachad is sizable infrastructure and as such is to be funded largely by the government, whereas the riverain development is to be accomplished largely with resources from the private sector.

Operation, maintenance, and replacement costs for riverain development are specified in the preceding section of the present chapter. For structures on the pachad, the annual allocation proposed is 1.5 percent of capital costs.

Evaluation of Alternatives

Alternatives are framed as follows for each of the four areas of the zone:

A Riverain Area (considered in the section on the Riverain Zone).

B. Hill Torrent (Pachad). These alternatives essentially relate to rates of implementation, because the ultimate objective is installation of the same works.

1. Install dispersion and control structures on the 13 main hill torrents during a 14-year period with a fairly uniform rate of investment, as proposed in the flood-management plan developed for the Federal Flood Commission.
2. Carry out essentially the same set of alternatives but with an intensive program during the next five years to achieve: (1) early relief of flood damages in the D.G. Khan and Dajal canal commands, (2) avoidance of future damages in the CRBC extension area and realization of economies through joint design and construction, and (3) extensive early watering of the pachad lands. Half of the works should be undertaken fully during the first five years. Some 40 percent of the expenditures

will be for works in Baluchistan in the upper Kaha catchment, if an interprovincial agreement is worked out or if the project can be federally funded. Work on the Mithawan, Kaha, Chachar, Kaura, Vehowa, and Sanghar hill torrents should be started. The intensive effort would be followed by a more leisurely program, which would accomplish the second half of the work during a 10-year period.

3. Initiate work on the Mithawan, Chachar, and Kaha on the pachad. Let work on the Kaura, Vehowa, and Sanghar proceed only after the CRBC Phase III construction has been undertaken. Pace the remainder of the work similarly to that in Alternative 1.

C. Hill Torrent Perennial

1. Do nothing.

2. Improve diversions and conveyance canals; increase flood-season flows in the perennial channels: extend the area sown.

3. Do Alternative 2 and introduce on-farm water-management techniques to expand the area sown and the unit area water supply.

These alternatives were rated in the light of Master Plan objectives and appropriate criteria as articulated in Chapter Five. The evaluation is summarized in Table VI-22. It is assumed that throughout the perspective plan period initiatives will be implemented to develop the water and agriculture of the D.G. Khan Zone fully.

The Action Program is based on Alternative 2 for hill torrent control and Alternative 3 for perennial development in the hill torrent area. As shown in Table VI-22, each of these alternatives has a high economic internal rate of return, and they all increase the supply of water available for agriculture, provide equity, and are sustainable.

Essential to implementation of the Action Program, within the perspective framework, is adoption of a series of policy and institutional initiatives These were specified in Chapter Five.

Recommendations

A schedule for the proposed five-year Action Program and costs for the action plan and for 20 year framework plan are given in Table VI-23. Although the timing for implementing projects within the D.G. Khan Zone is roughly outlined in Table VI-23, the timing of proposed implementation is modified in the total water – development program Action Plan of Chapter Nine. There the program is presented for high and low rates of investment, taking into account a reasonable division of resources between promotion of rainfed and of irrigated agriculture in the Barani.

As noted under costs, capital investments in flood control and irrigation works on the pachad (piedmont) are entirely in the public areon roads -- whereas the riverain investment is 80 percent blive largely infrastructure

SALT RANGE ZONE

Existing Resources and Conditions

The Salt Range Zone extends from the west side of the Indus River in the area of Isa Khel, across the upper limits of the Thal Doab along the Jhelum River, to the border of Jammu and Kashmir (Exhibit i). It includes portions of Jhelum, Chakwal, Khushab, and Mianwali districts. Rainfall throughout this area of 2 million acres varies from 10 inches in the west to 30 inches in the eastern portions of the piedmont. Water developments in the areas on the north slope of the Salt Range and the highlands of the Bunha and Kanshi rivers were analyzed in part earlier, in the section on the Potwar Plateau. This presentation will therefore be focused on potentials for water development in the riverain area of Isa Khel, the saline lakes above the escarpment, the piedmont along the southern slope of the range, and groundwater areas along the Jhelum River above the Rasul Barrage. Exhibit VI-15 shows the locations of the Salt Range tehsils.

The range itself is composed of sandstones and limestones alternating with shales, with varying degrees of tilt. Some slopes are very steep. Intermountain valleys, which have nearly level to moderately sloping surfaces, exist in much of the range. At the southern edge, the Salt Range ends abruptly in a steep escarpment. The adjoining plain, which was formed by hill torrent deposits, is gently sloping.

Elevations of the plain range from about 700 feet near the Indus River to M feet at the east end. The highest peak in the Salt Range is 5.160 feet in elevation from 2,500 to 2,900 feet in

Kallar Khahar south of Three large salty lakes have formed naturally on the north slope of the They receive drainage from enclosed basins Talagang city, Khabakki Lake northeast of Naushahra. and Somsakesar, or Uchhal Range. Lake, to the west. Namal, a large freshwater lake, outlets through the Wahi Rive westward to the Indus River.

Isa Khel, on the west side of the Indus River, is bordered by the Kurram River on the south and the Indus River on the east. The most significant area for agricultural development in Isa Khel is 27.000 acres of land in the Indus riverain sailaba zone.

The piedmont of the Salt Range is a strip of land some 100 miles long, which 5 to The bied wide and represents about 40 percent of the lands of the zone. Se 5 to 20re gentle to the west near the Thal Zone and steepen the the area from P eastward to the Bunha River. area from Bunha River up Dadan Khamore typical of the dissected plateau countryand the Potwar. The steep piedmont, in particular, is crossed by a series of nullahs that disrupt infrastructure when in flood and contribute to waterlogging and salinization of lower-lying land Land and groundwater in the Pind Dadan Khan area are particularly saline.

Soils

Approximately 60 percent of this planning zone was recognized as miscellaneous areas, having little or no soil material. The agricultural soils that do exist have been formed in parent materials of piedmont alluvium and loess. The loess soils an confined to the intermountain valleys. Soils of the piedmont alluvium are derived from the local rocks generally sandstones, limestones, and shales.

About 20 soil associations and 5 soil complexes were recognized in this 200. The largest units are the Chakwal association in the level to nearly level old loen plains and the Ghaznikhel association in undulating and gently sloping subrecent piedmont plain. Deep gullies exist in the loess deposits, but the uneroded areas have deep soils, mostly of medium texture. Because of the high salt content of some of the piedmont parent material and the lack of adequate drainage, some soils of the plains are highly saline.

Land Use

Much of the Salt Range has steep rocky slopes and is used mainly for grazing. The agriculture on the piedmont is restricted by localized areas of salinity and is most developed in the east, particularly near the Jhelum River.

Water Development Trends

The area toward Jhelum town has groundwater that can be developed on both the high ground and in the riverain zone. There is also potential in the area from Jalapur to Hasanpur.

Salt Range lands are essentially undeveloped so far as irrigated agriculture is concerned, except in the area of Nammal Lake. About 12.000 acres of land are irrigated from the Nammal Canal, which draws water for one season along an alignment through Musa Khel. There are some 300 private tubewells in the Isa khel riverain area and more near Jhelum. A small area of about 8,000 acres in the Jalalpur-Pind Dadan khan was irrigated by lift. Both this area and the Jhelum riverain area have suffered diminished water supply since Mangla dam was built.

Past and Current Project Proposals

Two large-scale irrigation developments have been proposed for the Sait Range Zone. They are the Jalalpur Canal Project, which would irrigate lands along the right bank of the Jhelum River below the Rasul Barrage, and the Mohajir Branch canal, across the north of Thal Doab, which has the potential to serve lands of the zone if water is lifted. A Kalabagh-Rasul Link Canal proposal report is now being prepared by WAPDA. In addition, a Left Bank Canal from Kalabagh could serve portions of Isa Khel, although this project is now being proposed as an NWFP project.

Jalalpur Canal

The Irrigation Department has an outstanding PC-1 for development of 159,000 acres of cultivable land stretching 75 miles along the piedmont from the Rasul Barrage to Khushab District (Exhibit VI-16),29

The project would be served by a 1,374-cfs canal, which would divert Jhelum River water at the Rasul Barrage for irrigating at 90 percent intensity during the kharif season. The project would cost Rs 613 million (1984 costs) and would enjoy an IRR of 19.5 percent.

The canal must be built in its upper to middle reach on the soft, poorly structured murum soils. Also, cross-drainage works in the upper reaches of the canal are of particular importance because of the difficult flood conditions there.

Of the cultivable area, a third is strongly saline and half is salinity free. The rest of the land is slightly to moderately saline. It is proposed in the PC-1 that extensive reclamation work be undertaken for a period of years.

RAP Jalalpur Alternate

During the preparation of the Revised Action Program (RAP) in the late 1970s, WAPDA planners proposed that the lower, better lands of the jalalpur project be served from the Indus River via a remodeled Mohajir Branch canal of the Thal Canal (Exhibit VI-18, presented in the Thal Zone analysis). They also proposed that some 50,000 acres of land between the Mohajir Branch Canal and foothills of the Salt Range be lift irrigated.

Kalabagh-Rasul Link Canal (Kalabagh Left Bank Canal)

A very large link canal project is now being studied to transfer 15,000 cfs of water from the proposed Kalabagh reservoir to the Rasul Barrage on the Jhelum River. The canal will flow through an eight-mile tunnel on the left bank of the Indus River at Kalabagh, go southward eight miles to the east of Mianwali, then turn eastward across the nullahs of the Salt Range to the Rasul Barrage a distance of 170 miles. Along the route 400,000 acres of land will be irrigated, and the link will transfer 15,000 cfs to the Rasul Barrage. From there it will be possible to distribute Indus water to any water-short area of the Punjab. Realization of the project must await construction of Kalabagh Dam and agreement on division of the Indus waters.

Kalabagh Right Bank Canal

This canal is also being planned. It will pass through Isa Khel and irrigate large areas of the Northwest Frontier Province. It has potential to serve lands of the Punjab, especially in the junction area of the Kurram and Indus rivers. This project, like the Kalabagh-Rasul Link Canal, is for the future and could probably not be implemented during the Perspective Plan period. If Kalabagh Dam is built, however, this canal could provide a measure of equity to the NWFP.

Opportunities for Water Development

Groundwater

Two classes of groundwater development are contemplated for the Salt Range Zone. Riverain development with centrifugal pumps is proposed for a gross area of 15,000 acres in Isa Khel and a limited area along the Jhelum River between the Mangla Dam and the Rasul Barrage. The second area is an integral part of the extensive sand and gravel aquifer lying north and south of Jhelum city, which is shown at the mouths of and upstream along the Bunha and Kahan rivers (Exhibit VI-14). The second area will require development largely by turbine pumps. The Jhelum aquifer extends over more than 100,000 acres, and it could yield perhaps 65,000 acres feet of water per year.

Riverain Areas

It is proposed, as detailed in the discussion of the Riverainio Zone, that the riverain area at Isa Khel be developed during the five-year Action Plan period Some 15,000 acres of unirrigated land would be developed by private entrepreneur Some farmers with help from the government to build roads, assist with financing, and level the land. Total capital expenditures for the areas would be Rs 11 million from private sources and Rs 19 million of public funds.

Jhelum Area

There are 90,000 acres of cultivable land lying above the Jhelum River between its junction with the Bunha River and Jhelum town. Exhibit VI-14 shows that here there also is a good tubewell aquifer. The presence of these two important resources is confirmed by the 1980 Census. Tubewells and dug wells serve half to two-thirds of the land. This area, too, should be studied to determine whether an entrepreneurial type of water-pumping operation would be beneficial. Provision is made for typical riverain development with centrifugal pumps in the Jhelum to Rasul portion of the riverain developments. Further investigation is required, however, of the possibility of developing most of the area by means of deep tubewells and turbine pumps.

Surface Water

There are potentials above the escarpment of the Salt Range and in the eastern area for the development of dams, springs, and saline lakes. On the piedmont, there is the potential for development of two large canal commands Jalalpur and Mohajir and a distant future potential to serve these and adjacent lands from a Kalabagh-Rasul Link Canal.

Salt Lake Region

It is proposed that the potential for partitioning flow into the saline lakes of the high country Khabbakki Khahar and Soon Sakasser Khahar for possible irrigation use be investigated. Development of a freshwater body within a lake could be achieved by diking the portion of the lake where water enters in greatest quantity. That arm of the lake would freshen, and water could be diverted or pumped. Alternatively, an outlet channel with control structure could be constructed. The lake could be drained completely or again partitioned and drained, so that an inflow of fresh water could be used and not be allowed to become saline. The surrounding salt flats should also be flushed during the process of draining or diking. Sources of saline inflow should be restricted to lake sections or evaporation ponds of a size adequate to balance inflow and evaporation.

It is proposed that a concurrent investigation of groundwater potential as evidenced by the many flowing springs in the area be conducted. These investigations would be coordinated with investigations of the Potwar Talagang area. The costs of the program are budgeted at Rs 5 million.

Springs

Even though most springs of the high country of Khushab District are in use at present, some facilities could be updated and in some cases springs now in use could be improved. The Makrach Irrigation scheme has been presented in an updated PCI (1988). It is designed to deliver more than 2 cfs of perennial water from two rivers through 3,200 feet of mild steel pipe and 1,100 feet of open channel to 1,410 acres of land near Makrach in Tehsil Pind Dadan Khan, 13 miles southwest of tehsil headquarters on the road to Khushab. The expected cropping intensity is 100 percent. The Irrigation Department estimates a B:C ratio of 4.97:1. An amount of Rs 30 million was allocated for this improvement program in the budget for the Potwar.

Dams

It is expected that Domeli Dam on the Bunha River and Pattian Dam on the Kanshi River will be built during the 20-year Perspective Plan period to service several thousand acres of Salt Range lands. The costs of these projects are estimated at Rs 240 million for the dams, Rs 40 million for canals, and Rs 100 million for watercourses and land preparation.

Canals

Noted in the discussion of the Potwar Zone is the possibility of developing a sizable storage capacity in the Soan River Basin and releasing the water to the Jinnah Barrage for diversion through the Mohajir Branch canal to the Jalalpur area. These and other adjacent lands would all be developed by gravity irrigation, if the Kalabagh-Rasul Link Canal were eventually built.

Operation Potentials

If the Jalalpur project, as proposed in the 1984 PC-1 pro forma, cannot be authorized because of a water shortage, because of technical concerns with difficult cross-drainage problems in the canal head reach, or because of the extensive soil-reclamation program that is necessary, then the following project approach may succeed in initiating plan recommendations.

1. Build storage on the Soan River to control 1 to 1.5 MAF of annual flow.

2. Release water to the Jinnah Barrage.

3. Transfer water through a remodeled Mohajir Canal.

4. Pump water to good Salt Range lands en route, serving approximately 50,000 acres.

5. Irrigate lands of the Jalalpur command in Khushab and downstream Jhelum District.

6. Support private development of tubewells in the good groundwater area from Jalalpur to Hasanpur.

Costs

Capital Costs

The program for water development in the Salt Range is a combination of investment proposals and investigations, as shown in Table VI-24. Total costs of Rs 568 million, including Rs 123 million for riverain groundwater development, for the 20-year Perspective Plan period are shown. Within 20 years, the total investment could be considerably greater if canal command projects were to be formulated and built.

Operation, Maintenance, and Replacement Costs

Operation, maintenance, and replacement costs of the dams and associated canals are estimated to be 1 percent in the public sector. Maintenance of on-farm systems is assumed to be the responsibility of the cultivators. Total annual maintenance and replacement costs of tubewells will be about 10 percent of investment costs. Estimated total operation, maintenance, and replacement costs, exclusive of roads in the riverain, are Rs 3.0 million per year in the public sector and Rs 1 million annually for the private sector exclusive of the riverain.

Areas for Future Study

It is proposed that detailed groundwater investigations be undertaken early during the five-year Action Plan period and that development of a tubewell field be immediately authorized if water and aquifer prove to be of good quality and as extensive as indicated in Exhibit VI-14. The investigation is budgeted at Rs 5 million. Another Rs 20 million is proposed for a prefeasibility study of a Soan storage system. It may be well to couple this study with a broader study of a linked storage system on the plateau.

Recommendations

It is recommended that groundwater development be undertaken in riverain areas, that the Makrach Springs project be undertaken, and that monies be made available for a series of investigations, as shown in Table VI-24. The most likely project to progress beyond investigations during the five-year Action Plan is development of groundwater in the Jhelum area.

Evaluation of Alternatives

The question concerning the alternative options that are available in each of the three development areas groundwater, dams, and canal commands essentially that of which to do first (short- vs. long-run distinction). The choice is to conduct groundwater development early because of the relative ease of implementation and the fact that the riverain component can be developed largely in the private sector. Investigations, too, are indicated for early investment, because the basic information on groundwater of the high plateau that is available is wholly inadequate, and studies of alternative solutions for the Jalalpur command must be accomplished early.

Groundwater development in the Jhelum area, which is more expensive than development of riverain areas in the plains, is still attractive. This development will require a higher percentage of public input than the downstream riverain projects, since more costly turbine pumps and deeper wells are required.

Appropriate sequencing of dam projects of the Salt Range, Domeli, and Pattian can be determined only after detailed feasibility studies have been made. Evaluation of the projects with respect to Master Plan objectives and criteria follows.

To provide equity of development across the zone, groundwater and spring projects should be undertaken the riverain project in Isa Khel, the springs at Makrach, and at least part of the groundwater development near Jhelum. Early investigations of the salt lakes, springs, and groundwater above the escarpment of the Salt Range are required.

The riverain area and the springs project should be readily sustainable, because the private sector will finance most of the riverain project, and beneficiaries will be cognizant of the spring development, since it will supply drinking water as well as water for irrigation. Productivity will be good, with high benefit-to-cost ratios, and conservation figures most importantly in the diversion of spring water from the salt plain to beneficial use. Riverain groundwater, much of which is lost through evaporation, will be salvaged.

THAL ZONE

Existing Resources and Conditions

The Thal Zone that portion of the Thal not commanded by canal irrigation -- is located between the Indus and the Jhelum rivers, south of the Salt Range (Exhibit i). It covers part of the districts of Khushab, Bhakkar, Jhang, Leiah, and Muzaffargarh and consists of 3,600 square miles of sand dunes and interdunal valleys. Traces of long-abandoned river channels abound throughout the Thal desert. Many present-day drainage lines indicate the location of earlier main courses of the Indus River. The western edge of the Thal has a well-developed network of canal irrigation. Tubewell irrigation is practiced, somewhat poorly, in the interdunal areas. The rainfall ranges from 6 inches in the south to 16 inches in the north. Exhibit VI-17 shows the locations of the Thal tehsils.

Soils

Since sand dunes dominate the Thal Zone, they occupy 70 to 75 percent of some areas. Five main forms of sand ridge have been recognized in the area: longitudinal ridgy sands, ridgy alluvial sands, alluvial sands, transverse ridges, and symmetrical and nonsymmetrical barchans. The formation of the various ridges depends on local wind regimes.

Longitudinal ridgy sands in the northern part of the zone have:

uniform, evenly spaced, parallel ridges several kilometers long and five to ten meters high separated by inter-ridge valleys approximately the same width as the ridges long, stable, gently sloping (2 to 6 percent) windward slopes, and short, sloping or moderately steep (6 to 25 percent) slip faces narrow, recently stabilized ridge crests and partly crescentic shaped belts of nonvegetated soils, with a surface crust, at the base of the windward slopes of the ridges. 31

Terrace ridges are somewhat rake-shaped, 15 to 40 feet high, 400 to 600 feet, wide, and separated by interridge hollows of approximately the same width. They occur in the south of the zone in parallel; they do not interconnect E-W or ESE-WNW ridges at right angles to the seasonal winds.

Alluvial and ridgy alluvial sands occur to the north of the transverse ridges as transitions between the longitudinal ridgy sands system and the transverse ridges. The latter occur where the opposing winds are of equal strength, while the alluvial sand systems occur where one of the opposing winds is predominant over the other -- slightly so for the alluvial sands and strongly so for the ridgy alluvial sands. Cross ridges join the transverse ridges at right angles, giving a honeycomb appearance.

Barchan sands normally take the form of symmetrical crescent-shaped dunes seven to 20 feet high, with the apex pointing in the direction of the prevailing wind and with the wings extending downwind. They have long, gently sloping windward slopes (10 to 15 percent) and short, steeper leeward slopes. Intensive use has caused them to be completely devoid of vegetation. A barchan sand dune occupies an area of two to five acres or more and constitutes a severe hazard to cultivation.

Soils of the Thal Zone are formed directly or indirectly from mixed calcareous alluvium deposited by the Indus and Chenab rivers. The parent material consists essentially of fine gray sands derived from igneous and metamorphic rocks of the Himalayas. This alluvium has been resorted by the wind into variously aligned sand ridges and hollows. Wind erosion continues to be an active force.

The soils of the ridges are deep, fine sands, without well-defined structure. Fine material from the ridges has washed into the hollows and, where it has been allowed to accumulate, has formed deep, moderately calcareous, weakly structured soils. Water has reworked the soils of the abandoned channels, and the deposited materials are predominantly deep, fine, loamy sands with some loams and silty clays.

Ten soil associations and three soil complexes were recognized in the area of the planning zone. e.32 The most extensive are the Khumbi and Thal-Khumbi complexes (about 25 percent) and Dad-Agiwala and Thal-Bhakkar associations (about 20 percent).

Land Use

Eighty-two percent of the cropped area (20 to 25 percent of the gross area) is dry-farmed. More than 200,000 acres of the area have been allotted to private owners under various tubewell schemes. Hardly 10 to 20 percent of the allotted area is actually served by tubewells, because of soil and groundwater difficulties, which will be noted in the following section. Small patches of land, two to three acres, grow fodder, melon, and vegetables with water lifted by animal power from dug wells. The 80 percent of the area that is farmed under barani conditions is cropped with gram, wheat, melon, and guara. Grazing is general across the area.

Water Development Trends

Irrigation systems have been built in the Thal or Sind Sagar Doab across the north from the Jinnah Barrage, along the entire length of the Indus River from the Jinnah, Chashma, and Taunsa barrages, and in the southeast served by the Trimmu barrage on the Chenab River. (Exhibit II-1). Development has carefully skirted the Thal Desert The remaining uncommanded area, called the Greater Thal by the Irrigation Department, is infested with sand dunes and underlain by groundwater of not fully defined quality (Exhibit VI-18). The WASID studies of the 1960s show a picture of a complex geo-hydrologic system, as the exhibit shows. The isosalinity lines hardly reflect the fact that fresh water overlies saline water, and the areal delineations are not well defined.

Since the area is one of frequent sandstorms, it is nearly impossible to maintain canals unless they flow year round and have multilayered windbreaks of trees.

There have been attempts by private parties to develop groundwater for irrigation. Many are reported to have failed, although there are operating tubewells and Persian wheels. Failures and successes are the result of the variable depth of the groundwater table, water quality, sandy soils, and the broken nature of the land. The Punjab Land Utilization Authority (PLUA) reports groundwater to be 100 to 110 feet below the land surface, except near canal sources of recharge, which necessitates the installation of expensive turbine pumps. The water output often irrigates only 20 percent of the design area because of the coarse nature of the soils. Thus, tubewell developments are often uneconomic.

Opportunities for Water Development

There are opportunities for both surface and groundwater development, as will be proposed below. The fundamental constraints to development, however, are poor land that is costly to develop, large losses in water conveyance and application because of sandy soils, and a lack of allocated surface water. Proposals that could overcome or compensate for several of these problems are made in this report. As will be seen, excess flood flows of the Indus River could be used to fill the groundwater reservoir, through irrigation and canal and reservoir leakage, and the reservoir would become the water conduit to tubewells. The tubewells would be powered by comparatively cheap centrifugal pump units.

Groundwater

Groundwater development is possible at high cost under present conditions, while the potentials for more economic development are associated with surface water schemes, as will be outlined in the following section.

Surface Water

The alternatives for surface water development are between construction of a traditional canal command system, as advocated by the Irrigation Department, and promotion of resultant groundwater development of an aquifer that has been filled with diverted flood flows.

The Greater Thal Canal Project: Alternative 1.

The Irrigation Department has proposed the Greater Thal Canal Project. The main canal would divert nonperennial water for the kharif season only from the Chashma-Jhelum Link Canal at RD 19.3 and extend approximately 120 miles to the south. It would irrigate 1.56 million acres.

The area is hot and dry, with only 8 to 14 inches of rainfall. The soils are mostly sand. There are scattered villages in the area, and sheepherders use the range. The population is sparse.

Revised Plan: Alternative 2.

The Master Planning and Review Division (MP & RD) of WAPDA proposed in their Revised Action Program Report of 1978 that the project area be reduced and divided into two sections: 818,000 gross acres in the good groundwater areas of the south, to be fed by the Chashma Barrage Pool, and 105,000 acres in the north, commanded by the Chashma-Jhelum Link Canal (Exhibit VI). The MP & RD considered it urgent that any canal development in the Thal be combined with development of a reservoir. The reservoir, besides conserving surface water, would provide recharge to groundwater and would thus support pumping of water during the rabi season.

A newspaper account of proposed Thal development by Ahmad Hassan, former Irrigation Secretary, Government of West Pakistan, was cited by the Barani Commission in their draft report. His ideas for development of the desert seem to be efficient, rational, and implementable.

Mr. Hassan proposed that excess capacity of the Chashma-Jhelum link could be used to spread flood water in bunded areas. This would not only provide irrigation but would also contribute to a build-up of the groundwater.

Both Hassan and MP & RD were confident that a water table build-up would provide water both for pumping and for river regeneration along the Jhelum to the southeast. Hassan further recognized the considerably greater benefit that accrues to an underground reservoir than accrues to a surface reservoir. Underground the water flows to points of use, and there is little or no evaporation.

Costs

Capital Costs

The proposed capital investment program for the Thal Zone is as shown in Table VI-25.

Operation, Maintenance and Replacement

Total annual tubewell operation, maintenance, and replacement cost will be about 10 percent per year of investment costs.

Evaluation of Alternatives

The riverain projects are evaluated in the corresponding report section of this chapter.

Canals would be difficult to maintain because of drifting sand. Keeping non-perennial canals clear during the no-flow season will be difficult to impossible, even with wind breaks. Build-up of the groundwater table to act as a substitute for part of the conveyance system conveyance is therefore the preferred approach, if development is to proceed.

Recommendations

In view of the difficulties anticipated with a surface system and because of the known problems of present groundwater exploitation, it is proposed that a pilot project be undertaken. The project would be located near the C-J Link Canal, along the upper reach of the Nurpur Canal. The project would consist of the following:

- A tank of 100,000 acre-feet capacity for storage of flood waters conveyed by the C-J link;
- An area of 10,000 acres to be irrigated from the tank;
- A monitoring system to measure the build-up of groundwater under the reservoir and in the irrigated area; and
- Eventually, private tubewells to supplement the water supply.

The effects of windbreaks developed around facilities would also be monitored. Date palms could be used and could merge with a formal date plantation. If the groundwater build-up proved successful, it could be expanded and operated as visualized by Hassan, in which case there would be no need to level dunes. Private individuals could indeed drill tubewells and irrigate between the dunes.

It would be desirable to locate 2,000 acres of government land in the good groundwater area to set up a bunded area and the necessary colony to house the operators and monitoring crew. It is proposed that Rs 30 to 40 million be allocated to ensure that investigations can be thorough and that a sound plan can be drawn, with all interests accounted for.

Areas for Future Study: Riverain Initiative

Under the program for the Riverain Zone are a number of projects for the Thal, wherein the greatest development potential in the riverain lies. A project recommended for early action is the Khushab-Trimmu area, which is part of the Thal Zone. It is estimated that some 45,000 acres of this actively farmed area is still in need of tubewells. A public input of Rs 16 million would be required and the farmer and private entrepreneur would contribute Rs 21 million for tubewell development. It is proposed in the riverain investment schedule that the project be brought on line during the five-year Action Program.

Of the 170,000-acre Darya Khan-Taunsa project 60,000 acres should also be completed during the five-year period, and the Trimmu-Panjnad project of 55,000 acres should be completed early in the twenty-year plan.

These recommendations are made with a view to efficient, high-yielding projects early into the Thal Zone interest of equity and conservation. When considered from the limited availability of resources in the barani, they will have compared with projects from other zones. introducing potentially particularly in the point of view of the to be evaluated and

THE SIWALIK ZONE

Existing Resources and Conditions

The plains of the Siwalik Zone are the most productive of the entire barani Groundwater of the area has been developed with thousands of private area. tubewells. In some areas, these are used only occasionally because of the rainfall of 35 inches, which is nearly adequate for cultivation of both kharif and rabi crops.

The area is divided into the Sialkot-Shakargarh plain and the Gujrat plain. The 900,000-acre Sialkot area is bounded by the Chenab River on the west, the canal commands along the Marala-Ravi Link Canal to the south, and the Indian border on the north and east. The 600,000-acre Gujrat plain is composed of two tehsils, Kharian and Gujrat, which lie between the Jhelum and Chenab rivers, the Indian border to the north, and the canal commands to the south.

Soils

Much of the zone is a nearly level alluvial plain, without the spectacularly visible soil erosion that exists in the other zones. Slopes are generally 1 to 3 percent. The Pabbi hills, which constitute less than 5 percent of the zone, are rugged. The area near the Jammu hills is somewhat dissected, with entrenched streams and some erosion. Most of the area has been deposited by surface water run-off from the adjoining Jammu and Kashmir hills.

Soils are generally deep and well drained, with loamy texture. proportion of clayey soils is located in the northwestern sector. A small The Pabbi hills have gravelly soils, which are shallow on the upper slopes and deep on the lower slopes. Gullied land exists in the center and has soft silty deposits. Almost the entire cultivated area has deep loam and clay loam soils, which, in the subhumid climate of the area, make this land the best dry-farmed crop land in Pakistan.

Water Development Trends

Cultivable lands, two-thirds of which are irrigated, occupy 90 percent of the gross area. Unirrigated lands are in pockets across the whole area, but the largest tracts are in the areas with difficult groundwater conditions. While the quality of the groundwater in underdeveloped areas is almost all good, it is fairly deep. In 10 percent of the area, and on the border area along the Ravi River, development has been retarded on account of security considerations.

Opportunities for Water Development

Water development potentials for agriculture in the Siwalik Zone are limited to groundwater. There are several important nullahs Deg, Aik, Palkhu, and Bhimber -- which traverse the Siwalik Zone and cause flood damage. It is also occasionally possible for a few farmers to lift water by pump from nullah flows. The proposals set forth herein are therefore limited to groundwater developments, and even these are fairly limited in scope, because of the high rainfall of the area and the already demonstrated willingness of farmers to develop groundwater by private means. Development has, however, progressed to the point that future development must accommodate the poorer farmers, whose holdings are small, and must account for areas in which aquifer development conditions are difficult and costly.

Riverain Areas

Along the Ravi River, development is taking place on lands previously classified as unused because of periodic inundation. Here private tubewells are already operating, with removable pumping units. PLUA recently initiated a small project to assist in the process of bringing land into production. This project should be strengthened and speeded up. Part of the project lands lying in the channel of the Ravi River should also be developed, now that floods have subsided as a result of water diversion in India. The closeness to the border and consequent special security arrangements needed may prevent establishment of any large processing facilities that require all-weather paved roads.

Groundwater Development

To assist in exploitation of groundwater on the approximately 5,000 acres of cultivable land not now irrigated because of excessively deep groundwater covered by a layer of hard rock, a project to support development by the use of tubewells with turbine pumps is suggested. Each one-cfs well could be conservatively expected to irrigate 100 acres of cropped agriculture under localized patterns of rainfall. Because of the specialized nature of the problem and the need for technical expertise and equipment, this project will require adequate funding and careful attention to details of organization and implementation and it is recommended for early investigation. Exhibit VI-19 shows the groundwater potentials of the Siwalik Zone.

The Jhelum and Chenab Riverain Lands

Monies for traditional riverain development along the Jhelum River, from Mangla to the Rasul Barrage, are included in the Riverain Zone costing. The Chenab riverain lands that border the Siwalik Zone extend from Marala Weir nearly to Wazirabad Bridge. At present these lands are exploited as an integral part of the Sialkot and Gujrat areas. This area is part of the lands that have been proposed for special investigations.

Costs

The costs of implementation of the project are similar to those proposed for the riverain areas along the Indus, Jhelum, and Chenab rivers. They are shown in Table VI-26.

Recommendations

Owing to the momentum already built up through private efforts to bring riverain land along the Ravi River into production, this component of an overall riverain development effort should be undertaken early during the five-year Action Plan. Parallel to this effort, there should be investigations of groundwater potentials in those areas in which resources are underexploited.

A private entrepreneur operation, if launched for any of the riverain areas. should be extended across the entire zone to serve pockets of land now without water.

CHAPTER SEVEN

THE EFFECT OF IRRIGATION ON AGRICULTURE[1]

INTRODUCTION

Irrigation affects agriculture in direct proportion to the available moisture from rainfall. When rainfall produces valuable crops, irrigation provides smaller net returns over and above existing production. Thus, the benefits of investment in irrigation must be considered in relation to the benefits of improving rainfed agriculture.

In drier zones of the barani tract, there is no alternative to irrigation in a drive to improve agricultural production. As the rainfall dips below 10 inches per year, agriculture turns marginal and depends upon special circumstances, as in the valleys between sand dunes in the Thal, used to "harvest" available moisture.

But in the wetter zones, investment tradeoffs must be made between improved rainfed agriculture, and irrigation. Since the Potwar has the potential for both, it serves as the model to be used in analyzing productive capacity and economic returns.

ANTICIPATING THE FUTURE OF BARANI AGRICULTURE IN THE POTWAR

The barani agricultural system in the Potwar is wheat dominated. Arguments have been presented, as in the original Barani Commission Report, that, since the rabi growing season for wheat misses the heaviest monsoons, an alternative cropping solution would make better use of the rainfall. In the barani areas, the kharif rainfall, although heavier, comes in heavy downpours that run off and is combined with higher temperature. The rabi rainfall, in contrast, comes in gentle showers, which are more effective at a cooler time of the year. In the higher rainfall areas, where a kharif crop is possible, its harvest coincides and interferes with planting of the rabi crop. Furthermore, the problem of weeds is much greater in the kharif. Given these technical impediments to kharif cropping, combined with the fact that wheat is the staple food and provides an adequate yield in most years from the rabi rains and the residual moisture and that the preferred kharif cereal substitute--maize requires a high rainfall, the farmer's practices are easier to understand.

Wheat began as a subsistence crop, but grows to have commercial value 35 fertilizer increases yields above family requirements. Yields have risen steadily within the barani tract since 1975, and field investigations reveal the increasing use of fertilizer combined with improved seed varieties in the medium and higher rainfall areas. The cultural techniques for high-yielding wheat are known. It is a crop that has great potential for doubling of production and returns movebaranjo farment with s percent of Punjab's production in 1986, the Potwar could move to 10 percent within the next 15 years, even if yields continue to increase in the irrigated areas.

No other agricultural option for the Potwar can be pursued with the same confidence other that of a concentrated public sector program that supports and mobilizes farm enterprises to achieve production gains from the commercialization of wheat production in the Potwar. Although not all of the technology for maximizing product production hand, there is sufficient existing knowledge to begin today to match what is known with the resources and farm inputs, and concurrently to develop research that adapts and fine tunes the production system to the special farming environments contained within the Potwar. Barani and irrigated wheat production should be a prime thrust of the 20-year agricultural development plan in the Potwar.

Deciding that wheat will be the principal crop in the Potwar allows the government to intervene with economies of scale. Research, mechanization, tillage, extension, harvest, storage, and transportation can all be developed to create a major shift in production and cropping efficiency. Mechanized tillage and harvest are important answers to labor constraints at critical periods of the production cycle. The low-cost method is for the machines to work a large, contiguous area, ending the lengthy drives from one small plot to another. Such consolidation in mechanized land preparation, planting fertilizer, and harvesting may happen naturally over three generations. A special project devoted to hastening the process should see demonstrable changes within five years.

But wheat cannot be the sole thrust of an agricultural development plan. A wheat production program, organized as a one-crop campaign, will fail to deliver the full potential of the agricultural system. Wheat follows or precedes a second crop, or fallow, depending upon the rainfall available. At the same time that adaptive research customizes wheat production to particular areas, the other crops must be improved. Wheat is interplanted, on many Potwar farms, with mustard to provide winter feed for animals in a low-output livestock system. The intercropped fodder and the fallow rotation is necessary to sustain the animals at current herd sizes. But the animal production systems are as far from optimum as is the wheat production system. And they are directly interrelated. Both agricultural and livestock components of the farm enterprise must be secured by a ratchet upward, together, away from subsistence farming toward high technology production.

The solution is a farming systems approach to agricultural development in the Potwar that accepts wheat as the dominant rabi crop, where it makes agronomic and economic sense; deals with increasing returns from the second cycle kharif crops when they can be grown; and makes livestock an important cash component of each farm enterprise. Both farming decisions and investment of resources, land, and labor will be managed by the farm enterprises. A suitable environment for large-scale production increases must be created. By a judicious program of information, organization, subsidy, and resource provision, a project can focus attention and resources on specific areas; mobilize the farming population; and, by so doing. collapse the timetable to introduce change. An area development project can maintain an equitable distribution of wealth by deliberating seeking solutions that incorporate smallholdings, while bringing high technology and commercialization to the Potwar.

Projecting the Next 20 Years of Rainfed Agriculture

The policy issue is the level of commitment of public funds to develop the natural resource base in the Potwar. Analysis earlier in this chapter has shown a resource base with far greater potential than its existing use that can be far more fully utilized if support is rendered and constraints overcome. The faster the Potwar moves toward commercialization of agriculture, to the integration of a farming system that exploits the opportunities without degrading the environment, the more public funds must be used. Insofar as public funds are intended to leverage private investment, correct specification of the fulcrum is critical to success.

The following large structural movements are needed to make optimum use of the natural resource base:

- Continue with wheat as the dominant rabi crop for barani lands; double yields in low rainfall areas to 2,000 kilograms per hectare, and triple yields to 3,500 kilograms per hectare in medium and high rainfall areas;
- Commercialize the kharif season crop with increased yields and crop selection that responds to market price changes, for example, oil seeds, maize, and pulses;
- Reduce fallow periods by increasing fodder production, using fertilizer, and controlling moisture better;
- Commercialize livestock production. Eliminate bullocks from the animal herds by using tractor power for tillage and farm transportation. Triple milk production from locally maintained buffalo by orienting smallholder production toward local selling or exchange of milk for other farm produce. Integrate animal production from barani farms with fodder production under irrigation. Produce goats and sheep for wool and meat under conditions of adequate nutrition for optimum growth and reproduction. treatment and prevention and improve breeding stock; and Improve disease
- Develop privatized rangelands to increase the carrying capacity of the land. Utilize farm forestry and range improvements, watershed development, and catchment basin regeneration when animal management makes these attractive investments for public subsidy.

These changes, taken across the 1.6 million acres of barani land in the Potwar (after all irrigation is completed), will provide significant production, yield, and net income returns to barani farm units operating in rainfed conditions. An analysis of the potential returns to cropped agriculture is presented below, showing that a farm of 6.5 acres, operating in medium rainfall area with a "before" and "after" farm budget. The analysis includes only cropped agriculture, omitting the important variables of the use of fodder for milk and meat production, a subject detailed in the feasibility study for the Potwar Integrated Agricultural Development Project. For purposes of comparison, Tables VII-1 to VII-8 present the basic assumptions for the estimates and show farm income levels before a project (Table VII-2) and estimated income levels after the introduction of a farming systems improvement project (Table VII-7). Exhibit VII-3 (shown later in the text) depicts the estimated increase in farm incomes from a cropping systems improvement project in the Potwar. In a subsequent section, the returns to irrigation in Potwar are considered.

Conclusion of the Cropping Systems Analysis in Rainfed Agriculture in the Potwar

A six-fold increase in income from cropped agriculture is possible from interventions into the rainfed agriculture production system. are still less than Rs 7,000 per year for a 6.5-acre farm. But the total returns potential to move the total income from the farm unit far particularly as it moves the cropping intensity from 86 percent in production to 150 percent, under irrigated conditions. Irrigation has the beyond this level, rainfed agricultural

Anticipating the Future of Irrigation in the Potwar

The analysis of the potential for water resources development (Chapter Six) provided two recommendations that would lead to the development of 150,000 or 400,00 acres of the best lands in the Potwar. Full irrigation could increase cropping intensity to 150 percent, 90 percent in kharif and 60 percent in rabi, with important gains in predictability of crop yields. Lowering the risk of production greatly increases the willingness to invest in long-term improvements and commit resources to farm management. Irrigation of the full amount of 400,000 acres would bring a gradually shifting crop mix, as higher value crops might be substituted for wheat, currently grown on more than 50 percent of the land under irrigation in the Potwar. The irrigated areas. can produce quality livestock through integrating fodder production and animal systems, small grains for the expanding poultry industry in the Potwar, cash crops such as maize and pulses, and high value fruit and vegetable crops.

For the 400,000 acres that could eventually be irrigated in the Potwar under the high investment options (perhaps exceeding the time period of the 20-year Master Plan), cropping patterns have been estimated with production, yields, and returns to average holding farms. Without developing either expanded irrigation or improved rainfed practices, no significant increase in cropped area is expected and the yields of the existing crops are expected to increase by 1 percent per annum. Assuming irrigation of 400,000 acres of Potwar lands during the life of the Master Plan, major increases in agricultural production and farm income will result if all agricultural services are directed at obtaining the same level of agricultural intensity from irrigated agriculture as from a special project to promote rainfed agriculture.

With irrigation available, the cropping pattern and cropping intensities will change. The ultimate rabi cropping pattern proposed has been set at 88 percent and the kharif cropping pattern set at 62 percent, with 20 years allocated to reach the new patterns and intensities. Table VII-11 provides an estimate of the rabi cropping intensities over the next 20 years.

A similar analysis conducted with kharif season crops with new intensities estimated at 62 percent provided the new total increment to production from irrigation across 470,000 acres (400,000 irrigated). The increase in cropping intensity, and an assumption of higher yields under irrigation, provided the table of gross and net benefits (Table VII-12).

Relating the Benefits to the Costs of Project Support

What can be accomplished within proven technology and the existing resource base seems clear. Irrigation, when it increases cropping intensity by more than 40 percent, combined with a special project designed to obtain maximum yields, delivers farm income between three and five times that of rainfed agriculture. This is why irrigated agriculture is a full-time occupation in the Punjab, while barani agricultural production provides only partial family income. After a sufficient period to ensure that maximum yields gains can be adopted by all farm units (calculated at 20 years), the Rs 4,800 million investment in the Potwar linked canal and groundwater irrigation systems, and the Potwar Integrated Agricultural Development Project (since major support to obtaining production increases would still be necessary under irrigated conditions) would return approximately Rs 1,600 million per year in increased incremental production. Each 6.5-acre farm has a potential net income of Rs 27,000, nearly four times the "after project" return from cropped rainfed agriculture.

Such figures are based upon many easily questionable assumptions, and are not intended to be either projections or predictions. The only safe conclusion from the analysis is that, when irrigation can be developed at reasonable cost, even in wetter barani zones such as the Potwar, irrigation can pay high dividends and cover the cost of installation, if the resource base is used to full capacity. If the base is not used to capacity, irrigation over the full plateau will suffer a similar fate of prior Small Dams schemes, expensive water not used efficiently in the service of high-value agricultural production. Other irrigation initiatives bear out this conclusion; the internal rate of return on small irrigation structures proposed for inclusion in the Potwar Integrated Agricultural Development Project was calculated at a conservative 19 percent, providing benefits from isolated small irrigation structures such as minidams and lift pumps on a few acres of cropland.

How to accomplish the needed production shifts and obtain the optimum allowable production is less certain under either rainfed or irrigated agriculture. Since the micro-environments of the Potwar do not allow general cropping recommendations or supporting services solutions, the answers must be obtained locally. Determining locally the answers to critical constraints to increasing production takes field workers with vision, resources, and management direction. There is an indivisible minimum concentration in any one area of research, extension, supporting services, organizational efforts, and subsidies that deliver the required changes in farm unit behavior. The policy issue is how fast to multiply these subproject concentrations, how quickly to bring each area of the Potwar into commercial production.

There are good opportunities to develop rainfed agriculture. This approach is cheaper than building irrigation structures and can return high dividends. This type of project also mobilizes all available extension and resource personnel in support of production gains. If or when irrigation is made available from large-scale developments, the extension services, credit sources, marketing linkages, and research organizations will, if they have participated in a rainfed integrated development project, be ready to make efficient and effective use of irrigation supplies. The alternatives are not mutually exclusive. First, increase returns from rainfed agriculture where possible, building the capacity of the government to support integrated agricultural services. Second, add irrigation and obtain the heightened benefits from a new resource. This is a strategy that provides for early quick returns and maximum long-run benefits from investments in the agricultural resource base.

CHAPTER EIGHT

PERSPECTIVE FOR WATER RESOURCES DEVELOPMENT

FORMULATION PROCESS

An inventory of water and land resources was made for the entire Barani Master Plan Area. The potentials were examined zone by zone because of diversities their viability was assessed. Identified irrigated agriculture projects were catalogued, and peculiar to each zone. Conservation and small water development dug wells, minidams, and lift irrigation sphere of rainfed agricultural development. such as were not included, since they are in the

Additional conceptions or modes of development of the water resources were proposed. The objective was to overcome present constraints impediments to early exploitation of water resources. or outright The two most radical departures from the present situation are the idea of the mobile tubewell pump for the Riverain Zone and the linking of reservoirs by canals on the Potwar Plateau to implement magnet projects.

New ideas and already proposed projects were merged into programs or projects and expressed in the form of investment schedules. Evaluations were made, zone by zone, to assess the potential of each project to meet the four objectives for development as articulated in the Master Plan. Further evaluations were made in order to judge the technical soundness of the projects.

THE TWENTY-YEAR VIEW

Options in the development of water resources and the associated costs were presented, zone by zone, in Chapter Six. The possible resultant agricultural output was described in Chapter Seven. A summary of the water development options and their 5-year and 20-year investment levels is given in Table VIII-1.

The indicated levels of investment are notional and were developed independently for each zone. The 5-year and 20-year levels will be adjusted subsequently to reflect two possible levels of financing: high and low.

Full development, whether during the 20-year Perspective Plan period or during a longer period, should lead to increases in agricultural production as indicated in the preceding chapter.

Availability of Resources

Review of the budgets and expenditures of the Annual Development Program and of donor programs, both ongoing and in the pipeline, indicate that as much as $50 million per year could be mobilized for development of agriculture in the Punjab barani tract. If half this amount were devoted to development of water-based agricultural projects in the barani, then Rs 160 million would be available annually.

The total resources available would be Rs 800 million for the 5-year Action Plan period and Rs 3,200 million for the 20-year Perspective Plan period.

There is considerable likelihood that this level of investment will not be sustained for long periods. A second view of development potentials was therefore derived for a low rate of investment equal to half the high rate.

DEVELOPMENT OPTIONS BASED ON THE AVAILABLE INVESTMENT

The Case

At the High Investment Level, Rs 800 million will be available during the first five years and Rs 3,200 million during the entire 20 years. This represents a considerable shortfall from the total amount required to carry out the individual zonal programs, which are summarized in Table VIII-1. The investment available would fund a third of the 5-year program and only 55 percent of the 20-year plan as it is now designed. The only scope for significant reductions in public investment required is in the Potwar and D.G. Khan zones. In fact, it will not be possible to complete the Potwar linked canal project if the first year of the Action Plan is to be, say, 1990. Even if a vigorous plateau program were implemented the High-Level Link Canal system could probably not be built until beyond the Perspective Plan period. Also, some substantial percentage of the cultivable lands in the Low-Level Link Canal system will be above command and will thus not be developed by the gravity system.

High-Level Investment Rate

A High-Level Investment program might be as shown in Table VIII-2, financed precisely to cover a 5-year horizon. The continuation through a 20-year time span would allow additional projects to be introduced between the sixth and twentieth years.

Low-Level Investment Rate

The program shown in Table VIII-2 was scaled back on the basis of the assumption that only half the high-level investment monies would be available. Resources would be Rs 80 million per year, or Rs 400 million for 5 years and Rs 1,600 million for 20 years. Only the proposed 5-year program is shown in Table VIII-3, since the 20-year program of Table VIII-2 is almost the same as the resources available. A balance is achieved for the five-year program and availability of funds.

The Five-Year Action Plan includes investment schedules, by project, and will be presented in Chapter 10.

CHAPTER NINE

FIVE-YEAR ACTION PLAN

Investment schedules for the high and low-level investment options are presented in Tables IX-1 and IX-2. The projects are all described in Chapter Six, but for convenience, a brief summary of each is given in this Chapter.

Projects included in the Low-Level Investment Schedule will require mobilization of Rs 400 million (1987 base year) by the public sector and Rs 390 million in the private sector. Equivalent requirements under the High-Level Investment Scenario are Rs 792 million in the public sector and Rs 614 million of private funding.

PROJECTS INCLUDED IN THE FIVE-YEAR INVESTMENT PROGRAM

Twelve projects are proposed for execution in the Low-Level Investment Program costing a total of Rs 365 million of public monies and Rs 35 million in separate investigations and studies. The High-Level Investment Program differs from the Low-Level Program only in that more groundwater development is called for on the Potwar Plateau, additional hill torrent work is proposed for Kaha Hill Torrent, pumplift and reclamation projects are proposed for the Salt Range Zone, and miscellaneous works and more detailed investigations are programmed. recommended for early execution will be described in the following sections. Projects

Chach Plain Groundwater Development

The Chach Plain occupies an area of 280 square miles between the right bank of the Haro and Indus rivers at their junction. The most important city of the area is Attock. Some 40,000 acres of cultivable land is shown in Exhibit VI-3. At present, less than 10 percent of the area is irrigated. The central part of the area around Shamsabad town is waterlogged.

An aquifer with transmissivities of 12,000 to 417,000 gpd/ft and water of good quality extends over 80,000 acres. It is estimated that 40,000 acre-feet (Table VI-7) of pumpage can be developed annually in addition to groundwater already being pumped.

Tests by the WAPDA Groundwater Hydrology Project indicate that tubewells with specific capacities of 24 gpm/ft drawdown can be developed. A one-cfs tubewell would have only about 20 feet of drawdown. The most obvious initial program is therefore to develop about 40 percent of the area. Considering that effective precipitation in the area is estimated to be eight inches during the kharif season and six inches during the rabi season, 30,000 acre-feet of water should serve about 14,000 acres with a 60/90 kharif/rabi cropping intensity.

If private tubewells are to serve the area, there should be one tubewell for approximately 50 acres. If one tubewell serves 50 acres, 280 wells will be required. Since the water table is near or at the land surface in part of the area and at 20 feet in other parts, it was assumed that tubewells would be powered with diesel-driven centrifugal pumps.

Provision is also made for leveling perhaps 25 percent of the land, and watercourses will be built with permanent checks, drops, crossings, and outlets. Financing of the tubewells would be private, whereas watercourse construction and land leveling should be financed in part through volunteer labor and some part of the remaining either as direct contribution or as a loan to the farmer. a Government water rates should be established to recover any subsidies as well as the government's share of construction cost.

It is noted that cash outlays will probably not equal the Rs 100 per acre, because farmers will do their own land leveling and watercourse maintenance. Nearly half the estimated O&M and replacement cost is for diesel fuel, oil, and lubricants, and most of the other half is for amortization of investment and replacement costs.

Irrigation System on Link Canal Area Lx

It is recommended that an initial or pilot irrigation project of 10,000 net cultivable acres be planned and implemented as early as possible in the Taxila-Fateh Jang area. It would be served by construction of the first-stage, partial-capacity segment of the Low-Level Link Canal from Taxila Junction to the area shown north of Fateh Jang in Exhibit VI-12.

The gross cultivable area is probably in excess of 20,000 acres. It is assumed, however, that because of frequent slope reversals and rapid topographic changes, it may be possible to command by gravity flow considerably less than the gross area. The project is proposed, as shown in Table IX-3, at an estimated capital cost of Rs 165 million for canals, watercourses, and on-farm development. A detailed mapping program of topography and soils, which may require as much Rs 7 million, must be carried out. A substantial provision has also been made for design, layout, and preparation of contract documents.

Execution of this project will demonstrate how large-scale development of the lands along the link systems can most readily and economically be accomplished. This program should be started as soon as possible. Khanpur water is there, not being used. Operation and maintenance of the system may cost the Irrigation Department 0.75 percent of construction cost plus 0.25 percent office and transport support, for a total of 1 percent, or Rs 600,000 per year. It is assumed that once in place the watercourse systems would be maintained by the landowners.

Riverine Zone

It is proposed that tubewell water and access roads be provided to five parcels of riverain land totaling 175,000 acres. The projects would be developed around the mobile pump system proposed in Chapter Four and costed in the Riverain Area section of Chapter Six. The approach is to have farmers put in tubewell bores, screen, and casings. They then would pay a water charge approximating Rs 19 per acre-inch pumped (Table VI-19) to a private entrepreneur, who would pump water at weekly or other agreed-upon intervals.

The advantages of the system for the farmer are the low cost of Rs 140 per acre-foot pumped, a low investment cost to the farmer, and maintenance of the farmer's independence, since a cooperating group is not required. The government will benefit, because the development should be financed largely through private resources. The government will build access roads into the area and assist with land leveling. Also, the government will support low-cost financing during the first three to five years of development and put a strong advisory and assistance team, such as the On-Farm Water Management Project, onto the project to guide land leveling and watercourse development. A small cost for establishing such initiation is included in the overall costs of the project. A provision of Rs 20 million is made to support land-leveling operations and watercourse work, which have traditionally been accomplished by farmers of the riverain area.

The program is scheduled to give early development attention to all corners of the barani area D.G. Khan, Thal, the Salt Range, and Siwalik. Costs by area are shown in Table IX-1. Average operation, maintenance, and replacement costs of the tubewells are estimated to be 33 percent of investment costs. For details see Chapter Six.

Mithawan Hill Torrent

Very large nonperennial streams (hill torrents) exit through gaps (darrahs) in the eastern ridge of the Sulaiman Mountains onto the sloping piedmont plain of Dera Ghazi Khan. Traditionally intense, short-duration floods have been diverted downstream from darrahs by systems of temporary earth-channel closures into dike areas (laths). Ponded water in the laths percolates into the ground, and crops are grown on the residual moisture in the soil.

The streams have changed channels, have eroded deeply, and can no longer be diverted into the laths. The torrents now pass water directly downstream into settled areas of the D.G. Khan Canal Command. Structures are destroyed and agriculture is disrupted.

A primary objective of the government is to reestablish flood-based agriculture in the piedmont area and, consequently, to reduce or eliminate downstream flood damage. The Irrigation Department has developed gabion dam structures (weirs), which are relatively low in cost and can withstand the ravages of the intense, sediment-laden floods of the hill torrents.

Only a few structures have been built so far. Local effects on agriculture and their performance have been more than satisfactory. It is now proposed that a project to control the flow of an entire hill torrent be implemented. The Mithawan Hill Torrent has been studied, modeled, and selected for early implementation. The project consists of extensive bund systems, two distributors (gabion weirs), and an escape structure. The cost of construction is estimated to be Rs 78 million at 1987 costs.

This is a high-priority project that will not only increase agricultural benefits substantially, but, even more important, will reduce flood breaching of the Dajal and D.G. Khan canals. NESPAK consultants who prepared a feasibility study for Mithawan estimated an EIRR of 17 percent for the project.

Costs of operation and maintenance should be higher for these structures than is traditionally required for monolithic structures. An appropriate allowance is probably 2 percent of construction cost; Mithawan costs would thus be about Rs 1.5 million per year.

Perennial Areas of Hill Torrent

Approximate 18,000 acres of land lying along three of the hill torrents--Sarnhar, Vehowa, and Kaha are irrigated by the only perennial, or year-round. flows of the D.G. Khan hill torrents.

The low-flow stream, rabi water supply, is conveyed through fairly lengthy channels from high up on the piedmont to the cultivable area. There are two water-related opportunities to increase intensity of cultivation and to extend the area of irrigation. The first is to improve diversion channels from the takeoff point to the cultivated land. These channels can be increased in capacity to divert more kharif-season flood flows. At the same time, it is anticipated that a concrete or brick-lined cunette in the bottom of the channels will save nonbeneficial losses during the rabi season. The saving may be 20 percent, or 16 cfs, of rabi-season flow.

The second opportunity for water saving exists within the perennial command Here there is opportunity to implement typical on-farm water management area. practices. It was estimated that 7 percent, or eight cfs, could be saved.

Yields on farms would increase as a result of improved water delivery. Increases in acreage for high-intensity cultivation could be 1,600 acres in the rabi season and 22,000 acres in the kharif season. The total cost of the channel and on-farm works would be Rs 27 million, Rs 1.5 million of which might be repayable by landowners. On the basis of studies in adjacent areas, the estimated IRR for the project could be as high as 26 percent.

Costs of operation and maintenance should be about 1 percent for the channels, or Rs 0.15 million, and the farmers should in general care for on-farm works.

Makhrach Springs

Two springs issue from aquifers of the Salt Range and flow across piedmont lands near Makhrach in Tehsil Pind Dadan Khan. The water is not fully fit for use, since it dissolves salts as it flows overland. It is proposed that 3,200 feet of mild steel pipe be placed and 1,100 feet of channel be constructed to carry the flow of 2 cfs, salt free, to 1,400 acres of cultivable land. facilitate diversion at the source. Small weirs would be built to facilitate diversion at the source.

A PC-I was prepared earlier for the project and was updated in 1988. In it the Irrigation department reports an estimated B:C ratio of 4.97:1. The cost of implementation may be Rs.250,000 annually, if the Irrigation Department has to shoulder the entire burden. It is assumed, however, since local is so great, that operation and maintenance costs to the Irrigation Department - mostly for structural repairs - would be quite low.

Ravi Riverain Groundwater Development

This 20,000-acre riverain project differs from those proposed earlier in the following ways: rainfall is quite high and only occasional irrigation is required, much of the land is now unused river channels, the Punjab Land Utilization Authority (PLUA) is active in part of the area, and access to much of the area is restricted because of security conditions along the international border.

Along the Ravi River, development is taking place on lands that have been Here private tubewells are already operating, unused because of periodic inundation. Development of a total project would generally with removable pumping units. require minimal organization, management, and subsidy to establish viable agriculture. The closeness to the border and special security arrangements preclude establishment of processing facilities in the area. military may be built. Also, only roads of a type acceptable to the

Even with these impediments, good water and soil conditions may make this a suitable area in which to initiate production of essential oils for extraction outside the border zone or to produce other crops with international markets.

Critical to the success of the project is an organization that can unite the various components and make them function successfully, harnessing the energy and efficiency of the private sector to the services and credit facilities of the government. Land-reclamation projects of a similar nature have been undertaken successfully by PLUA, which has promoted development of both small diesel-driven tubewells and electrically driven tubewells. Such an organization, with flexible funding and charter, is needed to organize the Ravi Riverain Groundwater Development.

Success will be difficult to achieve for the project if roads are not constructed to tie farming units together and provide access for the inputs and outputs necessary to commercial farming and for transport of mobile pumps.

Total costs of the project are Rs 56 million, of which Rs 18 million is public funds, as shown in Table IX-1. A modest component of cost is needed to establish project personnel for an oversight agency, funding for a mobile tubewell pumping system, roads and costs for watercourses, and on-farm work. In addition, a small credit facility will need to be established.

Costs of operation, maintenance, and replacement for the water-pumping operations are included in water charges, which approximate Rs 140 per acre-foot. Maintenance of roads should be outside project financing, even though it would be wise to include their construction costs in the project budget. There will also be an annual cost associated with operations of the coordinating organization for the three to five years required to ensure start-up of the project.

Investigations and Studies

It will be noted in the investment schedules that funds are allocated in the early years of projects to investigations, designs, and studies. These are considered to be a normal part of the cost of the project. There is, however, another class of monies that are specifically and totally allocated to investigations and studies, as shown in Table IX-1. Four such programs are proposed, at a total cost of Rs 35 million. They are for the following:

- An initial study of a Link Canal and Reservoir system of the Potwar Plateau (Rs 10 million);
- Groundwater investigations north of Sialkot (Rs 5 million);
- A study of alternative methods of irrigating the Jalalpur area from the Soan River via the Jinnah Barrage and Mohajir Branch Canal and determination whether areas with poor soils should be excluded from the project (Rs 10 million); and
- A study of a pilot project whereby flood water will be carried along the Chashma-Jhelum Link Canal for impoundment in a Thal desert reservoir for irrigation. A well-instrumented monitoring system to record build-up and migration of groundwater will be an important component of the project (Rs 10 million).

As shown in the schedule of Table IX-2 better-financed studies and investigations are proposed for these same projects. The higher level of funding will permit more fieldwork, including drilling, mapping, and soil surveys.

ADDITIONAL PROJECTS INCLUDED IN THE HIGH-LEVEL INVESTMENT SCHEDULE

Kaha Hill Torrent

Scheduled in Table IX-2 is that portion of the Kaha Hill Torrent project which is located in Punjab Province. The Kaha has the largest drainage area of any of the 13 main hill torrents. Its drainage extends back into the valleys of Baluchistan, between ridges of the Sulaiman Mountains. Its flood waters are quite destructive in the D.G. Khan Canal Command.

The rationale for early government intervention is quite similar to that discussed for the Mithawan Hill Torrent. There are two sets of measures proposed for management and reduction of flow: in the catchment between the mountain ridges of Baluchistan, and a set of structures across the stream channels on the piedmont (Exhibit VI-11). Total costs of the two main gabion dams and some watershed work in Punjab will be Rs 78 million.

As with the proposed Mithawan structures, costs of operation and maintenance may amount to 2 percent of construction costs, or Rs 1.5 million.

Immediate Hill Torrent Work

Small local measures, such as bunds near towns and minor channel works, are proposed for early construction on several of the hill torrents. of these works are Rs 54 million. Total estimated costs

Reviving Pind Dadan Khan Canal

The Pind Dadan Khan Canal has been abandoned because of construction of the Mangla Dam, and the area is no longer cultivated. To restore the irrigation water supply and bring the area under cultivation, 15 cfs of water will be lifted from downstream of the Rasu Headworks into an existing channel about 9.5 miles long. This channel will be lined to save water losses and to maximize the use of water for irrigation purposes. About 2,200 acres of land around villages of Jaitepur, Fatehabad, Adwal Kot Pior, Harranpur, Kot Phapra, Usman, Daffar, Quammar, Naiji, and Pind Dadan Khan will be irrigated.

The projected cropping intensity will be 135 percent and the sowing of high-value crops will be encouraged. Surveys have been made and a study is being revised. Revised cost estimates were unavailable, but the required investment has been estimated to be Rs 10 million.

Costs of operation and maintenance will be about 1 percent for all works except the pumps. These costs were not available, but they will be largely dependent on the costs of electricity for pumping and the cost of maintenance of the pumps.

LAND PROTECTION, GHARIBWAL

The objective of the project is drainage of saline water from the Salt Range in the Gharibwal area Tehsil Pind Dadan Khan to protect the land from salinity and bring it under cultivation. During the rainy season saline water coming from the Salt Range spreads over the area and affects the productivity of the soil. Drainage of saline flows into the Jhelum River will protect the lands and increase agricultural production. A survey has been undertaken, and cost estimates have been prepared by the Small Dams Organization of the Irrigation Department.

It is estimated that required works will cost Rs 10 million. Costs of operation and maintenance will amount to about 1 percent of construction costs

GROUNDWATER DEVELOPMENT, POTWAR PLATEAU

With the high level of investment available it is proposed that additional tubewell projects with potential for high early returns be carried out. These tubewells will be somewhat more costly to construct that will the wells in the Chach Plain. Also, they will pump against a higher head and consequently cost more to operate.

The developments are:

- Hasan Abdal 10,000 acre-feet of waters and 5,000 acres;
- Near Pindi Gheb 13,000 acre-feet of water and 6,000 acres;
- Left Bank, Scan River 30,000 acre-feet of water and 14,000 acres; and
- Guhan Khan (Kanshi Ridge) 10,000 acre-feet of water and 5,000 acres.

It is proposed that tubewells with turban pumps be installed, the government to assist with construction and to subsidize perhaps half the cost. The total cost of developing these well fields will be about Rs 40 million. Watercourse and on-farm work is provided at an estimated cost of Rs 10,000 per acre, 25 percent of which will accrue to the public sector.