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NEPAL

Status of the national small hydropower program and recommendations for assistance

NRECA Small Decentralized Hydropower (SDH) Program

Nepal: Status of the national small hydropower program and recommendations for assistance

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Small decentralized hydropower program

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EXECUTIVE SUMMARY

Even though Kathmandu and several of the larger urban areas of Nepal are served by the national grid, most of the population is dispersed and resides in areas which will not be served by the grid for years to come. Nepal does, however, have a significant small-hydropower potential which can be harnessed to serve district headquarters, market centers, training institutions, and other loads in the remote areas and contribute to the development of these areas.

The Small Hydel Development Board (SHDB), established under the Ministry of Water Resources, has been charged with the responsibility of meeting the needs for power in these rural centers. It is already operating several hydropower plants that it has implemented and is currently implementing on the order of 20 more plants, ranging in size from about 50-1000 kW. In the process, it has encountered a number of difficulties which have led to schemes which are increasingly costly to implement, with little chance for recouping the investment or even covering their recurring costs. At the request of the SHDB, the National Rural Electric Cooperative Association (NRECA) provided assistance through its Cooperative Agreement with the Energy Office of the USAID Bureau for Science and Technology (S&T/EY). The NRECA Small Decentralized Hydropower (SDH) Program sent a four-man team to review the obstacles to a more viable small hydropower program and to propose means of addressing these.

This report outlines some of the basic issues facing the SHDB: the high cost of implementing small hydropower schemes, the low load factor and the lack of promotion of income-generating activities, the need for gathering and processing appropriate hydrologic data, the lack of coordination among relevant organizations, and the need to analyze the institutional and organizational structure of the implementing agency. This report also includes, in the appendix, an analysis of the hydrologic data available in Nepal and a derivation of formulas for minimum and flood flows.

Although there is a range of options which might be pursued, from short-term efforts in specific areas of need to a long-term effort on a broad front, resources available through the Cooperative Agreement compel the use of an intermediate approach which may, in the end, be the most effective. In this report, the team recommends that an effort for developing appropriate technical designs and approaches to implementation, operation, and management be based around one or more demonstration projects which may be among those being proposed by USAID/Kathmandu as part of its Resource Conservation and Utilization Project. A local engineering firm, such as Himal Hydro, which has considerable experience in implementing small-hydropower projects in Nepal would, with the SHDB, the USAID Mission, and NRECA, develop designs and approaches on a turnkey basis. These would address the current obstacles to a viable small-hydropower program in Nepal and would be replicable elsewhere in the country and have relevance in other developing nations. As part of a training effort, several engineers from the SHDB would be assigned to Himal Hydro for the duration of the project. If this proposal is adopted, NRECA recommends that a small team, composed of individuals with small-hydropower experience in Nepal, return for a 1-3 man-month effort to design an approach to achieve the objectives of development and training and to prepare an agreement acceptable to all parties so that funding can be committed and the effort initiated.

CONTENTS

Executive summary, iii

Background, 1

Summary of findings and recommendations, 5
- Civil works, 5
- Hydrology, 7
- Income-generating activities, 10
- Institutional and organizational issues, 12
- General issues, 15

Options for assistance, 17

Recommendations for development and training assistance, 23

Appendices,
- Appendix A: List of small hydropower schemes in Nepal, 25
- Appendix B: Summary of the hydrologic and meteorologic situation in Nepal, 27
- Appendix C: Preliminary analysis of hydrologic data, 34
- Appendix D: Possible short-term assistance efforts, 42

BACKGROUND

> If you give a man a fish, he will have single meal.
> If you teach him how to fish, he will eat all his life.
>
> Kuan-Tzu, Chinese philosopher

Nepal is largely a mountainous nation with a significant portion of its population living in small settlements in remote areas not accessible from its very limited network of roads. These people have restricted access to government services, a limited market for their goods, few of the amenities available to those who have moved to the towns, and no possibility of benefitting from electric power from the national grid for years to come. Their situation is exacerbated by the need to farm increasingly marginal lands in order both to feed a growing population and to generate some income to cover the cost of goods they require and by the dwindling supply of fuelwood required to heat their homes and cook their food.

However, Nepal does have the option of exploiting its large indigenous hydropower resource estimated at 20,000 MW. A large percentage of this potential can be harnessed only by large hydropower schemes, but this will not be available to most of the population. Because of a low initial demand for electrical power in these areas and a limited ability of its inhabitants to pay, extension of transmission lines will prove uneconomical for at least several decades to come. Energy from large schemes will, therefore, only be accessible to more densely populated centers. In addition, exploiting these resources is costly, with little evidence of economies of scale. Costs for 14, 30, and 66 MW schemes at Devighat, Kulekhani II, and Marsyangdi, respectively, have recently been set at $4000, $2000, and $5000 per kilowatt. It is also being recognized by international institutions that implementing these large schemes poses an increasingly difficult burden on the country, regardless of the foreign exchange they may generate by the sale of electric energy to neighboring countries.

But a small, yet very significant, portion of this potential is found scattered throughout the remoter areas of the country where a majority of the population live. Nepal has been aware of this potential for generations and at least 20,000 traditional small water-powered mills can be found scattered over the countryside.

In addition, hundreds of modern, locally-fabricated turbines with capacities up to about 15 kW continue to be successfully installed and operated by rural entrepreneurs to drive agro-processing machinery throughout the country. An increasing number of these very profitable mills, costing on the order of $1000/kW are now generating electric power for nearby residences and shops.

The success of the modern small hydropower mill programs has been a result of two factors. First, these installations are part of a well-conceived and planned approach which stressed meeting existing needs for power in rural areas (mechanical power, often replacing diesel power, to drive agro-processing machinery already found throughout the hill and mountain regions of Nepal), maximizing use of local resources (using locally fabricated turbines, tapping the irrigation experience of the local population, and developing simple designs), and relying on the private sector to build the equipment and supervise implementation

of these small hydropower schemes on the one hand and to manage, operate, and maintain them on the other.

The second factor which was significant to their success has been the recognition that a significant commitment of time and resources was necessary to achieve this impact. The initial efforts for the first mill projects began 10 years ago in the mid-70s and these efforts had their basis in development assistance initated in the 1960s.

The modern, small-hydropower mills which have evolved from this effort are an example of an appropriate technology in the broader sense of this term. Not only is the technology contagious, with the implementation of mills moving at an increasing rate, but it is reproducible, with a growing number of small workshops in bazaars and towns beginning to fabricate their own turbines and associated hardware to meet the growing demand. But now there is a new need, that of effectively harnessing small hydropower resources with larger plants, primarily to generate electric power to serve larger rural load centers.

Aware of this need, the Small Hydel Development Board (SHDB) was established under the Ministry of Water Resources of the Government of Nepal to select, implement, operate, and maintain small hydropower projects with capacities up to 1,000 kW to initially meet the power requirements of district headquarters, and the more important markets and tourist centers in the hill and mountain areas. It is currently involved in about 30 projects (Appendix A).

Funds for the implementation of these projects have come from a variety of sources: the UN Capital Development Fund (5 sites), the OPEC Fund for International Development and government resources (3 sites), the Asian Development Bank (6 sites), the Swiss Association for Technical Assistance (1 site), the Austrian and Yugoslavian governments (1 site each), and the Government of Nepal financing for the balance. But whereas financing for the implementation of small hydropower schemes has been readily forthcoming, the overall effort of assisting with the promotion of small hydropower in Nepal by overseas donors has generally been short-sighted. There has been little concomitant interest in developing the indigenous manpower resources and institution necessary to effectively implement all these schemes. Forced to go outside their organization to subcontract most phases of the work, the SHDB's costs are high, delays significant, and designs not well developed. Furthermore, rather than building up a central body of expertise, the numerous parties who have been involved to date have had little opportunity to move up the learning curve, to learn from past experience in order to improve future designs. In areas which are more directly under their purview, such as plant operation and maintenance or streamgauging, the SHDB has been given little guidance and training on which to build. The SHDB has been charged with the important task of harnessing the nation's small hydropower resources to contribute to the development of the rural areas as well as of the nation as a whole yet few seem to have recognized the need to commit the time and resources necessary to develop its institution and manpower resources.

The new Director of the SHDB, Mr. Atma Shrestha, has been concerned about these issues and their impact on the viability of small hydropower in Nepal. After assuming this office less than two years ago, he proposed that several qualified experts work within the SHDB for several years and, in association with its engineers, build up the capability of the organization in the detailed investigation

of sites and in the preparation of feasibility reports and detailed engineering designs.

In a proposal for consultancy services, the SHDB carefully summarized the overall objectives of the assistance follows:

- to provide guidance on the conception of projects, particularly in regard to site selection and survey, hydrology and the basic layout of new schemes, both on individual schemes and on the formulation of general criteria for this stage of the work;

- to review and assist in the work of SHDB staff carrying out detailed design and tender document preparation; and

- to ensure transfer of knowledge to SHDB personnel (training). It is essential that the engineers who are to provide the assistance have experience in the design and construction of small hydropower projects in developing countries; that they appreciate the social and economic values of the projects and the need for simple and cost effective designs; and that the schemes they formulate relate to the communities they are to serve.

These objectives reflected the broad needs of the SHDB which have, to date, not been effectively addressed. Donors and financial institutions may contract overseas or Nepali firms to underake the necessary design work (with the results to date, not being very encouraging), but they do not address the real need, not for projects but for guidance, assistance, and training to the SHDB to develop its capacity and expertise. They have given this institution "fish," and increasingly expenses ones at that, rather than teaching it how to fish.

Having found little interest among donors and financial institutions to address its needs, the SHDB sent, in January 1983, a request via the Ministry of Finance for NRECA technical assistance. The objectives of this assistance were stated as the following:

- preparing an inventory of potential small hydel projects, and

- upgrading SHDB's capacity to design small hydel projects which maximize use of local resources.

The following activities were suggested in order to achieve these objectives:

- a study of Nepal's power development plan to identify areas which cannot be economically served by the national grid;

- a detailed study of all isolated areas which could be served by small hydel plants, including site identification;

- criteria for prioritizing potential sites;

- preparing a basic set of engineering designs appropriate to Nepali conditions;

- assessing SHDB's long-term manpower and training requirements for planning, investigation, design, construction, and operation and maintenance of small hydel schemes; and

- local in-service and overseas training for SHDB engineers.

Though the financial resources available from USAID S&T/EY through NRECA's Small Decentralized Hydropower (SDH) Program are insufficient to undertake such a broad range of activities, NRECA felt that it might be able to have a catalytic effect by undertaking an initial assistance effort which could lead to tapping other funding sources for the additional assistance required. In July 1983, NRECA sent a two-man team to briefly review the needs of the SHDB in order to determine in which areas NRECA should concentrate its effort.

As a result of that visit, it was decided that an initial visit by specialists in the areas of concern—civil design, hydrology, end-use, and organization—be sent to probe the specific needs in greater depth as well as to review the broader issues. This team spent approximately two weeks in Nepal in mid-Febrary 1984. This report first summarizes the team findings and associated recommendations in each of these areas of concern. It then reviews several options for providing technical assistance, recommends one which is described in greater detail, and then lays out recommendations for the next steps toward finalizing an agreement for a plan for technical assistance to the SHDB.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

There are basically four areas of concern to the SHDB:

- civil designs and approaches to implementating small hydro plants to increase their appropriateness, decrease their cost, and shorten the period between project conception and operation;
- hydrologic techniques to make better predictions of flow patterns in small ungauged basins;
- approaches for increasing the financial return from small hydro schemes by active productive end-use promotion; and
- institutional and organizational changes necessary to effectively address the task of implementing more viable small hydropower schemes.

The team's findings in each of these areas will be summarized below. In addition, some broader issues were uncovered which had an impact on the performance of the SHDB and also have to be considered in the preparation of plans for future assistance. These will also be summarized below.

Civil works

In attempting to evaluate SHDB experience to date in order to find approaches and designs for reducing costs of small hydropower schemes, two obstacles were encountered. The first was that any cost data was difficult to obtain and that the reliability of the available data was generally unclear. Any analyses of cost were, therefore, rendered difficult, if not impossible. Secondly, because of the remoteness of most SHDB sites, only two sites relatively close to the main road, Dhading and Syangja, were visited. Both were designed by the SHDB and local firms and there, therefore, did not permit evaluation of designs prepared by overseas consultants.

A major concern to the SHDB is the high capital costs associated with implementing small hydropower plants. These costs can be found in Appendix A. Several factors seem to be responsible for these costs:

- Remoteness of sites. Since many sites are located in remote areas, construction materials such as cement, re-bar, penstock pipe, and turbo-generating equipment have to be flown and/or carried by porters significant distances. Consequently, transportation costs can account for as much as 15%-20% of the total project cost. This points to the need to try to reduce the transportation component of civil costs through designs which minimize the use of materials which have to be imported into the area or make better use of these materials (such as possibly using fiberglass penstock or increasing the use of gabions).
- Costly staff housing. The operation and maintenance of a completed plant is performed by SHDB field staff who reside at or near the plant. The size of the staff is significant. Even at the 32 kW Dhading site, approximate staff size is 14 full-time individuals. For this staff, housing and administration buildings

are often built on-site, and the cost of these can add as much as 15% to the cost of a plant. In many countries, small hydropower facilities are operated and maintained by a very small staff and, even then, an administration building and staff housing are not provided. This factor may point to a need for the SHDB to possibly reduce staff and rent housing for them, if necessary, in the local village or town. Local individuals might be employed and trained for a number of the positions. Or, yet other options for operating and managing remote schemes might be considered.

- Non-optimum site selection. The selection of a site is a critical factor affecting the cost of developing that site. Though a signficant amount of time would have been required to verify whether the sites selected by the SHDB represent the optimum site, several sources, including the SHDB, acknowledged that site-selection procedures need to be improved.

- Inappropriate plant size. It is not unusual in Nepal to find a site where the plant is not properly sized in view of the available water resources. A 300 kW plant developed with German assistance on the Saraudi Khola near Pokhara, for example, which was visited by the team, did not even have sufficient water to run its Ossberger turbines at part-flow at the time of the visit, and several months yet remained before the rains would reappear. Oversizing a plant means not only that equipment costs are higher than necessary but also that the same is true with the oversized civil works. This may point to a need to refine hydrologic methodologies for determining minimum flows in small catchment basins.

- Costly conventional designs. A fairly high portion of the costs at many sites is associated with the diversion structure, sedimentation basins, power canals, and, in some cases, off-stream storage facilities. For some of the projects, the design of the diversion structure and sedimentation basins tend to be sophisticated, fairly difficult to construct, and rely heavily on concrete. Other designs should be considered. A simple diversion structure of stones and branches which have been used to divert water into irrigation canals for generations, for example, could easily be used with a side intake at numerous small hydropower sites, rather than concrete diversion weirs spanning a stream. Unlined canals used on irrigation schemes throughout the country should be more widely considered as an alternative to linings of concrete or stone masonry.

- Imported turbines. In all except the two sites visited by the team, imported turbines have been incorporated in the design. The principal reason for this is that locally fabricated turbines are not available in sizes larger than 50 kW. Wider use of local turbines in staged installations should be considered. Reduced cost, power generation over a wider range of flows, less sophistication, low-cost turbine runner replacement, and standard parts among units are all factors encouraging the use of local crossflow turbines where suitable.

A second concern of the SHDB is the high recurring cost of their projects which are not always covered by the revenues collected. This points to a need to evaluate present staffing patterns and actual needs at operating sites to determine more cost-effective patterns. Are several shifts of watchmen necessary if staff lives on-site? Does a monthly reading of 200 meters warrant a full-time meter reader? Could this be done on a quarterly basis? Are linesmen

required on a permanent basis? There is a need to first establish staffing needs at each site and then, also possibly review alternative management options which might place the burden of the day-to-day running of the plant on the beneficiaries rather than on the SHDB.

It would have been useful if, given the information gleaned during the team's visit, it would have been possible to indicate, even within broad limits, the cost savings which could be incurred by the use of more appropriate designs and materials, improved siting, more optimum plant sizing, plant management, etc. But for the reasons covered previously and others, this was not possible.

A determination of the potential costs of implementing small hydropower plants in Nepal would probably require that all tasks from site selection through to operation and maintenance be undertaken in a coordinated manner at one or two "typical" sites to ensure a well-planned and integrated development. In this way, more appropriate designs could be developed and implemented on the one hand and, on the other, all the necessary data can be gathered and analyzed. This would permit a basis for determining the true costs of small hydropower in Nepal and whether, if appropriately implemented, small hydro can be a viable technology for providing power for development in the rural areas of the country. Evaluating past experiences can also provide the necessary feedback which should be used in the preparation of designs for new schemes, civil designs as well as designs for approaches to management, construction, and end-use promotion.

Hydrology

For the purposes of this report, the hydrological findings have been divided into three areas. Findings as well as recommendations dealing with the status of the data and the data-gathering and analysis network are reviewed below. A summary of the meteorologic and hydrologic situation in Nepal is found in Appendix B. And a preliminary analysis of available data as it applies to small catchment basins is found in Appendix C.

Hydrologic records and analysis

The Ministry of Irrigation is responsible for maintaining the network of hydrological stations in Nepal. This includes 38 hydrological stations and 120 meteorological stations with over 8 years of data. The quality of meterological records is considered "good." Only 11 of the 38 hydrological stations have records that are considered "good" according to crosschecks of several reports studied during the field visit. The rating of good is considered to mean an accuracy of ±10% for the Nepal data. Persons interviewed in Kathmandu guessed that the stream gauging station data was in error by 10%-20%.

Hydrologic stations equipped with continuous stage recorders are experiencing serious stage recorder maintenance problems that should be addressed. Hydrologic stations equipped with staff gauges that are visually read one or more times daily are also experiencing problems in that several persons interviewed expressed the concern that some of the observations were not actual readings and that a good deal of data was made up by the observer.

It was also learned that some of gauging stations sites have shifting beds that could change the rating curve and that an inadequate number of current meter

measurements were being taken for proper rating curve adjustment. It was also learned that current meters have not been calibrated for some 20 years since the termination of the UNDP project in the 1960s, but there is just beginning to be a calibration effort undertaken by sending the current meters to Dhaka where proper facilities apparently exist. Nepal is just beginning to use the salt dilution technique for flow measurement. Nepal has some sediment data from some of the hydrological stations.

Rating curves should be corrected and updated using calibrated current meters, salt dilution techniques, or some combination thereof. Use of continuously recording water stage recorders should be expanded to all stations and a comprehensive maintenance program should be devised to care for these instruments.

Basin studies

In addition to upgrading the hydrologic station instrumentation, rating curves, and data reduction, Nepal should expand the hydrologic network to include many more smaller basins in the range of 50-500 km^2. The water resource in Nepal dwarfs all other resources, yet a totally inadequate effort is being made to properly measure and analyze this resource.

Nepal should begin on a program of study that would lead to better prediction techniques in ungauged drainage areas. This is the very practical and applied research that is necessary to understand such phenomenon as precipitation-runoff relationships, aquifer-stream flow relationships, and so forth. Such work uses the careful statistical analysis of long-term high quality hydrologic stations in addition to meterological data, and basic data on soils, bedrock, ground water, land use, vegetation, hill slope processes, and so forth.

A beginning must be made in such a program before reliable low-flow estimates can be made. Low-flow estimates are critical to the small hydropower program because many hydropower schemes will be designed on the basis of this flow. Construction of a sufficiently large reservoir storage to augment dry season flow is not feasible.

Low flow is the least predictable portion of a hydrograph. Sound statistical analysis of longer term flow records of better quality from a wider range of basin sizes is a necessary framework for low-flow studies. However, statistical analysis alone will never provide an adequate and reliable basis for low-flow predictions in ungauged basins.

Analysis of a basin for low-flow potential must focus on aquifer-stream flow relationships because low flow in rivers is sustained by return flow from aquifers to the river channels. Such studies should be initiated by examination of several gauged drainage areas in the 100-500 square kilometer range in each of the four major river basins. Studies would require about 6 days per drainage and the combined expertise of several disciplines.

The distribution of low flows is controlled chiefly by the geology of the basin and the aquifer-river flow relationship. This is because a drainage area under extreme low-flow conditions contributes nearly all of the river channel flow from water flowing out of bedrock aquifers to the channel. Soils generally contribute an insignificant amount of water to low flow except where aquifers may exist in the

unconsolidated zone. Low flow is therefore a function of the storability and permeability of the aquifers of the drainage area.

In ungauged basins, a field reconnaissance by trained personnel is required in order to obtain a reasonable estimate of low flow. The reconnaissance should take place during lowflow conditions. Interrogation of local residents often provides useful information that will help the investigator categorize the channel flow that is observed during the investigation. Field data taken during the investigation should include careful observation and measurement of flow in the channel as the investigator walks upstream from the site being investigated. Current meter measurements of flow should be taken at the site and at every observed change in the geologic formation through which the river flows. Tributary flows should also be measured. Because rivers sometimes flow along bedrock faults, the geology and, therefore, the low flow may be quite different in tributaries on the left bank as compared to the right bank. Location and flow from distinctive seeps and springs should also be recorded. In some basins significant ground water contributions to channel flow occur at bedrock fracture zones that are associated with lineations that can be observed in aerial photographs of the basin prior to the field visit.

Even if the geologic formation is the same throughout the basin, other factors such as variations in permeability, jointing patterns, stream orientation, and the depth of incision of the stream into the water bearing formation affect the low flow at a particular point on a stream. Low flow does not increase uniformly with distance from the head waters. In such a field study, the observations of flow and geology are used to explain differences in low flow that may occur between basins or sub-basins but are rarely used to make quantitative estimates of low-flow potential. Such studies must be made during extreme low-flow conditions when the aquifer contribution to channel flow is highly significant.

Such a series of studies, although not completely definitive, is necessary for a better understanding of the low-flow phenomenon in Nepal and would permit a much more rational and precise estimation of flow in ungauged basins. Without such studies, estimations of low flow will continue to be in error with the consequent high cost of over- or under-designed hydropower schemes.

Training

One engineer in the Department of Water Resources believes that Nepal has an adequate number of trained engineers and hydrologists but that there is a totally inadequate number of trained technicians to carry out the field work. In any case, the SHDB would most definitely benefit from a comprehensive in-country workshop/training session in hydrology. Such training should be geared for both upgrading of graduate engineers and development of a trained cadre of technicians. Such training should cover all of the usual basic subjects covered in a hydrology course. The training should be supplemented by some background in open channel flow. Emphasis should be placed on the practical and proven field methods for measuring the various hydrologic phenomenon accurately. Methods for applying these data to assist with the solution of practical problems should be taught. A curriculum for such a workshop could be developed so that the material could be presented in about eight 6-hour sessions. This is the minimum training needed. Technician level people would require an additional workshop of equal length dealing with hydrological instrumentation. Such a workshop generally deals with proper selection of sites for meterological and hydrological measurement,

types of instruments, care and maintenance, calibration and repair, data-gathering and note-taking, and data reduction techniques. Emphasis can be placed on current metering, sediment measurements, ground water flow nets or other particular subjects that would be of value.

Income-generating activities

There were no accurate statistics available on load factors. This was, in part, due to lack of monitoring equipment at the power plant and in consumers' homes or establishments and to inadequate data collection by operation and maintenance crews. Consequently, conclusions regarding load factor relied upon conversations with field crews and SHDB staff. Consensus is that load factors are probably running around 10%-15% for most systems. Some systems do experience running at peak load during the evening hours between 6:00 and 9:00, when domestic lighting is the major demand. There seems to have been little change in load growth over the past few years; systems have been installed and it was hoped that activities and end uses would appear on their own. This has not happened and growth—other than domestic lighting—has been very slow. Consequently, the SHDB has come, more and more, to believe that it must directly address this issue. In its attempt to get better projections of potential load, the SHDB has had consulting firms which do feasibility studies gather an increasing amount of information on potential end uses. However, beyond the survey of limited existing potential uses, these surveys have resulted in no further activity after the initial feasibility study.

The Department of Cottage and Small Industries has over 800 different types of establishments. The potential list of those which would use electricity is substantially shortened because many of the SHDB sites are not located near roads; therefore, many of these industries would not be located in such villages. Also, many of the cottage industries are not amenable to electric power because of the Department's emphasis on creating jobs; electrical power should not compete with manual labor in these situations. However, there are still substantial opportunities for cottage and small industries to make use of electrical power for selected applications.

The use of off-peak electrical power for cooking is, thus far, problematic. An inexpensive electric heat-storage cooker has yet to be perfected; work is currently underway in Butwal by the United Mission to Nepal. For most systems, the use of normal hot plates comes into conflict with the lighting load in the evening and, hence, peak demand period. Moreover, very little cooking with electricity has been evidenced so far, due in all probability to the lower cost of wood.

Except in establishments related to the tourist industry or in administrative buildings, it is unlikely that heating with electricity will be a major end use in the near future. This is due mainly to the income level of most people in the villages served by the SHDB. This may change in the future, but it is not anticipated to be a major item for the population at large within the next decade.

There are numerous applications in agricultural processing for the use of electricity. Many of these fall under the general heading of "small industries." The main application which does not is irrigation. This would also seem to be a major potential productive use of electricity in the hill and mountain regions of Nepal. Financial and economic analyses done by the Agricultural Development

Bank in Kathmandu and by, for example, the Agricultural Research and Development Planning project of AID, have shown that in many circumstances irrigation can be quite profitable. This application, therefore, is one which should be given a great deal more attention by the SHDB than it has to date.

There is currently a tariff policy which sets the rate for domestic consumers, industrial consumers, and irrigation as Rs 1.00, Rs 0.30, and Rs 0.20* per kilowatt-hour, respectively. After gathering load data at operating sites, it might be advisable to review this policy to determine the best policy to pursue to encourage maximum benefit from hydropower schemes.

In summary, numerous opportunities do exist to expand the productive use of electricity and the income-generating situation for individual plants. These potential end uses and the tariff policy to be followed may need to be adapted for each economic and geographic region of the country, as well as for the particular hydro installation. In order for this to happen, a series of actions and policy changes must be undertaken by the board. The team's findings indicated that:

- load factors seem to be extremely low and data being kept on both generation and consumption at SHDB sites are inadequate;
- there is a lack of knowledge among people and villages serviced by the SHDB as to the opportunities which may exist for use of electricity;
- other than some initial and superficial surveys of possible uses of electricity carried out by consultants during their feasibility and design studies, little has been done by the board to either determine or develop end-use opportunities at SHDB sites;
- without information being provided to local people at SHDB sites and the necessary resources brought in to help them, it is unlikely that the income-generating capacity of small hydro plants run by the SHDB will achieve an attractive level; and
- skills, such as the capability to carry out survey work in the villages and economic analysis of various end-use possibilities, do not currently exist within the SHDB staff.

To address these needs, a new organizational unit might be formed at both SHDB headquarters and the regional offices—an extension unit. This unit should be headed by an energy economist/planner in Kathmandu and by extension workers/community organizers at the regional level. This unit need not be large and it might be staffed in part by individuals already in SHDB. How SHDB staff at system sites would carry out this extension work and be integrated into the SHDB extension unit is not yet clear. Responsibilities and activities of the headquarter's unit would include:

- carrying out, or overseeing consultants' work on end-use related surveys during feasibility studies;

*Rs 1.00 = $0.06

- developing materials and information concerning possible uses of electricity (cottage industries, agro-industries, irrigation) and information on where to obtain equipment, technical assistance, financing, etc., for distribution to local people;

- serving as the day-to-day liaison for inter-agency cooperation and SHDB public relations;

- training regional and local SHDB staff on how to provide information, carry out promotional activities, and help organize local people towards better electricity usage; and

- identifying and developing specific plans for expanded electricity usage in each SHDB locality.

Without this kind of activity on the part of SHDB, it is unlikely that the experiences of past load factors will change drastically. Even with an active unit of this type, substantial change will only occur if other government and private groups do their part. SHDB must, however, take the lead in analyzing end-use options, promoting electrical use at the local level, and serving as a catalyst and organizer of integrated development as it relates to energy use in rural Nepal.

Institutional and organizational issues

The current organizational chart for the SHDB is shown in Fig. 1. Staffing levels are not full, as some posts—especially the more senior engineering posts—remain vacant due to a shortage of skilled personnel in Nepal. The SHDB is probably staffed at about 80 percent of their organizational charge. Staffing at each of the regional offices is between 30 to 40 people, and operation and maintenance staff at operating stations varies from 12 to 35 people, depending upon the size of the station.

The SHDB seems to have capable and strong leadership at the top, and both the GON and the SHDB seem strongly committed to small hydro. However, the team found that the current organizational structure and internal skills are not adequate to achieve the task of implementing more financially viable small hydropower schemes. Specifically, some of its findings are as follows:

- Lack of well-articulated program goals. At present, the SHDB does not have a well-articulated set of program goals or plans. There is a strong need for project staff to arrive at a shared articulation of clear goals and objectives. There is also a need to state the priorities related to those objectives and to then show how the operational and day-to-day plans of the SHDB relate to those plans and objectives. The SHDB should carry out a basic institutional planning process, starting with clarification and clear articulation of goals, objectives, and a general operating plan that lays out a realistic scenario of how SHDB will attempt to achieve them. This should not be viewed as an empty exercise; if done properly, it will achieve three important institution-building objectives:

    - It will help clarify SHDB's process of choosing towns or geographic areas of development and should also clarify the technical questions or areas of concern that need to be addressed.

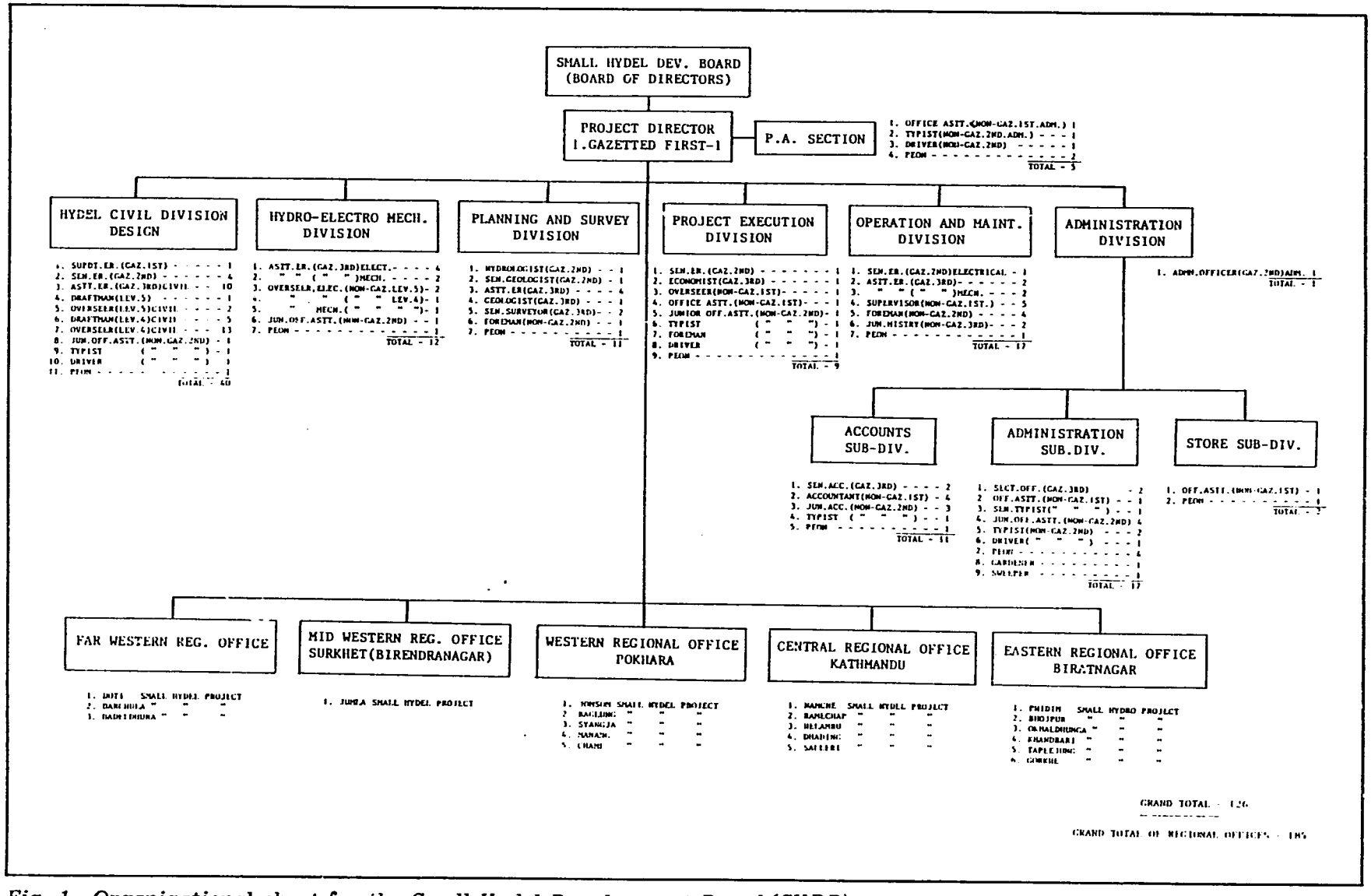

Fig. 1. Organizational chart for the Small Hydel Development Board (SHDB).

- It will provide a clear and prioritized plan which will then allow SHDB to articulate this to other institutions and individuals so as to improve understanding and regard for SHDB.
- And it will afford the opportunity to clarify SHDB's responsibilities, mandate, and approach to the end-use issue.

Until this task is done, it will be very difficult to give clearer and better direction to staff members or to articulate the board's operational plans to other institutions and organizations. Hopefully, such a process might, in the end, also increase the level of commitment and morale of SHDB staff.

- Need for coordination with other organizations. In addition to the need for articulation of the board's doctrine and program to other organizations, there is also a very strong need for coordination with those organizations. Many of the people the team spoke to on visits to other government agencies had not heard of the SHDB except by name, i.e., they did not know much about the board's activities. Furthermore, none of them had had any direct contact with the board, nor had they been involved in any of the board's projects, although they were often working in the same geographical areas. Unfortunately, according to the director of the SHDB, ministries and deartments have often not even responded to letters from the SHDB requesting meetings to discuss cooperation.

  Coordination among government agencies is not easily achieved. This difficulty was acknowledged by numerous individuals. However, willingness to do so was expressed and the need to do so was brought up by almost all agencies as critical to a successful coordination effort by the SHDB. Coordination is often easier at the regional and local level and this is, of course, most important. Relative success in coordination has been achieved by previous projects and agencies and, in effect, the SHDB must attempt to coordinate.

  One area where inter-agency coordination is especially critical is in promoting and developing end-use activity in areas served by SHDB schemes. To increase the frequency and quality of inter-agency contact, a working committee and an established procedure within a broader SHDB plan will probably need to be created for bringing about successful field activity. Without this inter-agency effort, the SHDB would have to develop an inordinately large staff that would in actuality be carrying out the mandate of other ministries and agencies.

- Training. At the moment, there is no written training plan for the SHDB, although the staff have given thought to training needs and articulated some of them to the NRECA team. Because of the obvious needs, a training plan and associated training program should be worked out following the development of an overall SHDB plan.

- Duplication of personnel. There appears to be duplication of personnel and responsibility, leading to inefficiency, between the Kathmandu and regional offices. This is most apparent in the area of civil engineering design. It would seem more appropriate to have this work carried out at the central office.

General issues

In addition to findings in specific technical and institutional areas, several findings were found to be common to all areas or would be of general concern in designing an approach to effectively address the needs of the SHDB. These deal with the lack of data, staff motivation, approach to training, and the viability of small hydropower in Nepal.

Lack of data

An essential requirement for proper planning of small decentralized hydro schemes is adequate appropriate and reliable data. The team found that little relevant data exists -- small catchment basins are ungauged; breakdown of final costs for implementing already operating schemes are not available; load and load-growth information for decentralized plants is largely qualitative; operating and maintenance difficulties at existing plants, which could be remedied through improved designs, have not been evaluated.

Previous funders of specific SHDB schemes not only have frequently permitted the design of their projects based on incorrect or incomplete data, but most have made no provision to provide a more meaningful input to the Government of Nepal than capital for plant construction. Consequently, schemes continue to be implemented without any assistance being given to the SHDB to develop its capacity to begin gathering and reducing the range of data necessary if it is to improve its effectiveness at implementing more viable small hydropower schemes.

Staff motivation

In Nepal, as in a number of countries around the world, it must be recognized that financial remuneration on its own often provides employees little incentive to work productively. The SHDB is no exception. This fact must be recognized if one is to have any chance of success at developing an effective institution. Though providing supplemental salaries to some engineers who are working on specific projects has been tried before, an honest effort at increasing the effectiveness of the engineerrs must recognize the fact that this is probably not a viable option across the board. Therefore, other than financial incentives must be found. For example, a training effort might rather be specifically designed to engender an esprit de corps among the trainees, a desire to get involved in a challenge, to master new technique and information; it cannot be the run-of-the-mill effort often associated with "training." The possibility of engendering this spirit is probably enhanced in the case of the staff of the SHDB since many may also be motivated by their involvement in small engineering firms on off-hours. Any mastery of new material can therefore be viewed as a benefit gained by involvement in training efforts which improves the quality of work undertaken by the SHDB but which could actually pay off financially in their other work.

Approach to training

It was felt by the director of the SHDB that any training effort should be site-specific rather than dealing with generalities or stressing the theoretical aspects of a subject. This is clearly the most effective approach to training—it ensures that the training is more relevant, it becomes a more meaningful experience for the trainees, and the consequent increased motivation of the trainees leads to broader benefits.

Viability of small hydropower in Nepal

It is well recognized that there is significant small hydropower potential in Nepal, that it is widely distributed throughout the country, and that there are few, if any, other options to providing energy for development for a majority of its people. However, with the present trend in Nepal pointing to a continuing increase in the price of small hydropower projects, the appropriateness of this technology is being brought into question. But while small SHDB hydropower schemes as well as large multi-megawatt plants are found to be expensive, there seems to be the promise for more cost-effective and appropriate schemes in Nepal. Examples of this are found for sites bracketing the size of plants being implemented by the SHDB. At the low end, an increasing number of local metalworking shops are fabricating 5-15 kW turbines which are a component of schemes whose total costs range from $600-$1000 per installed kilowatt. At the higher end, a 1 MW plant at Butwal was implemented for $800/kW (1983 dollars) and the cost of a 5 MW plant currently being constructed on the Andhi Khola is projected at $1000/kW.

There are aspects obviously unique to both these large plants (i.e., economies of scale) as well as the small schemes (i.e., private-sector approach) but these are not the only reasons why these schemes are frequently only 20%-40% the cost of the SHDB-implemented schemes. If Nepal is to harness its small hydropower resources to benefit larger remote rural settlements throughout the country, it is essential that the SHDB develops both technical designs and approaches as well as the institution which can cost-effectively undertake this task. Without this, though the physical potential for small hydropower in Nepal looks promising, the prospects for exploiting it do not.

OPTIONS FOR ASSISTANCE

There appear to be three basic options for providing assistance to the SHDB, each requiring a different level of effort and funding. For the sake of completeness, these, as well as some advantages and disadvantages of each, are briefly described below. The third option, recommended by the team as the most effective approach, is described in considerably more detail.

Option 1

If very limited resources were available to fund an assistance effort, short-term efforts to address specific, well-defined needs could be considered. Two examples of this can be found in Appendix D. The first would be to assist the SHDB in clarifying its goals and developing a plan of action to achieve these goals. The second effort recognizes the need for increasing load factors and ensuring integration of productive end uses of otherwise unused energy at isolated schemes. It proposes to assists the SHDB in analyzing the end-use patterns at existing sites as well as other potential end uses and in implementing a program to promote productive end uses.

Though short-term efforts might provide some satisfaction that something is being done, the fact that effective technology transfer, institution-building, and training require long-term efforts should not be overlooked. Short-term efforts permit little time for these processes to take place and, though these efforts might be useful steps, there are several valid reasons why there is generally little to ensure a follow-on once the initial effort has been completed. Without this follow-on, any such effort may not have a long-term impact.

Option 2

On the other hand, if significant funding were available, a suggestion proposed 1-2 years ago by the SHDB might be pursued. This involves the full-time services of several qualified experts to work within the SHDB for several years and to be concerned with training of the staff and institution-building. Short-term services for individuals to address specific needs would also be included.

This would clearly be a major effort and the organization providing this assistance would be faced with simultaneous efforts on numerous fronts. An effective job might well be impossible for several reasons. It assumes that this organization has already developed an overall integrated approach to implementing small hydropower plants, involving design, organization, training, management, and so forth, which would be suitable in Nepal. The reality is that this approach may well have to evolve. This takes time and suggests that a smaller-scale effort (Option 3) might be more appropriate. In addition, a number of projects have already been embarked upon and these will be difficult to change mid-stream. And finally, locating funding of such a major training effort would pose a difficulty in a period of tight money. The needs proposed by the SHDB previously referred to are quite valid; the question is whether such a major training effort is realistically possible.

The Swiss Association for Technical Assistance (SATA) has recently terminated a training effort patterned somewhat along this option. The apparent reason for a

generally unsuccessful effort is that, for one reason or another, the approaches of the two parties to the task could not be reconciled. The SHDB felt that the SATA effort became one where emphasis turned more to doing the job rather than training the staff to do it. Irrespective of the validity of this impression, it highlights a potential difficulty which can arise to the detriment of any assistance effort. A knowledge of the content portion of a training effort is essential, but as equally important is an awareness of what effective training involves. Neither task is easy in the Nepali context and, in the case of this option, the difficulty would be compounded by the scale of the undertaking.

Option 3

Available from experiences around the world is a wide range of technical design options for small hydropower plants, a wide range of techniques for addressing technical problems such as synthesizing streamflows at ungauged sites or transmitting power to relatively distant load centers, and a wide range of institutional or organizational structures which might be used to address the tasks of running a national small hydro program, managing individual remote decentralized schemes, or promoting the productive end-uses of the power generated. But from the experience of NRECA's SDH Program to date as well as from the findings of the team, it is apparent that a viable overall approach to developing a country's small hydropower resources is largely country-specific and that an approach to this task in the Nepali context will have to be synthesized. There is no ready overall approach which can be immediately adopted to effectively resolve the range of problems facing the SHDB.

This option proposes the implementation of one or two small hydropower schemes over 1-3 years as a vehicle for developing both appropriate designs and a general overall approach to the implementation of such schemes. These would be synthesized based on an evaluation of existing implementation, operation, and maintenance experiences with small hydropower schemes throughout the country. The implementation of these "demonstration plants" would provide the occasion for the gathering and analysis of data necessary for realistic future planning, such as data dealing with hydrology of small basins, civil costs, load and load-growth at decentralized rural centers, and economic and other benefits. And it would permit the opportunity for the immediate, on-the-job training of several SHDB engineers.

The SHDB would contract to a local firm experienced in undertaking such projects, on a turnkey basis, the entire task of implementing these one or two small hydropower schemes, from site selection through to initial operation and maintenance. This firm would be instrumental in developing appropriate designs and implementation approaches which are suitable for adoption by the SHDB. The SHDB would also designate several of its engineers to be assigned to this firm for on-the-job training for the duration of the project. By actively involving the SHDB in all aspects of the implementation of the schemes, the possibility of integrating new approaches and designs into SHDB capability and procedures will be increased.

The implementation of the demonstration scheme(s) would involve the following tasks:

- evaluation of existing plants (technical designs, O&M staffing, tariff structures, and load patterns and growth),

- end-use planning,
- organizational planning for construction management and operation and maintenance,
- site selection and basic layout,
- construction,
- end-use development and promotion,
- coordination with appropriate ministries,
- streamgauging,
- data collection and analysis,
- training of several SHDB staff in all above aspects, and
- documentation of all aspects of the effort.

It will address many of the area-specific recommendations covered in the previous section of this report.

Implementing these schemes on a turnkey basis by an experienced local firm is essential because it provides the opportunity for the coordination of all aspects of the job, from initial conception through to operation. It gives the SHDB the chance to develop more appropriate designs and approaches without being encumbered by impositions by funding agencies that lead to technical designs which are developed by firms not experienced with implementing small hydropower schemes in Nepal. While under overall SHDB control, it permits an approach to be developed independent of constraints which might be imposed if it were undertaking this task under its existing structure.

In order to most effectively address this task, this firm should probably have the following qualifications:

- a significant history of implementing a range of small hydro projects;
- a guiding philosophy of maximizing the use of indigenous material and human resources;
- a knowledge of, and sensitivity to, social conditions prevailing in Nepal; and
- a commitment to the development of Nepal before partisan objectives.

Though it would have to be verified, it appears that there may only be one firm, namely Himal Hydro and General Construction Pvt. Ltd., which satisfies these conditions. This is, parenthetically, the firm with staff who have been involved directly and indirectly in the low-cost micro-hydro as well as larger (1-5 MW) schemes covered in the previous section. It is also the local firm whose resources the SHDB has recently begun tapping for some of its other projects.

For its part, NRECA would provide a full-time individual to furnish the coordination and oversight required to ensure that all necessary aspects of this project are properly undertaken and that the efforts of all interested parties are effectively integrated to achieve the project objectives. He would initiate, with the SHDB, a rational and effective system for gathering a range of data (load, hydrology, designs and cost, etc.) which is to be integrated into the planning process and would be responsible for the complete documentation of these and other aspects of the project. This aspect is critical if the experience gleaned is to be used to improve the performance of the SHDB and not merely add to the tally of plants completed. He will also contribute to training efforts as appropriate. NRECA may also locate short-term assistance to address specific areas of need encountered during the implementation of the project.

The small hydro schemes which are to serve as vehicles for the proposed development and training project would probably be schemes for which the SHDB will have the ultimate responsibility of implementing anyway and for which funding other than from USAID S&T/EY (which funds NRECA's SDH Program under a cooperative agreement) will have been committed. The organization providing the capital for construction of the small hydropower schemes will not only be providing a vehicle for development and training but will have contributed to a schemes and an approach to implementation which should become a prototype for replication by the SHDB elsewhere in the country. At present, such funders are merely contributing another expensive scheme with little chance of replication elsewhere and, therefore, also have considerable to gain from the effort being proposed here.

One candidate for such a scheme which has already been discussed would be one or more of the schemes being considered as a component of USAID's Resource Conservation and Utilitzation Project (RCUP) which are to be implemented by the SHDB. Though survey and detailed study work has already been completed by local engineering firms, these schemes exhibit the same potential problems facing others being implemented by the SHDB—high costs on the one hand and little productive end-use and revenue generation on the other. In addition, a careful review of several of these studies points out that the local firms who undertook them are new to the design of small hydropower schemes and have adopted a textbook approach. This is disturbing because of the implication this has regarding their ability to come up with appropriate designs. These studies could clearly be redone, as necessary, as part of the final design work. Another possibility, not yet discussed, would be a small hydropower plant to be implemented as part of a joint USAID/World Bank project on the Lamjung campus of the Institute for Agriculture and Animal Sciences (IAAS). No known small hydro studies have yet been undertaken at that site.

Whereas the first possibility suggested above is funded by USAID/Nepal whose primary concern is generally technology transfer and institutional development, the second possibility involves capital financing from the World Bank, which is primarily concerned with development of the physical infrastructure. It is unclear whether conventional constraints imposed by the Bank would frustrate any effort to develop less conventional but more appropriate designs at their site. In addition, the interest of USAID/Nepal and the South-East Consortium for International Development (SECID, AID's contractor for the RCUP project) clearly goes beyond the mere installation of a few more small hydropower plants. They are concerned about the overall viability of the technology, its replicability, and maximizing benefits from such an undertaking. Given the nature of the World Bank component to the IAAS project, this may not be the case in that project. For any project which is to be adopted as a vehicle for a development and training project, it is essential that the funder of the site is concerned about all aspects of small hydropower projects beyond strictly the plant's technical design and performance.

This option permits a more appropriate approach to the implementation of small hydropower schemes to be synthesized and SHDB staff training to be initiated without being overwhelmed by the size of an effort such as that involved in Option 2. It also permits optimizing the effectiveness of limited funding resources. One perceived disadvantage of such an approach is that, over the next several years, only one or two schemes would be developed as part of this development and training program while other, generally expensive, schemes

already embarked upon will continue to be constructed. While this may be less than pleasing to some, several thoughts come to mind. First, given the nature of the problems being faced, it is difficult to see how these all can be resolved simultaneously. Secondly, implementing cost-effective schemes requires suitable inputs from the beginning of a project. Once implementation of a small hydropower scheme has been initiated based on non-optimum site location, incorrect load projections, etc., it is difficult to significantly change its course. Where appropriate, some changes might still be incorporated at schemes concurrently being implemented if improved techniques or designs have been developed in pursuing the demonstration schemes. And finally lessons learned should be integrated into the approach used by the SHDB as it embarks on other new projects.

Upon successful completion of this option, the SHDB will have begun developing an approach better suited to the realities facing it in implementing a national small hydropower program. Once it has been proved that small hydropower can indeed be a viable option for providing energy for development in Nepal, then a larger training effort could be developed. Then would be a more appropriate time to begin thinking of preparing an inventory of potential sites to serve specific load centers and addressing the remaining concerns of the SHDB.

RECOMMENDATIONS FOR DEVELOPMENT AND TRAINING ASSISTANCE

Recognizing that developing appropriate technical designs, institutional models, and approaches to implementing small hydropower schemes as well as providing training require long-term efforts which must be undertaken around actual project, the team recommends Option 3 as the most effective approach to accomplishing these objectives. In line with this general recommendation, it is proposed that the following steps to be taken. Each step is conditional on the performance of the steps preceding it.

(1) If the SHDB concurs with this recommendation, USAID S&T/EY and NRECA will follow up with USAID/Nepal to determine their interest in committing the funding necessary for the implementation, along the lines proposed in Option 3, of at least one of the small hydropower plants proposed as part of the RCUP.

(2) NRECA will then assemble a small team including one or more individuals who are experienced in the design and implementation of small hydropower plants and have worked in Nepal for several years. This team will undertake a 1-3 man-month effort with the SHDB, USAID/Nepal, and S&T/EY to more carefully design an approach to achieve the objectives of development and training, to evaluate the abilities and interest of Himal Hydro in this effort and its other commitments to date which might affect the timing of this project, and to prepare an agreement acceptable to all parties so that funding can be committed and the effort initiated.

(3) Upon agreement by all parties, the project would be initiated under the coordination of a full-time NRECA small hydro engineer.

It is envisioned that NRECA, under its cooperative agreement with USAID S&T/EY, would fund the first two steps outlined above and that USAID/Nepal could support the project coordinator from the funds already planned for the project.

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APPENDICES

Appendix A: List of small hydropower schemes in Nepal

Site name	Current status	Designed by	Plant size (kW)	Cost[1] million NR	Cost[1] $/kW
Sites developed by the SHDB					
Gajouri[2]	commissioned		25	NA	NA
Baglung	commissioned 1983	SHDB	175	5.7	2,100
Doti[3]	commissioned 1982	Yugoslavia	240	9.8	2,600
Phydian	commissioned 1983	SHDB	260	6.5	1,600
Dhading	commissioned 1983	SHDB	32	2.2	4,400
Namche	construction	Austrian	720	44.3	3,900
Jomsom	commissioned 1983	Nepal-DCS	260	13.3	3,300
Salleri/Chialsa	construction	Swiss-SATA	400	15.0	2,400
Jumla	commissioned 1984	Nepal Elec. Dept.	260	14.4	3,500
Tapeljung	tender	Chinese	125	13.0	6,600
Khandbari	tender	Chinese	250	22.5	5,800
Okhaldhunga	tender	Chinese	125	14.7	7,500
Ramechap	tender	Chinese	75	11.0	9,400
Bhajpur	tender	Chinese	250	17.7	4,500
Therathum	tender	Japanese	100	17.6	11,000
Tatopani	tender	Japanese	1000	63.1	4,000
Serpodah	tender	Japanese	200	29.5	9,400
Chanrjari	tender	Japanese	150	21.3	9,100
Bajura	tender	Japanese	200	23.2	7,400
Bajhang	tender	Japanese	200	19.7	6,300
Gorkhe	commissioned 1983	SHDB	64	2.23	2,200
Helambu	construction	SHDB	50	2.25	2,900
Manang	construction	SHDB	80	5.40	4,300
Dandeldhura	design	SHDB	100	3.5	2,200
Sayangja	construction	SHDB	80	5.7	4,600
Darchula	redesign	SHDB	50	5.4	6,900
Chame	construction	SHDB	45	NA	NA
Partial listing of sites developed by others					
Dankuta	commissioned 1971	Nepal Elec. Dept.	240	2.8	750

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Surkhet	commissioned 1977	Nepal Elec. Dept.	345	13.5	2,500
Saraudi Khola	commissioned 1977	German	285	5.95	1,300
Tinau Khola	commissioned 1978	Nepal-DCS	1000	12.8	820
Namche	commissioned 1983	UNESCO	27	1.27	2,900
Andhi Khola	construction	Nepal-DCS	5000	78.2	1,000
Pokhapani	study	Nepal-consultant	150	11.2	4,800
Kagbeni/Mukinath	study	Nepal-consultant	300	20.9	4,4[illegible]

[1] Cost data was obtained from SHDB. Some costs are based on actual construction costs while others were obtained from final design estimates or feasibility studies. Most of the projects include costs for electrical transmission and distribution facilities.

[2] Plant out of operation for past 2 years.

[3] Plant out of operation since August 1983 due to major flood.

Appendix B: Summary of the hydrologic and meteorologic situation in Nepal

Nepal is a mountainous country of over 141,000 km^2. Elevations range from 65 m above mean sea level in the Terai to over 8000 m. Mean runoff for the country is nearly 1600 mm, compared to 230 mm for the co-terminous United States.

The country is divided into several physical regions on the basis of elevation and topography as follows:

1. The Terai belt, the Piedmont zone of the Gangetic Plain, with elevations in the range of 65-100 m, dense jungle and intensive agriculture, hot summers and warm winters, heavy monsoon rains between May and October, and water deficient between November and April.

2. The Siwalik Hills, north of the Gangetic Plain, with elevations up to 1600 m, sterile soils generally not fit for agriculture, sparse forests, severely eroded slopes, heavy monsoon rains from May through October, and water deficient from November through April.

3. The Mahabharat Range, north of the Siwalik Hills, with elevations up to 3000 m, some agriculture, sparse forests, severely eroded slopes, heavy monsoon rains from April through October, and water deficient from November through April.

4. The inter-montane midlands, with elevations ranging from 700-2000 m, warm summers and moderate winters, intensive agriculture and forests, severe erosion, heavy monsoon rains from April through October, and water deficient from November through April.

5. The Himalaya Mountains, north of the inter-montane midlands, with elevations ranging up to 8848 m, some pastoral agriculture, very cold winters and cold summers, severe erosion, monsoon rains to an elevation of about 3000 m with very little precipitation in higher elevations, and water deficient from October through April at lower elevations and year-round at higher elevations.

Annual precipitation reaches a maximum in the southeastern part of the country which experiences about 2500 mm. Precipitation declines to the north and west, with the lowest mean annual of 250 mm experienced in the extreme northwestern part of the country. Local maxima and minima are determined by the local topography.

Temperatures range from sub-tropical in the Terai to arctic in the Himalaya. Mean annual temperature decreases about 5 ^{o}C per 1000 m increase in altitude. Snow rarely falls below the 1500 m level and is a regular winter event above the 2000 meter level.

The 6000 rivers in Nepal are usually grouped in four major basins as follows: the Karnali basin, the Gandaki basin, the Saptkosi basin, and the southern rivers, being all of those flowing south of the Mahabharat range. In addition, Nepal shares with India parts of the Mahakali river basin on the west and the Mechi basin on the eastern border.

The Karnali, Gandaki, and Saptkosi basins all observe the same pattern of flow which differs only in magnitude. Extremely large flows occur during the monsoon from the middle of June to the middle of September, and flows then gradually decrease until the end of February. From about March through August, snow melt also contributes to the channel flow in those basins with significant winter snowfall. The coincident monsoon rainfall and snowmelt produces distinct single peak annual hydrographs on most rivers in Nepal. A high mean flood discharge is in the range of 260 $l/s/km^2$, which compares with 750 $l/s/km^2$ for New England (northeastern U.S.) rivers.

July, August and September are the high runoff months in Nepal, with about 65% of the annual runoff occurring in those 90 days. In contrast, many rivers in northern New England experience 50% of the annual runoff in 30 to 45 days. During the six month dry season, flows are sustained by ground water contributions, but very little data are available on ground water flow conditions and scientific analysis of this phenomenon is not possible at this time.

Figure 2 shows a profile of Nepal indicating the major regions described above. Figure 3 shows a typical annual hydrograph for the Karnali River. Figure 4 shows a profile of the Karnali river basin. Figure 5 shows the four major river basin classifications in Nepal and the location of hydrological stations. Figure 6 shows an iso-hyetal map of mean annual precipitation for Nepal.

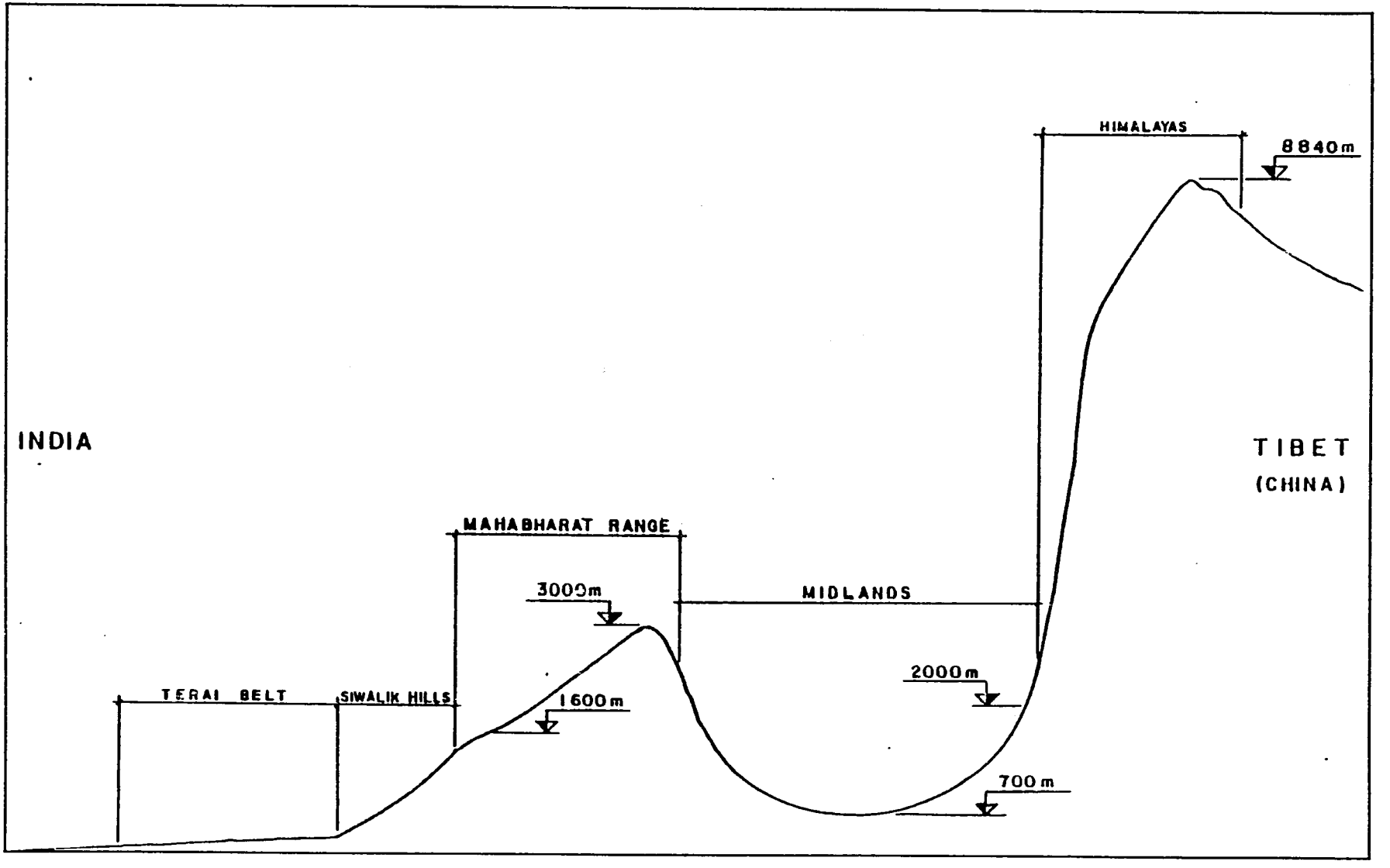


Fig. 2. Schematic profile of Nepal.

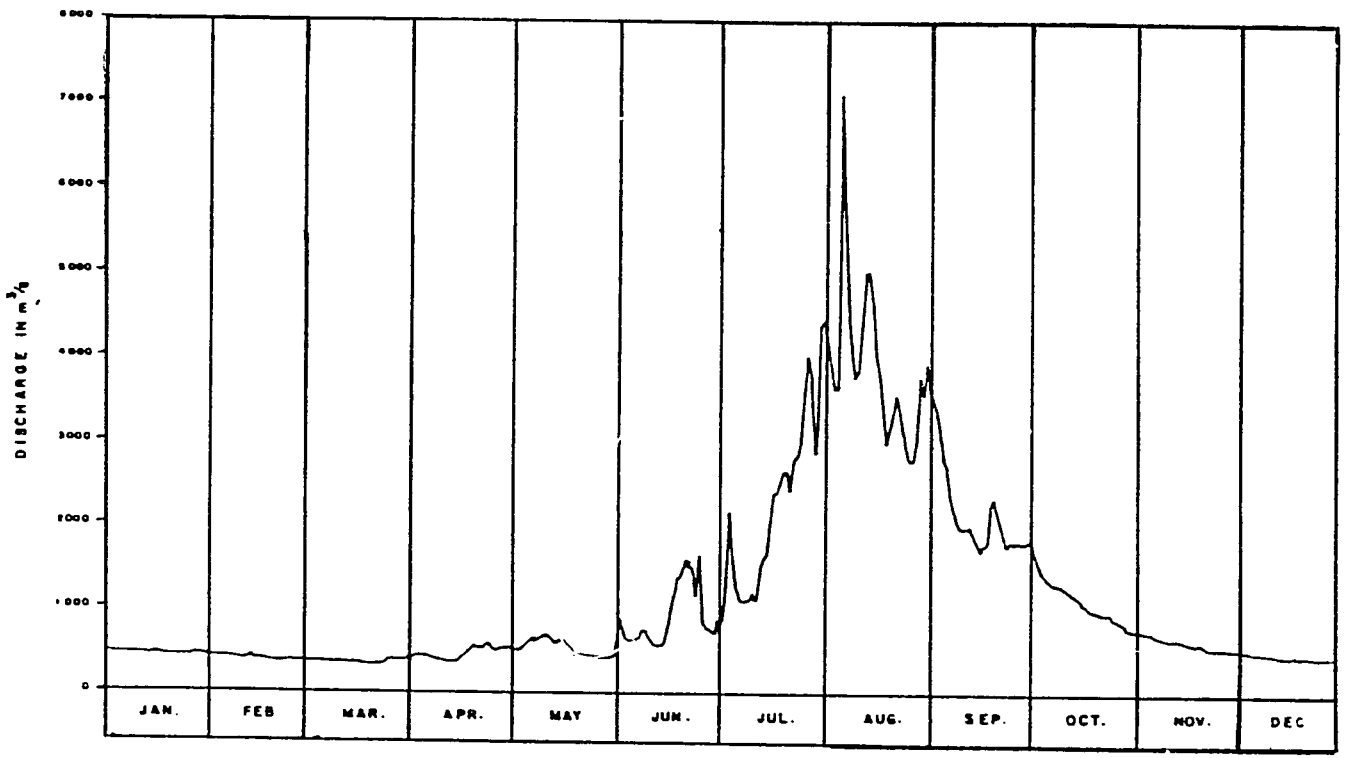


Fig. 3. Annual hydrograph for the Karnali River, Gauge 280.

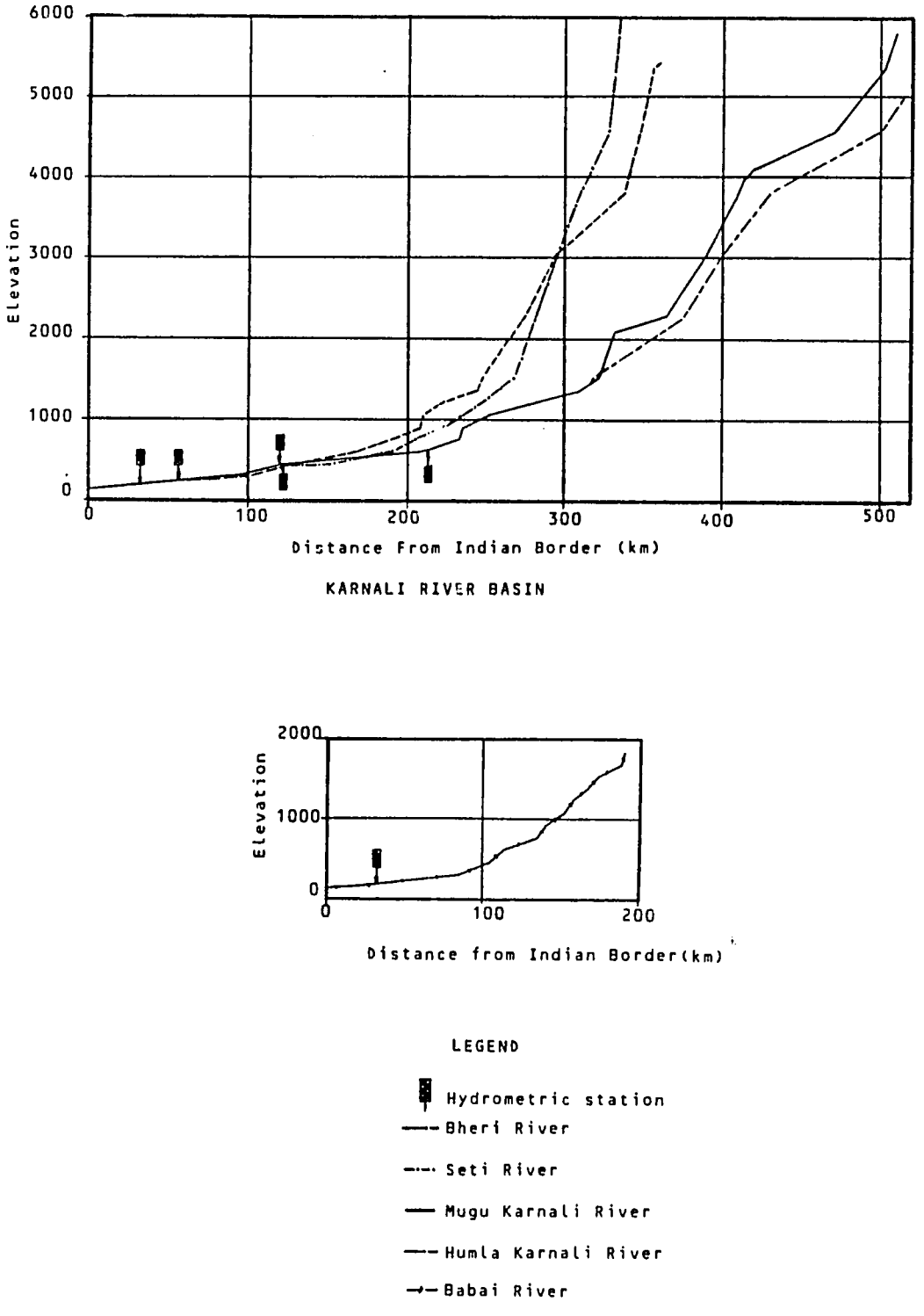


Fig. 4. Profile of the Karnali River (Ministry of Water Resources).

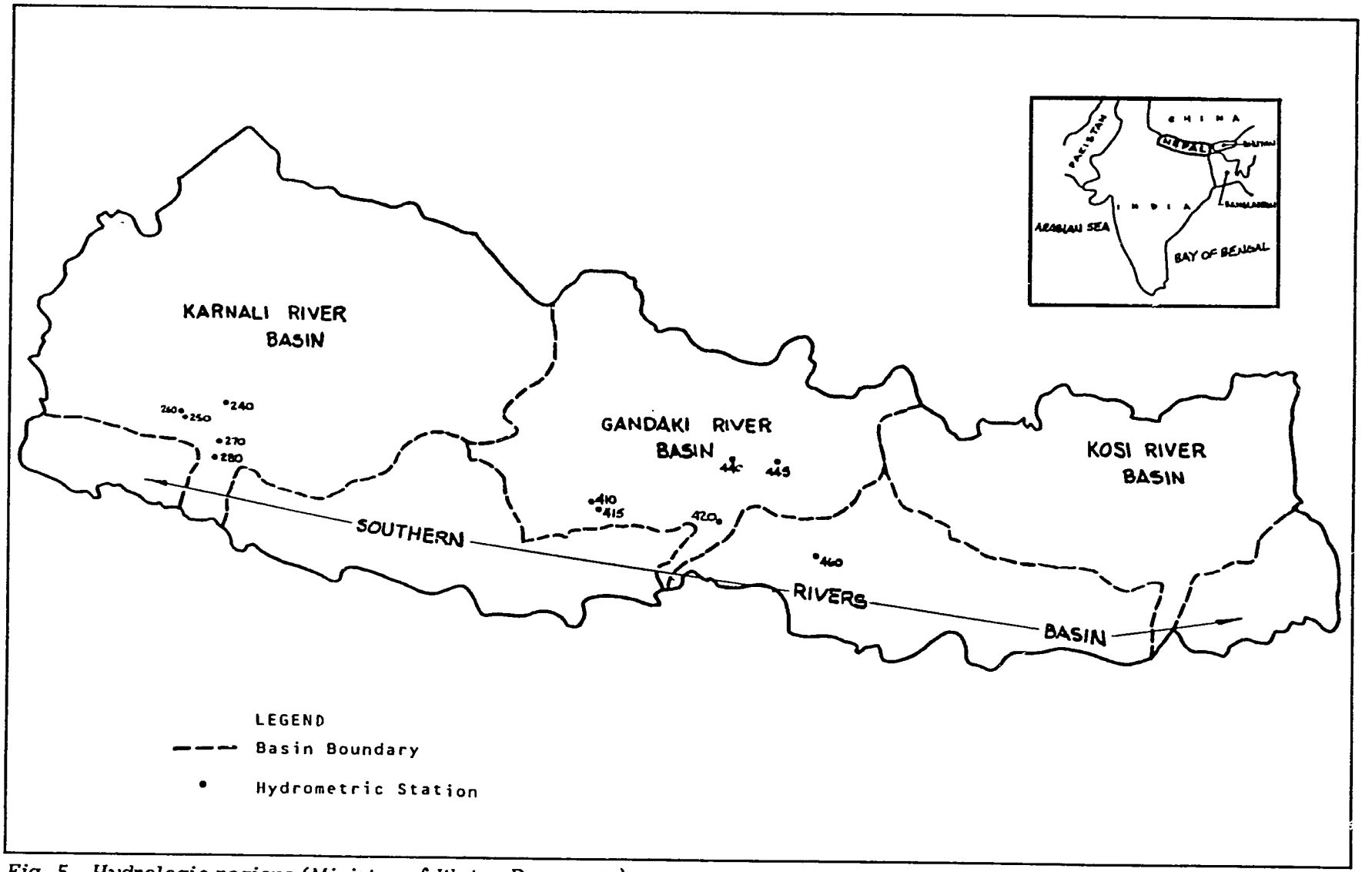


Fig. 5. Hydrologic regions (Ministry of Water Resources).

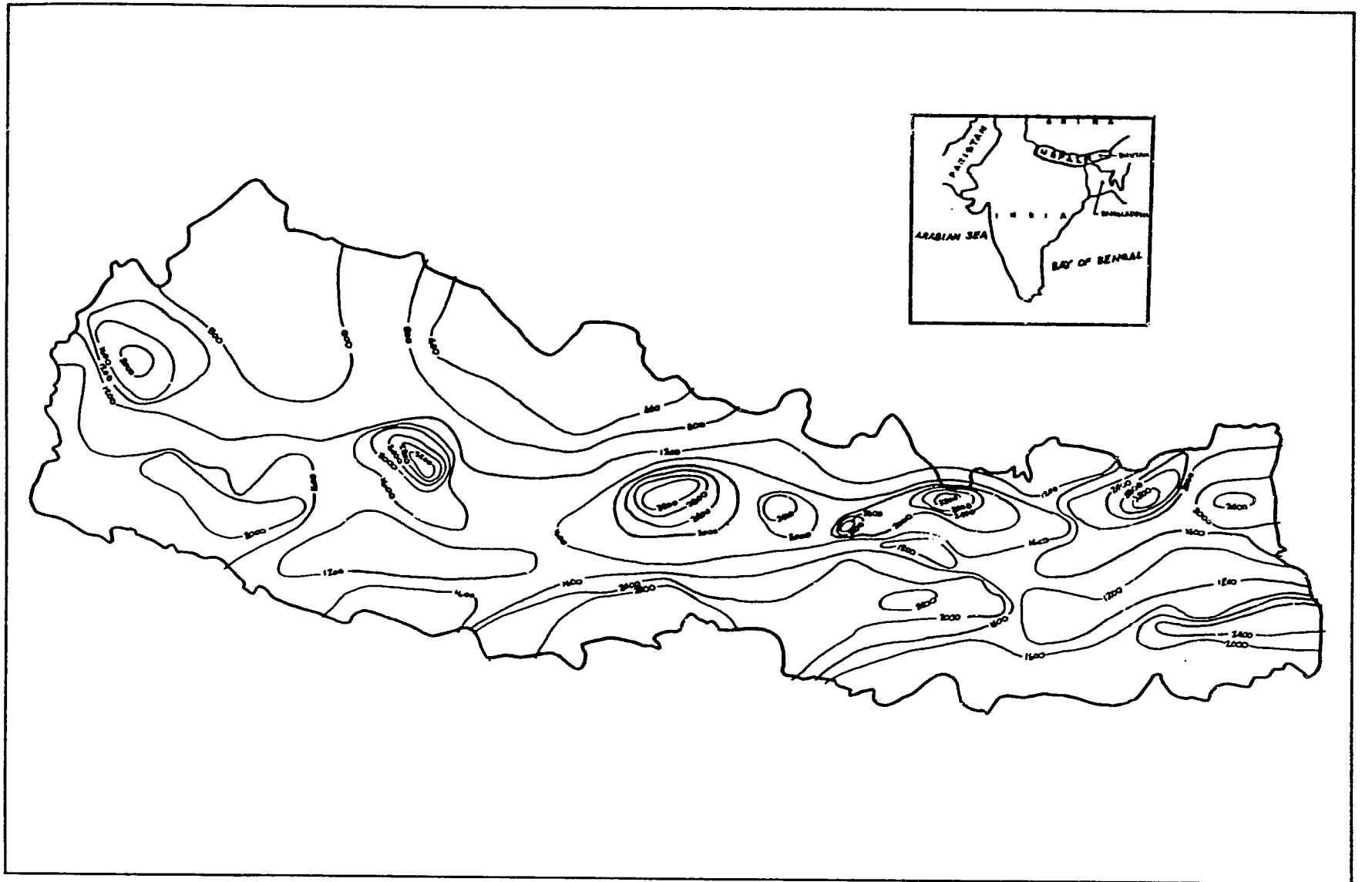


Fig. 6. Map of mean annual precipitation (Ministry of Water Resources).

Appendix C: Preliminary analysis of hydrologic data

The most comprehensive analysis of hydrologic data in Nepal that has been examined is the report entitled Hydrological Studies of Nepal prepared by the Water and Energy Commission, Ministry of Water Resources, March 1982, with Canadian assistance. This report contains some problems that cast some doubt on the validity of the methods contained therein when used to predict runoff in ungauged basins.

The report uses data from different hydrologic stations that cover different periods—data that are not concomitant. The report treats all data as being of equal accuracy and averages good data with poor and short-term data with long-term. Because the accuracy of the data may vary from ±10% up to ±30% or more there is no way to ascertain whether differences are real or not. The data could be improved by adjusting records to the same concomitant period and by extending short-term records using standard techniques.

However, further statistical analysis of such short-term records is only of limited use. Furthermore, there is a great risk of compounding the problem of predicting runoff from ungauged basins when one uses statistical techniques that are founded on unsound methods applied to inaccurate data.

It is essential that the data base be improved, that only sound statistical methods be applied to the data, and that comprehensive aquifer-streamflow relationships be studed in selected basins.

During the February 1984 team visit to Nepal, the hydrologist with the team spent several days analyzing hydrologic records of Nepal. The purpose of this analysis was to determine if the data indicated any short cut method for estimating flow in ungauged basins.

Several criteria were set as controls for this brief analysis. These were:

- The only hydrologic data that should be used in the analysis are data rated as "good". Such data are considered accurate to within ±10% by most of the persons interviewed in Nepal, although there were a few comments indicating that the error may be greater than 10%.

- Records must be of at least 10 years in length and all records utilized should cover the same 10 year period.

- Records selected for analysis should cover a range of drainage basin sizes.

- Prediction techniques devised should require only the drainage area of the ungauged basin as the independent variable.

These criteria led to the selection of 11 drainage basins with 11 years of concomitant data and with basins that ranged in size from 308-42,890 km^2. The basins were distributed as follows:

- 5 in the Karnali region;
- 5 in the Gandaki region; and
- 1 in the southern rivers region.

There were no records found that met the criteria from the Saptkosi region.

The first analysis considered low flow. The first parameter selected for estimation was 3Q10—the lowest mean 3-consecutive-day flow with a recurrence of 10 years. This parameter was selected arbitrarily as a reasonably good and conservative flow for those hydroelectric stations designed on a low-flow basis. Any other similar parameter, such as 7Q10 or 3Q5, could be selected for a similar analysis.

First, the mean annual three-day low flow and the standard deviation were calculated for each basin using all years of record (Table 1). The 3-day low-flow values were put in specific discharge terms (units of flow per unit area). These values were then plotted on log-normal paper and the 10-year return points were read from the log-normal relationship for each basin analyzed. These 10-year return values were plotted on log-log paper against drainage area and the envelope curves were constructed for the data points (Figure 7). In this case, the most conservative envelope curve is the one that would predict the lowest 3Q10. That envelope curve was a vertical line with an intercept of 0.0033 $m^3/s/km^2$. By applying this curve, the 3Q10 of an ungauged drainage basin (in m^3/s) might be conservatively estimated by multiplying the drainage area (in km^2) times 0.0033 (data and graphs are shown in the Appendix C).

Table 1. Three-day low flow data—all years of record

Basin number	Basin area (km^2)	3Q10 (m^3/s)	Specific 3Q10 ($m^3/s/km^2$)	Standard deviation	Specific standard deviation (km^{-2})	10% recurrent value
240	19260	103.1	0.0054	17.82	0.00092	0.0043
250	21240	125.2	0.0059	13.61	0.00064	0.0052
260	7460	57.6	0.0077	11.02	0.0015	0.0059
270	12290	75.2	0.0061	9.23	0.00075	0.0053
280	42890	300.9	0.0070	43.66	0.0010	0.0058
410	6630	29.8	0.0045	6.81	0.0010	0.0033
415	476	2.0	0.0042	0.42	0.00088	0.0033
420	11400	66.2	0.0058	16.21	0.0014	0.0042
440	308	3.0	0.0097	0.56	0.0018	0.0076
445	4270	27.8	0.0065	5.42	0.0013	0.0050

The next analysis was based upon the record values of low flow for those basins studied. First, the records were searched for the lowest 3-day flow in the record for each basin—the extreme value. These extreme values for each basin were converted to specific units (flow per unit area) and are shown in Table 2. These values were plotted on log-log paper and envelope curves were developed for the data points (Figure 8). The equation of the conservative envelope curve produced the following predictive relationship:

3Q record = the lowest 3-day flow during the 11-year period of record studied

$$= (0.0006436\ A^{0.175})\ A$$

A = area of drainage basin (km^2)

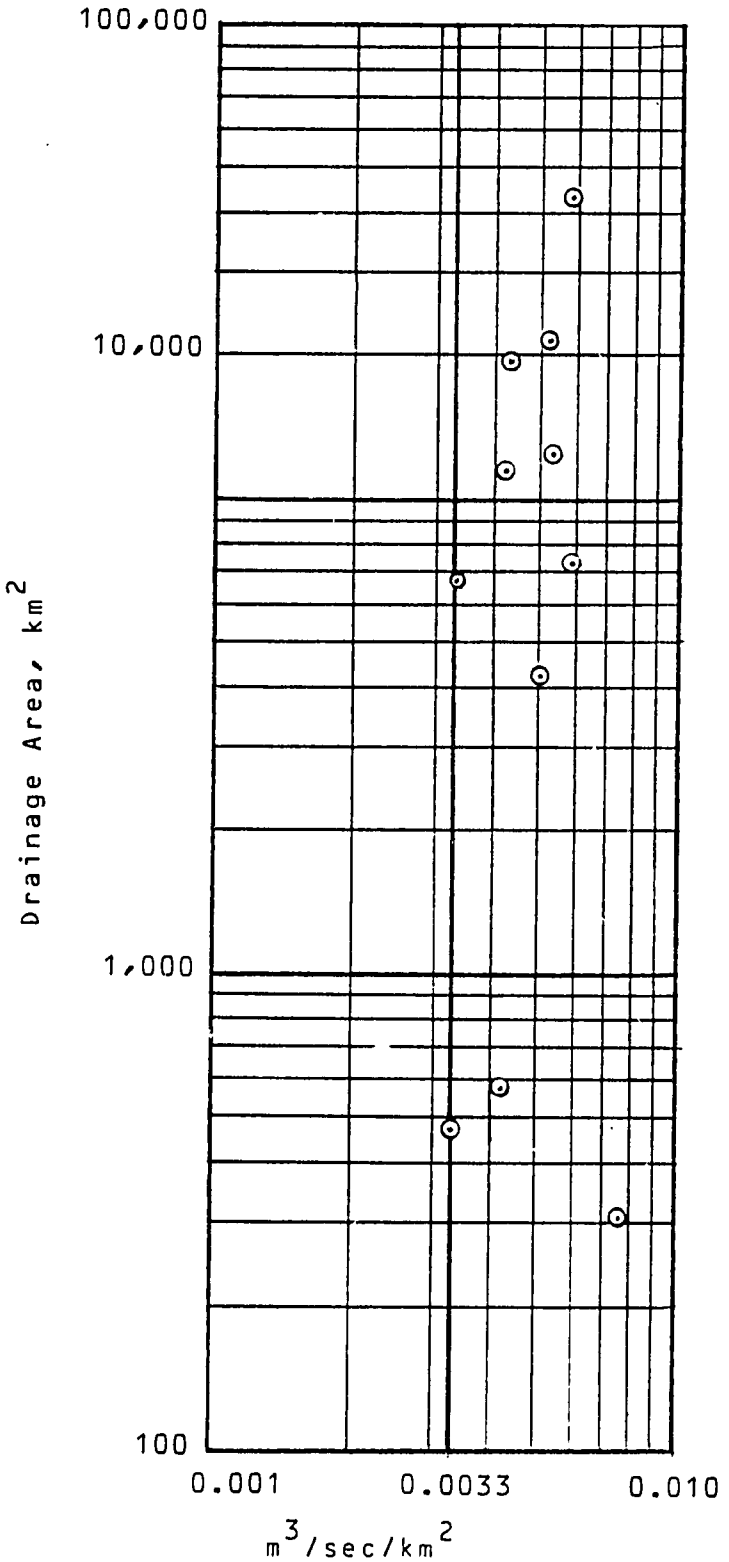
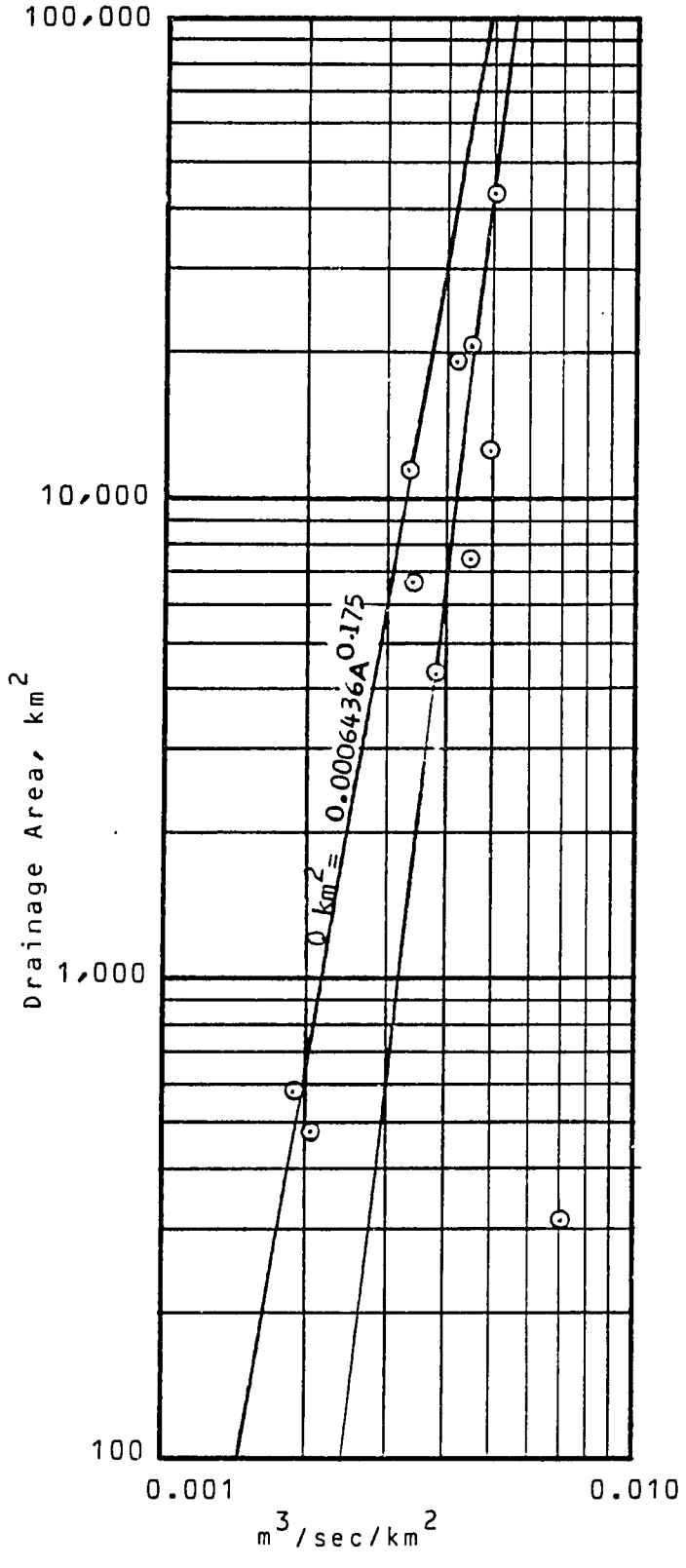


Fig. 7. Drainage area vs. specific 3Q10 for all basins.



The minimum flow is the mean three-day low flow based upon all gauging station records in Nepal that have an accuracy rating of "good" and a continuous record of daily flows from 1965-75 inclusive (with three nonsignificant exceptions). This is based on extreme values.

Fig. 8. Regression of flow on drainage area to obtain the minimum flow per square kilometer.

Table 2. Extreme values—3-day low flow, 1965-75 inclusive

Basin number	1-day low (m^3/s)	Drainage area (km^2)	Specific Yield
240	83.9	19,260	0.0044
250	95.0	21,240	0.0045
260	33.7	7,460	0.0045
270	60.1	12,290	0.0049
280	214.0	42,890	0.0050
410	22.5	6,630	0.0034
415	1.0	476	0.0021
420	38.0	11,400	0.0033
440	2.2	308	0.0071
445	16.1	4,270	0.0038
460	1.1	579	0.0019

A prediction formula for estimating the 100-year flood in ungauged basins was developed in a similar fashion. Flood frequency curves were developed for each basin. The 100-year flood was converted to specific units, and the specific units were plotted against drainage basin area. (Figure 9) In this case, the conservative envelope curve was the curve producing the highest estimate. The formula for this conservative envelope is as follows:

$$Q100 = 20\ A^{-0.2575}$$

in which

Q100 = the instantaneous peak rate of flow of the 100-year flood (m^3/s)
A = drainage basin area (km^2).

It was also found that Q50 = 0.86 Q100.

These methods for estimating flows in ungauged basins were compared with data from other sources. These comparisons are shown below. All values of Q are in m^3/s.

Khandbari (121 km^2)

3Q10 = 0.42	Chinese consulting firm
Min. monthly = 0.465	Chinese consulting firm
3Q10 = 0.71	Water and Energy Commission
3Q10 = 0.40	this report
3Q record = 0.18	this report
Design flood = 718	Chinese consulting firm
Q100 = 704	this report
Q100 = 605	this report

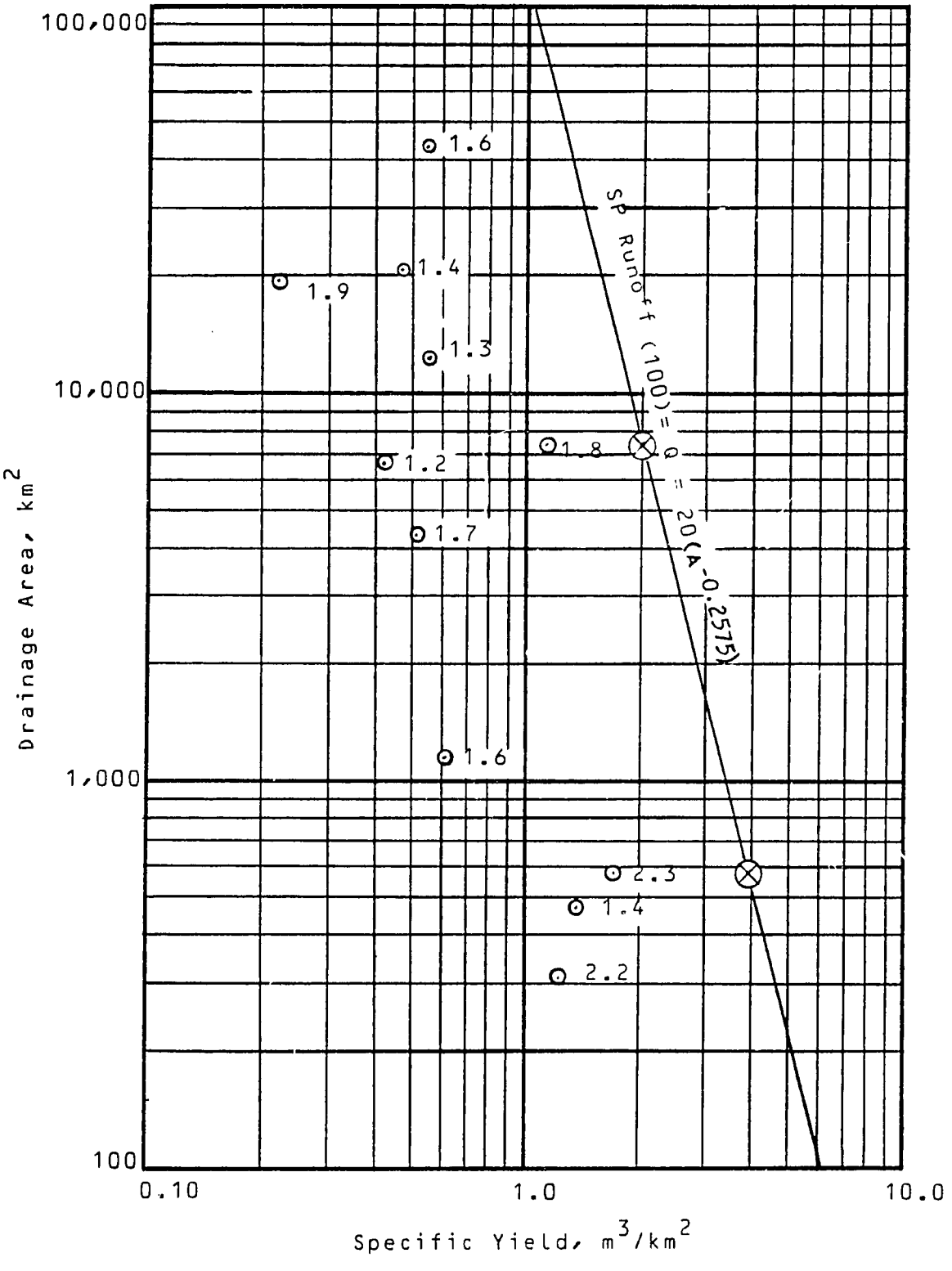


Fig. 9. Specific Q100 for eleven river basins in Nepal. The curve is conservatively the high envelope of all values.

Dandeldhura—Satkata Khola (28.9 km^2)

Minimum Q = 0.087	Norwegian firm
3Q10 = 0.095	this report
Design flood = 170	Norwegian firm
Q100 = 243	this report

Dandeldhura—Ghatal Khola (64.6 km^2)

Minimum Q = 0.033	Norwegian firm
3Q10 = 0.21	this report
Design flood = 200	Norwegian firm
Q100 = 441	this report

Ghogsila Khola (15.6 km^2)

Minimum flow = 0.08	Nepali consulting firm
Design flow = 0.10	Nepali consulting firm
3Q10 = 0.05	this report
Design flood = 245	Nepali consulting firm
Q100 = 154	this report

Surkhet (49 km^2)

Minimum flow = 0.0272	German consulting firm
3Q10 = 0.16	this report
Design flood = 200	German consulting firm
Q100 = 360	this report

Kagbeni (86 km^2)

Minimum Flow = 0.700	Nepal consulting firm
3Q10 = 0.30	This report
Design Flood = 72	Nepal consulting firm
Q100 = 546	This report

Several other predictive methods were tried without success. These analyses resulted in several conclusions as follows.

There is very little to be gained by an intensive statistical analysis of the hydrologic data of Nepal. The data are too inaccurate and short-term to place any great reliability on sophisticated statistical techniques. When the approximately 8 years of gauge readings now archived are reduced to useable form, the data base will be much stronger and will warrant more elaborate statistical analysis. At this point the data rated "good" and possibly the data rated "fair" should be analyzed using routine statistical methods with the goal of refining the prediction methods attempted herein.

Drainage areas of less than 100 km^2 are highly unpredictable and variable and estimates of flow should be made with extreme caution.

Flash flooding due to land slide dams, especially during the monsoon, makes flood prediction difficult. This is particularly true in the smaller drainage areas. According to the records examined, some of these debris dam floods are several times the 100-year flood.

It is most likely that hydroelectric stations that are not connected to the grid will be designed on the basis of low flow. 3Q10 is a low flow which probably occurs for a few hours or a day or two each year. Any other low-flow parameter could be designed for in order to meet whatever flow reliability is required by the hydroelectric station under design.

Probably not much low-flow information can be gleaned from the data. Geomorphological studies of selected basins are required in order to understand relationships between low flow and such basin characteristics as aquifer-streamflow relationships.

Appendix D: Possible short-term assistance efforts

Among the needs of the SHDB are that of (1) carrying out a solid planning process and (2) developing materials and a strategy for local activities which are directed at increasing system load factors. There are a variety of ways to approach the provision of consultant services to help the SHDB. This depends mainly upon the particular mix of skills that the consultant who is assigned these tasks possesses. It is conceivable that one person could carry out the complete scope of work listed below. However, they have been separated since it may be easier to find two separate individuals. Moreover, the duration of the total time and the possibility of staggering their presence also probably lends itself to using two people.

Scope of work for assistance in organizational planning and development

Objective:
To carry out, with SHDB senior staff, a goal and objective clarification process and then develop a broad plan of action directed toward achievement of those goals and objectives.

Tasks:

- Carry out a review of all planning literature written by SHDB and of all enabling government documents.
- Facilitate a series of meetings with SHDB staff which clarify the goals and objectives of the organization.
- Provide a written identification and short analysis of the main problems which SHDB must resolve in order to achieve its objectives.
- Review, with SHDB staff, the current responsibilities of various units and offices within SHDB with the aim of suggesting possible changes. This should relate specifically to duplication of effort between regional and central offices and to the establishment of organizational structures to address the extension issue.
- Work with SHDB to develop the outline of a long-term general plan.
- Work with SHDB staff to develop a written, specific plan for addressing the most current high-priority problems that SHDB must resolve.
- Outline, in detail, the staffing responsibilities and operational plan for an extension unit in the central office, at the regional level and at local sites.
- Establish linkages with organizations which SHDB deems to be appropriate for inter-agency coordination.
- Prepare a plan for formalizing inter-agency coordination and cooperation.
- Help SHDB staff determine individual job descriptions and the responsibilities of each administrative unit.

The duration of this exercise should be from six to eight weeks, in-country. The consultant should be an experienced organizational planner and should also have

some background in energy issues or in rural extension. The consultant should have as his counterpart either a newly appointed energy planner or the deputy director of SHDB. End products of the visit would include:

- short analysis of main organizational problems,
- outline of a long-term plan,
- specific plans for adressing most pressing SHDB problems, and
- final report covering all aspects of scope of work.

Scope of work for assistance in energy extension and end-use specialist

Objective:

To aid SHDB in developing materials and information for promotion of electricity usage at the local level and to initiate promotional activities in at least two site areas already in operation.

Tasks:

- Review previous end-use survey work, load patterns and current electrical usage in rural areas of Nepal. In cooperation with the SHDB working group,* identify the most promising end-use possibilities and put these within an appropriate Nepalese regional/geographic division.

- In cooperation with SHDB and other agencies, develop a basic set of resource information on both these activities and their configuration of electrical usage, including electro-mechanical equipment.

- Pull together descriptions of all programs by important agencies and organizations working in rural Nepal and areas where SHDB is, or shortly will be, active.

- In cooperation with appropriate agencies, obtain or prepare information on finance possibilities for local people.

- Prepare an updated, improved and concise survey to be used both for feasibility and for post-construction studies. In cooperation with appropriate members of the working group, survey possible activities for two SHDB sites areas. In cooperation with SHDB staff, prepare a written plan for each of these two areas.

- In cooperation with SHDB staff, prepare concrete and workable plans for promotional and extension activities in SHDB.

- Prepare a training plan for the extension unit.

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*SHDB will also have to designate who, within SHDB, will make up the working group and, based on the previous planning work that has been done, identify and obtain involvement of an individual, or individuals, from the relevant ministries and organizations. The group should be small and, probably, have not more than six people.

- Establish load-related site selection criteria that is adapted for any regional differences which need to be indicated.

Duration of this consultancy would be eight weeks. If at all possible, SHDB should attempt to collect as much of the material required beforehand as is possible. Ideally, this activity should follow right behind, or overlap with, the planning activity. Outputs of this effort would be:

- information organized and present at SHDB on local end-use possibilities and financing;
- improved survey;
- plans for extension units' promotional activities and applied to two currently operating sites; and
- final report on all activities in scope of work.

Scope of work for assistance for training in hydrology, data collection and analysis

Objective:

To assist the SHDB in developing a field program that would lead to better prediction techniques in ungauged drainage areas and to work with the SHDB staff in carrying out a training workshop in hydrology and one in data collection.

Tasks:

- Organize and initiate a practical field program of geomorphic data collection in several typical small drainage areas in Nepal.
- Develop the procedures and process for collecting and applying the geomorphic data to low-flow prediction in ungauged watersheds.
- In cooperation with SHDB staff, develop a curriculum and organize a training workshop on applications of hydrologic techniques to drainage basins in Nepal with the goal of improving SHDB staff understanding of hydrologic phenomena.
- In cooperation with SHDB staff, develop and organize a training workshop on the techniques of data collection and hydrographic measurement with the goal of improving the understanding of proven field techniques for the acquisition of accurate data.