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SMALL HYDROPOWER PLANTS (SHP) PROJECT

REPORTS

by Eric Bernhardt, UNIDO Consultant

29 September 1989

I. Techno-economic analysis of the viability of the Ethiopian proposal

II. Analysis of the different proposals from the selected countries

III. Supporting document

IV. Model procedures to be used and data to be collected for the SHP schemes being considered

29 September 1989

TECHNO-ECONOMIC ANALYSIS OF THE VIABILITY OF THE ETHIOPIAN PROPOSAL

by Eric Bernhardt
Consultant

1. Summary

Careful study of the Ethiopian proposal was carried out by the Consultant. It consists of two documents i.e. a feasibility study (dated April 1989) and a project proposal (dated June 1980).

The Ethiopian intentions i.e. the implementation of a SHP scheme which would be a training ground to enhance efficient transfer of know-how for national and regional development agree well with the following immediate objectives i.e.:

- establishment of SHP standardized prototypes
- minimum design costs
- development of local engineering capabilities
- promotion of regional and interregional co-operation

From the technical point of view the SHP (Achani project) proposed by the Ethiopian authorities - subject to some constraints which will be commented furtheron - would be a very suitable object to test the effectiveness and quality of the measures proposed in the UNIDO document.: Report on standardization of civil works for SHP (February 1989).

The situation in regard to the electro-mechanical part of the plant is - as had been expected - less significant, the relation between foreign and local components being about 3.3. to 1.

From the financial point of view the Ethiopian authorities expect a foreign component - owing to the relatively high capacity of the SHP proposed - of some 4.5 million US$ to be donated.

Finally, it should be emphasized that the proposed SHP responds to the needs of a particular area of Ethiopia and that compared to other methods of power supply, diesel generation and transmission from a grid system, it provides energy at the lowest cost.

2. Detailed analysis

2.1. Introduction

The following terms will be used:

"Achani Study"	for the Achani feasibility and the project proposal
"EWI Report"	for the Electrowatt Engineering Report on Standardisation of Civil Work for SHP
"SHP"	for Small hydroelectric plants

2.2. General remarks

- The Achani Scheme is a relatively large SHP with correspondingly high investment costs (about 9 million US$). This figure is however consistent with those of similar plants.

- Technically the Achani Scheme is a high head but run off river plant. It includes also a limited pondage for meeting the daily peak load, the pondage being obtained by a structure consisting of an earth-filled dam and spillway at the water intake.

- The characteristics of the plant (output, head) preclude the use of a cross-flow turbine. Pelton turbines will be used. Local fabrication of the generating equipment cannot be considered in this case. Standardization is therefore to be concentrated on the civil works.

2.3. Detailed analysis and observations in relation to the "applicability" of the EWI Report for the Achani Scheme

2.3.1. Topographic Survey Chapter 5 of the Achani Study
Chapter 3 of EWI's Report

Whereas the general maps of the site appear to be available in particular a 1:50.000 map with 20 m contour intervals, the 1:10.000 scale maps appear to be based on an aerial survey taken in 1967, said to be inaccurate.

There would be the necessity of re-working and correcting the now available topographic data in accordance with EWI's report.

UNIDO will recollect that EWI have repeatedly emphasized the importance of an accurate topography within the limits set in their chapter 3.3.

2.3.2. Geology   Chapter 4 of the Achani Study
                  Chapter 4 of the EWI Report

Chapter 4 of the Achani Study contains detailed information; it fulfills generally the requirements of chapter 4 of EWI's report. The conclusion reached that: "Generally from the geological and geotechnical points of view the conceived development is considered to be technically feasible" appears well founded. However, if Achani is being implemented a more detailed review of geology would be indicated; proposals to this effect are indicated in paragraph 4.7 (Recommendations for future investigation program) of the Achani Study. These recommendations are generally also in accordance with those made in the EWI Report.

2.3.3. Hydrology   Chapter 2 of the Achani Study
                    Chapter 5 of the EWI Report

Actual discharge measurements were apparently only started in 1988 and suitably compiled (see page 2.8 in which the data compiled are in accordance with EWI's report).

It can be said that the hydrological data available in the Achani Study is considerable and carefully completed; nothing which might be required in EWI's Report is missing, quite to the contrary. Normal and flood conditions have been thoroughly examined. Comparisons with neighbouring catchment and run-off areas (Gojeb) are taken into account; this was all the more necessary owing to the short time since Achani run-off gauging has been carried out. The problem of sediments appears to be minimal, thus eliminating the desilting arrangements repeatedly advocated in the EWI Report. Ecology and Security (failure of dam structure) problems have been touched albeit lightly in the Achani Study.

The Achani Study (paragraph 2.12) makes a number of recommendations to which one can subscribe i.e.

- One additional gauging station (below crater lake) to be installed
- Improvement in regard to the installation of the existing gauging station in the Achani and Beko river
- Obtention of more meteorological data
- Taking into account the water requirements of a new coffee plantation located at crater lake

2.3.4. Capacity and Energy Computations Chapter 3 of the Achani Study
Chapter 5.5. of the EWI Report

The Achani Study ascertained that the plant based on the available dry season flow would only supply part of the demand (1,5 MW), but that this would suffice to take care of future supply to the two main load centers up to the year 2009, with certain limitations which would involve some "load management" measures. The plant would operate in an "island" system with some already installed limited diesel generating capacity (135 KW).

2.3.5. Water intake Paragraphs 6.1.3., 6.1.4., 6.1.5., 6.1.6. of the Achani Study
Chapter 6.2. of the EWI Report

There is a considerable difference between water intake conditions as foreseen in EWI's report and the Achani Study. EWI's report makes a very clear distinction between intakes for a run off the river generally low head plants and drop intakes (high head plants). The Achani scheme however combines a run off the river intake with a high head plant. Furthermore, on account of the necessity for a daily pondage during the period of dry season flow, the Achani intake structure consists not only of a weir with sluice (EWI) but of a dam with spillway. Although EWI's Report does mention "a weir or a small dam across the river" at the intake works, such a structure could not be the subject of standardization; its design and construction would vary very much from one plant to another. Sedimentation which was taken care of below the weir in EWI's report, now takes place in the reservoir which is formed upsteam of the dam-structure. No drop intake is therefore required for the high head Achani plant.

The reasons that have motivated the arrangement of the water intake as described in the Achani Study are evidently correct mainly on account of the Tepi area load conditions; the dam will obviously increase somewhat the total investment. If the Achani Scheme is implemented, the dam and spillway forming the water intake may have to be considered, designed and realized as a separate and additional part of the scheme.

2.3.6. Desilting Basin Chapter 7 of the EWI Report

EWI's chapter dealing with a desilting basin is no longer relevant as sedimentation is being dealt with by the reservoir (see 2.3.5. above).

2.3.7. Adduction canal

There is obviously a similitude between EWI's adduction canal and the head race of the Achani Study. The water velocities specified in the feasibility report agree generally with those of the EWI report. There are some differences in the design of the proposed canals; Fig. 8.2. for $Q = 1.0\ m^3/s$ of EWI's report shows a somewhat different solution to the one selected for Achani, however both designs emphasize the fact that manual labour - and not machinery - would be used during construction.

2.3.8. Forebay

In principle the Forbebays foreseen for Achani and those described in EWI's Report are based on very similar lines.

2.3.9. Penstock Paragraphs 6.1.9 of Achani Study
Chapter 10 of EWI's Report

EWI's Report goes into details in regard to the design of the penstock. It would appear however that there is concordance of views on the main dimensions and design. Both advocate a penstock above ground. It is noted however that for Achani no calculations have been carried out for water hammer stress. Also very little information is available on joints and anchors.

This item should be re-worked on the basis of EWI's report.

2.3.10 Surge Tank Chapter II EWI's Report

At Achani no provision for a surge tank has been made. As the adduction canal is not under pressure there would be no necessity on this account to include a surge tank. On the other hand the maximum head being above the value indicated in EWI's Report i.e. 150 m (220 m) the question whether a surge tank is required or not should be looked into.

2.3.11. Power House Chapter 6.1.11. of Achani Study
Chapter 12 of EWI's Report

No particular remarks are required. The Achani design appears simple and adequate. Some savings might be effected by reviewing its design in the light of EWI's Report.

2.4. Mechanical/Electrical equipment Chapter 6 of Achani Study

Chapter 6 of the Achani Study concerns itself with the mechanical/electrical equipment. EWI's Report is not concerned with those parts. It is noted however that part of the required equipment (about 25-30%) could be obtained from local suppliers. The fact that a cross-flow turbine, which is eminently suitable for local manufacture, cannot be used for Achani has already been mentioned above (see 2.2. General remarks)

3. Financial situation[1/]

It is one of the prominent features of the Achani feasibility Study that it goes into details in relation to the economics of the scheme. This concerns two cardinal points i.e.

(a) which alternative power supply has the least cost
(b) whether the least cost solution is economically feasible.

1/ Note: There are sometimes some inconsistencies between the various figures given for investment and budget costs of the Achani Study. Some of them are listed in the Annex 1; eventuel corrections do not affect significantly the results. The may perhaps be corrected occasionally by EELPA.

3.1. Alternative Power Supply

It should first be noted that the authors of the economic study have expressed strong reservations in relation to the financial guidelines prescribed to them in accordance with Guidelines to Project Planning in Ethiopia issued in 1981 by the Development Projects Study Agency.

The feasibility document also mentions that those guidelines are being reviewed and changes are imminent. Should such changes take place it would be imperative that EELPA carries out the necessary corrections.

It would however appear to us that as the same criteria have been applied to the various alternatives for power supply in the Tepi area, the results of the analysis should "à défaut d'autre chose" be taken as valid, all the more so that - as the authors remark -, one of factors i.e. the undervaluation of foreign exchange applied now tends to favour import intensive schemes (transmission lines, diesel generator) to the detriment of relatively less import contents schemes as would be a SHP. In other words a revision of the foreign exchange guideline should favour even more the SHP.

In view of the thoroughness with which the economic study has been carried out we believe that, after careful consideration we should abide by their conclusions which are the following:

Discounted value of Kwhr in 1989		
Diesel generator	77.6	Cts/Kwhr
Transmission line		
Wushwush-Tepi	91.8	Cts/Kwhr
Achani River SHP	50.3	Cts/Kwhr

Although the authors have gone into further details relating mainly to the influence of the development of the load in the larger Tepi area, it would appear to us that the above figures are sufficiently significative to justify the installation of a SHP in preference to other modes of energy supply.

3.2. Financial analysis

This part of the Achani feasibility refers to the tarif to be charged to customers. It is calculated that the cost to a Tepi area consumer is 58.6. Cts/Kwhr. Assuming that the foreign part would be donated a theoretical consumer price of about 41 Cts/Kwhr would emerge which would correspond to the 40 Cts/Kwhr grid customers now pay, thus eliminating at least a large portion of Government's subsidy.

4. Conclusions and Recommendations

1. As will have been ascertained by the foregoing there are some few adaptations and additions to be considered if the Achani civil works are to be carried out as "standarized works" in accordance with the EWI Report. However, Achani is from the technical point of view a desirable scheme for a pilot model plant as envisaged by UNIDO.

2. It has been pointed out that the Achani scheme because of its relatively high output requires a significant amount of foreign currency in equipments and services until the plant is in operation, the Ethiopian Authorities being ready to provide the amounts required for local currency expenditure.

3. It is threfore suggested to proceed by steps as follows, the first step being:

1. The completion of the work mentioned under 1. above - in principie the complementation of the feasibility study - be part and parcel of the feasibility studies to be undertaken in accordance with UNIDO's intentions to further SHP in other African countries that had been selected as prospective candidates namely Kenya, Tanzania, Senegal, Guinea, Republique Centre Africaine, Gabon.

On completion of said feasibility stage the most favourable schemes can be selected and the further steps to be taken i.e. detailed design and realisation, can be decided upon.

From the point of view of making available finances from donor countries, it is felt that this step by step approach offers best advantages.

ANNEX I

The following lists some discrepancies of cost figures indicated in EELPA documents which are difficult to explain

1. Project proposal

Some errors of calculation appear to have been made in Annex VII. We believe the table should be revised as follows

Cost estimate design and construction

	Local Component Birr	Foreign Component US$	Foreign Component expressed in Birr at the rate of 2.07	Total Birr
Hydro-Power Plant	7.555.010	1.557.420	3.223.859	10.778.869
Expatriate Services		816.000	1.689.120	1.689.120
Expatriate Travel		32.000	66.240	66.240
Per diem (DSA in Eth.)	385.560			385.560
Construction equipment	400.000	1.952.500	4.041.675	4.441.675
Total	8.340.570	4.357.920	9.020.894	17.361.464

On the 1st page of the project proposal the total cost should therefore be amended to:

ETH 17.361.464
(Birr)

instead of ETH 16.613.789

2. **Feasibility study**

Page 1.2. indicates a total project cost of Birr 13.920.000

Page 6.26 Table 6.4.1. indicates a total project cost of Birr 10.140.150

US$ 2.496.660 .. Birr 5.168.086 Birr 15.308.236

Table 8.6. indicates a total project cost incl. transmission	=	Birr	15.282.000
the latter figure (Birr 15.282.00) taking into account inflation and interest during construction arrives at a project budget cumulated of		Birr	19.801.000

As is apparent from the above the US$ part is indicated as	US$	2.496.660
or in round figures	US$	2.497.000
(according to table 8.6.)		
If adjusted roughly for inflation and interest during construction the above US$ 2.497.000 become	US$	3.246.100
(Factor 1,3)		
This figure does not coincide with the figure of	US$	4.357.920
indicated in the project proposal		

It is suggested that the US$ discrepancy above be checked again by EELPA.

29 September 1989

ANALYSIS OF THE DIFFERENT PROPOSALS FROM THE SELECTED COUNTRIES

by Eric Bernhardt
Consultant

1. Summary

Seven African countries have expressed a lively interest for SHP involving a total of 18 possible projects. 2 of the projects are high head, 5 are medium head, 8 are low head, and the rest are unspecified. It is interesting to note that all projects proposed appear to be run off the river type including the high head Ethiopian plant. The proposed outputs all exceed 400 KW which means that the investment cost for the complete plant will be significant in local and foreign components. With the exception of the Ethiopian project, all others are very summarily described which means that the choice of a favourable location for applying the standardization being advocated cannot be made. Additional information must be asked for. It is suggested that arrangements are made to work out with the countries concerned the relevant feasibility studies. They need by no means be as elaborate as the Ethiopian feasibility. However it would be recommendable that with an expert consultant nominated by UNIDO, the reports be compiled with the help of the authorities concerned in the country itself. This procedure would also ensure a uniform interpretation and presentation of the results; imperative is also the necessity for the expert consultant to visit the site.

2. Details

The various proposed schemes are indicated on Table 1. The following comments will apply:

2.1. Ethiopia Achani Scheme 3 x 500 KW

In the separate document: Techno-economic analysis, it has been concluded that this scheme would be valid for the application of standardization of civil works and to serve as a model plant. For more details further references should be made to this document.

2.2. Kenya

The Ministry of Regional Development has proposed 2 sites. The lake Basin Development Authority which comes under the above Ministry, would be directly responsible.

From the very spare information received (letter of 16 August 1989), it can be deduced that both plants, AWACH A and AWACH B are run off the river plants

For AWACH A which in accordance with the flow and head indicated a plant output of some 830 KW is obtainable, the Ministry indicated a possible installed capacity of 1000 to 2000. Either the plant is overdimensioned or the actual hourly/daily/seasonal flows above the annual mean discharge can be made use for power generation (secondary capacity).

The same considerations apply to AWACH B where for the flow and head indicated a plant output of 1000 KW would be obtainable.

2.3. Tanzania

The Permanent Secretary of the Ministry of Regional Development has indicated 8 possible sites with installed capacities between 450 and 7600(!) KW, however, with no other details. It would appear that an immediate elimination of the higher output plants would be advisable. Malagarasi with a plant capacity of 7600 KW is unlikely to be suitable in view of the financial constraints imposed upon the eventual donors; it is anyhow at the top capacity limit for SHP's.

2.4. Senegal

The Ministre du development industriel et de l'artisanat has indicated one site with a capacity of 628 KW. On the basis of flow discharge and head about 570 KW would be obtainable. The yearly production of 1,33 GWHr. would correspond to a mean hourly output of some 152 KW. A question that may be asked: Would the plant only run part-time?

2.5. République Centre-Africaine

4 sites are indicated by the PNUD Representative Resident.
A list of sites and main data are given in the table below:

Station	KWinst	Qm^3sec	Hm	KW producible	Yearly production GWhr.	Continuous output corresp. to yearly prod.
Carnot	600	1.5	32	400	2.17	247
Kaga Bandoro	400	13.5	10	1112(?)	1.48	169(?)
Bambari	1000	5	10.5	437	3.94	450(?)
Kombé	500	4.47	14	521	1.74	199

There seem to be some contradictions in the above figures, for Bambari and Kaga Bandoro in particular.

2.6. Guinée-Conakry

The Ministre de l'Economie et des Finances, via the PNUD Représentant Resident has indicated two sites:

Only installed capacity, water volum and head are indicated.

The figures indicated are consistent.

2.7. Gabon

The Chef du Reseau Francophone, Direction Générale Energie/Resources Hydrauliques has expressed Gabon's lively interest. Enquiries are being made in regard to likely sites.

3. Conclusions

The replies received from all countries show that there is considerable interest in realising standard SHP.

Whereas Ethiopia has submitted very detailed and valuable data, the countries' replies are rudimentary and do not permit decisions to be taken as to which "standardized" plant or plants should be selected in which country. It is likely that only one installation could accomodate a cross-flow type turbine which as said elsewhere is particularly suitable for local manufacturing.

From the above comments it will be clear that apart from Ethiopia, the information provided, notwithstanding the great interest showed, is insufficient; it would not permit decisions to be taken, especially financial ones. Decisions will only be possible when the schemes proposed are more thoroughly examined for their technical and financial implications; in other words feasibility studies are to be undertaken which will give UNIDO and donor countries a solid basis on which decisions can be taken.

In order that these feasibility studies are consistent and comparable it is recommended that they be carried out by a correspondingly qualified and experienced consultant and expert in the matter. The studies would be undertaken in the relevant countries with the help the of local authorities.

Encl.: Table 1

Table 1

Country	Location	Authority dealing with the project	Capacity KW	Qm^3/S	h_m	GWhr.	Studies available	Comments
Ethiopia	Achani	E El. Light + Authority	3x500	3x.26	220	6.3GWhr.firm 6.34GWhr. secondary	Detailed Feasibility Project Proposal	Owing to high output may be difficult to finance. A number of technical features and requirements deviate from the EWI Report content, however, a good case for a model plant. Government finances local details
Kenya	AWACH 1	Ministry of Regional Development	1000-2000	4	25		-	no details
"	AWACH 2	"	1400-2000	4	30		-	-
Tanzania	Piyine	Tenesco	450	?	?		not available	details and map promised shortly
"	Njombe F (Ruhudji R)	"	2000	?	?		"	"
"	Kifunga F (Ruhudji R)	"	3600	?	?		"	"
"	Kasongenye R	"	840	?	?		"	"
"	Kaonjuba (Kamwana R)	"	800	?	?		"	"
"	Malagarasi	"	7600	?	?		"	"
"	Luamei R	"	1200	?	?		"	"
"	Sunda F (Ruvuma R)	"	3000	?	?		"	"

Country	Location	Authority dealing with the project	Capacity KW	Qm^3/S	h_m	GWhr.	Studies available	Comments
Senegal	Yerongueto (Thiokoye R)	Ministère du Developpement Industriel et de l'artinasat	628	3.4-4	20	1.33	?	Expect data from UNIDO finance local part other sites also possible
Rep. Centre Afrique	Carnot	PNUD Representative(?)	600	1,5	32	2.17	?	Cost calculated 952.10^6CFA= $2.64.10^6$US$ 4400 US$/KW
"	Kaga-Bandoro	"	400	13,5	10	1.48	?	cost calculated 777.10^6CFA= $2.16.10^6$US$ 5400US$/KW
	Bambari	"	1000	5	10,5	3.94	?	Diesel req.during dry periods, cost calcul. 1936.10^6CFA= $5,38.10^6$US$ 5380US$/KW
	Kombé	"	500	4.47	14	1.74	?	Cost calculated 568.10^6= $1.58.10^6$US$ 3160US$/KW
Guinée	Kérourané	Ministère de l'Economie et des Finances	1100-1282	4.23	46	?	?	run of the river type
	Siteede Bagata (Kioma R)		700-900	1,5(?)	80	?	?	"
Gabon	no information	Direction Générale Energie/Resources Hydrauliques		no information				

29 September 1989

SUPPORTING DOCUMENT

by Eric Bernhardt
Consultant

1. INTRODUCTION

The present document dealing with the standardisation of civil works for small hydropower plants represents an abridged version of the Report compiled for UNIDO by their Consultants Electrowatt Engineering Services.

UNIDO's aim was to collect and develop in a simple form the data and information required to enable developing countries to provide electric power in remote and isolated areas, utilizing as far as possible their own resources.

Recognizing that the main problems impeding the development of such plants are, on the one hand the lack of simple generally applicable procedures and methods of realization and on the other hand, the disproportion between design costs and total cost of the installed plants, a serious effort has been undertaken to standardize the design and the main components of such plants.

Whereas the standardisation of the mechanical and electrical components is relatively easy (it is not dealt with in the Report) standard designs for the civil construction have been more difficult to develop. Nevertheless the Report based on considerable experience, represents an important step forward by providing developing countries with designs simple to realise, simplified data and practical calculation methods.

Standardization of small hydroelectric plants for countries in which a potential for such installations exists, brings about a number of advantages, the most important ones being:

- savings in non-renewable energy sources
- easier and simplified realization

- minimum design costs
- realization by local and possible less highly trained personnel
- maximizing the use of locally obtained components (civil, mechnanical and electrical
- enabling technological transfer
- reducing expenditure of foreign currency, in particular in relation to import of combustibles
- encouraging local manufacture and contracting

2. SUMMARY

The Report, and therefore the present document are subdivided in 3 main parts.

The first deals with the more general subjects of hydro-electric generation i.e. topography, geology, hydrology and power analysis: it aims at giving a suitable background to the entire subject, by defining the terms used and - this is the point of importance - to provide the "philosophy" with which a project can be handled correctly and efficiently right from its inception.

The second part deals with more specific matters, namely the main components of the plant such as water intake, desilting plant, forebay, penstock, surge tank and power house.

Finally the third part contains lay-outs, details of construction, legends and explanations culled from practical examples i.e. from realised plants. They cover the range generally understood for small hydro-electric plants.

We now turn to the details.

3. GENERAL CONSIDERATIONS

3.1. Topography

Without carefully carried out topographic preparations, a considerable risk of failure - or at least of difficult execution and unsatisfactory operation of the plant - would be taken.

The Report clearly states the requirements of an adequate survey, their correct interpretation and clear compilation of its results; it lists the data and information (for instance maps) required, specifies the methods of control and the accuracy required from the survey work; in short what the surveyor has to produce.

3.2. Geology

Another determining factor, contributing to the success or failure of a particular SHP project is the availability of sufficient geological information. The Report's relevant chapter deals with the necessary consecutive steps to be taken i.e. the desk study, the reconnaisance, the detailed site investigation, the follow-up during construction. In the fulfilment of the geological task no cost limitation, no shortcuts should be permissible. The Report lists the activities of the desk study; they are mainly based on the integration and interpretation of the results of the topographic study. The following reconnaissance and detailed site investigations, the aims of which are also clearly stated in the Report, will complete the geological "picture". Pro memoria, the Report also mentions that some specific geological activities should take place during the construction period.

3.3. Hydrology

Before entering into details, the Report offers some general information on the subjects of hydrological cycles, water balance and basic considerations relating to run-off. The specific requirements of information of the site being considered become therefore clear.

As fulfilment of these requirements is not always possible, the Report provides some useful ideas as to how information gaps can be overcome.

Once the hydrological situation has become clear the studies can proceed to determine plant capacity, energy production, dependable and secondary energy.

As an introduction to the subject of energy production, the Report provides the definitions of the terms used; the relationship between flow and energy generation is fully explained with a flow diagram.

4. CIVIL WORKS, MAINPLANT COMPONENTS

The Report provides information on standardization of the main HSP components. It emphasizes that such information is eminently practical and of "do-it-yourself" nature. Simple design calculations are suitably complemented by sketches, tables, drawings and lay-outs. The majority of the data thus provided refers to plants that have actually been designed and realised; it is therefore practical experience that is being provided.

On the basis of the above information, local engineering and construction should be in a position to take in hand the design and realisation of projects without - or only with punctual - outside help.

The main plant parts for which standardisation principles could be successfully applied are:

4.1. Water intake

A distinction is made between run-of-river and drop intakes, whereby for both types data is provided which enables the local engineer, by careful approach, to take care of this important part of the plant.

4.1.1. Run of the river intake

The Report examines the different types of weirs, pointing out favourable and unfavourable site locations on the river. The positioning of the intake is shown to have a considerable influence on sedimentation. Aprons may be required upstream from the weir structure. A number of "musts" are mentioned as for instance:

- Access roads to the intake to be provided
- Irrigation requirements to be taken into account as they may influence the intake design.

In the following part the Report deals with:

- the intake structure design considerations
- the stream flow conditions in front of the intake structure
- the main elements of the intake i.e. weir, intake entrance, forebay, flushing channel, etc.

Weir structure design considerations include:

- the requirement to allow passage of the 1000 year flood
- the avoidance of overturning forces and shear sliding
- the avoidance of erosion

The positioning of the intake works is shown to have a considerable influence on sedimentation and river bank erosion. Thereafter simple calculation methods and designs are indicated for

- various types of weirs
- overflow conditions (1000 year discharge)
- spillway coefficients
- design form of spillway or weir
- forces acting on the structure

An entire chapter deals with stability requirements considering overturning, base shear, overstressing and uplift water pressures.

4.1.2. The second part of the same chapter examines in detail drop (Tirolean) intakes.

It goes into details in regard to its desgn. A calculation of rack slope and of typical rack arrangements in accordance with volume discharge is given, thus providing the designer with main dimensions and construction details.

4.2. Desilting basin

Desilting is shown to be essential if sediments are entrained with the water. Damage to the equipments in particular to the turbines is the disagreable consequence of badly conceived or insufficient desilting. Although mention is made that there exist many systems of desilting, the Report describes in detail a type suitable for run off the river plants and another for drop intakes. The latter must be particularly well designed as drop intakes are usually associated with operations with large quantities of entrained sediments and sands.

The smaller the SHP plant becomes, the more important it is to desgin a simple but economic method of desilting.

The conventional examples of desilting basins for run off the river plants presented in the Report have been elaborated taking into account the practical experience gained in other similar projects.

Tables and sketches indicate the main dimensions and design features of conventional desilting plants for run-off-the-river waterflows comprised between 1.5 and 3.5m^3/sec.

In regard to desilting after drop intakes, the design used and the methods of calculation are all the more detailed owing to their greater importance. They cover the range of flows between 1.1 and 2.5m^3/sec.

4.3. Adduction Canal

The corresponding chapter in the Report describes the use and the main criteria applicable to typical SHP adduction canals. They apply to a range of flows between 1.0 and 3.5m^3/sec. Practical values for slope, maximum water velocities to prevent erosion and sediment velocity are recommended. Main dimensions of the canal are listed in a table, a number of sketches showing sections of adduction canals (1.0 to 3.5m^3/sec.) is also to be found at the relevant chapter's end.

4.4. Forebay

Whilst the functions of the forebay (reserve volume, preventation of air entering the penstock, water storage for starting and regulation of the turbines) is explained, a table gives the recommended areas for water flows between 0 and $50m^3$/sec., both for low run of the river and high head plants.

4.5. Penstocks

A considerable part of the Report has been dedicated to this important item, for both above ground and burried execution. The subject handled in said chapter comprises some general remarks about penstocks including penstock location and size, head losses in penstock, the waterhammer and its effects on the penstock, pipe shell thickness, design conditions, penstock materials and allowable stresses, civil works, protection against corrosion, anchors and expansion joints.

As saftey has to be carefully balanced against costs, the penstock's design must be carefully selected in function of topographic and geological conditions, material of penstock, surrounding conditions, anchoring and expansion joints, water velocities, head with "water-hammer" additional pressure, etc.

The minimum water velocities admissible are indicated for various ratios of length/head of the penstock.

4.6. Surge tanks

A fairly extensive part of the chapter on surge tanks relates to the water hammer, its origin and implications. Formulas - including parameters based on experience, enable water velocity and pressure wave speed to be calculated; the increase in head due to water hammer can thereafter be deduced. The whole process is somewhat complicated as it depends on a number of factors such as pipe diamter, pipe material used, temperature, and methods of anchoring the penstock.

As a corollary to the above consideration, the Report goes on computing the required plate thickness of the penstock pipe.

The above calculations are carried out for both types of penstock i.e. of the surface and burried types.

4.7. Power Station

The relevant chapter includes ideas and suggestions which will help the designer to design and construct a building that will combine simplicity, low cost, easy operation and maintenance. Up to now because SHP power plants have been developed from the design of their much larger medium-size sister power stations, little thought had been given to their own functional and practical design. The relevant chapter of the Report should help to improve the situation.

5. References

The Report includes a list of useful references which should help the designer of an SHP to tackle and solve special problems the solution for which needs more profound consideration.

6. Layout drawings

To illustrate the contents of this document, a few examples of layouts with their legends have been selected from the Report; they are:

Example 3: Conventional water intake with desilting basin for $Q = 3.5m^3/s$

Example 4: Drop intake for $Q = 1m^3/s$

Example 8: Penstock for $Q = 2.6m^3/s$

Example 13: Powerhouse for $Q = 2.6m^3/s$

EXAMPLE OF A CONVENTIONAL WATER INTAKE WITH $Q = 3.5 \ m^3/s$

LEGEND

1. WEIR CREST El. 200.10 m a.s.l.
2. LIMITS OF THE ROCK SURFACE
3. LEFT SIDE RETAINING WALL
4. MAIN GATE OPENING 2.70 m x 2.40 m (MOTOR OPERATED)
5. SLUICE GATE 1.00 m x 1.00 m (MOTOR OPERATED)
6. SUBMERGED SILL El. 198.90 m a.s.l.
7. SLUICE CHANNEL S = 0.08
8. GUIDING WALL El. 201.00 m a.s.l.
9. GATES OPERATING PLATFORM El. 201.90 m a.s.l.
10. FLOOD PROTECTION WALL
11. RETENTION:
    - ◊ NORMAL LEVEL: 200.00 m a.s.l.
    - ◊ FLOOD CASE 1: 200.85 m a.s.l.
    - ◊ FLOOD CASE 2: 201.20 m a.s.l.
    - ◊ FLOOD CASE 3: 201.50 m a.s.l.
12. RETAINING WALL RIGHT
13. TRASH RACK 5.30 m x 1.25 m , inclined 75°
14. ACCESS AND AERATION PIT 0.70 m x 0.70 m
15. ENTRANCE GATE 1.00 m x 1.00 m (WITH MOTOR-CONTROL), ALSO USED AS FLOOD CONTROL.
16. WATER LEVEL
17. STILLING RACKS
18. FOOTBRIDGE.

19. **DESILTING BASIN FOR Q = 3.5 m^3/s**

L = 32.00 m

W = 4.00 m

D = 3.50 m

V = 0.25 m/s

d = 0.25 - 0.50 mm

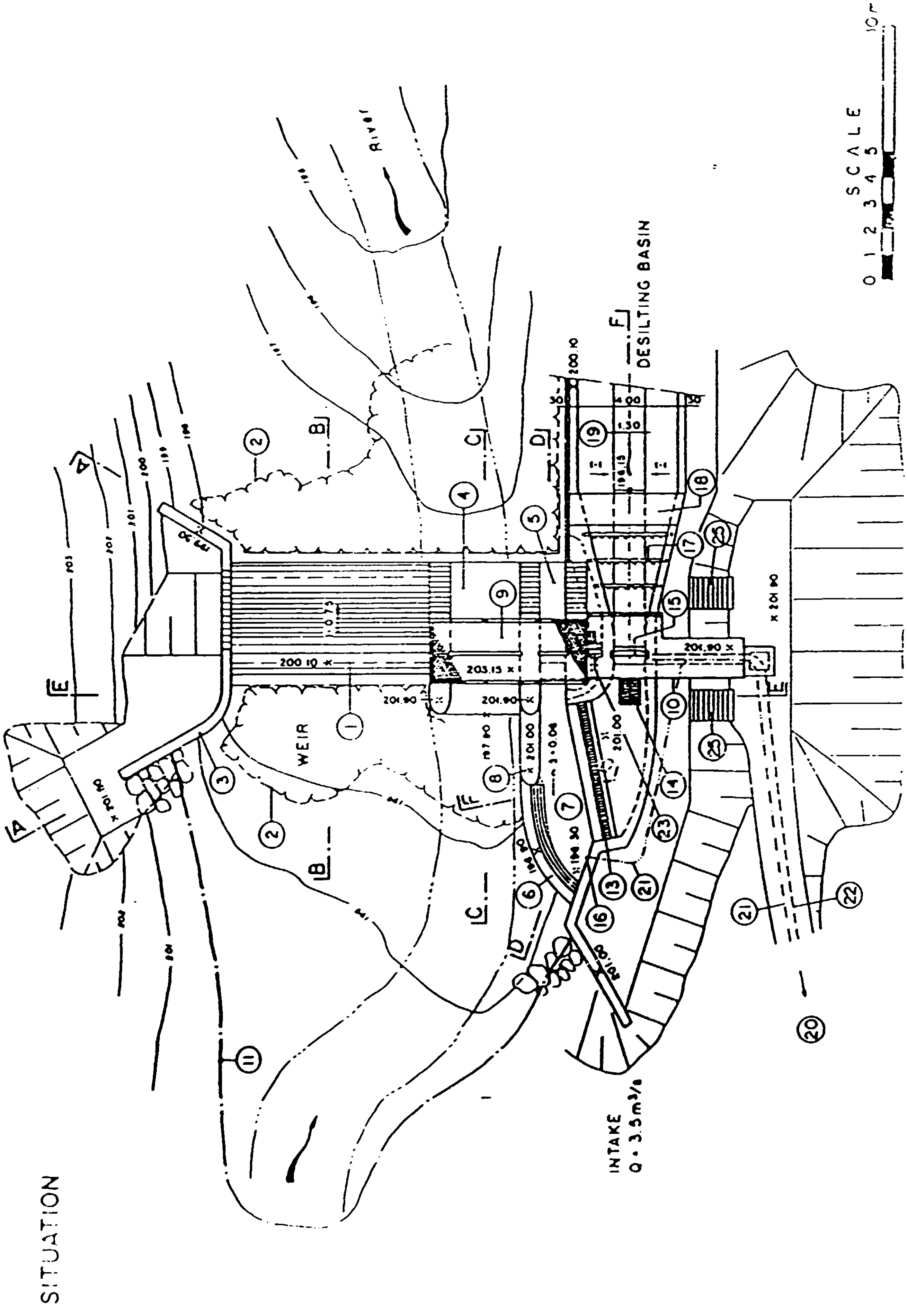
Bottom slope = 0.03

Flushing gate 1.00 m x 1.00 m. (For more details of desilting installation see example of desilting for Q = 2.6 m^3/s

20. OPERATING BUILDING
21. REMOTE CONTROL CABLE
22. LOW TENSION POWER CABLE
23. DOTATION GATE 0.30 m x 0.40 m WITH MANUAL OPERATION
24. SEAL MADE WITH CLAY
25. STAIR

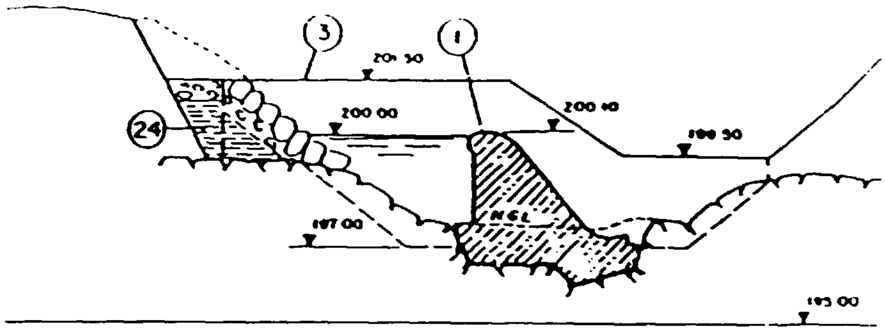
N.G.L.= NATURAL GROUND LINE

R. B. = RIVER BED

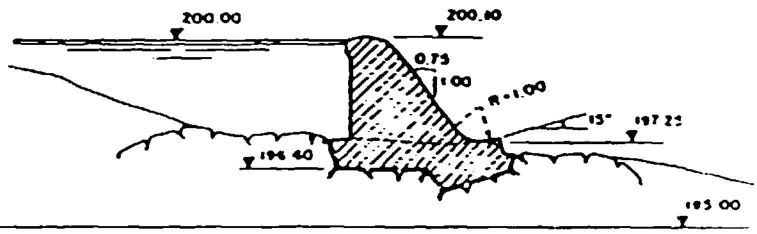


UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION	EXAMPLE 3
DRA: RIEL	

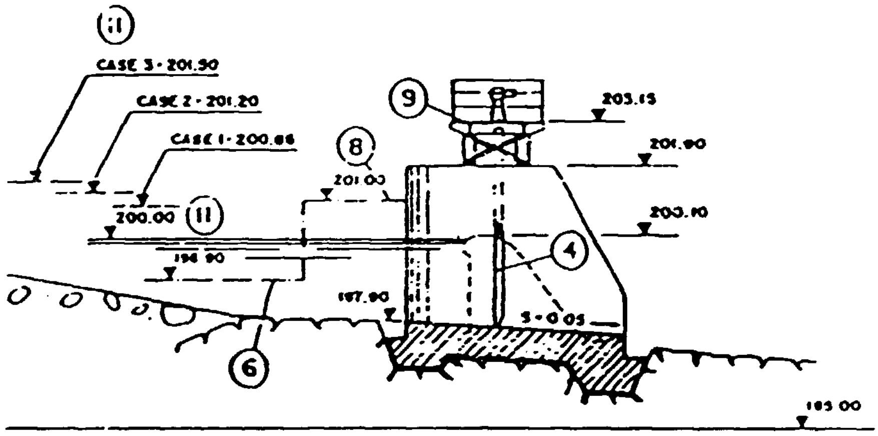
SECTION A - A



SECTION B - B



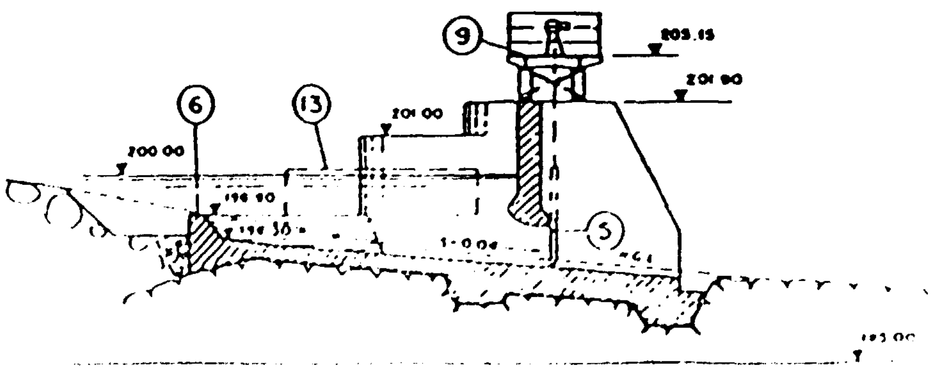
SECTION C - C



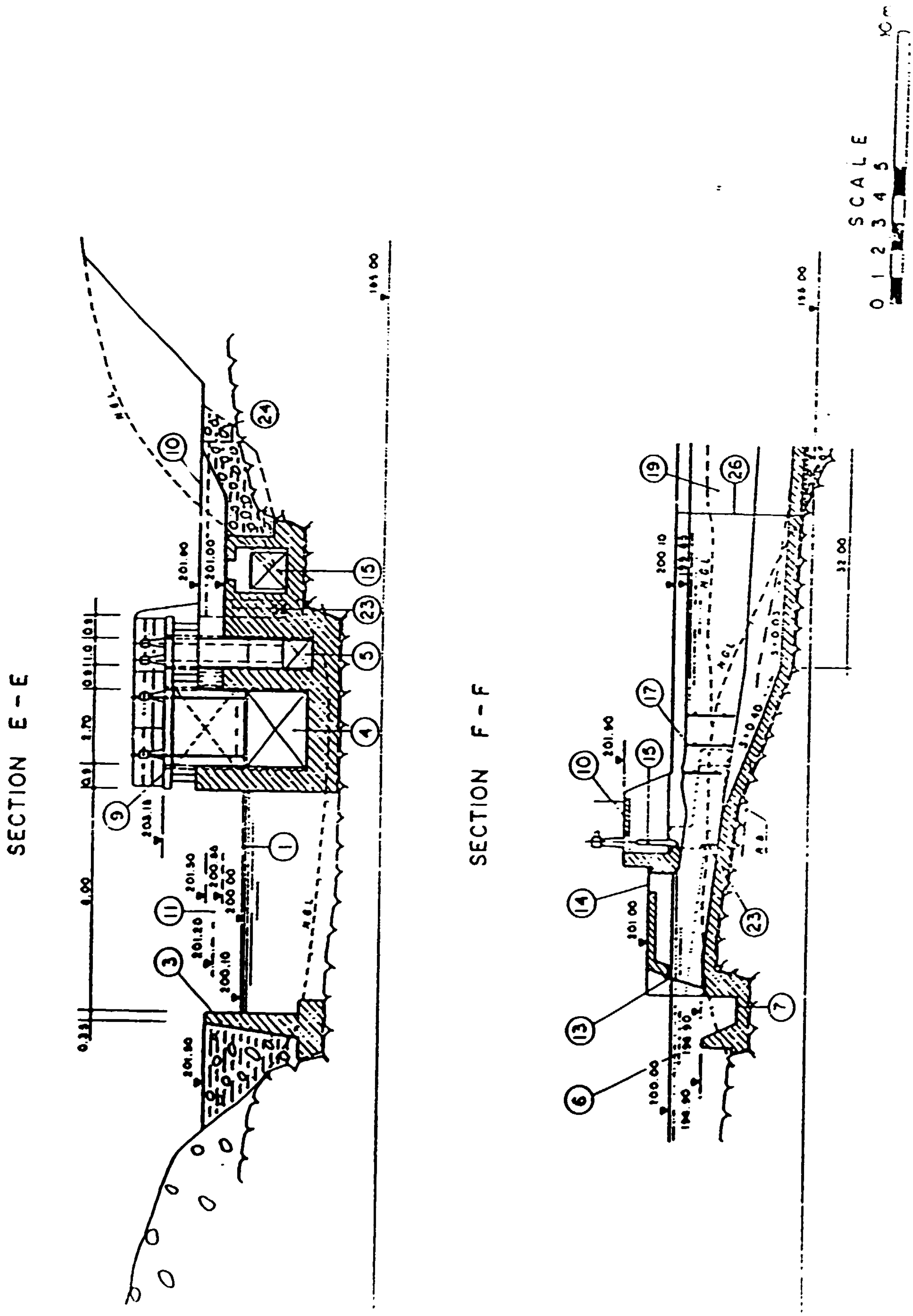
SECTION D - D

SCALE

0 1 2 3 4 5 10m



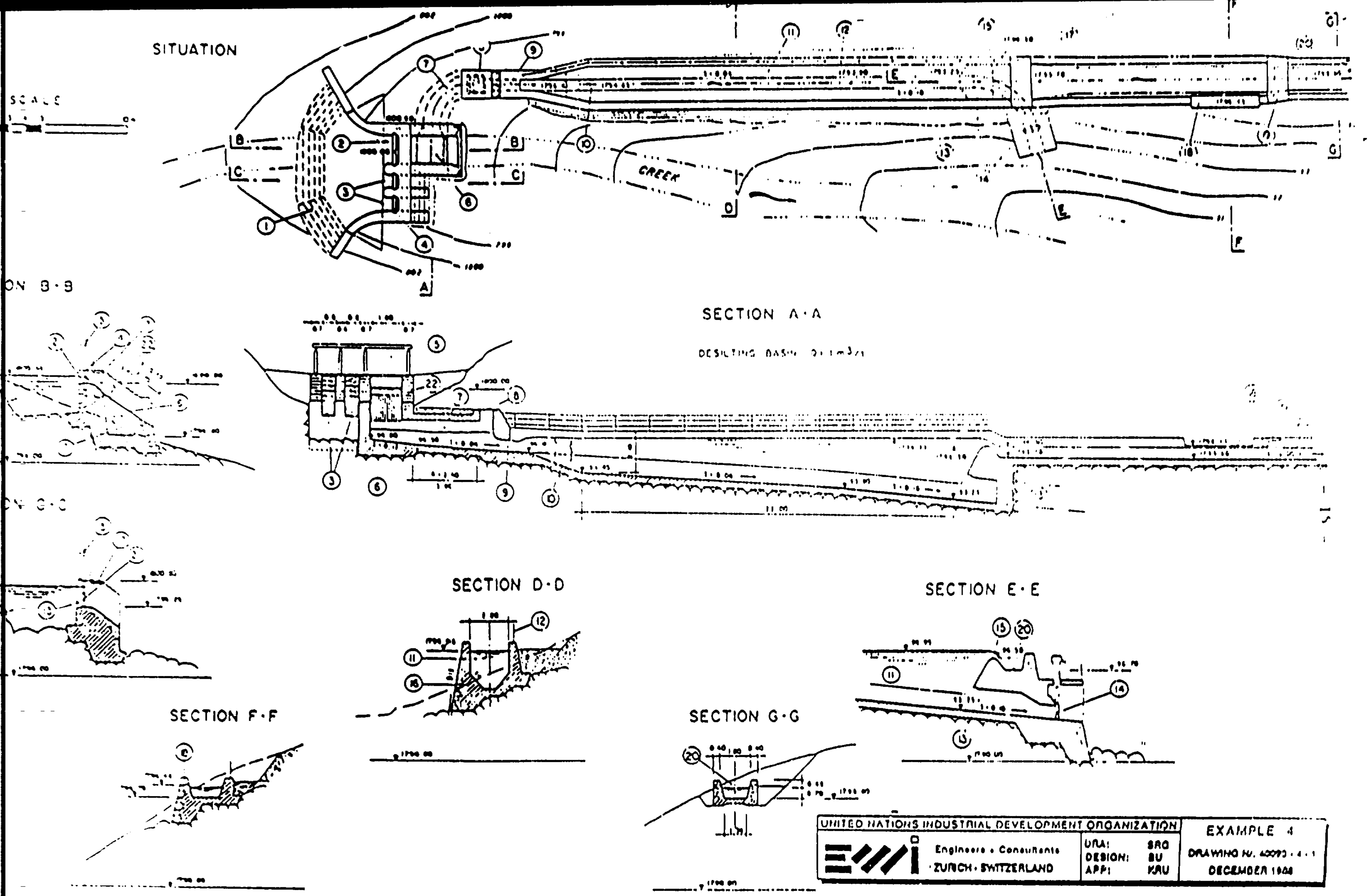
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION		EXAMPLE 3
Engineers + Consultants	DRA: SRG DESIGN: BU	DRAWING Nr. 40093 - 3 - 2

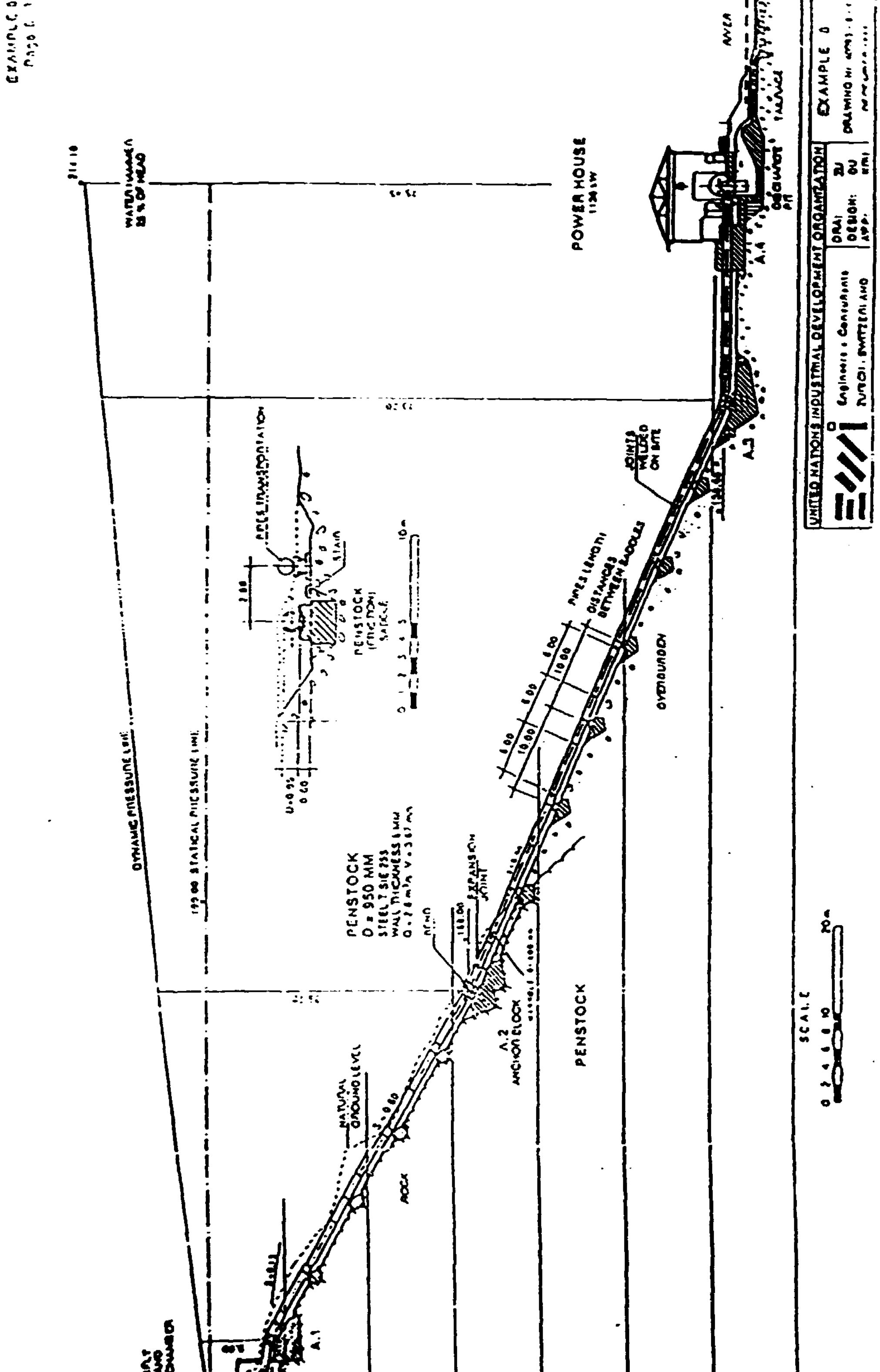

SECTION E - E
SECTION F - F
SCALE
0 1 2 3 4 5 10 m

DROP INTAKE AND DESILTING DESIGNED FOR Q = 1m³/s

LEGEND

1. FOREBAY
2. INTAKE SILL ELEVATION 1800.00 m a.s.l., W = 1.80 m
3. TEMPORARY DIVERSION, OPENING SILL ELEV. 1799.25 m a.s.l., W = 0.80 m.
4. STOP LOGS SLOTS
5. STOP LOG PLACING DEVICE
6. TRASH RACK S = 0.70 m, BARS Ø = 24 mm, SPACE 25 mm
7. ENTRANCE CANAL
8. ACCESS AND AERATION PIT
9. NARROWED SECTION 0.65m / 0.65m
10. STILLING RACKS
11. DESILTING BASIN, L = 22 m, W = 2.20 m, Q = 1 m^3/s, d = 0.30 - 2.00 mm, v = 0.25 m/s, W_o = 0.035 m/s
12. HANDRAIL
13. FLUSHING CHANNEL
14. FLUSHING GATE (MANUAL) 0.80m / 0.80 m
15. END SPILLWAY
16. MASONRY
17. FOOT BRIDGE
18. FLOOD SPILLWAY
19. FOOT BRIDGE AND FLOOD CONTROL
20. ADDUCTION CANAL Q = 1 m^3/s, S = 0.0012
21. STOP LOGS
22. AERATION


SITUATION
SCALE
CREEK
SECTION A·A
DESILTING BASIN
SECTION B·B
SECTION C·C
SECTION D·D
SECTION E·E
SECTION F·F
SECTION G·G
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Engineers + Consultants
ZURICH · SWITZERLAND
DESIGN: BU
APP: KRU
EXAMPLE 4
DECEMBER 1984

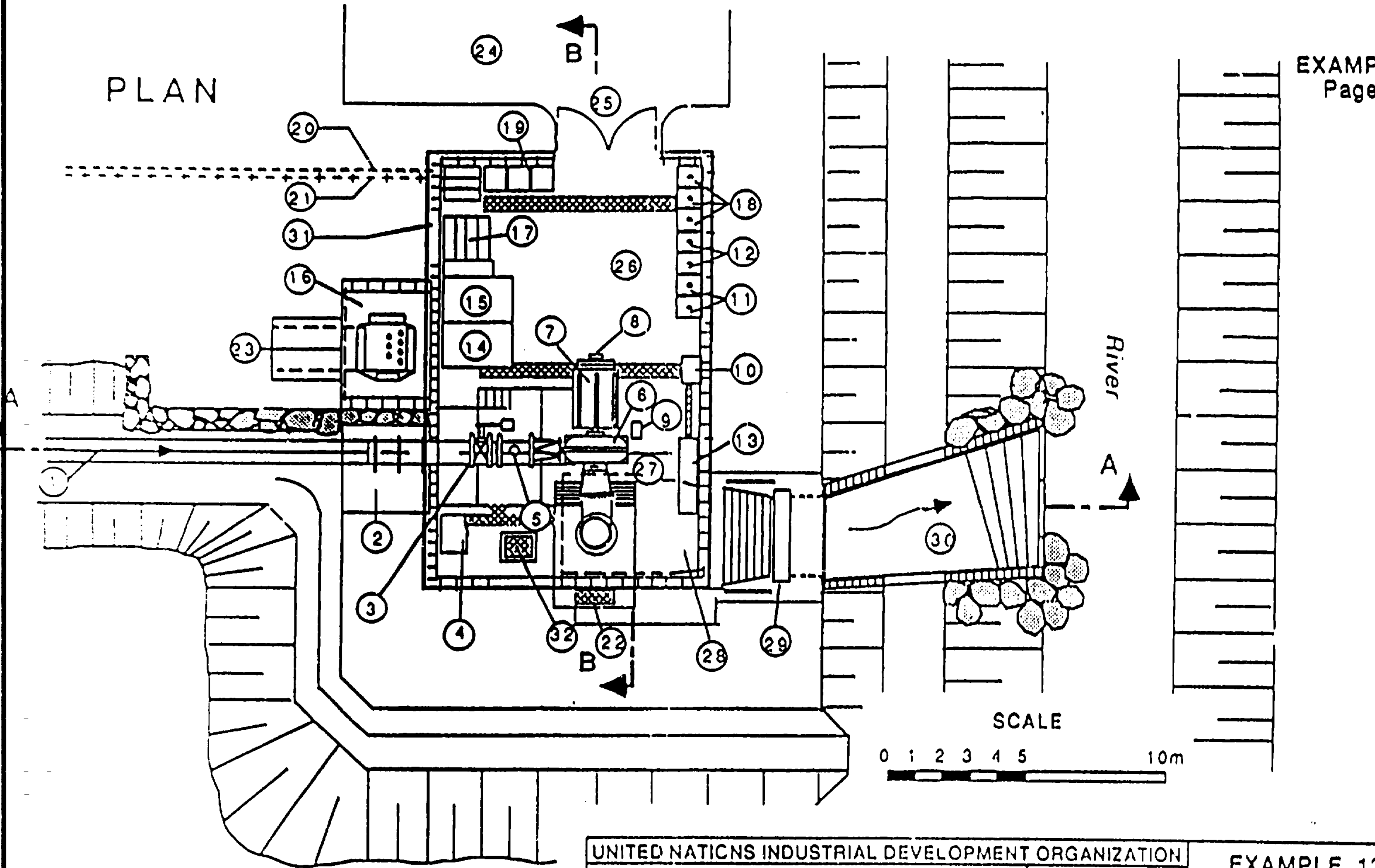


DYNAMIC PRESSURE LINE
STATICAL PRESSURE LINE
WATERHAMMER 25 % OF HEAD
POWER HOUSE
PENSTOCK
FOREBAY
BUTTERFLY VALVE AND WINCH CHAMBER
NATURAL GROUND LEVEL
ROCK
OVERBURDEN
A.1
A.2
ANCHOR BLOCK
A.3
A.4
EXPANSION JOINT
BEND
JOINTS WELDED ON SITE
PIPES LENGTH
DISTANCES BETWEEN SADDLES
PENSTOCK
D = 950 MM
PIPES TRANSPORTATION
STAIR
PENSTOCK (FRICTION) SADDLE
TAILRACE
RIVER
SCALE
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
EXAMPLE D

THE POWERHOUSE FOR Q = 2.6 m^3/s

1. PENSTOCK
2. ANCHOR BLOCK
3. BUTTERFLY VALVE D = 900 mm
4. OIL PRESSURE UNIT
5. MANHOLE
6. TURBINE
7. GENERATOR
8. FLY WHEEL
9. GOVERNOR
10. GENERATOR NEUTRAL CUBICLE
11. CONTROL BOARD
12. EXCITATION CONTROL
13. MCC
14. GENERATOR SWITCHBOARD
15. SERVICE TRANSFORMER
16. MAIN TRANSFORMER
17. BATTERIES
18. LIGHTING AND DC DISTRIBUTION BOARD
19. REMOTE CONTROL OF WATERWAY
20. CABLE FOR LOW TENSION
21. CABLE FOR REMOTE CONTROL
22. AERATION OF THE TAILRACE
23. FENCE DOOR
24. ACCESS
25. ACCESS DOOR
26. ERECTION AREA
27. DRAFT TUBE
28. DISCHARGE PIT
29. STOP LOGS GROOVE
30. TAILRACE
31. WINDOW AND VENTILATION
32. DRAINAGE SUMP
33. LEAN CONCRETE PC 200

34. REINFORCED CONCRETE PC 300
35. STEEL BEAMS
36. CRANE 6 ton.
37. CONCRETE MASONRY BLOCKS
38. POSSIBLE NOISE INSULATION
39. TIMBER WORK OR STEEL WORK
40. ROOF: CORRUGATED METAL SHEETS WITH FIBERGLASS INSULATION BELOW
41. RIP-RAP



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION			EXAMPLE 13
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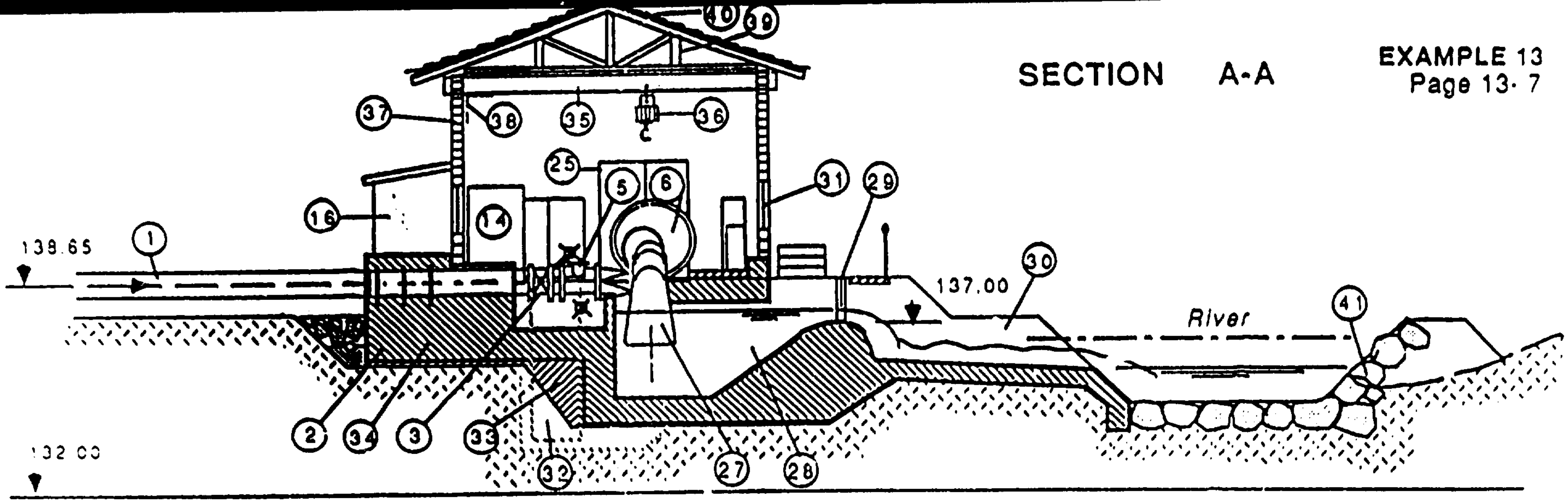
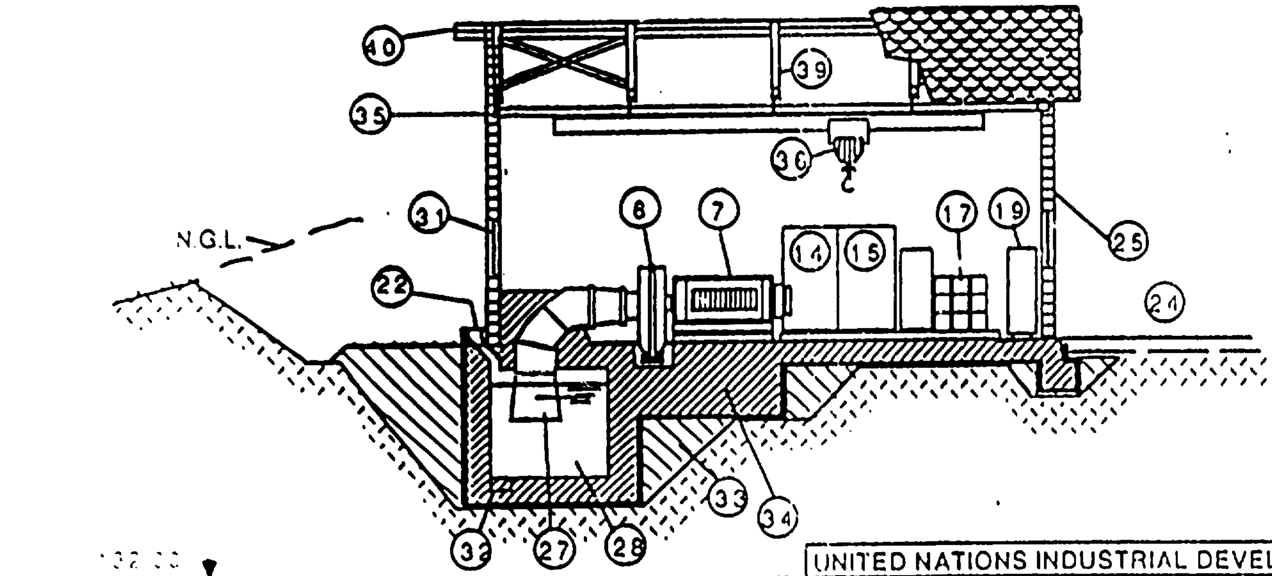
EXAMPLE 13
Page 13- 7

SECTION A-A



SECTION B-B



SCALE

0 1 2 3 4 5 10m

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION		EXAMPLE 13
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29 September 1989

MODEL
PROCEDURES TO BE USED
AND DATA TO BE COLLECTED FOR THE
SHP SCHEMES BEING CONSIDERED

by Eric Bernhardt
Consultant

1. INTRODUCTION

From the replies received from various countries interested in the installation of a "model" standardised SHP, it is evident - this has already been pointed out in the separate document "Analysis of the different proposals" - that the authorities concerned are experiencing some considerable difficulties in providing the information required by UNIDO to finally select the site(s) for the "model plant".

An exception is Ethiopia who have proposed one plant and have submitted a comprehensive project document and a feasibility study.

2. PROPOSAL FOR PROCEEDING

For furthering the SHP project and in order to enable decisions to be taken, the Consultant proposes the following procedure:

2.1. Formation of a small mission of not more than 2 persons including a Consultant to visit the 6 interested countries (whether a visit to Ethiopia is also required - more from the "diplomatic" than technical point of view - can be decided later).

2.2. The visit would serve the following main purposes:

- **Personal contact with the authorities concerned**
- **Data gathering in accordance with paragraph 3 below**
- **Visit to the proposed sites.**

As data gathering would be carried out on a uniform basis in each "candidate" country, comparable results would be obtained, thus facilitating the final choice of a suitable site for the model plant.

3.8. Finances

- Availability of funds for meeting the cost of the local part of the scheme
- Financing desired for local and foreign expenses
- Local interest rates valid for project financing
- Rate of exchange
- Inflation to be considered.

3.9. Availability of materials and fabricated and semi-fabricated components.

3.10. Othei significant features which may influence the selection of the site.