A STUDY OF THE INCIDENCE OF COST OF AUXILIARY WORKS ON WATER RESOURCES PROJECT COST

A DISSERTATION
submitted in partial fulfilment of
the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

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CERTIFICATE

Certified that the dissertation entitled, " A STUDY OF THE INCIDENCE OF COST OF AUXILIARY WORKS ON WATER RESOURCES PROJECT COSTS" which is being submitted by Sri S.R. LASKAR in partial fulfilment of the requirement for the degree of Master of Engineering in Water Resources Development of the University of Roorkee is a record of the student's own work carried out by him under my supervision and guidance. The matter embodied in this text has not been submitted for any other Degree or Diploma.

This is to further certify that he has worked for more than six months, staying at Roorkee, for the preparation of this dissertation.

DATED: ROORKEE

The 11 May, 1981.

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(S.R. LASKAR)

S Y N O P S I S

The water resources project cost as a whole is influenced by different factors such as size, importance, location, design and planning, while a completed project comprises of a number of groups of works. Therefore, the cost of any group of works also generally influences the cost of the project."Auxiliary work" is one of these groups of works. A study of this has been taken up in this dissertation.

The dissertation comprises of five chapters. In the first chapter the description of the philosophy behind this dissertation is given.

In the second chapter the definition and identifications of auxiliary works have been done.

The third and the fourth chapters consist of the projects under study and their cost analysis. The fifth and final chapter contains discussions and conclusion from the study.

It is observed that the incidence of the cost of "auxiliary works" varies much from project to project and therefore, to obtain a more generalised relation further study is recommended.

C O N T E N T S

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CHAPTER-I

INTRODUCTION

Government is carrying out programmes to develop country's water resources. Many multipurpose objectives have engaged government's attention, such as, irrigation of cultivable land, control of floods, generation of hydro-electric power, supply of water for domestic and industrial uses, provision of recreational facilities, improvement of our navigable streams and so on. As the economy has expanded, the need for these activities has also grown. The value of the property vulnerable to floods and the demand for power has increased in recent years. The expenditure on these projects has correspondingly increased. Therefore, it is important that these developmental activities are carried on with efficiency, that the needs of the country are met, and that the money is optimally spent.

The primary emphasis on cost analysis and control and utilization of cost data by management in formulating policies is of paramount importance. Planning, specially that of hydraulic projects, is generally not feasible in the final form. The right course of planning is gradual approximation. Within a generally wide scope of technical possibilities the most favourable solution is determined ultimately by economic considerations. Therefore, the fact that in the course of planning" the technical and economic problems are inseperable" can not be given sufficient emphasis. Therefore, classification and manipulation of cost data is necessary to draw inferences as it is more natural to begin with data analysis and end with models, for this is the order in which things usually arise in real world.

The present study is concerned with the costs of the four largest types of water-resources programmes: flood control, navigation, irrigation and hydro-electric power. In particular the units of costs of the project had to be classified and a statistical study of the different classes of costs were made. The procedure followed might become the subject of considerable controversy, yet it is hoped that this will make some contribution toward improving classification and analysis of the cost and its incidence on development of water resources project.

CHAPTER-II

DEFINITION OF AUXILIARY WORKS

2.1. INTRODUCTION

Water resources projects comprise of a number of works. Some of these are classified as main works and some as an auxiliary works. Although all projects detail their costs under "main" and " auxiliary" works there is no clear cut distinction between the two types of works. In this chapter the existing state of the art is summarised and guidelines are presented to enable planners to classify their works under the two main categories.

2.2. DICTIONARY DEFINITIONS

Thorndite Barnhast Dictionary defines " auxiliary" as " helping, assistant, additional".

The Oxford English Dictionary defines " auxiliary" as-

i) helpful, assistant, affording aid, rendering assistance, giving support or succour,

ii) subsidiary to the ordinary, additional.

Webster's New Twentieth Century Dictionary of the English Language Unabridged defines " auxiliary" as -

i) helping, aiding, assisting, giving aid or support by joint exertion, influence;

ii) subsidiary,

iii) additional, supplementary

Here the word " auxiliary" is used as adjective. And the different dictionary definitions indicate that it commonly means helping and subsdiary. Therefore, the works that help the main works should be auxiliary works.

2.3. PROFESSIONAL USAGE

In published literature little has been written about qualifications of works to be classed as auxiliary. However, some kind of a standard format for presenting the data on water resources projects has been deviced and published by the Central Board of Irrigation and Power in their publication No.48 in which the following works have been identified as auxiliary works:

1) Surplusing works - such as Spillway or Waste weir,
2) Outlet works,
3) Scouring works,
4) Inspection facilities,
5) Fish pass,
6) Means for dissipating energy below the spillway,

The above classification is made more on personal judgement of the author than upon any clearly specified criteria. Therefore a deeper study of the problem comprising published works, project reports and discussion with experts is needed before guide lines for classification could be developed.

2.4. OPINIONS OF EXPERTS

2.4.1. In order to elicit expert opinion discussions were held with officials of various organizations. These included: experts at Water Resources Development Training Centre, engineers of Irrigation Department, U.P. and officers of Central Water Commission. The views expressed by these experts are summarized below.

2.4.2. Opinions of Experts at WRDTC:

Some Professors were of the view that if a spillway is a part of the dam it should not be considered as an auxiliary work. However, the means of dissipating energy for this spillway could be considered as auxiliary work. In a hydroelectric project the dam and the power house constitute the main work while all other structures are auxiliary works. Therefore, they defined the auxiliary works as " all additional or subsidiary works constructed for realization of the purpose or functioning of the main works".

A senior Professor opined that all works in a water resources project are included in it according to the purpose, topography, planning, design and economy of the project and as such the term auxiliary works was vague. The term auxiliary or appurtenent could be used with respect to some such works as the road or highways over the top of the dam, cross drainage works in a canal system, etc. Some other faculty members also expressed similar views. However, according to them the construction diversion works such as Coffer dam, diversion tunnel (or diversion channel), cummunication facilities, haul roads, residential buildings, temporary sheds could be taken as auxiliary works.

A Professor from the Civil Engineering Department, was of the opinion that the spillway and its means of dissipating energy could not be classified as auxiliary works since the spillway and its energy dissipating facilities were inter-related and unavoidable when provided as part of the dam.

2.4.3. Opinions of Experts of Irrigation Department, U.P.:

Most of the experts of Irrigation Design Organization at Roorkee were of the opinion that no work was entirely auxiliary under all situation. Rather this a relative term. Therefore, if a project is mainly a hydro-electric one the works required for rendering other extra facilities such as water supply, irrigation etc. by the project could be termed as auxiliary works.

An Executive Engineer of the Irrigation Research Institute expressed the view that in a hydroelectric project the dam and the Powerhouse are the main works. An auxiliary work is one " which is a permanent feature in the project and the main function of which is to facilitate operation, maintenance or safety of the main structure". He also said that the means of dissipating energy of spillway was an integrated part of spillway and the spillway was a part of the dam and so the spillway and its dissipating facilities could not be termed as auxiliary works. However, auxiliary spillway, chute spillway, saddle dams etc. could be said to be auxiliary works. The diversion arrangements for construction, such as Cofferdam, diversion tunnel (or channel), temporary communication facilities and haul roads were not anxiliary works.

2.4.4. Opinions of Experts of Central Water Commission:

Discussions were held with persons in the different Directorates of the Commission in New Delhi on the comprehensive definition and identification of auxiliary works of a water resources project.

Some Directors, including the Chief Engineer (D.S.O.), opined that they had not come accorss any project report in which works had been classified as main and auxiliary. Neither they had ever felt it a necessity to classify works as auxiliary for preparing project reports. The Chief Engineer(Designs) expressed the view that any structure or work required for a project according to its design should not be considered as auxiliary work. The various structures which are mostly built for temporary purposes during construction may be categorised as the auxiliary works.

2.5. COMMENTS ON THE VIEWS OF EXPERTS

The opinions of the experts regarding the definition and identification of auxiliary works are conflicting. But it is a fact that there exist a number of auxiliary works in a water resources project. Therefore, various structures usually met with in water resources schemes need to be critically studied to identify the auxiliary works, based on the criteria evolved as a result of studies and discussions.

2.6. CRITERIA FOR IDENTIFICATION OF AUXILIARY WORKS:

An auxiliary work may fulfill the first and any one or more than one of the remaining criteria as listed below.

i) It should be a permanent structure and a helping device to realize main objectives of the project.

ii) It should be moderate in cost and effort as compared to the main units of the project.

iii) It is needed to work occasionally and not all the time for the realization of the purpose of the project.

iv) It may be excluded from the project under special planning and design conditions.

2.7. CRITICAL STUDY OF VARIOUS STRUCTURES:

The above criteria could now be applied to each structure to judge whether it could be classified as an auxiliary work.

2.7.1. Diversion Structure:

When the water is flowing in a river it has to be diverted through a canal to the field for irrigation or through a water conductor system to the power house. The structure meant for diverting the water is known as the diversion structure and may be weir, barrage or a dam. This diversion structure is invariably a main structure. Temporary diversion structures like Coffer dam are neither main works nor auxiliary works. Such works could be considered as construction facilities.

2.7.2. Spillway:

The main function of a spillway is to dispose off surplus water from the reservoir. The spillway is a safety valve for the dam and adjacent country side. Therefore it may be considered as an auxiliary work. But when it is a part of the dam it can not be an auxiliary work as it also serves the purpose of storing water like the dam itself. Same consideration should be given in case of its means of dissipating energy.

2.7.3. Intakes:

An intake structure is an arrangement by which water is satisfactorily diverted for the required use, i.e., the intake is an arrangement which allows for water to be taken from its source and then discharged into the Conveyance System from which it is led to the desired use. The desired use of water may be for domestic water supply, flood or irrigation discharges out of a dam through outlet out sluices, or for the purpose of generating electricity.

The main purposes of intake structures are :

a) To prevent or at least to reduce, the silting of the canal or in other words, toprovide for protection against Sedimentation in the canal bed.

b) To secure with small head losses the entrance of water to the power canal.

c) To keep ice and other floating matter off the canal.

Large parts of floating debris are of no consequence if occuring in irrigation canals, whereas their entrance to the power channel and to the wheels must be prevented. Since intake structures greatly increase the investment costs of the entire power project, it is highly desirable to omit them if conditions permit this . Some times intake structures are abandoned in the course of building a complete river harnessing scheme. Therefore, the intake structures are considered as auxiliary works.

2.7.4. Outlet Works :

An outlet work serves to regulate or release the water for downstream committed use. It is a device **built** at the head of a water course to control the flow of water in it. An outlet connects the water course with the distributing channel and may provide a measure of discharge passing through it. Outlet works can be classified according to the purpose which may be one of the following :

i) River Outlet : One which empties directly into the river.
ii) Canal Outlet: One which discharges into a canal.
iii) Pressure Pipe: One which delivers water into a closed pipe system.

In case of hydroelectric plant outlet serves the purpose of release of water for downstream committed uses, when power station is closed as such it is an auxiliary work. On the other hand in case of irrigation projects it can not be considered as an auxiliary work as from the outlet the water is taken over by the cultivators to various parts of its command by constructing the " water course".

2.7.5. Scouring Works:

These works like scouring sluices being protective devices are auxiliary works.

2.7.6. Sediment Excluders or Ejectors:

These may be defined as tunnel type sediment excluding devices. The Excluders are the preventive measures while Ejectors are the curative measures. Therefore, these are auxiliary works.

2.7.7. Headrace and Penstock:

This is a feeding arrangement to the power house and is a subsidiary work. By special planning and design of power house the use of headrace and penstock may be avoided. Hence they are also considered auxiliary works. Tail race channel or tunnel is also an auxiliary work.

2.7.8. Surge Tank:

The purpose of the surge tank is to provide sufficient water to the power house in case of sudden load acceptance during the time taken by water to flow from the reservoir to the penstock. The other purpose of the surge tank is to prevent the high water pressure being transmitted to the headrace tunnel during load rejection or sudden stoppage of the machine. Hence this is a protective and helping device and is an auxiliary work.

2.7.9. Power House:

It is an unavoidable unit for development of hydropower. Therefore, this is not an auxiliary work.

2.7.10. Inspection Facilities:

These are meant for monitoring the continued safety of the structure as well as to provide a check on the design assumptions and methods of computation in vogue. These includes inspection gallery, instrumentation etc. and are additional works. Therefore, they are included in auxiliary works.

2.7.11 Fish Pass:

This is also an additional work meant for completely different pupose than the objective of the water resources project unless fisheries is defined as an objective. Hence this is an auxiliary work.

2.7.12. Irrigation Canals:

In an irrigation project canal is the main work. Irrigation canals are generally divided into two classes - (A) Permanent canals and (B) Innundation canals. And the parts of a canal system are -

i) Head works,

ii) Main canal,

iii) Branch canal (usually called " Branches")

iv) Major distributaries (usually called (Distributaries")

v) Minor distributaries(usually called " Minors").

Head works, the components of which have been described earlier is an auxiliary work while canals are main works.

2.7.13. Buildings:

The permanent buildings are auxiliary works as these helps in maintenance of the project while the temporary buildings required for construction period are not considered as auxiliary works and could be classified as construction facilities.

2.7.14. Communications :

Run of the river schemes will commonly be found to be more advantageous as far as communication lines are concerned, those crossing the river being affected to a small extent, and in some cases the weir or barrage or dam will even offer possibilities for the establishment of a new highway and/or railway crossing. Extensive relocation of highways and railroads running parallel to the river may, on the other hand, become necessary specially if the head created is substantial. Costs of highway relocation are to be charged against power generation. This is an auxiliary work.

2.7.15. Plantation:

This item provides for planting of avenue, trees, arboriculture etc. and is an auxiliary work.

CHAPTER-III

PROJECTS UNDER STUDY

3.1. LAKHWAR VYASI PARIYOJNA, DEHRADUN, UTTAR PRADESH

3.1.1. The Project:

A sizeable block of electrical energy could be quickly made available from the proposed thermal and nuclear power stations. But for optimum utilisation of these thermal and run-off hydroelectric river schemes and to meet the grid load factor, in U.P., it is essential to have a matching peak power capacity. For this purpose, a storage scheme is required which can be commenced immediately and completed to best match the requirements of peak power (in U.P.) after the fifth five year plan. With this objective in view, it is proposed to undertake construction of a high concrete dam across river Yamuna at Lakhwar.

At present all the non-monsoon flow in river Yamuna is committed for irrigation on Western and Eastern Yamuna Canals. There is an acute and increasing demand of water for extension of irrigation in the area presently catered by the Eastern Yamuna Canal and the adjacent areas. Construction of Lakhwar reservoir would help in extending irrigation facilities in the un-irrigated areas of the region as well as in intensification of irrigation facilities in the areas in the command of the Eastern Yamuna Canal.

The project as now envisaged comprises the construction of a 192 m high cored gravity concrete dam across river Yamuna near Lakhwar village. It would be the highest dam of its type and will store 580 million m^3 of water with full reservoir level at EL 796. A head of 159 m will be created for generation of power at the foot of the proposed dam. The power house shall have installed capacity of 300 MW consisting of two units of 150 MW each. Arrangement will also be provided for a possible future installation of two pumped turbines of 150 MW capacity each in an underground cavity on the right abutment of the dam.

Another auxiliary concrete dam of height 61 meters is proposed 5 KM downstreamof the Lakhwar dam near Vyasi. Water collected at the proposed Vyasi dam shall be conveyed through two 7 metres diameter power tunnels each 2.5 KM long to a surface power house at Hathiari with an installation of 240 MW capacity consisting 4 units of 60 MW each. Both, the Lakhwar and Hathiari powerhouses shall run as peak load stations and a barrage at Katapathar shall be built for balancing the discharges released from Hathiari. A uniform discharge will thus be released from Katapathar.

The Lakhwar-Vyasi project would thus add a potential of 540 MW of peak power to the U.P. grid initially and will have arrangement for future installation of 2 pumped turbines of 300 MW capacity when sufficient " off-peak" thermal power is available for conversion to " on-peak" power.

3.1.2. Abstract of cost:

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below. (Ref. Project report, April 1979).

3.1.3. Main Works

			Rs. in Lakhs
i)	Lakhwar dam	...	5429.01
ii)	Lakhwar Power house	...	619.30
iii)	Vyasi dam	...	1066.62
iv)	Hatihiari Power House	...	272.81
v)	Power plant and Electrical system	...	7559.10
vi)	Katapathar Barrage	...	496.25
	Total	...	15443.09

3.1.4. Auxiliary Works

i)	land	...	425.25
ii)	Lakhwar intake and penstock	...	269.04
iii)	Vyasi intake	...	60.93
iv)	Vyasi-Hathiari tunnel	...	588.04
v)	Surge tank	...	77.21
vi)	Penstock (Hathiari power house)	...	52.80
vii)	Head regulator	...	39.55
viii)	Permanent buildings	...	407.15
ix)	Instrumentation	...	11.00
x)	Communication	...	265.35
xi)	Plantation	...	6.50
	Total	...	2202.82

3.1.5. Construction Facilities:

i)	River diversion for Lakhwar dam and Katapathar Barrage	...	325.85
ii)	Temporary buildings	...	232.24
iii)	Transportation and procurement of timber	...	38.50
iv)	Special tools and plants	...	111.07
v)	Ordinary tools and plants	...	198.00
	Total	...	905.66

		Rs. in lakhs
3.1.6. Others:		
i) Preliminary	...	169.35
ii) Maintenance	...	204.16
iii) Miscellaneous	...	1183.35
iv) Losses on stock	...	53.08
v) Capitalised abatement of land	...	21.74
	Total	1631.68
3.1.7. Indirect Charges:		
i) Audit and account	...	212.30
ii) Establishment	...	2102.46
	Total	2314.76
3.1.8. Contingency :		
i) Contingency	...	350.66

3.1.9. Total Project cost :

Class		Cost in lakhs of rupees
Main works	...	15433.09
Auxiliary works	...	2202.82
Construction facilities	...	905.66
Others	...	1631.68
Indirect charges	...	2314.76
Contingencies	...	350.66
	Total -	22847.65

3.2. MANERI BHALI HYDRO-ELECTRIC SCHEME, STAGE-I MANERI (DISTT. UTTAR KASHI), U.P.

3.2.1. The Project :

Maneri Bhali Hydro-Electric Scheme Stage-I harnesses the power potential of river Bhagirathi between village Maneri and Tiloth in Uttar Kashi district of U.P. for generation of about 5450 m Kwh annually. The scheme has an installed capacity of 90 MW.

The discharge data of the river Bhagirathi at Maneri Dam site has been adopted as actually observed since 1964. Structural design of important works of the project has been carried out for a flood of 7500 cumecs and the hydraulic design for a flood of 5000 cumecs.

The diversion of the river for construction of main dam, intake works etc. was carried out through a diversion tunnel of 7.0 m internal diameter and about 142 m length constructed on right side of the river for diverting for maximum non-monsoon discharge of 311 cumecs. Suitable upstream and downstream Coffer dams were constructed and the top of the upstream Coffer dam was so kept that during monsoon period also, discharge through the diversion tunnel did not normally exceed 311 cumecs. However, during unprecendeted floods of 1978, a very high discharge accompanied with very heavy bed load passed through the diversion tunnel which caused intensive damages to the tunnel and the surrounding rock strata.

The diversion dam is a concrete gravity dam 39m high and 127 m long. Its spillway has 4 spans of 13 m width each separated by 4 m thick piers. Further extension of dam towards right abutment has become necessary due to heavy damages caused by the unprecedented flood on August 1978 to the diversion tunnel which was running close to the right abutment of the dam. The additional length of 61.5 m is being constructed as a composite section of concrete core wall and compacted earth fill on either side.

The intake consists of three bays each of 9 m width with a provision of 9 m wide bye-pass channel on the left flank. Eight hoppers, four in 2 rows in the sedimentation tank would remove the bed load from the river water which would be passed back to the river downstream of the dam through a steel lined underground flushing conduit of 2.2 m diameter.

The head race tunnel is concrete lined having an internal diameter of 4.75 m and a length of about 8.631 km.

The surge system comprises of a 69 m high, 11 m diameter underground surge shaft of restricted orifice type with a 316m long, 6 m diameter upper expansion chamber and a 89.5 m long, 6 m diameter lower expansion chamber. A ventilation tunnel 4 m (wide) x 4.5 m (high), 118 m long has been provided to permit entry or exit of air from surge shaft during oscillations of water in the surge tank.

A single penstock of 3.8 m diameter and 450 m long takes off at the end of head race tunnel which trifurcates into three unit penstocks of 2.5 m diameter.

A surface power station located on the left bank of river Bhagirathi at Tiloth consists of three Francis type hydroturbines with total installed capacity of 90 MW.

An open tail race channel, about 120 m long has been provided to lead the water from draft tubes back to River Bhagirathi.

3.2.2. Abstract of Cost:

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below : (Ref. Project Report, July 1980).

3.2.3. Main Works:

			Rs.in lakhs
i)	Diversion dam	...	694.65
ii)	Power house	...	704.59
iii)	Power plant and electrical system	...	1116.40
		Total	2515.64

3.2.4. Auxiliary Works :

i)	Intakes	...	678.47
ii)	Head race tunnel	...	1164.97
iii)	surge shaft	...	328-74
iv)	Penstock	...	285.48
v)	Permanent building	...	42.34
vi)	Land	...	21.52
vii)	Plantation	...	3.34
viii)	Communication	...	137.88
		Total	2662.74

Rs. in lakhs

3.2.5. Construction Facilities:

i)	Diversion arrangement	...	95.55
ii)	Temporary buildings	...	65.03
iii)	Special tools and plants	...	17.62
iv)	Ordinary tools and plants	...	39.42
		Total	217.62

3.2.6. Others:

i)	Preliminary	...	45.22
ii)	Maintenance	...	293.73
iii)	Miscellaneous	...	59.44
iv)	Losses on stock	...	15.16
v)	Telephone, lights and power system including illumination of power house, dam site, etc.	...	12.00
vi)	Capitalised abatement of land revenue	...	1.08
		Total	426.63

3.2.7. Indirect Charges:

i)	Audit and account charges	...	62.70
ii)	Establishment	...	870.32
		Total	933.02

3.2.8. Contingency:

i)	Contingencies	...	67.63

3.2.9. Total Project cost:

Class		Cost in lakhs of rupees
Main works	...	2515.64
Auxiliary works	...	2662.74
Construction facilities	...	217.62
Others	...	426.63
Indirect charges	...	933.02
Contingencies	...	67.63
	Total	6823.28

3.3. NATHPA-JHAKRI HYDEL PROJECT- HIMACHAL PRADESH STATE ELECTRICITY BOARD

3.3.1. The Project :

The Nathpa-Jhakri project is essentially a run-of-the river diversion scheme taking advantage of the steep bed slope of the River Sutlej such that the abundant natural flow diverted through a 28 km long tunnel is dropped through about 488 m back into the same river to generate a large quantum of power. The main units of the project include a 53.5 m high diversion dam at Nathpa to create a diurnal pondage of 457 hectremeters, a tunnel 9.15 m in diameter and about 28 km long taking off from the storage pond and running approximately parallel to the river on its left bank to carry a maximum discharge of 284 cumecs, at the tail end of the tunnel, a 20 metres diameter and 140 m high surge shaft with 2 expansion galleries, and three inclined pen-stocks taking off from surge shaft droping the water through approximately 488 m to run 6 hydro generating units, each of 170 MW capacity to give an aggregate installed capacity of 1020 MW at the Jhakri power house.

The diversion dam is such that the required diurnal storage is held behind 4 radial gates (15 m x 15 m); and by lifting up these gates during floods,debris and even large boulders which come with the flood water can move down the river without damaging the structure.

3.3.2. Abstract of Cost :

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below: (Ref. Project Report, December 1975).

3.3.3 Main Works

		Rs. in lakhs
i)	Diversion Dam	985.42
ii)	Power house	753.66
iii)	Power house equipment	8576.88
	Total =	10315.96

3.3.4 Auxiliary Works

i)	Land	50.88
ii)	Intake works	37.00
iii)	Approach tunnel, gate shaft, Desilting basin, flusing tunnel	900.52
iv)	Head race tunnel	7381.26
v)	Crossing over Mangalad Khad	392.45
vi)	Surge shaft	597.44
vii)	Penstock tunnel	744.62
viii)	Tailrace chamber and Tailrace tunnel	207.41
ix)	Permanent buildings	628.54
x)	Plantation	5.00
xi)	Communication	444.39
xii)	Inspection gallery	30.77
xiii)	Instrumentation	5.00
xiv)	River training	31.10
	Total =	11456.41

3.3.5 Construction Facilities

		Rs.in lakhs
i)	Upstream and downstream coffer dam	22.18
ii)	Temporary building	48.87
iii)	Special tools and plants	159.46
iv)	Tools and Plants	295.08
	Total =	525.59

3.3.6 Others

i)	Preliminary	170.00
ii)	Maintenance during Construction	211.61
iii)	Miscellaneous	1124.20
iv)	Losses on stock	52.70
v)	Telephone,power and light system	54.00
	Total =	1612.51

3.3.7 Indirect Charges

i)	Audit and account charges	95.40
ii)	Establishment	2463.34
	Total	2558.74

3.3.8 Contingency

i)	Contingency	637.79

3.3.9 Total Project Cost

Class	Cost in lakhs of rupees
Main works	10315.96
Auxiliary works	11456.41

	cost in lakhs of Rs.
Construction facilities	525.59
Others	1612.51
Indirect charges	2558.74
Contingency	637.79
Total	27107.00

3.4 LOWER BORPANI (LANGPI) H.E.PROJECT
MIKIR HILLS, ASSAM

3.4.1 The Project

North Eastern Region offers the greatest scope for development of Hydel Power, the total potential being of the order of 12 Million KW. But the power shortage in Assam is very acute. It has become much more acute due to recent bifurcation of Assam State Electricity Board into Assam State Electricity Board and Meghalaya State Electricity Board. The proposed Lower (Longpi) and Upper Borpani Hydro-Electric Projects in the district of Mikir Hills (now Karbi Anglong District), Assam, with installation of 100 M.W. in the Ist stage and 60 MW in the second stage will go a long way in meeting a part of the load demand of Assam. The Ist stage of the Borpani river development known as the Lower Borpani (Langpi) Hydro-electric project will comprise of the construction of a diversion weir (concrete gravity) of 37.5 m high on River Borpani near Hatidubi. The diverted water will be carried through a low pressure tunnel 4600 m long and 4.3 m in diameter, a surge shaft and two steel lined penstocks of 2.6 m dia each and 755 m length to the Lower Borpani Power Station with an installation of 2 x 50 MW for utilising an average drop of 235 M. Initially, till the creation of the Upper Borpani reservoir, Lower Borpani Power Station will be running in co-ordination with the Thermal stations of Assam only as Lower Borpani project will be the Ist hydro-electric project in Assam. The annual energy generation from the Lower Borpani Power Station will be 390 m.kwh in 90% years and 454 m.kwh in the average year.

3.4.2 Abstract of Cost

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below : (Ref. Project Report, October 1976).

3.4.3. Main Works

		Rs.in lakhs
i)	Hatidubi weir	332.06
ii)	Power house	113.05
iii)	Power house equipment including erection etc.	1352.07
	Total =	1797.18

3.4.4 Auxiliary Works

		Rs. in lakhs
i)	Land	6.40
ii)	Approach channel, Intake & Intake tunnels	19.31
iii)	Low Pressure tunnel	295.86
iv)	Surve tank	60.86
v)	Steel linear and Penstock for Lower Borpani Power House	257.35

		Rs. in lakhs
vi)	Permanent buildings	66.05
vii)	Plantation	2.00
viii)	Communication	180.54
ix)	Instrumentation	8.00
x)	Interconnection and transmission	219.00
	Total =	1115.37

3.4.5 Construction Facilities

i)	Diversion tunnel and Cofferdam	15.00
ii)	Temporary building	53.50
iii)	Special tools and plants	35.00
iv)	Ordinary tools and plants	30.42
	Total =	133.92

3.4.6 Others

i)	Preliminary	40.00
ii)	Maintenance during construction	15.54
iii)	Telephone, light etc.	25.00
iv)	Miscellaneous	86.00
v)	Loss on stock	5.00
	Total =	171.54

3.4.7 Indirect Charges

i)	Audit and accounts	23.61
ii)	Establishment	241.63
	Total =	265.24

3.4.8 Contingency

i)	Contingency	81.55

3.4.9 Total Project Cost:

Class	Cost in lakhs of rupees
Main works	1797.18
Auxiliary works	1115.37
Construction facilities	133.92
Others	171.54
Indirect charges	265.24
Contingency	81.55
Total =	3564.80

3.5 RAMMAN HYDRO-ELECTRIC PROJECT STAGE-II
WEST BENGAL STATE ELECTRICITY BOARD

3.5.1 The Project

The project report for Ramman Hydel Project Stage-II envisages generation of 50 MW power output inclusive of seasonal power during monsoon. The scheme is one of the four stages of Ramman Development Scheme to harness hydro-electric potential of River Ramman and Lodhma situated in the district of Darjeeling in West Bengal.

A power draft of 2.27 cumecs (80 cusecs) from Ramman and 0.85 cumecs (30 cusecs) from Lodhma forming a total discharge of 3.11 cumecs (110 cusecs) under the gross head of 519.23 m (1703.5ft) is to be utilized for the proposed generation of 25 MW at 50% L.F. and 25 MW of seasonal power; and the total installed capacity has been proposed as 4 x 12.5 MW. The scheme comprises of the construction and installation of the following:

1) Construction of 21.37 m x 4.57 m (70' x 15') drop type weir across River Ramman and 21.37 m x 3.05 m (70' x 10') drop type weir across River Lodhama Khola.

2) Construction of 3254.04 m (10676 ft) long D-shaped 2.13 m (7 ft) diameter tunnel and 2.13 m (7 ft) dia D-shaped cut and cover duct of 182.88 m (600 ft) length on Ramman side.

3) 6644.64 m (21800 ft) long rectangular R.C.C. flume of size 1.83 m x 1.07 m (6' x 3.6') on Lodhama side.

4) Construction of 73.15 m x 12.19 m x 3.81 m(240'x40'x12'-6") desilting basin on the Lodhama side and 195.07 m x 30.48mx 6.86 m (640' x 100' x 22'-6") desilting basin cum balancing reservoir on the Ramman side.

5) Construction of one common forebay of capacity 0.014 Mm^3 (0.49 M cft) and 12.24 m(50') wide side spillway.

6) A couple of penstock pipes of 1.31 m (4.3') internal diameter from El 1424.06 m (EL 4672.10') will have bifurcation at El 912.88 m (El 2995') of internal diameter of 0.73 m (2.4') having total length of 932.69 m (3060 ft.) for each penstock.

7) Construction of power house building of size 51.82 m x 18.9 m x 10.06 m (170' x 62' x 33') and installation of 4 units of turbo-generators of capacity 12.50 MW each.

8) Construction of tailrace channel of length 72.54 m(238') from power house to the river through chute and stilling basin.

9) Out door switchyard area 91.44 m x 60.96 m (300' x 200') with anciliary foundations.

10) Construction of aqueducts and bridges for crossings over big and small streams.

3.5.2 Abstract of Cost

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below : (Ref. Project Report, October,1976).

3.5.3.	Main Works	Rs. in lakhs
i)	Ramman diversion weir	15.90
ii)	Lodhama diversion weir	12.27
iii)	Power House and Switchyard	57.73
iv)	Power generation equipment	966.43
	Total =	1052.33

3.5.4. Auxiliary Works

		Rs. in lakhs
i)	Lodhama desilting basin	10.25
ii)	Ramman desilting basin cum balancing reservoir	47.48
iii)	Lodhama flume	221.71
iv)	Ramman Tunnel	94.05
v)	Common forebay	89.05
vi)	Penstock	122.79
vii)	Tailrace tunnel	3.33
viii)	Permanent building	91.68
ix)	Plantation	1.00
x)	Communication	214.52
xi)	Land	18.10
	Total =	913.96

3.5.5 Construction Facilities

i)	Temporary diversion (for construction)	2.50
ii)	Temporary buildings	15.55
iii)	Special tools and plants	6.26
iv)	Tools and plants	21.97
	Total =	46.28

3.5.6 Others

i)	Maintenance	21.46
ii)	Miscellaneous	91.00
iii)	Losses on stock	5.36
iv)	Preliminary	21.97
	Total =	139.79

3.5.7 Indirect Charges:

		Rs. in lakhs
i)	Indirect charges(Audit & accounts)	22.88
ii)	Establishment	175.74
	Total =	198.62

3.5.8 Contingency:

i)	Contingency	62.68

3.5.9 Total Cost of the Project

Class	Cost in lakhs of Rs.
Main works	1052.33
Auxiliary works	913.96
Construction facilities	46.28
Others	139.79
Indirect charges	198.62
Contingency	62.68
Total =	2413.66

3.6 PENCH HYDRO ELECTRIC PROJECT (TOTLADOH)
(JOINT VENTURE OF MADHYA-PRADESH AND MAHARASHTRA STATE)

3.6.1 The Project

The Pench Hydro-Electric Project is an interstate multi-purpose project, generating 160 MW of power and irrigating 72800 Hectares of land. In addition to this, part of the water will be used for thermal power station at Koradi (Nagpur) and as

Supplementing water supply for Nagpur Municipal Corporation.

The project envisages the construction of the following works :

i) Composite dam at Totladoh 679 m in length having 210 m of overflow section.

ii) There are seven Saddles on which earth dams are proposed involving total earthwork of 1859 Tm^3 and a maximum height of 22 m.

iii) Intake structure and two pressure shafts of 275 m length each.

iv) Underground power house located 130 m below general terrain and has a cavity of 54.5 m x 22 m to accomodate two units of 80 MW (Francis Turbine). There is an approach tunnel of 853.50 m for the power house.

v) Tail tunnel race tunnel having a length of 8074 m.

3.6.2. Abstract of Cost

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below: (Ref. Project Report, October 1977).

3.6.3. Main Works

		Rs. in lakhs
i)	Totladoh Composite dam	2350.10
ii)	Earthen dykes	196.08
iii)	Power House	237.63
iv)	Generating plant & switchyard	1665.56
	Total =	4449.37

3.6.4. Auxiliary Works

		Rs. in lakhs
i)	Intake channel and structure	87.85
ii)	Pressure shaft	205.24
iii)	Tail surge	125.42
iv)	Approach tunnel	94.41
v)	Tail race tunnel	1273.70
vi)	Permanent Buildings	52.53
vii)	Land	257.81
viii)	Plantation	23.43
	Total =	2120.39

3.6.5 Construction Facilities:

i)	Weir for construction & water supply	2.32
ii)	River diversion during construction including cofferdam	25.80
iii)	Temporary buildings	167.75
iv)	Special tools and plants	95.70
v)	Communication	95.47
vi)	Tools and plants	77.38
	Total =	464.42

3.6.6. Others

i)	Preliminary	73.05
ii)	Maintenance	77.96
iii)	Miscellaneous	287.71
iv)	Losses on stock	16.29
	Total =	455.01

3.6.7 Indirect Charges

i)	Audit and accounts	78.16
ii)	Establishment	510.79
	Total =	588.95

3.6.8 Contingency

i)	Contingency	130.00

3.6.9 Total Project Cost

Class	Cost in lakhs of Rs.
Main works	4449.37
Auxiliary works	2120.39
Construction facilities	464.42
Others	455.01
Indirect charges	588.95
Contingency	130.00
Total =	8208.14

3.7 KISHAU DAM PROJECT
YAMUNA HYDRO-ELECTRIC SCHEME STAGE - III

3.7.1 The Project:

Kishau dam project would utilise the water of River Tons, a major tributary of river Yamuna, for irrigation and power production. The project envisages construction of a 253 m - high rockfill dam and a power house of 450 MW capacity near Kishau in Uttar Pradesh.

The river Yamuna and its tributaries have a large irrigation and power potential, but at present, only their run-off-the-river supplies are utilised for irrigation. There is no storage reservoir either in Yamuna or on its tributaries. The Kishau dam project would form the Third Stage of Yamuna Valley Development.

Since the growing of food for the country is very important, the releases from the reservoir have been worked out on the basis of irrigation requirement.

The Criteria adopted for operation of Kishau reservoir is as follows:

i) The power to be produced should be such that in normal years, the reservoir level should not fall below a particular elevation (El. 794 m).

ii) Power shall not be cut below 150 MW (firm power in more than 10% periods), and the power generated will not be reduced below 90 MW in any period.

iii) The water released below Kishau dam during monsoon will not be less than 58.62 cumecs (2070 cusecs), which is the minimum requirement of water of one unit, at Yamuna Hydel Scheme Stage II.

iv) During non-monsoon season from October to June, the free supply of the river as at present available at

Tajewala will not be reduced and a minimum of 169.92 cumecs (6000 cusecs) will be maintained during October.

v) The water available at Tajewala will not be reduced below 226.56 cumecs (8000 cusecs) during the monsoon period from July to September for the existing Kharif irrigation on Yamuna System.

The selected lay-out of the project comprises of the following :-

i) A 253 m high Earth and Rockfill dam.

ii) A chute spillway on the left flank

iii) 3 nos. 13.7 m diameter diversion tunnels on the left flank.

iv) A surface power house of installed capacity 450 MW between chute spillway and downstream toe of the dam on the left flank.

v) Two intakes of tower type in the approach channel to chute spillway.

vi) Penstock pipe in one of the diversion tunnels.

3.7.2. Abstract of Costs:

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below : (Ref. Project Report, December 1967).

3.7.3. MainWorks

		Rs. in lakhs
i)	Rockfill dam	7865.00
ii)	Power House	238.00
iii)	Power house plant and equipment	1591.58
iv)	Irrigation distribution system	670.00
	Total =	10364.58

3.7.4. Auxiliary Works

i)	Intake and Penstock	856.00
ii)	Chute spillway	852.00
iii)	Irrigation sluices	50.00
iv)	Permanent buildings	79.99
v)	Access road and bridges(permanent)	475.00
vi)	Land	227.11
vii)	Plantation	10.00
viii)	Soil Conservation	20.00
	Total =	2570.10

3.7.5. Construction Facilities:

i)	Diversion tunnels and cofferdam	1667.00
ii)	Temporary buildings	393.69
iii)	Access road and bridges(temporary)	350.00
iv)	Special tools and plants	344.65
v)	Ordinary tools and plants	1166.27
	Total =	3921.61

3.7.6. Others

		Rs. in lakhs
i)	Preliminary	107.00
ii)	Maintenance	407.25
iii)	Telephone, light and power system	8.00
iv)	Miscellaneous	449.00
v)	Losses on stock	20.00
vi)	Capitalised abatement of land revenue	33.75
	Total =	1025.00

3.7.7 Indirect Charges:

i)	Audit and account	166.27
ii)	Charges for procurement, purchase, inspection and transportation of equipment	200.42
iii)	Establishment	1338.18
	Total =	1704.87

3.7.8 Total Project Cost:

Class	Cost in lakhs of Rupees
Main works	10364.58
Auxiliary works	2570.10
Construction facilities	3921.61
Others	1025.00
Indirect Charges	1704.87
Total =	19586.16

3.8 BEAS PROJECT - UNIT II
BEAS DAM AT PONG

3.8.1 The Project:

Beas Project is the largest water and power development project so far under taken in the country. It is a part of complete plan for integrated utilization of the waters of three eastern rivers of Indus Valley System namely Satluj, Beas and Ravi for irrigation and power generation. According to the Indus Water Treaty concluded between India and Pakistan, the waters of these rivers have been exclusively allotted for use in India. With the completion of the Bhakra - Nangal project, the river Sutluj has already been fully harnessed. The Beas project comprising of two units, viz Beas - Sutluj Link (Unit - 1) and Beas Dam at Pong (Unit - II) has been executed to make maximum use of the flows of the River Beas (16,035 million cum) for irrigation and power generation. The project is primarily designed for meeting the irrigation water requirements of the States of Rajasthan, Punjab and Haryana, but would also produce power. The dam is located at Pong. This is the highest earthfill dam so far constructed in the country. It is 132.6 m high above the deepest foundation level. An earth core gravel - shell dam has been constructed in view of the nature and structure of the foundations, its location in Seismic zone and availability of suitable construction materials in the vicinity. A number of instruments of different types have been embedded in the body of the dam to observe its behaviour.

Five concrete lined tunnels, each of 9.14 m finished diameter were constructed for river diversion during construction stage. After serving their function as diversion tunnels, two of these tunnels were converted into outlets for controlled irrigation releases and the other three used as penstocks. Therefore, 50% of the cost of these tunnels could be considered under construction facilities and 50% under auxiliary works. A Chute Spillway has been provided for passing the floods and is located on left abutment of the dam.

On full development, waters stored behind the dam would provide perennial irrigation to an area of 1.6 lac hectares. The average power contribution from Pong Power Plant will be 72 MW at 100% load factor.

Flood control, though incidental, is yet another major advantage. The construction of the Beas Dam has practically eliminated the incidence of floods downstream, which in turn will help reclaim large tracts of valuable lands on both sides of the river.

The project has been planned, designed and constructed execlusively by Indian expertise.

3.8.2. Abstract of Cost:

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below: (Ref. Project Report, May 1968).

3.8.3. Main Works

		Rs.in lakhs
i)	Preparation of foundation of dam and Power House	557.74
ii)	Earth dam	2677.52
iii)	Spillway	1512.19
iv)	Power plant structure & appurtenant work	395.67
v)	Power-House equipment	874.00
	Total	6017.12

3.8.4. Auxiliary Works:

i)	Land	2403.18
ii)	Diversion works(used subsequently as power Penstock and outlet works)	1888.78
iii)	Providing roadway on top of dam and spillway bridge	77.13
iv)	Instrumentation and its appurtenant works in dam	44.08
v)	Permanent buildings	549.24
vi)	Plantation	7.00
vii)	Communication	426.44
	Total =	5395.85

3.8.5. Construction Facilities:

		Rs. in lakhs
i)	Upstream and downstream cofferdam	54.35
ii)	Muck and haul roads	53.31
iii)	Diversion works	1888.79
iv)	Transmission and distribution line for construction	14.45
v)	Job facilities	150.00
vi)	Temporary buildings	39.85
vii)	Special tools and plants	246.05
viii)	Tools and plants	133.21
	Total =	2580.01

3.8.6. Others

i)	Maintenance during Construction	239.63
ii)	Miscellaneous	397.87
iii)	Suspense	10.00
	Total =	647.00

3.8.7. Indirect Charges:

i)	Establishment	1558.18
ii)	Indirect Charges	147.21
	Total =	1705.39

3.8.8 Contingency:

i)	Contingency	81.33

3.8.9 Total Cost of the Project

Class	Cost in lakhs of rupees
Main works	6017.12
Auxiliary works	5395.85
Construction facilities	2580.01
Others	647.00
Indirect Charges	1705.39
Contingency	81.33
Total =	16426.31

3.9. RAJASTHAN CANAL PROJECT
RAJASTHAN CANAL BOARD
GOVERNMENT OF RAJASTHAN

3.9.1 The Project

According to the Indo-Pakistan agreement, on the utilisation of waters of mighty rivers of Punjab, the entire supply of the three eastern rivers, Sutlej, Beas and Ravi was allocated to India and that of three western rivers Chenab, Jhelum and Indus to Pakistan.

The Rajasthan Canal Project will utilise waters from the Beas and Ravi rivers and when completed will be one of the largest irrigation projects in the world. It seeks to transform a vast, inhospitable, wasted stretch of desert over 325 miles long and 27 miles wide with existing population in places as low as only six persons per square mile into a prosperous agricultural region. With 526.92 cumecs (18500 cusec) the Rajasthan canal will deliver life giving waters in ample measure to about 5 million acres of culturable area with agricultural produce exceeding 27 lakh tons per year. This canal water, besides benefiting irrigation, will give elementary amenity of drinking water and growth of animal husbandry and mineral industries.

It is proposed to make the canal navigable. The dimensions of the canal are suitable for navigational purposes. It may be possible in course of time to link the canal with the Kandla port by a navigation cut. If this is found feasible, it will link the land- locked area to the sea. The Rajasthan canal has under its command vast patches of plain fertile land measuring thousands of acres, mostly belonging to the Government. It will, thus, be possible to establish a large number of good sized agricultural mechanised farm.

The Rajasthan canal will afford an opportunity to create a community on the latest democratic conceptions. New villages and towns will have to be established. All this will be done in accordance with a well considered Master Plan.

Thus the Rajasthan Canal Project will play a very important role in the economy not only of Rajasthan State but of the entire country.

3.9.2. Abstract of Cost

The cost of the project as classified under main works, auxiliary works, construction facilities, others, indirect and contingencies is given below : (Ref. Project Report, April 1960).

3.9.3. Main Works

		Rs. in lakhs
i)	Main and Branch Canals	2810.27
ii)	Distributaries	409.03
iii)	Navigation	45.50
	Total =	3264.70

3.9.4. Auxiliary Works:

i)	Land	34.00
ii)	Regulators	75.97
iii)	Falls	10.67
iv)	Canal Crossings	5.16
v)	Cross drainage works	20.69
vi)	Permanent Building	167.77
vii)	Escaps	16.50
viii)	Plantation	18.19
ix)	Communication facilities including bridges	23.68
x)	Drainage and protective works	6.25
	Total =	378.88

3.9.5. Construction Facilities:

		Rs. in lakhs
i)	Temporary buildings	71.20
ii)	Service and boundary roads	8.73
iii)	Special tools and Plants	36.63
iv)	Tools and plants	63.98
	Total =	180.54

3.9.6. Others:

i)	Miscellaneous	33.91
ii)	Maintenance during construction	51.37
iii)	Unforeseen	21.29
iv)	Loss in stock	4.27
v)	Preliminary	28.61
	Total =	139.45

3.9.7. Indirect Charges:

i)	Establishment	354.00
ii)	Indirect charges as audit & account	45.21
	Total =	399.21

3.9.8. Total Project Cost:

Class	Cost in lakhs of rupees
Main works	3264.70
Auxiliary works	378.88
Construction facilities	180.54
Others	139.45
Indirect charges	399.21
Total =	4362.78

CHAPTER-IV

4.0 . COMPARISON OF COST OF DIFFERENT PROJECTS

Sl. No.	Name of Projects	Total cost (Rs.in lakhs)	Costs in Percent of Total: Main works	Aux.works	Constn. facilities	Others	Indirect charges	Contingencies
1	2	3	4	5	6	7	8	9
	HYDRO-ELECTRIC PROJECTS :							
1.	Lakhwar Vyasi Pariyojna, Dehradun, Uttar Pradesh, (Capacity-300 MW)	22847.65	67.59	9.64	3.96	7.14	10.14	1.53
2.	Maneri Bhali Hydro-Electric Scheme Stage-I, Distt.UttarKashi, U.P. (Capacity- 90 MW)	6823.28	36.87	39.02	3.19	6.25	13.67	1.0
3.	Nathpa-Jhakri Hydel Project, Himachal Pradesh State Elecy.Board, (Capacity - 1020 MW)	27107.00	38.06	42.26	1.94	5.95	9.44	2.35
4.	Lower Borpani(Langpi) Hydro-Electric Project, Mikir Hills, Assam (Capacity- 100 MW)	3544.80	50.41	31.29	3.76	4.81	7.49	2.29
5.	Ramman Hydro-Electric Project Stage-II, (Capacity- 50 MW)	2413.66	43.6	37.87	1.9	5.8	8.23	2.6
6.	Pench Hydro-Electric Project (Totladoh) (Joint venture of Madhya Pradesh and Maharashtra State) (Capacity-160 MW)	8208.14	52.21	25.83	5.66	5.54	7.18	1.58
	MULTIPURPOSE PROJECTS							
7.	Kishau Dam Project, Yamuna Hydro-Electric Scheme, Stage-III	19586.16	52.92	13.12	20.02	5.23	8.71	-
8.	Beas Project Unit-II (Beas Dam at Pong)	16426.31	36.63	32.5	15.7	3.94	10.38	0.49
	IRRIGATION PROJECTS							
9.	Rajasthan canal project, Rajasthan Canal Board, Govt. of Rajasthan	4362.78	74.83	8.68	4.14	3.20	9.15	-

CHAPTER-V

DISCUSSION OF RESULTS AND CONCLUSIONS

5.1. LAKHWAR VYASI PARIYOJNA

The scheme consists of two dams and a barrage at its different stages of development of water resources for hydro-electric power and irrigation. Therefore, these dams and barrages including the power houses serve the purpose of main works costing 67.59% of the total cost of the project. The auxiliary works cost only 9.64% which is comparatively low infact, lowest among all projects studied. This is perhaps due to the topography and planning of the scheme. The Water Conductor System is much smaller and simpler than that at Maneri Bhali Project.

The percentage cost of construction facilities is higher due to higher diversion cost. Others expenses are also higher due to high miscellaneous expenses.

Indirect charges are also high due to higher establishment costs while contingency cost is low.

5.2. MANERI BHALI HYDRO-ELECTRIC SCHEME- STAGE I

The diversion dam and power house constitute the main works costing 36.87% while the cost of auxiliary works is 39.02% of total cost. In this project the percentage cost of auxiliary works is higher than that of main works due to the higher cost of water conductor system such as Head race tunnel, penstock and surge shaft. This is due to peculiar topography and design of the project.

Percentage cost of construction facilities is also substantial due to difficult site conditions. High establishment cost is the cause of high indirect charges while contingencies are low.

5.3. NATHPA-JHAKRI HYDEL PROJECT:

In this run of the river diversion scheme the diversion dam and the power house are the main works and cost 38.06% of the total cost. The cost of auxiliary works is 42.26% of total cost. The auxiliary works which have influenced the cost include 28 km long head race tunnel, surge shaft and 3 penstocks of 620 m long each. The complicated water conductor system influences the auxiliary works costs.

Percentage cost of all other classes of works is quite low.

5.4. LOWER BORAPANI(LANGPI) HYDRO ELECTRIC PROJECT:

The lower Borpani(Langpi) hydro-electric project is the first run of the river hydro electric scheme in Assam having a diversion weir and power house as its main works costing 50.4% of the total cost with cost of auxiliary works as 31.29%. The auxiliary works consisting of low pressure tunnel of 4600 m long and 4.3 m diameter and two steel lined penstocks of 755 m long, 2.6 m diameter have influenced the cost. This high percentage is, therefore, due to the special topography, site conditions and designof the project.

The percentage cost of the other items is as low compared to the other hydro-electric projects under study.

5.5. RAMMAN HYDRO-ELECTRIC PROJECT STAGE-II

This hydro-electric project harnesses two rivers namely Ramman and Lodhama. Two diversion weirs in Ramman and Lodhma river for diverting water to a balancing reservoir along with power house constitute the main works costing 43.6% while the cost of auxiliary works is 37.87% of the total cost. Among the auxiliary works which influenced the cost are Lodhama flume, Ramman tunnel, the penstock and the common forebay due to its lengths and sizes. The reason for high percentage of auxiliary cost is again topography and special design feature of the project.

There is not much variation of percentage cost of other items when compared with the percentage costs of other projects under study.

5.6. PENCH HYDRO-ELECTRIC PROJECT (TOTLADOH)

The Pench hydro-electric project is an inter-state multipurpose project the main works of which consists of a composite dam, eathen dyke and power house. The cost of main work is 54.21% of the total cost. The cost of auxiliary works is 25.83% of the total cost. The higher percentage cost of auxiliary works is mainly due to tail race tunnel. The cost of pressure shaft, tail surge and approach tunnel also has enhanced the percentage costs. These are required due to the topography of the project site. Cost of construction facilities is quite high.

5.7. KISHAU DAM PROJECT:

This is a multipurpose project for irrigation and power. The main works consist of Kishau dam and the power house costing 52.92% of the total cost while the cost of auxiliary works is 13.12%. The chute spillway is included in auxiliary works as it is not a part of the dam, yet the percentage cost of the auxiliary works is comparatively low. This appears to be due to the reason that cost of the rock-fill dam is very high which increases the contents of cost under main works.

High percentage o f construction facilities is due to mechanised construction method while percentage cost of other classes of works is similar to other projects under study.

5.8. BEAS PROJECT UNIT-II (BEAS DAM AT PONG)

This project is primarily designed for meeting the irrigation water requirements of the states of Rajasthan, Punjab and Haryana but would also produce power. The Pong Dam along with its power house constitutes the main works costing 36.63%. While the cost of auxiliary works is 32.5% of the total cost on the basis of charging 50% cost of diversion works to construction facilities and 50% to auxiliary works. This is because the diversion works required to facilitate construction have been subsequently used as power penstock and outlet works.

The cost of land acquisition has influenced the percentage cost of auxiliary works. As it is the largest irrigation and hydro-power development project in the country so far undertaken. Therefore, land acquisition is also large and hence the percentage cost of main works and auxiliary works is approximately equal. Due to high degree of mechanization construction facilities cost is quite high.

5.9. RAJASTHAN CANAL PROJECT

This is purely an irrigation project in which the cost of main works is 74.83%. While the cost of auxiliary works is 8.68%. In irrigation scheme the influence of auxiliary works is found to be minimum.

The percentage cost of all other classes of works is low perhaps due to the fact that except canal system which falls under main works need of all other classes of work is minimum.

5.10. CONCLUSIONS

No two projects are identical in design requirements due to difference in topography, geology and their objectives. Therefore, it is difficult to draw any definite conclusions for comparing the costs of different classes of works unless these are taken under similar geology, topography and general objectives. However, this study shows that generally higher the total cost of the project lower the percentage cost of the auxiliary works.

For hydro-electric projects, in particular, it is found that when the length of water conductor systems increases the percentage of cost of auxiliary works increases. Generally, the % cost of main works is lower in case of power projects than in other projects.

Capacity of hydro-electric projects has no influence on the cost of auxiliary or other works. As the need of the power is great influence of cost of auxiliary works is perhaps ignored.

5.11. RECOMMENDATION

There are various factors which contribute to the increase in the cost of water resources projects. Therefore, more detailed case studies of selected projects with a view to ascertain the impact of each factor in quantitative terms, is needed.

The effect of site conditions on power projects deserves careful study, as these conditions substantially affect the cost of auxiliary works. If data on projects under similar site conditions could be collected it may be possible to quantify in terms of cost the effect of different factors of site.

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