MODIFICATION OF DESIGN OF AN EXISTING REGULATOR TO MAKE IT FISH FRIENDLY

Submitted by

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In partial fulfilment of the requirement for the degree of
Master of Engineering (Water Resources)

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CERTIFICATE

This is to certify that this project work has been done by me and neither this project nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

17.4.98

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We hereby recommend that the project work prepared by Md. Moinul Husain entitled **MODIFICATION OF DESIGN OF AN EXISTING REGULATOR TO MAKE IT FISH FRIENDLY** be accepted as fulfilling this part of the requirements for the degree of Master of Engineering (Water Resources).

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ABSTRACT

Bangladesh is a flood prone country and thus there is a necessity of flood management. Presently, most of the flood management project are aimed to support agriculture sector. The traditional way of flood protection has been in the form of construction of embankments, regulators, sluices and pumps. These projects interfere with the environment and ecosystem of the floodplain and the connected rivers and inevitably affects the open water fisheries sector as migratory routes and nursing grounds of many species of fish are hampered and disturbed. In recent years, majority of fresh water fish have declined both in abundance and bio-diversity.

Barriers to migration of fish has been identified as a major contributing factor in these declines. As a mitigation measure, fish pass and fish friendly regulators are to be constructed to support the natural migration pattern of fishes as far as possible. During the last several decades hundreds of sluices and regulators have been constructed without any provision for meeting the requirements of fish movement. Study are needed to see if the existing structures can be modified to make them fish friendly.

This study was taken up to develop an understanding of the migrational behavior of various species of fish available in Bangladesh and set up design criteria of fish passes. The study also aimed at determination of the cost of modification of an existing regulator as a case study.

The concept of a fish passes is of recent origin in our country. So far three fish passes have been constructed in the country. They are : Fish Pass in Kawadighi Haor of Manu River Project in Moulvi Bazar , Jugini Inlet of Compartmentalization Project, Tangail and Marichar Danra Regulator of Marichar Danra Sub-project in Nawabgonj district. Based on performance evaluation of these structures and review of available literature on fish passes, a set of design criteria have been developed.

The existing regulator of the Udghal Beel Project at Gilutia in Sunamganj was chosen for modification to make it fish friendly and to assess the probable cost of modification.

The study recommends a maximum exit velocity of 1.5 m/sec to be allowed by the regulator. To facilitate migration of fish fry, the gate should be operated in pre-monsoon season i.e. during April to June period. Presently gates are kept closed during this period. The design of the regulator should ensure overshot regulation with sufficient back water depth. Vertical gate may be placed below the floor of passage to regulate depth of water of 15 cm over it by raising the top of the gate. Maximum head difference between inside and outside the embankment may be limited to 3.00 m and minimum depth of water in the outflow channel in the country side must be maintained at 1.00 meter The sill level may be fixed on the basis of lowest water level available during April-May months

The design of the existing regulator of the Udghal Beel has been modified to meet the above mentioned criteria. The cost of modification of the existing regulator is approximately 25% of the original cost.

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CHAPTER I

INTRODUCTION

1.1 General

Bangladesh is a flood prone country and thus there is a necessity of flood management. Presently, most of the flood management projects are aimed to support agriculture sector. Several important river system and floodplain areas have already been brought under coverage of flood control and drainage (FCD) facilities for this purpose. Irrigation has also been introduced in FCD projects. The traditional way of flood protection has been in the form of construction of embankments, regulators, sluices and pumps and its history is very old. Major water resources development projects in the form of FCD projects started in early sixties in the coastal area in the name of Coastal Embankment Project. As the time advanced more and more such projects came into existence. Many of the new projects were smaller in size but their technical characteristics were the same.

These flood control, drainage and irrigation (FCDI) projects interfere with the environment and ecosystem of the floodplain and the connected rivers. This inevitably affects the open water fisheries sector as migratory routes and nursing grounds of many species of fish are hampered and disturbed (FAP-12 1993, Ali 1997). In recent years, majority of fresh water fish have declined both in abundance and biodiversity; researchers have identified barriers to migration as a major contributing factor (Lloyed et al. 1991). It is necessary to maintain conditions which help migrants reach their destination. As a mitigation measure, fish pass and fish friendly regulators are to be constructed in FCDI projects to support the natural migration pattern of fishes as far as possible (FAP-12 1993, FAP-17 1994) .

There has been substantial growth in rice production in flood protected areas in short run, but its environmental costs has been heavy (MPO 1991, FAP-17 1994). Environmental issues had largely been overlooked in apprising water management projects in the past. Flood management schemes in Bangladesh, prior to initiation of studies under the Flood Action Plan (FAP) in 1989, did not consider nor proposed mitigation against the negative impacts on flood plain fisheries. The FAP studies and also the National Water Plan prepared in 1991, have pointed out the importance of fishery resource and created awareness for its protection and preservation. Despite importance of fisheries in terms of nutritional value and rural employment and access to the common property, these resource are gradually decreasing (NWP 1991).

There is a necessity of integrated water management to support both agriculture and fisheries sector. Investigation are needed to evolve methods for efficient operation and maintenance of sluices/ regulators so that they help migration of fish in one hand and at the sametime productivity in agriculture is also maintained. Conflict between farmers and fisherman within the existing FCDI project needs to be resolved with proper engineering skill and institutional development. During the last several decades hundreds of sluices and regulators have been constructed without fish passage or any provision for meeting the requirements of fish movement. Study are also needed to see if these structures can be modified to make them fish friendly.

1.2 Fish Resource and Its Importance in National Economy

Within the national context the annual fish production of approximately 8.40 lac metric tons play an important role in the economy of Bangladesh. This sector accounts for 3% of GDP, 11% of export earning, 70% of annual protein intake of its population. Inland fisheries and aquaculture are the major contributors of fish covering 50% and 22% of the total production (DOF 1990, BBS 1989). Fish is a common property resource and main source of protein in the rural areas. Thus increasing the level of production of open water fisheries is all the more important in a country where bulk of the children suffer from malnutrition. About ten million people are dependent on the fisheries sector as fisherman or in some way or other.

The fisheries resources of Bangladesh are among the richest in the world. While tremendous genetic diversity is embodied in the over 500 species which inhabit Bangladesh inland, estuarine and coastal water, little substantive data on these species are available (NWP 1991). Report shows that fish intake in absolute term have declined from 33 gm. per person/day in 1962 to 21 gm per person/day in 1988. The decline of natural inland fisheries is due to various reasons viz pressure on land due to population growth rate and increase in demand, and conflicts with land and infrastructure development.

Bangladesh is endowed with extensive river system, ponds, *beels, haor, baors,* ox-bow lakes, reservoirs, etc. which are habitat of open water fisheries. During the rainy season the entire flood plain (with *Haors and Beels*), rivers and *khals* become a single block of water. Fishes are widely dispersed and access is freely open to public. In the dry season individual *beels* emerge and are over-wintering refuge/habitat for broodstock of many commercial and subsistence fish species. Over the past decades annual yield in closed water culture fisheries and in marine fisheries gradually increased but annual yields decreased in open water capture fisheries to the same extent. Potentials of the open water fisheries is being reduced every year as more and more fish habitats are removed and /or altered for crop production. The direct loss to the fishery of a FCD project will come from the land from which flooding is eliminated. Direct fish harvest loss from every hactare of flood plain removed has been estimated to vary between 37 kg to 110 kg (Ali; MPO, 1989). Loss of biodiversity is another impact of FCD development.

1.3 Adverse Impacts of FCDI Project on Fisheries

Fisheries and FCDI development are in conflict with each other. FCDI are required for foodgrain production. On the other hand, the sequences of annual flooding and post-flood standing water in the floodplain are of importance to fisheries sector. During flood fish move out to the flood plain for feeding, grazing, growth and reproduction. Pattern of actual movement, migration, spawning, harvesting, overwintering and other activities of major fish and prawn in a year is shown in Fig. 1.1. Interruption of natural cycle of flooding and recession of flood in any channel by FCDI project adversely affect its natural production system. Removal of fish production habitat in the floodplain results in reduced fish yield.

Impact of typical FCD/FCDI projects:

Embankment act as a physical barriers to migration, tending to prevent access of fish to their usual breeding, rearing and feeding ground. It has been observed that in *Haor* areas where there is no embankment and control structure, the migrating fishes are able to swim freely in and out between rivers and *Haors* via the network of *khals*. But with embankment, the natural fish migration is effectively blocked in both directions until embankments are over topped or

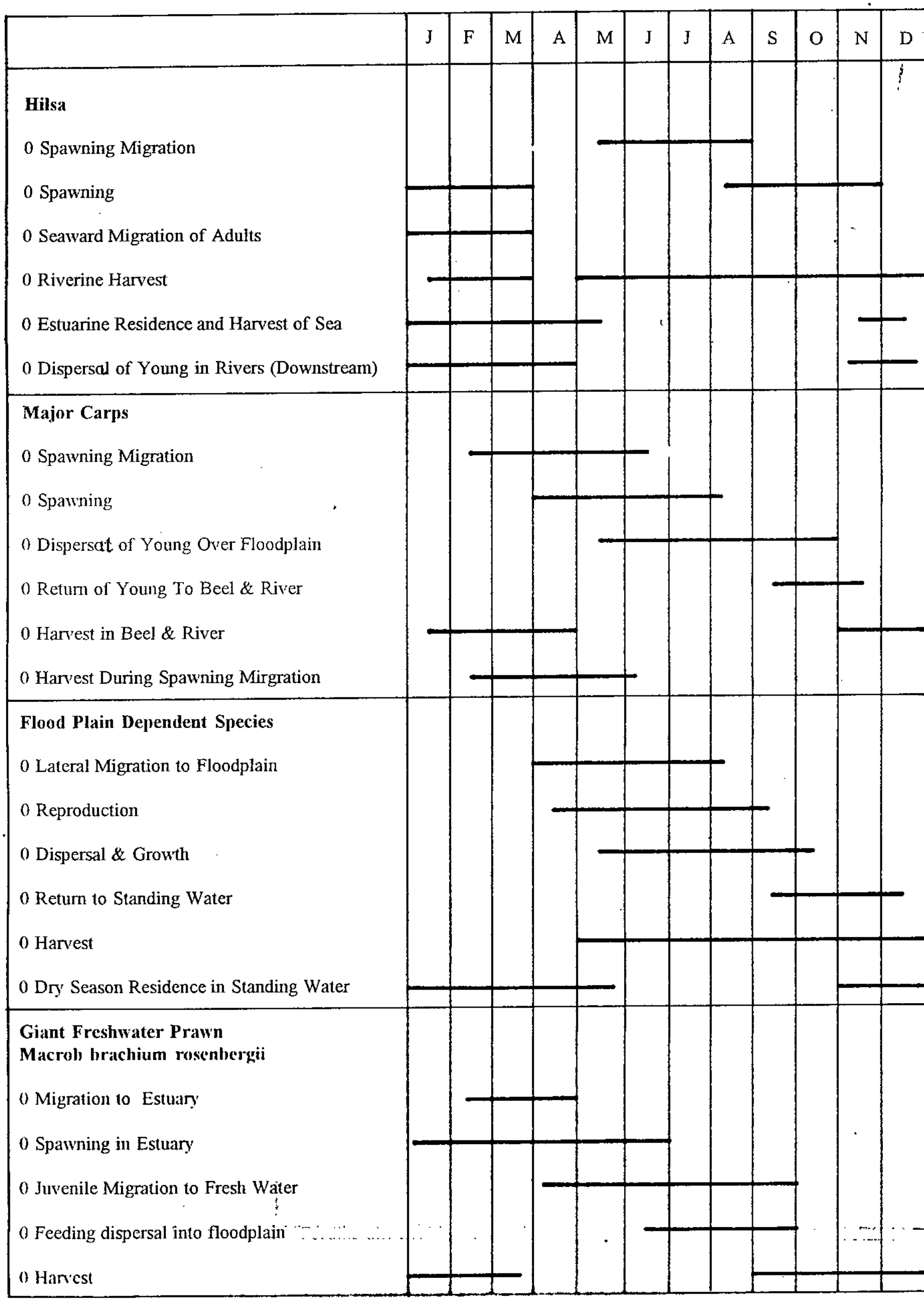


Fig. 1.1 Activities of major fresh water fish and prawn of Bangladesh
Source: MPO 1985 Technical Report 16

breached. The denial of migration may result in reduction of fish stock ranging from the lowering the levels of abundance to complete depletion. The typical pre- and post FCD conditions are presented in Fig. 1.2.

The following conditions prevail in open water flood plains before undertaking any project for flood management and drainage (MPO 1985):

- fish migration and movement into and out of floodplain occur freely;
- breeding and early growth of many species of fin fish and prawn occur in floodplains;
- spawning migration of many species of fish and prawn from rivers and *beels* takes place in the floodplains;
- with the recession of flood waters, fish population of the floodplains return to rivers, *beels* and other permanent water bodies; and
- fisherman harvest fish from floodplain for subsistence and income generation.

Under the post FCD project conditions the following changes usually occur in the floodplain ecosystem:

- open water fish production declines due to general reduction in the area of flood lands and beels (such as reducing the area of nurseries and feeding ground);
- regulators prevent movement, migration and recruitment of migratory species, specially major carp;
- small sized fish and prawn species replace larged sized species;
- elimination of oxbows by channelization destroys prime carp spawning grounds;
- cross dam on rivers prevent migration upstream, and consequently the upstream fishery disappears;
- embankment cut of channels (*khal*) which connects beels to rivers thus preventing both water and fish stock replenishment of beel;
- submergible embankment delay spawning migration, resulting in resorption of ova and milt in frusted broodstock;
- impediment to breeding, feeding and early development of foodplain breeding fish;
- fish harvesting activity is reduced;
- reduction of fish biomass contribution to rivers and beels; and
- surface water abstraction for irrigation reduces the area of dry season habitat for fish.

The ecological changes brought about by FCDI projects adversely affects both migratory and non-migratory species of fish. Consequent to embankment construction, substantial morphological changes takes place in the original environment which include segmentation of ecological niche, blockade of water discharging channels, conversion of running water into a body of slow discharge characteristics (in case of a reservoir) and radical transformation of long established ties and interrelationship between organism. Other changes also occurs such as alteration of physio-chemical conditions of spawning ground, destruction/ shrinkage of rearing and feeding ground, change in turbity and silting patterns which may result in failure of spawning or ineffective spawning of some species. Also when embankments are built around natural floodplain such as *Haors*, where fish spawn in shallow areas or when rivers are diverted from one system to another the natural genetic link in the life cycles of the fish is broken and some species might face extinction.

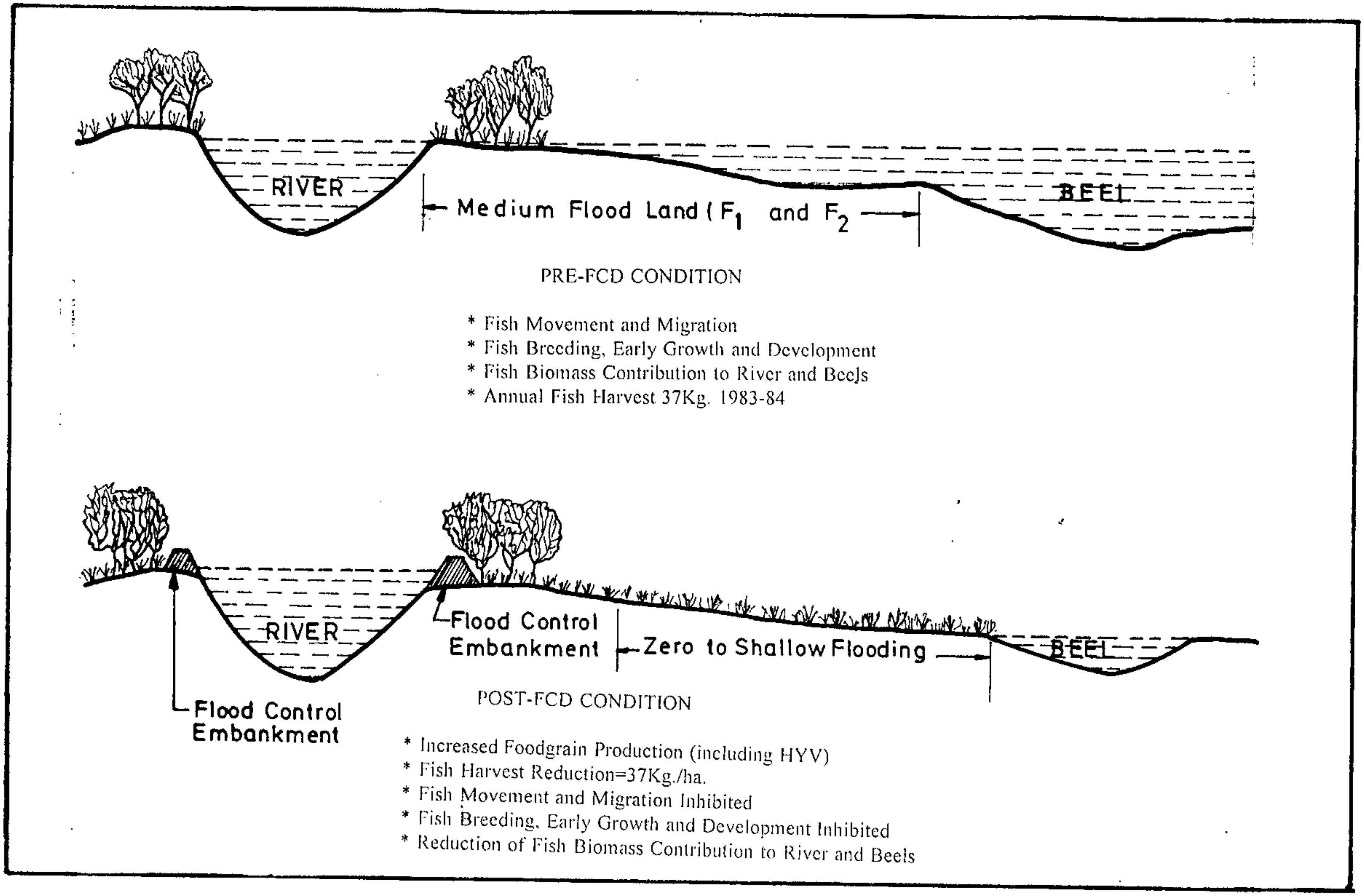


Fig. 1.2 Impact of flood control project on fisheries
Source: National Water Plan, 1986, MPO

Impact of polders in coastal areas:
Coastal areas before construction of polders used to be inundated regularly by tidal action and these inundated areas were a rich nursery and filling ground for the larvae, juvenile and fry of many species of estuarine and marine fish and shrimp. Construction of coastal polders has reduced their tidal plain habitat. However coastal polders have provided a more stable environment for the development of brakish water aquaculture.

Impact of FCDI project has been studied under FAP-12 and pointed out that FCDI projects have usually had a major negative impacts on capture fisheries resulting from substantial reductions in the areas of regularly inundated flood plains, in the areas of permanent beels and in the blockage to fish migration routes. Many fisherman have lost their livelihood or been diverted to river fisheries, leading to over fishing in these areas which are also adversely affected by the changes in fish migration potential. The magnitude of these losses in most cases appears to be substantially greater then has been previously estimated, and in some cases to be sufficient to severely reduce economic performance of projects which appear viable on agriculture performance alone. It also indicates that absence of integrated flood control and fisheries planning has led in some cases to acute social conflicts by fisherman & farmers (FAP-12 1993). In order to overcome these problems and to conserve and save the natural fish population within FCDI projects, a combined package or modification in project planning, regulator and sluice design and FCDI operating procedure would be needed (FAP-13, 1992).

1.4 Objective of the Study

The objectives of this study are as follows:

(a) to investigate the performance of the existing fish pass and fish friendly structures and establish design parameters of a fish friendly regulator; and

(b) to investigate the possibility of modification of the existing regulator to make it fish friendly and to estimate the incremental cost of such modification.

CHAPTER II

LITERATURE REVIEW

2.1 Relevant Aspects of Fish Biology

Interventions in the form of embankments, sluices and regulators for FCDI schemes create obstacles in the path of migrating fish. To over come the problem, structures may be designed so as to assist the fish to pass them. The efficiency of such fish friendly structures depends to a large degree upon the ability by designers to utilize knowledge of migratory behavior, spawning patterns and locations and swimming characteristics of the species.

2.1.1 Migration Characteristics of Various Fish Species

Few open water fish are confined to one habitat throughout the year. The periodic and directed travel of fish mainly for feeding, breeding and overcoming adverse climatic conditions is called migration. From the point of view of migratory habits, fishes occurring in the rivers and flood plains are classified as (FAP-17 1994), FAP-6 1993):

- resident species which remain confined within the local territories;
- local migrants which perform seasonal migration within short distance for feeding, breeding etc. (20-30 km); and
- long distant migrant which perform regular annual migrations for feeding, spawning or both. They migrate substantial distances, upto several thousand kilometers, between widely different habitat. Two terms "denatant" and "contranatant" are used to describe the movement of fish in relation to current. Denatant is swimming, drifting or migrating with the current and contranatant means swimming or migrating against the current.

The fish community have been divided into two categories viz. Black Fish and White Fish (FAP-17 1994). The Black fish are essentially resident on floodplain. They would normally retreat into *beels* or other residual water bodies after the flood have receded. They include testadineous, Hetero pneustes etc. The local *Kai* fish belongs to testadineous group and *Shing* fish belongs to Heteropneustes groups. During the dry period these fish move into the "*Kua*" or fish pits which are the last remnants of flood plain waters.

White fishes show some distinct migration within the river system, usually associated with spawning. The white fishes can be divided into three categories depending on the extent of migration: (i) those with considerable longitudinal migration, which may be followed by lateral migration on to the floodplain e.g. *Pangas, Maha Shoal*; (ii) those with limited longitudinal migration followed by lateral migration on to the floodplain (e.g. major carps such as *Rue, Katla, Mrigel* and *Magur*; and (iii) those species which are truly anadromus moving from sea into the freshwater to breed e.g. *Hilsha*.

The natural pattern of fish migration during the pre-monsoon period is for adult fish, mainly carp and cat fish, which overwinter in the river to move into shallow areas within the *Haor* for breeding purposes. Other adult fish which overwinter mainly within *beels* migrate in the opposite direction (out migration) from *Haor* to the river area for spawning.

The migration pattern during the post-monsoon is a reversal condition at pre-monsoon. Older mature adult and young new adult fish move from breeding/rearing ground to over wintering areas. The fish year can be divided into the following seasons as shown in Fig. 2.1 (FAP-17 1994).

i. Overwintering dry season (December to March) - Broodstock and juveniles approaching recruitment size are concentrated in river duars and *beels*. No migratory movement takes place during this period. The flood plain dries out and only water left is in rivers and beels, where entire fish population is lodged. Juvenile mature into adults and gonad begin ripening in anticipation of the coming breeding season and the annual cycle completes the fullcircle.

ii. Spawning migration season (April to June). This season usually begins during the pre-monsoon flood phase and continue into the first part of full monsoon flood phase. Fish generally move from deeper water to shallower water. Breeding takes place in shallower water.

iii. Nursery/Grow-out season (June-Sept). This is the season of rapid fish growth. Fingerlings of those fish which bred on the flood plain are on the nursery ground so they do not have an access problem but the fingerlings hatched from the river breeding species need to get up to the flood plain. This can be done in two ways either they are passively swept on to the flood plain, or are passively swept through a byepass structure when it is opened. Habitat area and food availability increase enormously during this season.

iv. Flood recession season (Sept to December). Flood water starts receding. As water area shrinks fish move into deeper water navigating along khals and river channel, majority migrate to deeper water during flood recession except a few species. A fish moving from flood plain laterally to deeper beel does not encounter much a problem. A fish moving from flood plain out into river normally moves along khal. FCDI embankment need to allow this to happen by constructing byepass structure.

To summarize for the majority of fish species the following principal fish migration takes place : active breeding migration of brood stock from over wintering grounds to breeding ground; passive hatchling/fingerlings migration from breeding ground to nursery/grazing grounds; active migration of juveniles and brood stock from breeding and or/grazing grounds to over wintering ground.

2.1.2 Spawning Patterns and Locations

Breeding begins during pre-monsoon flood. Most of the catfish start breeding at the end of March and early April. Flash floods, heavy continuous rain and thunder together stimulate fish breeding. When first pre-monsoon flood water enters the *beels*, fish begin to move against the current in search of suitable spawning habitat. Some species prefers to breed on newly inundated grassy areas where the current is slow, water depth is shallow and bush/reeds are present. During spawning period some species form groups or schools and at the time of mating the mating pair bend against each other when expelling eggs.and.milt. Normally.the schools are segregated by species. Usually the schools move at night during the new or full moon phase. Except for the snakeheads (*Taki, Shoal, Gozar*), most species do not have parental care for their off spring.

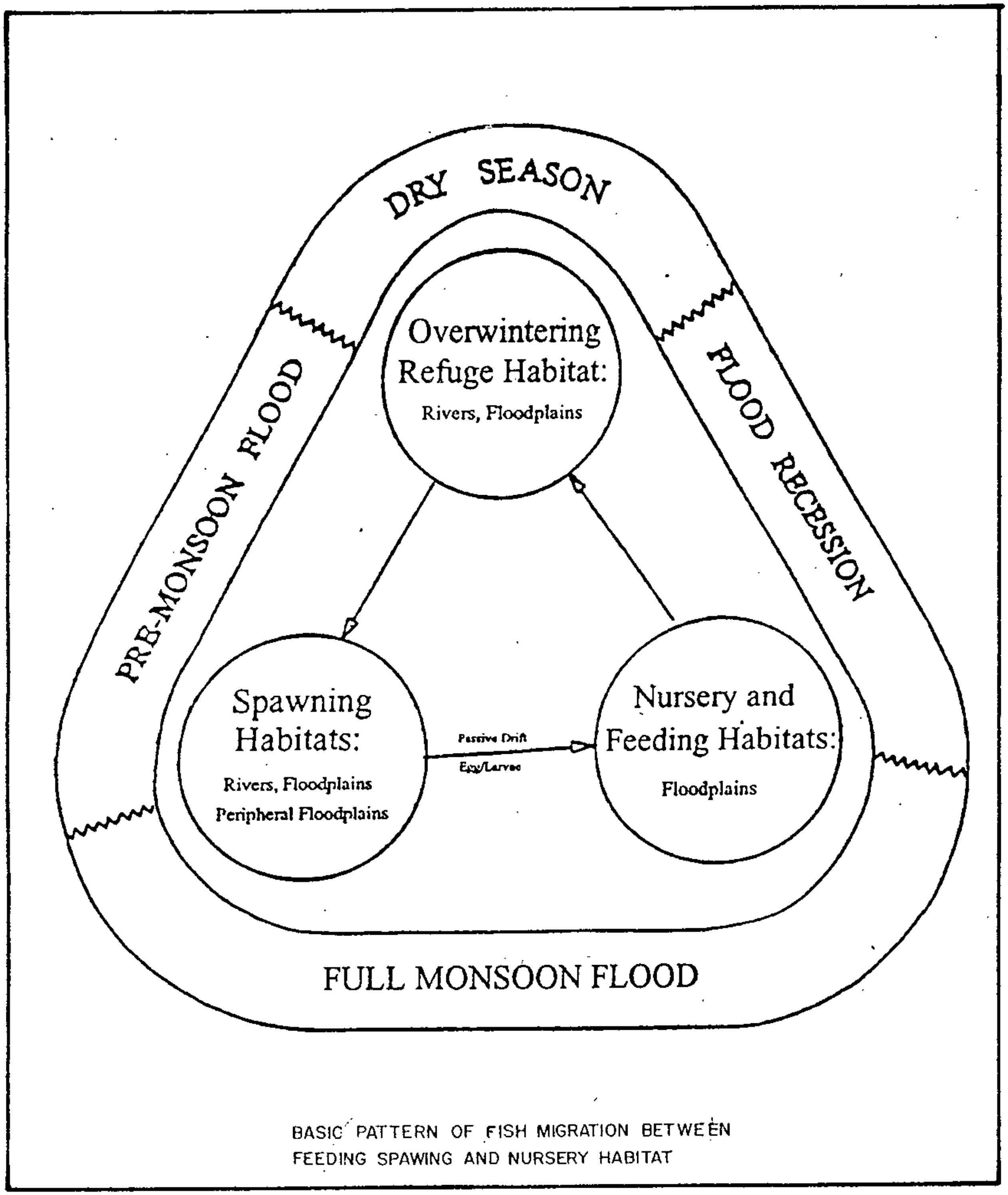


Fig. 2.1 Migration of fish to feeding, spawning ad nursery habitats
Source: FAP-17, Supporting Vol. 23, 1994

Reproductive patterns are more diverse among river breeders. *Air*, *Rita*, *Ghagot* and *Guizza* make pits in the shallower part of the river in April and May. *Chital* and *Foli* prefer to breed in shallower parts of the river over hard structures such as stones, bamboo or submerged tree branches. The breeding period of *Chital* and *Foli* is May & June. Shallow areas are selected by *Batashi, Ketchki, Bailla, Baim* etc. and breeding takes place in April. The breeding period of carps species is early April to June and depends on rainfall. From June to September large number of fry, fingerlings and juveniles are present in the *beel* areas.

The majority of local fish species can be grouped into flood plain and beel breeders and river breeders as follows:

- Floodplain and beel breeders: *Boal, Ghonia, Sarputi, Shingi, Magur, Koi Bheda etc.*
- River breeders, - *Rui, Catla, Mrigel, Kalibaush, Chitol, Foli, Air, Rani, Pabda, Shilon, Bashpata, Kazoli, Garua, Ghagat* etc.

2.1.3 Swimming Characteristics of Fish

A major factor in planning of a fish pass structure is the ability of migratory fish in terms of speed and endurance. Fish swimming speed is often expressed in terms of body lengths per seconds or the more fundamental unit of meters/sec (FAP-17 1994, NERP 1993).

Swimming speed:
In designing facilities for migratory fish in both upstream and downstream direction, the first question that occurs concern the swimming ability of the migrants, what is their cruising speed and their burst speed. Bell (1984) defines three levels or speeds that are critical in design as follows.

> Cruising Speed: One that can be maintained for a long period of time (hrs). Normally fish employ Cruising Speed for movement which is estimated as 3.5 times body length per sec for **pelagic** species and 0.75 times body length per sec for **benthic** species. Pelagic species means those species which move in the upper layer of sea and Benthic species means those moving in the bottom layer. *Katla, Silvercarp* belongs to upper layer moving group, *Karphew, Mrigel* belongs to bottom layer moving type and *Rui, Rajputi* belongs to intermediate layer group.
>
> Sustained Speed: One that can be maintained for minutes which is for passage through difficult river reaches. This type of speed may be estimated as 2 times the Cruising Speed. Sustained speed (maximum swimming speed) is assumed to be maximum water velocity that can be negotiated through a fish pass.
>
> Darting Speed: A single effort, (not sustainable) estimated maximum duration 10 seconds only for feeding, leaping or escape purpose.

Usually fish employ cruising speed for movement such as migration, sustained speed for passage through difficult river riches and darting speed for feeding, leaping or escape purpose. Only limited information on the relative swimming speed of fish such as Carp and Catfish are available. Specially the swimming speeds for carps (cyprinus carpio) common to Japan, China, Central Asia and parts of Europe are noted (Bell, 1973) as follows:

Table 2.1 Swimming speed for 0.75m long fish (m/sec)

Cruising	Sustained	Darting
0.46	1.22	2.59

The ratios of the above values, Cruising to Dart Speed (0.18) and Sustained to Dart speed (0.47) for carps are similar to equivalent ratios for other fish species where length of fish where used as a measure. There is no data available for swimming speeds of catfish.

Normally fish are able to swim at the upper range of their cruising speeds and no oxygen deficiency occurs at that. It is assumed that for movement through a fish pass structure with baffles and resting pools fish normally utilize all three levels of speed at different stages However, the flow properties of fish pass should be such that the effort required on the part of the fish to negotiate the fish pass remains well within the capability of fish to do so.

Two more critical speeds to the foregoing in dealing with bottom dwelling and pelagic species of the plain regions of southern European Russia have been defined by Paplov (1989). This regions includes basins of Volga, Don and Kuban rivers. These additional velocities which apply to juvenile fish are as follows:

- Threshold Current Velocities (V_{thr}): The minimum current velocities that leads to an orientation reaction against the current (values between 1 - 30 cm/sec).

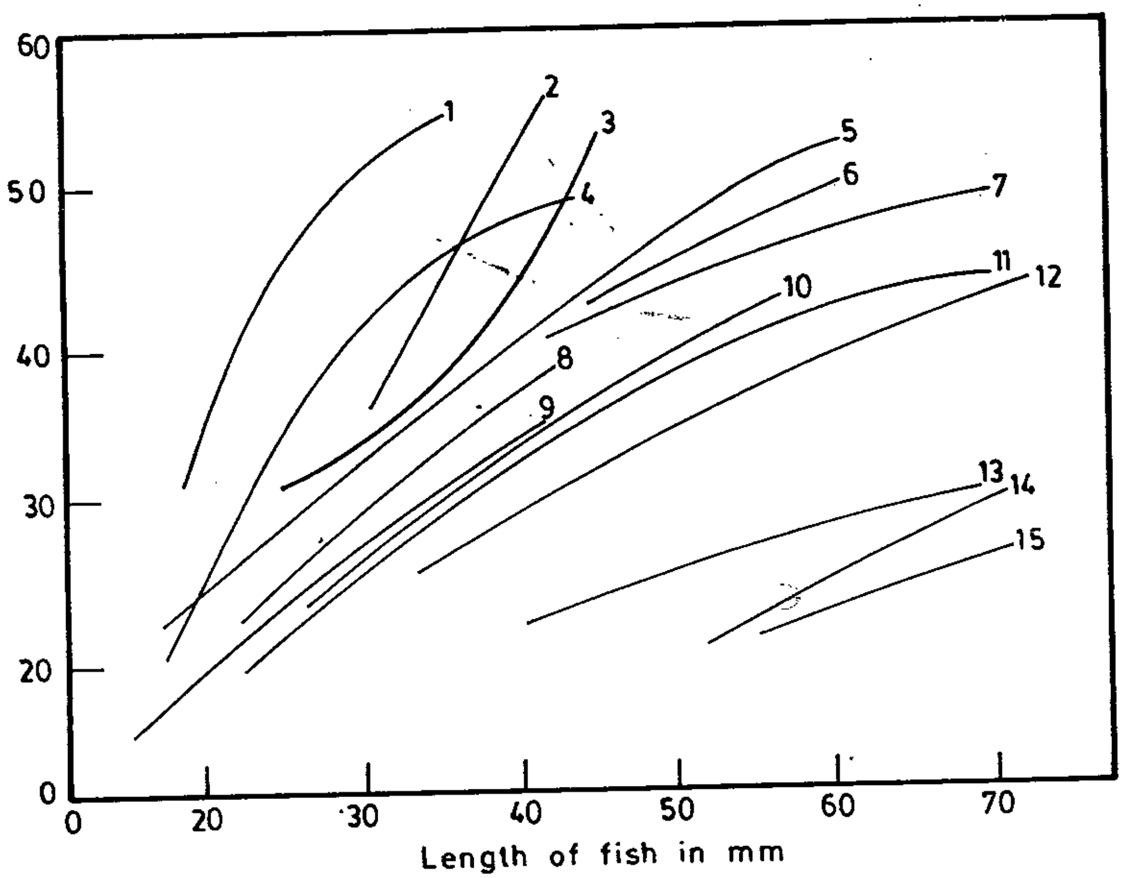
- Critical Velocity (V_{cr}): The minimum current velocity at which fish begin to be carried away by the flow.

The V_{thr} needs to be exceeded to stimulate the fish to begin upstream movement, assuming that physiological factors, such as hormone cycle of ripening fish are at the appropriate stage. V_{thr} and V_{cr} are water velocities rather than swimming speed, but the critical velocity V_{cr} is at least comparable to the maximum Sustained Speed and Darting Speed.

The V_{thr} and V_{cr} vary with size of fish and also according to species or category of fish (Fig. 2.2). Typically bottom dwellers have Critical Velocities 2-3 times lower the those for species living in mid or upper levels of water column. For these species there is a tendency for Threshold Velocities to be high and critical values to be low. The reverse is true for pelagic species. Fish are generally attracted to faster currents: attracting velocities are frequently 0.6 - 0.8 of the V_{cr}. For a wide selection of European species, the V_{cr} ranges from 0.7 - 0.9 m/sec (Malevanchik and Nikonorov 1984, after FAP-17, 1994).

2.1.4 Behavior of Fish:

Behavior of fish is critical in fish passage design and is often a function of individual species. Important parameters which may influence planning are the shore and depth orientation of the fish during migration, where they rest, how they respond to barrier such as gated control structures and associated hydraulics, how do they react to light and enclosure and possible diurnal variation in migration.



1. Alburnus alburnus. 2. Leucaspis delineatus. 3. Ruitilus rutilus caspius.
4. Carassius carassius. 5. Abramis ballerus. 6. Perca fluviatilis. 7. Vimba vimba.
8. Nemachilus barbatulus. 9. Cottus gobio. 10. Rhodues sericeus. 11. Tinca tinca.
12. Cobitis taenia. 13. Acipenser guldenstadti. 14. Husa huso. 15. Acipeuser stellatus.

Fig. 2.2 Critical current velocities for different species and sizes fish
Source: FAP-17, Supporting Vol. 23, 1994

There are several physical and chemical factors which influence migration and behavior of fishes. The physical factors are depth of water, bottom material, pressure, temperature, intensity of light, photo period, nature of water current and turbidity etc. The character like pH of water concerned, smell and taste of water, salinity are some of the important chemical character.

In addition to the above mentioned factors there are some biological factors also which include food memory, sexual maturity, physiological clock and endocrine glands. Presence or absence of predators and competitors is also considered as a biological factors.

Knowledge about the distribution of migratory fish within the river or *Haor* system is equally important in planing the location of access channels to or from the fish pass structure. Poorly located access channels will delay rather than attract migrants. Lack of knowledge of fish behavior and leaping capacities of migratory fish, combined with cost of fish pass, may prevent the construction of right type of fish pass.

2.2 Fish Pass and Fish Friendly Regulator

2.2.1 General

Fish friendly structures are structures which are designed, constructed and operated in such a way that adult carp can migrate upstream at the beginning of May and the hatchling can enter the flood plain in June/July.

Fish ladder or fish passes are generally provided to enable fish to ascend the head waters of the rivers and thus reach their spawning grounds for propagation or to allow their migratory habits in search of food. In order to permit fish migration in rivers and flood plains it is necessary to maintain conditions which help migrant reach their destination. To over come obstacles placed in the path of migrating fish structures must be designed to assist the fish to pass them. Fish pass is a structural initiative which is designed to mitigate negative impacts of FCDI/project on fisheries, specifically to allow normal breeding migrations to take place during the pre-monsoon. A number of structures which might collectively called fish passes or fish ladders have been devised to allow fish to by pass engineering structures in water management. Normally these are found in association with structures that are essentially dams which cut across the main flow of the river. Where barrages may be planned that require fish ladder for fish migratory upstream, the methodology of their design is already developed.

If the detail knowledge of the biology the fish concerned and the design parameter of the structures are available fish pass design can be tailored to the specific structure.

Fish ladder is a device by which the flow energy can be dissipated in such a manner as to provide smooth flow at a sufficiently low velocity not exceeding 3 to 3.5 m/sec. This object is generally accomplished by providing a narrow opening adjacent to devide wall and provide suitable baffles or staggering devices in it so as to control the flow velocity. Pool type and "steep channel type" are commonly used type of fish ladders in weirs and Barrages. In this type of ladder space between the weir and the devide wall is provided with oblique walls, and holes are also staggered so that the fish can take rest after passing one hole before they move into the other.

There are basically two types of fish pass, the type in which fish actively swim upstream aided by the device and type in which fish enter a strong compartment and are transferred over the obstacle without the expenditure of energy. The first category includes the pool and the weir and pool and orifice type fish pass. The second involves moving structures of fish lift and fish lock type.

The major characteristic of a fish pass is the height at which it is operationally effective. The basic intention of a fish pass is to allow the fish to circumvent a barrier , usually between different water levels. Pool and weir type passes are most effective at heights of less than 10m, whilst the pool and orifice variant may be used to negotiate heights of upto 40 m. The more elaborate fish lock can be effective up to 40 m whilst mechanical fish lifts which store and transport fish vertically can be used to any height (Pavlov 1989).

In Bangladesh, structures to be circumvented are generally relatively low, and differences in water height are likely to be small when compared for example to Hydro electric dam. However ideally there should be difference in water height across the structure since a flow of water is required to attract the migratory fish.

2.2.2 Types of fish pass structure

The following are the various types of fish pass structure:

(a) **Pool and Weir fish pass:** Sometimes referred to as pool and traverse pass (Beach 1984). This is the basis of the simplest fish ladder in which a downward sloping channel is cut into a sequence of pools by a series of traverse or weirs (Fig. 2.3). Each weir has a notch through which the migrating fish can swim in order to reach the next pool.

A particular advantage of pool and weir type of fish pass is that it also facilitates the downstream drift of hatchlings & fry. For this reason upper exit - should be placed in a position with regard to the upstream flow where it can be readily located by those young fish as well as by returning adults.

The pool and weir type pass has been extensively used in Europe and America although most commonly in connection with the passage of the members of the family salmonid (salmon & trout), most of which are powerful swimmers. Quiros (1989) documents 29 fish passes which have been built as a part of impoundment and regulation of south America rivers. All of these were pool and weir type.

The fish for which these South American fish passes have been built have more in common with Asian fish fauna of Bangladesh than the salmonids communities of northern latitude. They are used successfully by both the pelagic powerfully swimming characins, such as prochilodus spp, which may roughly equated to major carps and also be bottom moving types such as catfish (Quiros 1989).

The pool and weir type therefore seems to work with communities of tropical and sub tropical fish as well those from temperature region. This type of fish pass can be employed on a large scale. Cheap and simple design may be used to circumvent a weir 1-2 m in height. In south America passes to this type have been constructed to height upto 20 m. For the most parts, however passes of the height are associated with dams construction for hydro-electric schemes but they may be appropriate for Barrage in Bangladesh.

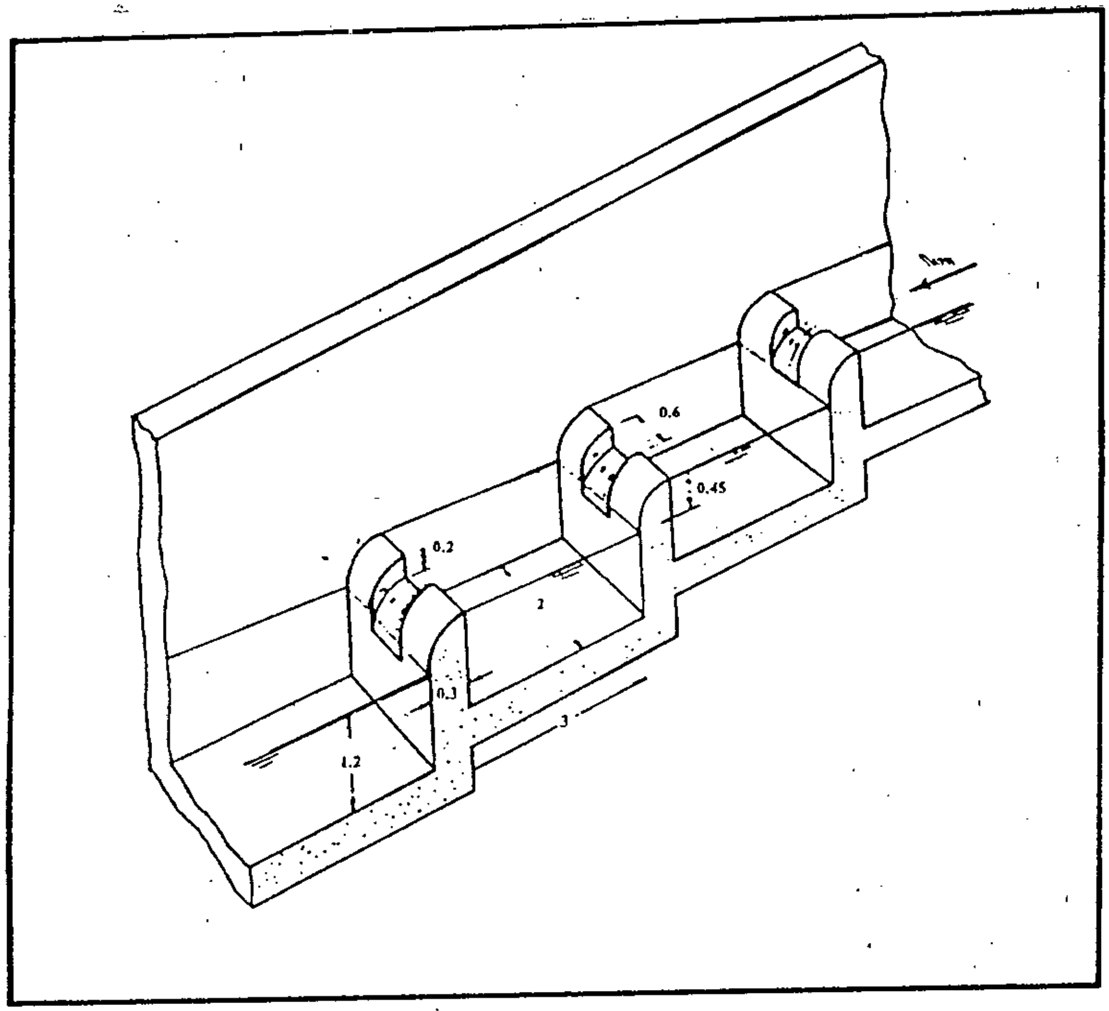


Fig. 2.3 A schematic diagram of Pool and Weir fish pass (After Beach 1984)
Source: FAP-17, Supporting Vol. 23, 1994

The pool and orifice fish pass differs from the pool and weir pass in that passage between the two pools is through a hole in the weir rather than over a notch. These facilities are particularly for the passage of bottom moving species.

(b) Denil fish pass: Similar to the pool and weir type, this relies upon the construction of channel around or through the obstruction. In this case the channel is traversed by a number of baffles which dissipate the energy of the current. The baffles are closely spaced and set an angle to the axis of the channel. The notches in the baffles have a relatively large portion of the channel available for the main flow through which the fish pass (Fig. 2.4). The shape and position of spacing of the baffles play an important part in the effectiveness of this type a fish pass. The hydraulics or passes of this type suggest however that most economic design with a readily located outflow and maximum space is one with a gradient as steep as possible (Beach 1984). This pattern have been used successfully for salmonids in Canada, UK and Denmark. Details have been given by Beach for a Denil pass constructed in U.K. At low tide the difference in water level to be ascended was 2.25 m and at high tide this was diminished. There are no records of Denil pas being used in tropics and sub tropics but it may remain a possibility for by passing the embankments of FCDI schemes.

(c) Fish lifts: Fish lifts typically comprise a collection gallery, an operation chamber with a fish retention grid where fish may be counted and samples taken, and a moving and releasing device. They are associated mostly with dams in hydroelectric schemes and in order to attract the fish, use the plume of water from both turbines and collection gallery. The migrating fish swim up the plume and into the collection gallery which may be over 150 m long. Periodically the inlet is closed by a crowding device which prevents the fish drifting back into the tail water pond. The crowding device is then moved towards the dam, which shepherds the fish into the operation chamber of lift itself from where they are raised to the outlet chute at the upper level of the dam. Such devices can be mechanically or hydraulically driven (Fig. 2.5).

Fish lifts can be very effective when correctly sited and operated. The volgogradsky hydraulic lift on the Volga rivers allows more than one million fish of all types to pass upstream each year (Pavlop 1989). Fish are attracted into the collection gallery by water velocities 0.8-1.8 m/sec. Fish lifts are expensive and only appropriate where a major device is being considered.

(d) Sluice fish pass: There are variants of fish lift design. They are operated rather like locks, by raising and lowering the sluice gates alternately at the entrance and outlet parts (Fig. 2.6). During the collecting period sluice gate is raised. This is closed periodically and the fish are concentrated at the distal end of the pass by the crowding screen by which time the water level in the operation Chamber has filled to the level of the reservoir. The upper outlet gates are then raised to allow the fish to move out in the reservoir. Again the sluice fish passes have been used for a wide variety of fish in the former soviet union (Paplov, 1989).

(e) Fish locks: The most commonly used pattern of fish lock is the Borland type (Clay 1961). This consists of a lower entrance chamber and upper exit chamber connected by an inclined shaft (Fig. 2.7). Fish are attracted into the collection chamber by the flow allowed down the inclined shaft from the upper water level. The lower sluice gates can then be closed to allow the inclined shaft to fill with water. The velocity of the flow coming down the channel and out through the entrance is governed by the aperture of the upper sluice. A substantial example of this type of fish pass was built against the salto grande dam on the middle reaches of the Uruguay river (Quiros, 1989). It proved successful for the passage of

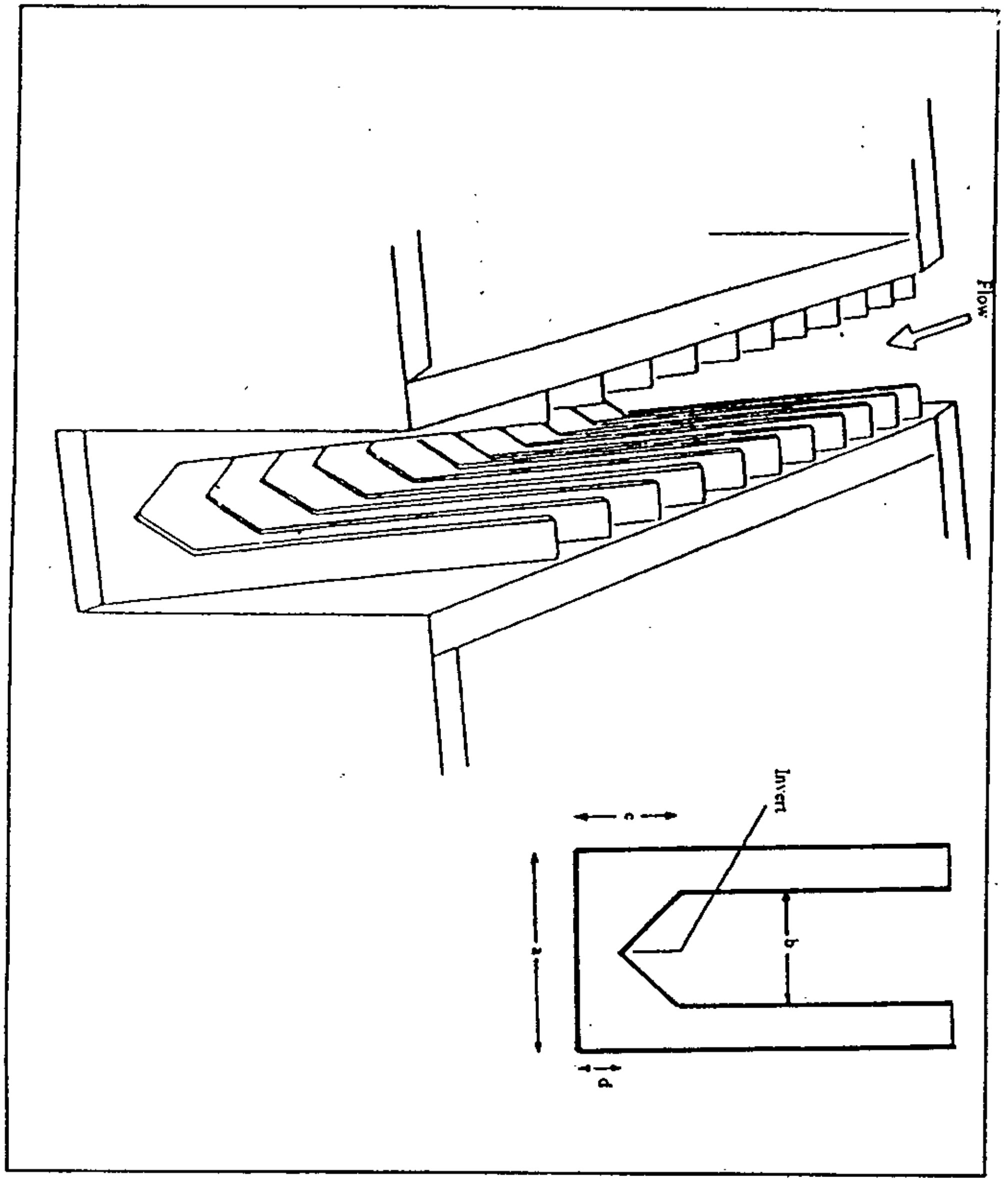


Fig. 2.4 A schematic diagram of Denhil fish pass (After Beach 1984)
Source: FAP-17, Supporting Vol. 23, 1994

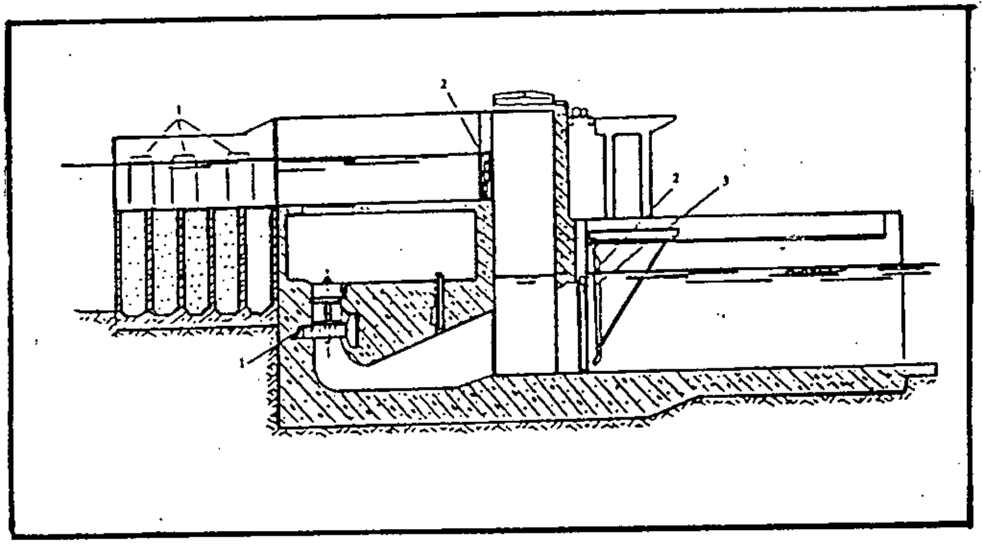


Fig. 2.5 Fish lock of the Volzhskaya hydroelectric dam on the Volga river
1. Outlet Orifice, 2. operational Gates, 3. Crowding Device,
4. Hydroelectrice Unit (After Pavlov, 1989)
Source: FAP-17, Supporting Vol. 23, 1994

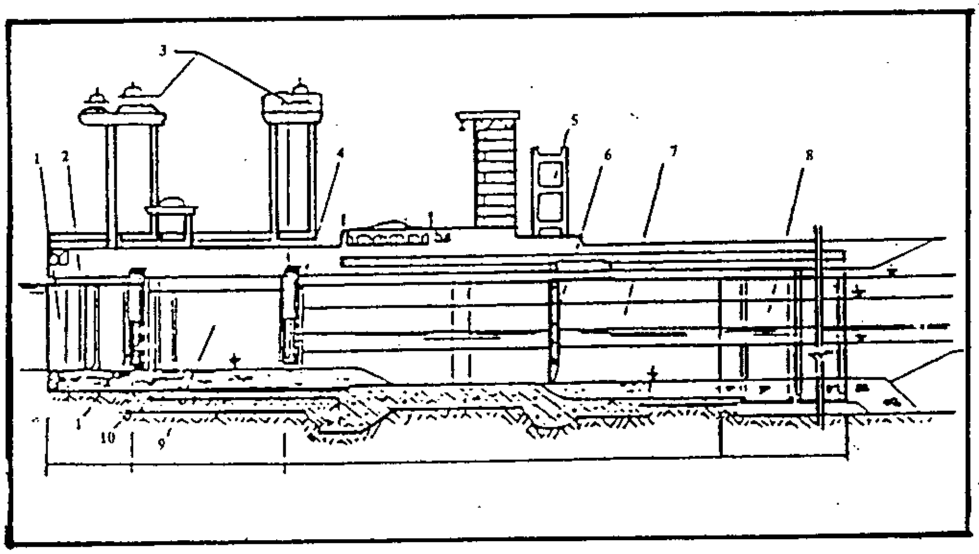


Fig. 2.6 Longitudinal section through the sluice fish pass at the Fedorovskie hydroelectric scheme on the Kuban river
1. Outlet chute, 2. Litter retaining screen, 3. Gate control mechanism,
4. Gate, 5. Control structure, 6. Crowding screen, 7. Fish collection Gallery
8. Low approach chute, 9. Working chamber, 10. Fish-Retention Grid
(After Pavlov, 1989)
Source: FAP-17, Supporting Vol. 23, 1994

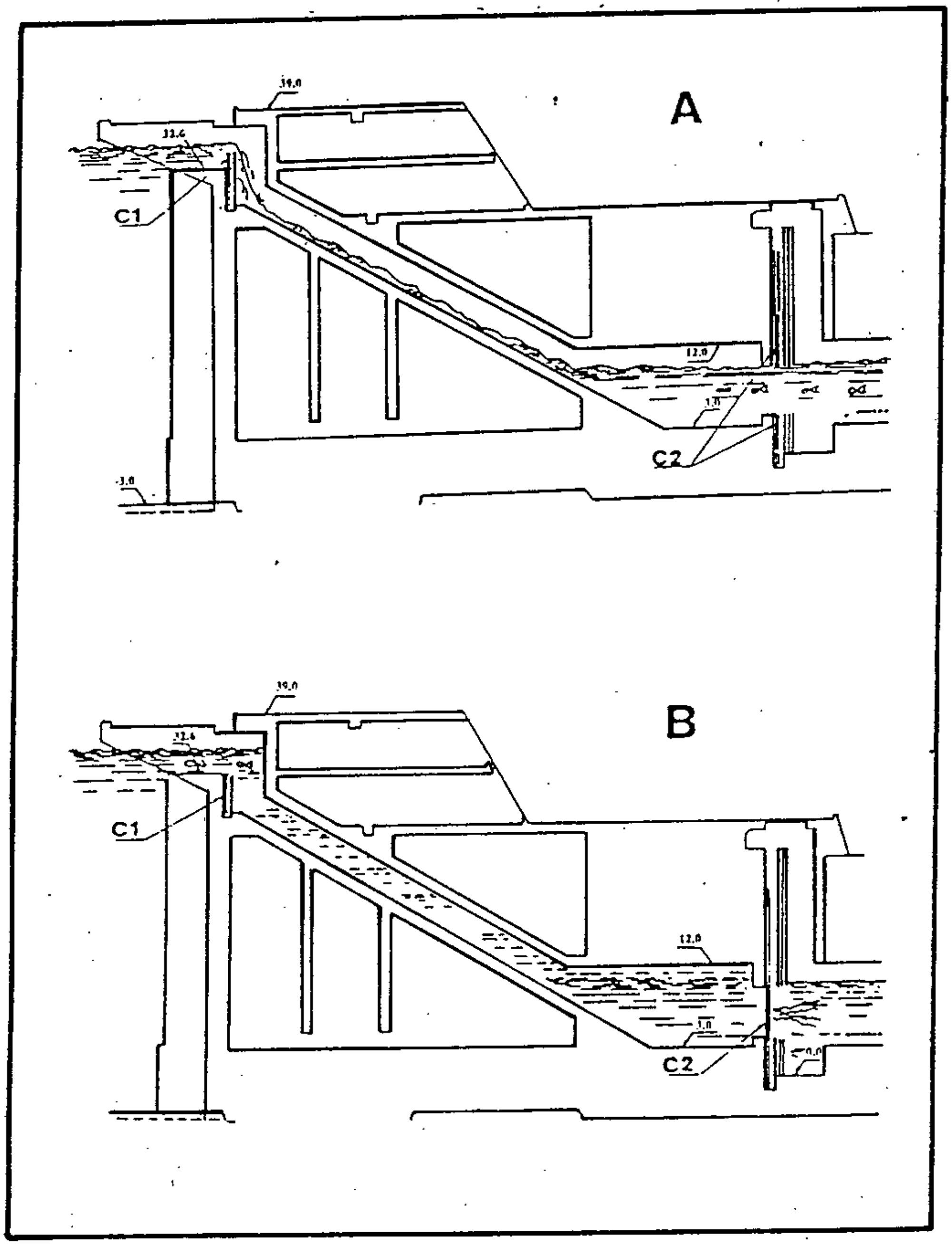


Fig. 2.7 Borland lock operation (After Quiros 1989)
A Fish entering the lock
B Fish leaving the lock
C_1 Upper sluice gate
C_2 Lower sluice gate
Source: FAP-17 supporting vol. 23, 1994

both pelgaic and bottom dwelling species. However it was noted that pelgaic species often shoaled out side the entrance for long periods, probably because inside there was no light and this initially inhibited their entry. It was also noticed that many fish did not enter, probably owning to extensive areas or turbulence near the entrance to the pass. It was felt that more detail planning of the fish lock should have been done before construction (Delfino et al. 1986). The two borland locks at salto grande cost around US$1.2 million. The flow velocities for attracting fish in this device ranged from 0.1 to 1.8 m/sec.

In the light of the cost of fish locks, they would probably be unsuitable for most flood control schemes in Bangladesh.

(f) Mobile device: In the former soviet Union mobile barges have been developed for use on large rivers. Each barge contains a collection chamber around 60 m long, and submerged pumps create the current to attract the fishes into the chamber (Paplov 1989). On occasions, electric devices are also used. The barge has an associated transport vessel which can transport the fishes through the navigation locks into the new area. This, however, is a very specialized form of fish pass.

2.2.3 Hydraulic aspects of fish friendly regulators

Flow through regulator and its interaction with fish:

Regulator is a control structure to regulate the flow into and draining out an area as needed. The sill level of the structure and width of the opening mainly control the regulation. Further regulation is provided with gates. Most often, the inflow is controlled by undershot sluices, the gate of which can be opened with rising water to allow controlled volume of water into the cultivated area (Fig. 2.8). Drainage may be done by undershot sluices by raising the gate. Sometimes flap gates are used which open automatically as the pressure builds up behind it. Simple overshot gates can be used for the same purpose (Fig. 2.9). If the discharge through a drainage regulator can be controlled to give a smooth free flow, correct current velocity, correct configuration and time it may help migration of fish. Again if inflow through a sluice without adverse hydraulic condition can be made, fish may be drawn in with the current. In particular it would allow eggs and hatchling to enter into the project area. In such a condition the regulator will act as fish friendly regulator.

Mode of gate operation:

The gate can be operated in three modes, undershot, overshot and retracted as shown in the Fig. 2.10. An undershot gate has a fixed flow area regardless of the upstream head and therefore discharge rises at a slower rate than the upstream head, whereas with an overshot or retracted gate, the discharge rises at a faster rate than the upstream head. Head is measured above the crest of the gate and the crest of the retracted gate is the regulator sill. Discharge of the overshot and undershot gate can be varied by changing the level of the top or bottom the gate respectively. Discharge of retracted gate is fixed relative to the upstream head and overall discharge can be changed independently by varying the number of openings as in multi gate structure. Regulators can have different effects on the movement of hatchling and fry, depending on the extent of reduction of flooding and the mode of operation of sluices. Regulators affect fish in two distinct ways: by changing the timing and pattern of flow onto the floodplain and by causing actual impediment or harm to the fish.

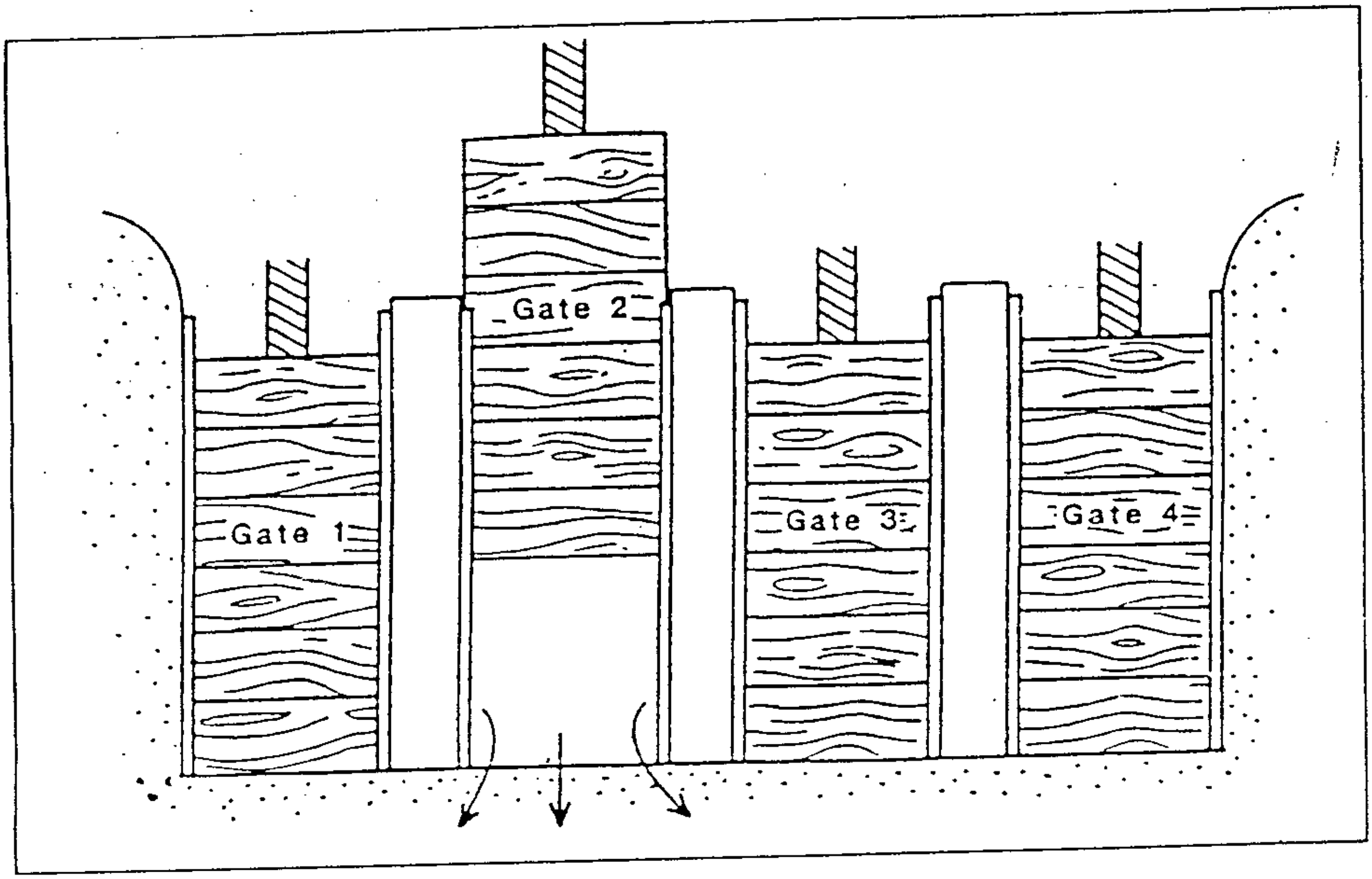


Fig. 2.8 Undershot sluices flow control
Source: FAP-17 supporting vol 23, 1994

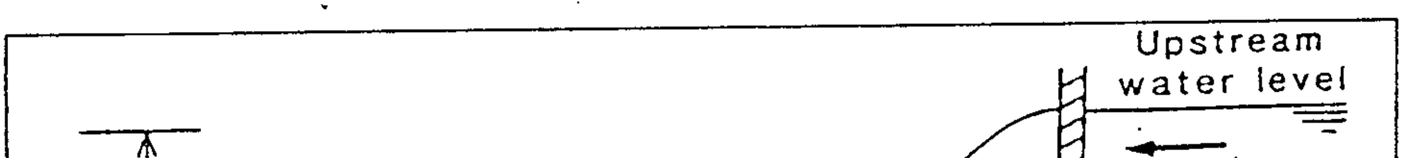


Fig. 2.9 Overspill sluice flow control
Source: FAP-17 supporting vol 23, 1994

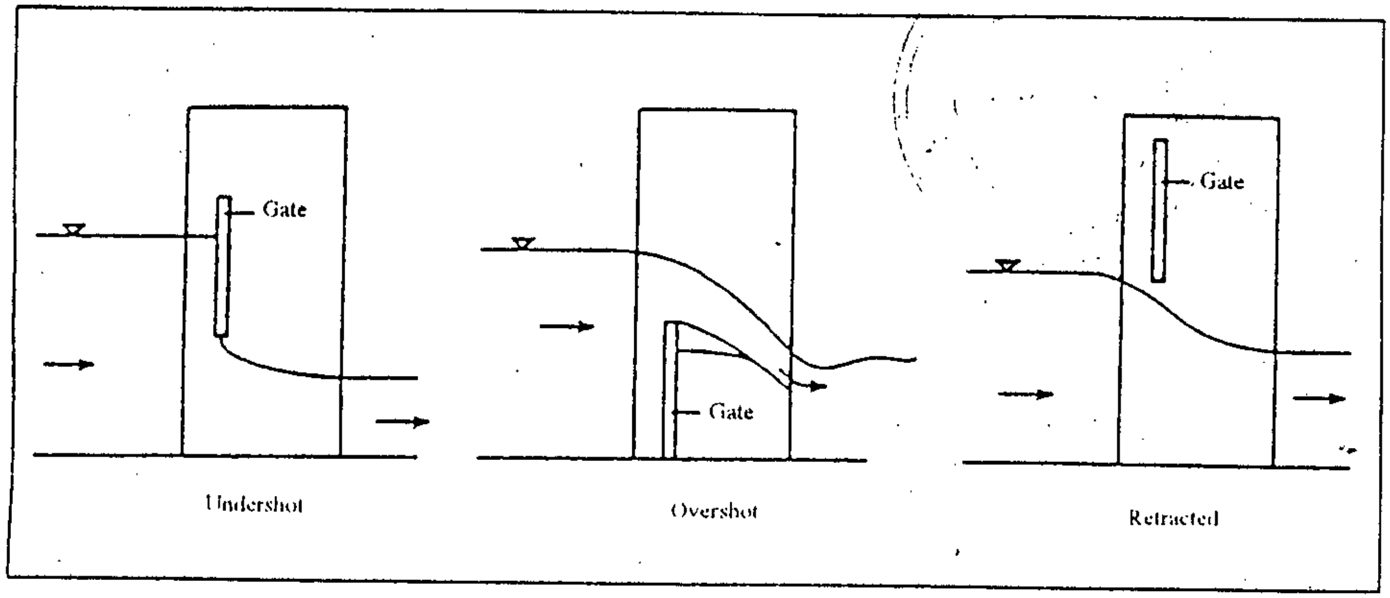


Fig. 2.10 Mode of gate operation
Source: FAP-17 supporting vol 23, 1994

Timing and pattern of flow through a regulator:
The pattern of flow onto the floodplain may be changed by the presence of the regulator, by the gate mode used and by the gate operation programme. Imposition of a regulator in the path of migrating fish influence their migration. When there is flushing of water through a regulator, the flow attracts the migrants to pass through it. If the flow velocity is too high the fish cannot pass through it. As an example it can be stated that catching of hilsha fish was observed in the downstream of Charghat regulator in Baral river in Rajshahi. It was an indication that fish could not pass the structure. With the advent of monsoon the volume in the natural floodplain increases linearly with time. With a regulator in position there is a time lag of reaching the same volume of water and regulated floodplain will get it later than natural floodplain. If the slow buildup of volume in the floodplain in the early stage of flood cycle coincides with the greatest abundance of fish fry or adults than regulated floodplain will not be as accessible as the natural floodplain. Thus the effect of regulator on the passage distribution of fish fry is dependent on the timing and duration of fish fry movement.

The influence of gate type on flow pattern:
The fully retracted gate gives maximum discharge for a given upstream water level. So the regulator should operate at this mode at the start of the flood cycle. To maximize volume of water in the floodplain while fish hatchling drift and fish movement is prevalent, retracted gate operation should continue upto the point where downstream level is at a height where gate regulation is required.

The influence on gate operation on flow pattern:
The prime requirement for fish passage is that there is flow through the regulator throughout the period where fish and fry move. So consideration should be given so that gate can be kept open at that time but in practice in some cases from flood control point of view the gate might have to be kept closed. In such case judgement is to be applied.

Sources of impediments and harm to fish:
Following effects are detrimental to fish:

- impassibility of structure to fish;
- damage to fish by rapid changes in pressure;
- physical damage to fish by contact with structure and
- damage to fish by turbulence.

Impassibility of structure:
Closed gate, too high sill level, undershot regulation are some of the impassibility of structures to fish. The closed gate or sill levels to high may result in no inflow during the first flood peaks and therefore there will be no migration of carp hatchling. If the sill levels are too high there may be too low flow to induce migration response. If the gate is partly closed or open the flow can be either too low to induce orientation or too high for the fish to swim against the current. In an undershot regulation there may be formation of pocket above undershot flow (Fig. 211 (a). Input to the pocket is mostly from surface layer of approach flow and as a result floating bodies will enter it which in turn will result in delay of eggs, hatchling or fry in the passage. Overshot regulation with low tail water (Fig. 2.11(b) can also develop pocket in the downstream side but the effect of this on the passage of fish may be insignificant.

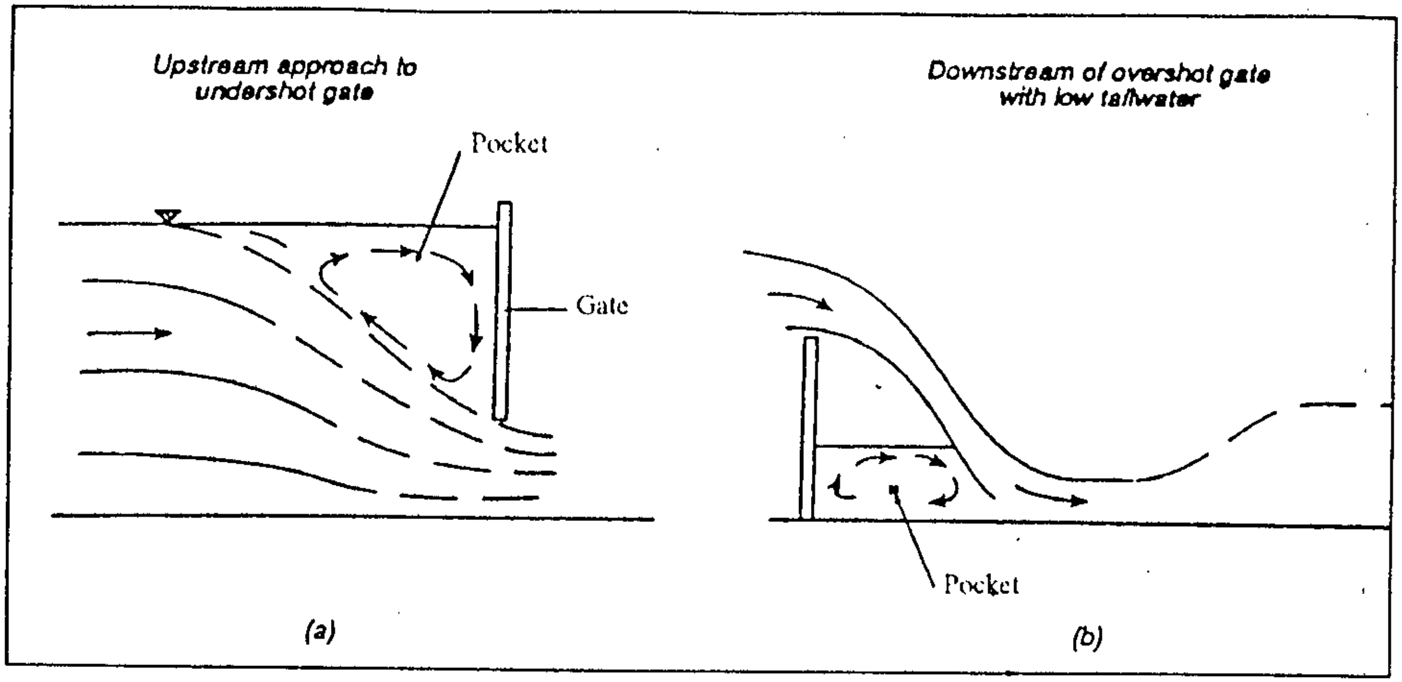


Fig. 2.11(a) Flow pocket in undershot gate
Source: FAP-17 supporting vol 23, 1994

Fig. 2.11(b) Flow pocket in overshot gate
Source: FAP-17 supporting vol 23, 1994

Changes in pressure:

Fish generally adjust to changes in pressure with the aid of swim bladder. For a given discharge and upstream depth, the undershot gate will show greater pressure difference and damage to the swim bladder of fish may take place. In such a case the very young fish will be at greatest risk. Overshot gate will also induce pressure change to the passing fish but it will be smaller and slowly than undershot gate. The retracted gate will give the least and slowest change of pressure.

Contact with the structure:

Sometimes when water has big contact surface with the structure it may harm hatchling. A sharp edged entry will increase the hazard of the passing fish. When energy is dissipated against a solid boundary it becomes a hostile environment for fish. It may happen in the downstream of overshot gate with low tail water.

Turbulence at structure:

Turbulence takes place in the downstream of regulator due to head difference. Turbulence is necessary for energy dissipation but it must be well controlled to avoid erosion. Fish in turbulent flow is subjected to rapid fluctuations in pressure, high G-forces, disorienting eddies. In an undershot gate when the,gate opening is small the hydraulic jump will be at its most intense and the turbulent will be most damaging to fish (Fig. 2.12a). If the tail water depth is too high for a stable hydraulic jump, the tail water will run over the jet as in Fig. (2.12b). Then there will be surging, turbulent water above the gate opening and it is dragged away by the jet and falls back. However most fish would be unlikely to pass through this area and the underlying flow will be relatively smooth. For an overshot regulator when the tail water is low (Fig. 2.13a), the jet pushes the water away and as with the undershot gate forms a hydraulic jump further downstream. If the tail water is high enough, the downstream condition will be as the (Fig. 2.13b) and in most cases a comparatively smooth dissipation of energy. Flow through a fully retracted gate over a broad sill is the smoothest form of passage through an overshot gate, and therefore generally the most friendly mode in terms of turbulence.

2.3 A review of Already Constructed Fish Friendly Structures

2.3.1 Fish passes in various regions of the world

North America: On the Pacific coast of North America, weir type fish ways with orifice through the baffles have a long history of use in dams and much first hand information is available from experiences gained at many large dams on the Colorado river. Most of these fish ways are operated with 1 ft (30 cm) of head per baffle. These has gradually been referred over the years. One of the more recent installation at iceharbour on the snake river near its confluence with Colombia includes a number of orifice baffles at the upstream end of the fish way, with the balance of the baffles being of weir type (Clay 1995).

The vertical slot baffle has been used to over some natural obstruction in streams along the pacific coast. It requires no manual regulation of flow under the condition where variations of head and tail water are reasonably comparable. This type of fish way was installed at concrete hydro-electric diversion dam of seton creek and at a concrete storage dam on great central lake both in British Colombia. It has also been used for temporary fish way around the cofferdam during construction of some of Colombia river dams. This baffle permits fish to ascend at any depth they choose. It is considered to be suitable for any migratory species provided the head conditions between pools are adjusted so that velocity and turbulence are within the swimming ability of the fish.

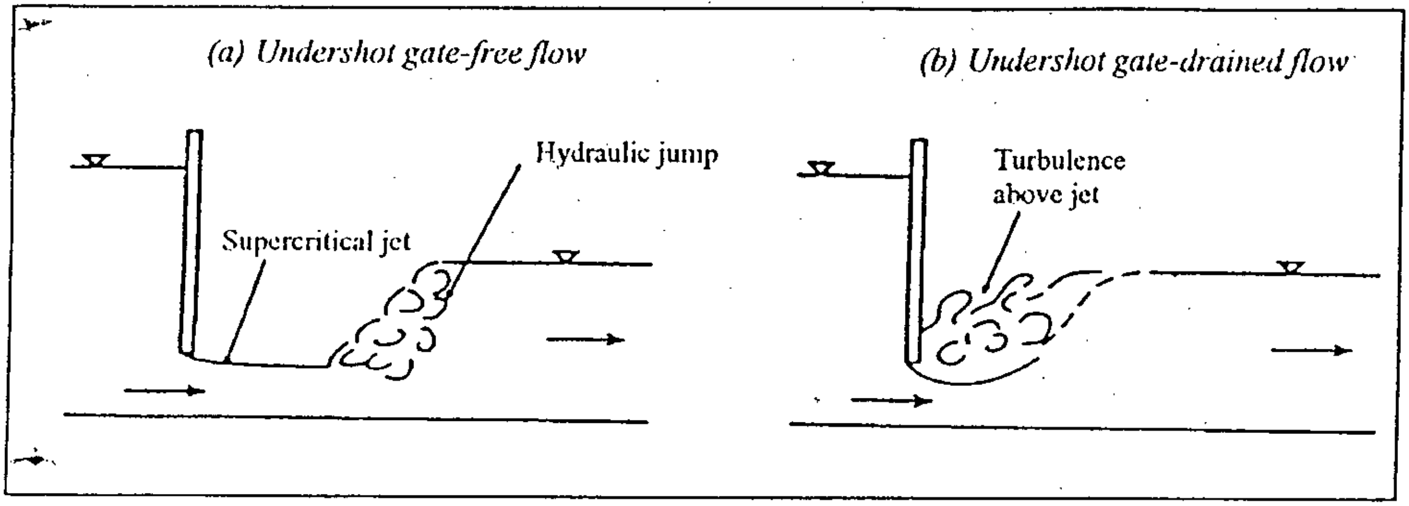
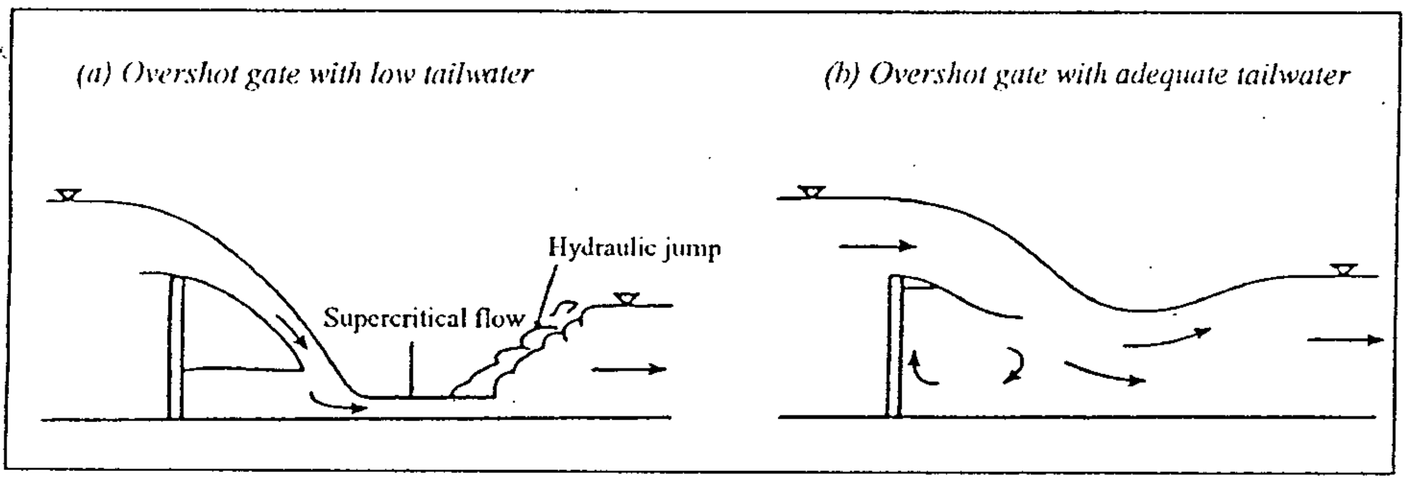


Fig. 2.12(a) Undershot gate free flow
Source: FAP-17 supporting vol 23, 1994

Fig. 2.12(b) Undershot gate drained flow
Source: FAP-17 supporting vol 23, 1994



ig. 2.13(a) Overshot gate flow - low tail water
Source: FAP-17 supporting vol 23, 1994

Fig. 2.13(b) Undershot gate flow - adequate tail water
Source: FAP-17 supporting vol 23, 1994

A weir type fish way was installed in a dam on the Yukon river near White Horse and came into operation in 1959.

A Denil has been used and on the pacific coast of North America to pass sockeye, chinhook, and coho salmon. An experimental installation was made at Dryden Dam on the Wenal Achee river in the State of Washington and was thoroughly tested as reported by Fulton et al. (1953). These tests indicated that two species of pacific Salmon (Chinook and Sockeys) would readily ascend a well designed Denil fishways as would other species such a Rainbow Trout, Dolly varden Suckers and Squafist. Denil fish way is not widely used however except in Alaska where its light weight and mobility when constructed of aluminum have proved invaluable for placement at natural obstruction that are inaccessible except by Helicopter.

Experimentation has been done recently with new type of baffle or pool and weir fish way for pacific salmon which requires the fish to jump over the baffle thus reducing the number of baffles in the fish way.

Fish lock have been tested on the pacific coast of North America but have not been found to be practical Fish elevators have been tested and used extensively at many of higher dams.

Central America:
There are a number of fish way installation in central Canada and U.S. mainly at water control dams. These are mostly pool and weir type. Showing varying degree or success, particularly with respect to passage of north pike and walley.

Greek Lakes area:
In Ontario Borland type lock was used for passing both Rainbow Trout and Chinook Salmon.

East Lakes area:
All types of fish ways used. In the maritime province of Canada fish ways of the pool and were type predominate. Fish lift have been used at relatively high dams on st john Denil river and tributaries. Denil fishways are less widely used than they are in new England and Europe

Western Europe:
The weir type fish way in a variety of configuration has been used in western Europe since early times. In addition there has been continuing interest in Denil fish ways. In Ireland weir type fish way at perteen weir on river shanon, submerged orifice fishways at two dam on river Erne, Borland fish locks at 3 dams on river liffey and river lee used.

In England and Wales, according to Beach (1984) only the weir type and the Denil type fishways are commonly used while other types such as weir with submerged orifice are not excluded, the concentration seems to be on the weir with notched baffle. In Scotland, the submerged orifice with weir type pass has been used for Atlantic Salmon but passes of weir and over flow type are also used as are fish locks of Borland type.

In Denmark, Denil fish ways is used. In Sweden pool and weir fish passes have been used as well as Denils. In Netherlands the country is low and flat and there is no need for fish ways to surmount anything higher than 5 m while most average 1 to 2m. A simple pool and weir type therefore is used by passing the low obstruction. In Germany there are the same type of installation as in Holland. In France passes of Denil type in many configuration has been used. In addition passes of pool and weir type and the vertical slot type have been used

Eastern Europe and Russia

Publication by Sakawic and Zarnackei reviewed fish passes in western and Eastern Europe and concluded that pool and weir passes were satisfactory for salmon but other types such as Denil have proved to be unsatisfactory particularly in Eastern. Europe (Russia).

Latin America

The migratory fish in Latin America are of completely different species than any encountered in the northern hemisphere. According to Quiros (1988) more than 50 fish ways were constructed in the region over the period from 1910 to the presents, most of these being in Brazil, All of them pool and weir type. In more recent project from 1980 onward, Brazil and Argentina have elected to use Borland type fish lock for dams over about 20 m in height. The most recently planned installation are of the fish elevation type based on the premise that passage should be provided for large member and all species.

Africa:

In Africa the need for efficient fish ways has become apparent only in recent year. The oldest fish ways are at Jebel Aulia Damon the Nile in the sudan, and some minor stream installation in South Africa. In South Africa there are many small dams and weirs on the coastal rivers, there is growing realization of the need for fish passage in many of these dam. The fish ways in the dam have been based on existing European or North American design on salmonid, thus they are successful for passing trout but do not meet the needs of other species.

Australia and New Zealand:

Harris (1984) has described a survey that identified 29 fish ways on coastal streams of South Eastern Australia. These represented about 9% or all dams weirs and cause ways in the area. Of the 29 passes 18 were 2 m or less in height and the rest ranged upto 8 m. General conclusion is that 75% were operating unsatisfactorily. There design had been based on early designs for salmonids fish ways in Europe and North America and a new orientation to the needs of indigenous species was required.

China:

Xiangke lu (1986, 1988) notes that 40 fish passes have been constructed at water control sluice gate in the country. 29 were constructed in Jiangsu province but only 3 have shown good results. It should be noted that china has a vast system of reservoirs numbering more the 85000. The fisheries of these reservoir are intensively exploited and four major carps are being stocked. For these little need has been felt for fishways as the outlet to help maintain stock.

Japan:

In Japan there are almost 1400 fishways, most of which are the pool and weir type in various forms. A small number (about, 0.1%) are Denil fishways and small percentage are fish locks and special eel fishways (Sasanbe, 1990).

South East Asia:

Pantula (1988) reports that there are fish passes in Thailand and India. He also refers to a fish pass at Farakka Barrage on the Ganga river. But not details could be obtained.

2.3.2. Fish passes in Bangladesh

There are some fish pass structures and fish friendly regulators already constructed in Bangladesh and some are planned to be constructed is near future. They are described in the following paragraphs.

Fish Pass Pilot Project of Monu River Project:
The Monu River Project (MRP) fish pass is located within the Kashimpur pump house compound between the six vent and 3 vent drainage regulators, about 160 m from the pumping plant.

A short link canal provides connection with Koradia river, which is the largest drainage channel of the Manu river project. It connects the Kawadighi Haor with the Kushiyara river. The 6-vent regulator checks the flow of the Koradia river. The location of the fish pass structures is shown in Fig. 2.14. A copy of pool and slot configuration for a fish way at Seton river dam in British Colombia, Canada has been adopted. A single vertical slot fishway with 18 baffles and 19 pools, was proposed for the MRP fish pass pilot project. Each baffle will help drop of 0.25 m to over come the total tail water difference of 3.0 m. The parameters adopted in the design of MRP fish pass structure are (i) maximum hydraulic head 2.7 m (ii) maximum water velocity 1.3 m/sec (iii) maximum depth of water (D) = 1.0 m (iv) the slot width 0.41 m (v) size of pool = 2.44 m x 3.05 m (vi) R/S invert level = 5.00 m PWD. The work has been completed in May 1995. The plan and section of the fish pass is shown in the Fig. 2.15.

Fish Friendly Regulator in CPP Pilot Project:
As a mitigation measure against the negative impact of FCDI Project the concept of fish friendly structure has been introduced in compartmentalization Pilot Project. Jugini main inlet is one of these fish friendly structures. It is a 5 vent regulator. The two end vents (1.50x2.80) will act as a fish pass. Sill level of these fish passage is raised. The sill level of these two openings 10.70 whereas that of the middle 3 vantage is 9.20 i.e. the opening for fish passage has a sill level 1.50 meter higher the than of the other vintages. The idea for the raised sill level is that there will be less discharge in these two vantage, consequently smaller velocity and less turbulence. The smaller velocity and turbulence will attract fish in these ventages and fish will enter into the project area for breeding, spawning etc. In the pre-monsoon there will be migration of hatchling. The two end openings will normally remain open except on special cases when complete closure of the structure in needed for retention purpose. Plan and section of the inlet is given in Fig. 2.16(a), 2.16(b), 2.16(c).

Marichar Danra Regulator
The structure is a 7-vent drainage regulator with 2 nos of fish pass. in Marichar Danra sub project of Nowabgonj District. The existing regulator has been in a very bad state and it has been planned to replace the structure by a new 9 vent structure (9-1.52*1.82m). The structure includes 2-vent at higher elevation to facilitate fish migration and 7-vents for drainage requirement. The structure is to be provided with flap gates on the river side and vertical gates on the country side. The fish pass vent to be provided with lift gates on both country side and river side. The purpose of the structure to be as follows:

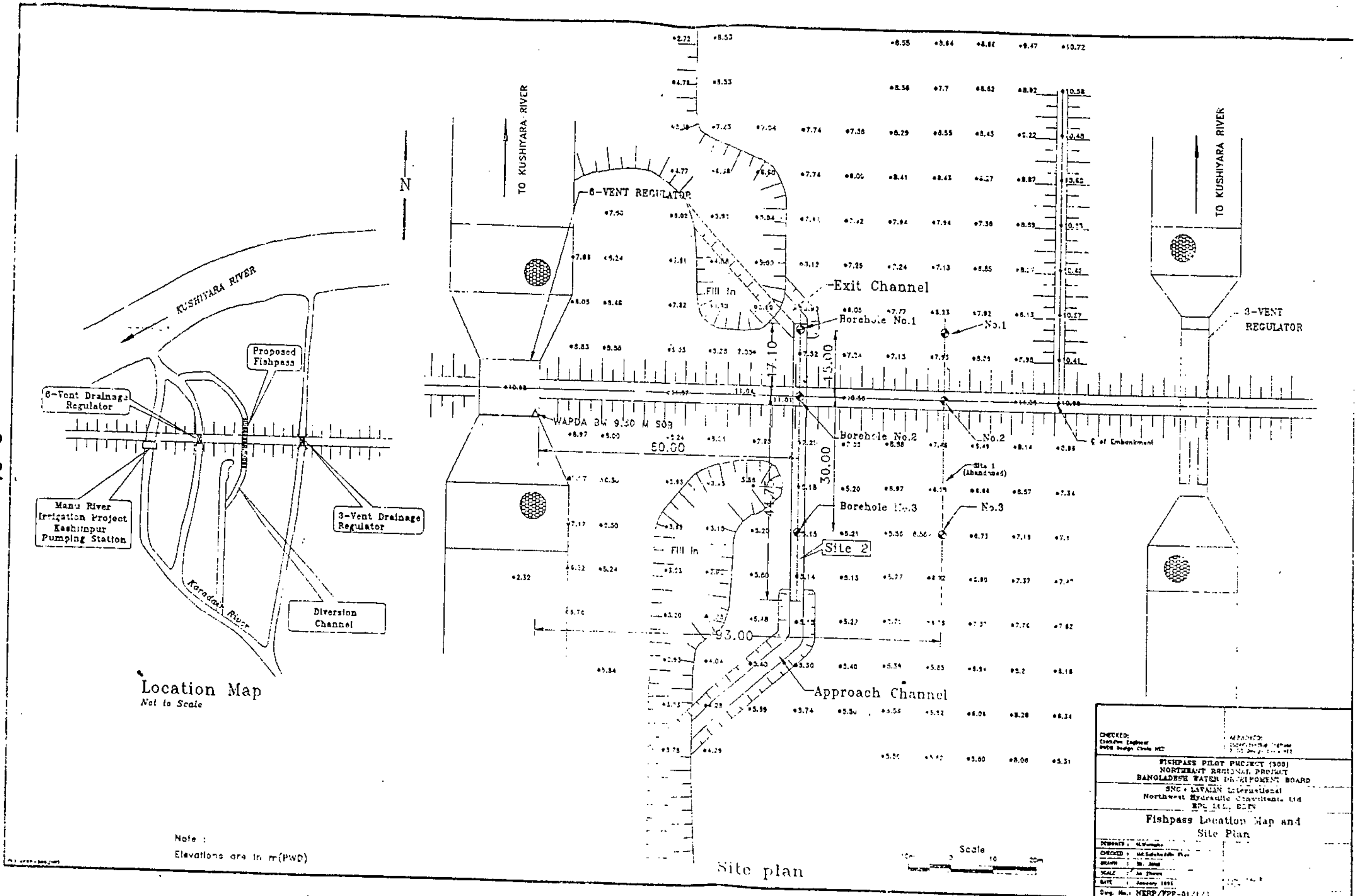


Fig. 2.14 MRP fish pass structure location map
Source: NERP (FAP-6) 1995

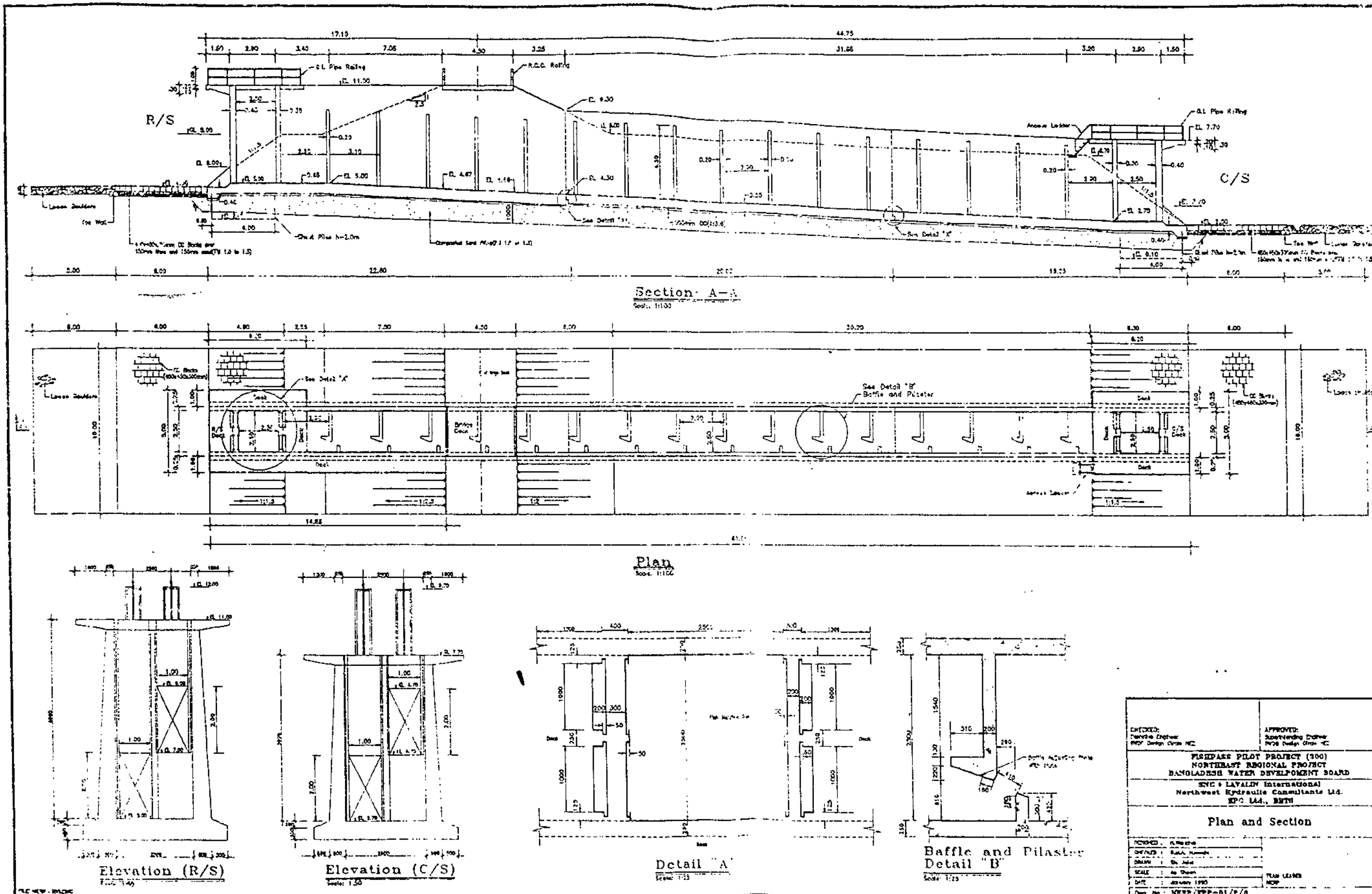


Fig. 2.15 Plan-elevation, MRP fish pass
Source: NERP (FAP-6) 1995

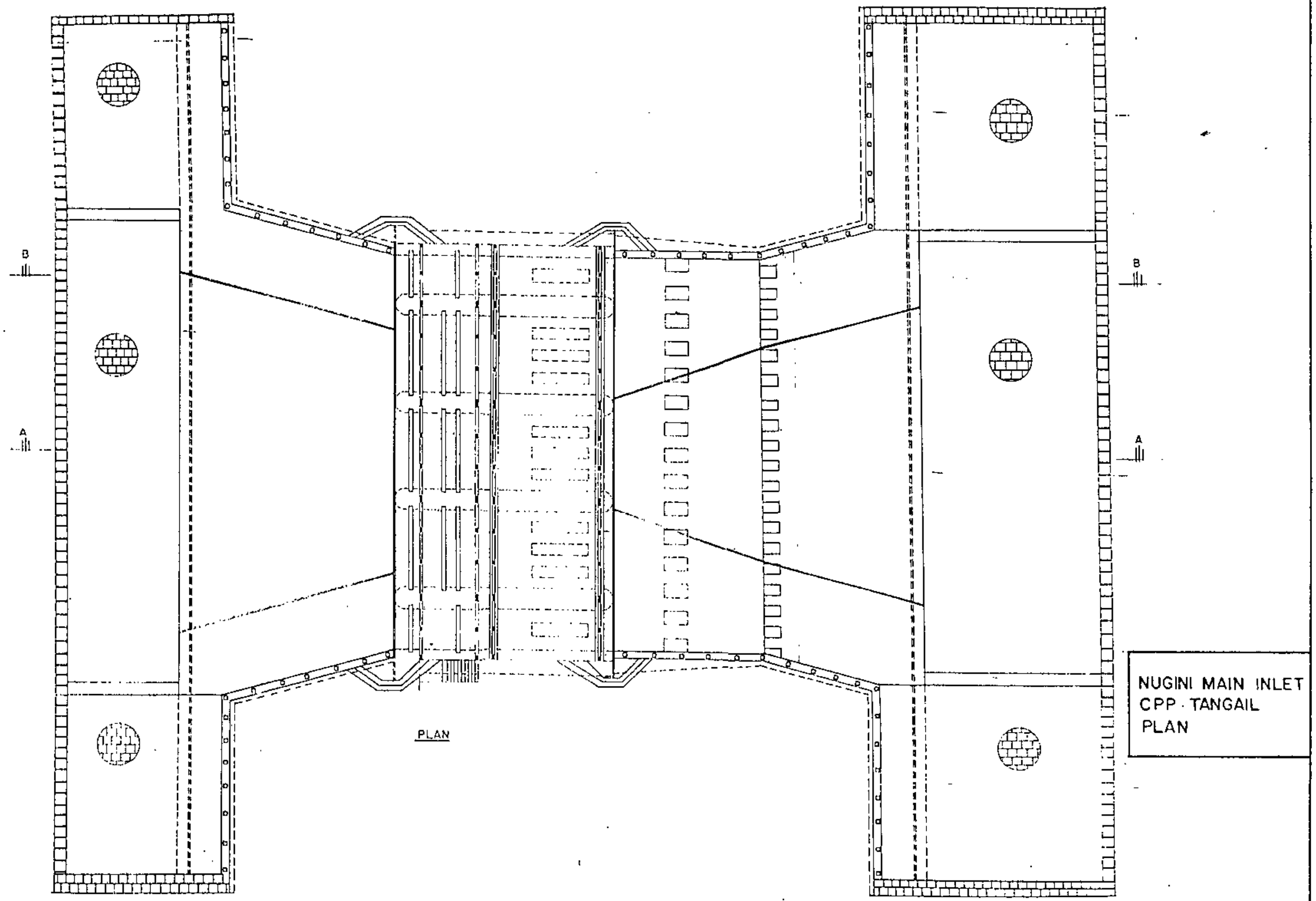


Fig. 2.16(a) Plan, Jugini Main inlet

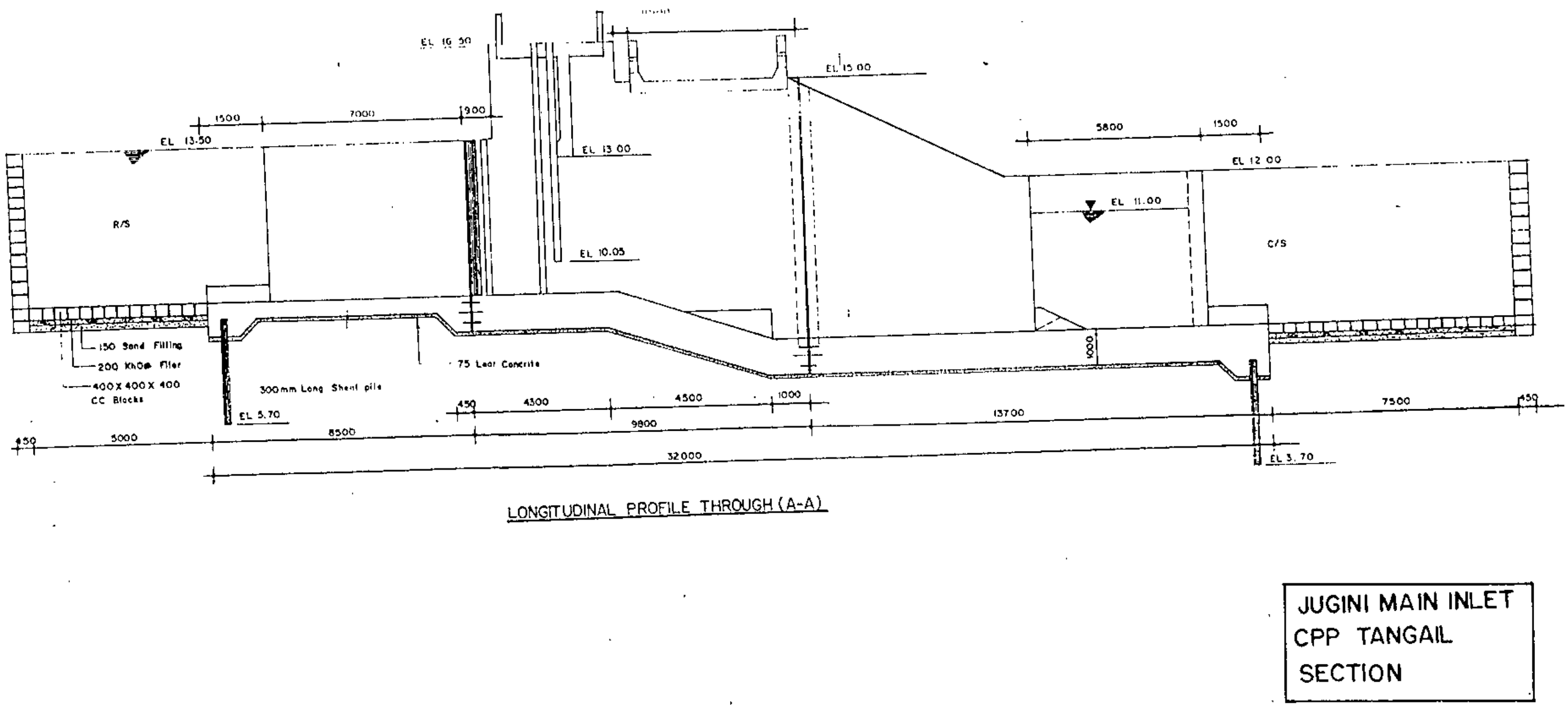
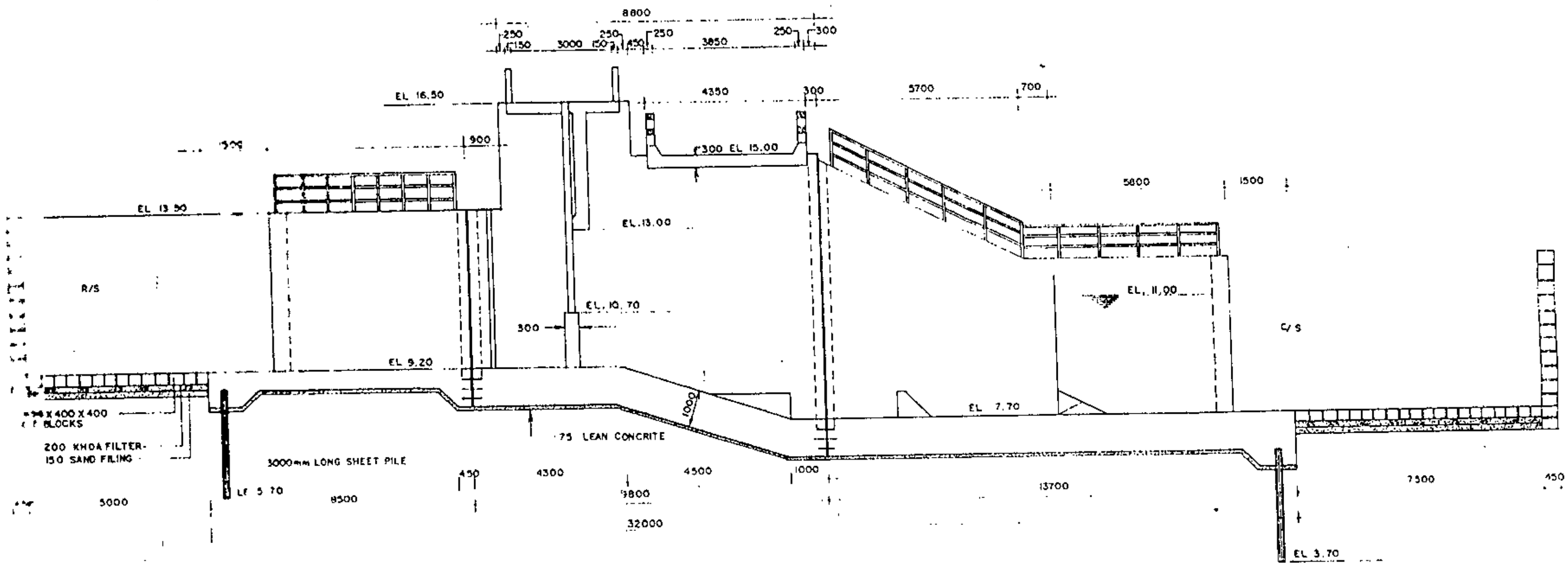


Fig. 2.16(b) Section AA. Jugini Main inlet



LONGITUDINAL PROFILE THROUGH (B-B)

Fig. 2.16(c) Section BB. Jugini Main inlet

JUGINI MAIN INLET
CPP TANGAIL
SECTION.

i. to prevent inflow from Mohananda river during high stage of monsoon;
ii. to permit drainage during pre-monsoon and post monsoon when external rivers are low enough;
iii. to store water in the beels during post monsoon; and
iv. the structure has been designed to allow easy passage of fish, spawn, fish fry from external rivers towards the project beels during the period of July-August.

The structure has been completed during 1996-97 but has not been brought under operation.

Horai river subproject fish pass at Belgachi and Dhanbaria:
As a part of mitigation measure, two fish pass structures under Horai river subproject have been designed (NHCL 1997). They are Belgachi and Dhanbaria fish pass structure. The criterion of selection of various parameters for these two passes are as follows:

(1) Sill level (R/S) = 1:2 year highest water level in June-1.00 m or bed level of the existing canal. The depth of water shall be 1.00 meter minimum.
(2) Sill level c/s = Av ground level - 1.00 m
(3) El. of Bottom of head wall 1:5 year HWL in June + 0.30 m
(4) Crest level of Bridge deck = 1:20 year HWL +.90 m or existing embankment level which ever is higher.
(5) Operating deak (R/S) = 1:20 year HWL (river) +0.30m
(6) Design head (operation) = 1:5 year HWL in (June) - (ground el in c/s - 0.30) or (1:5 year HWL in July-ground elevation of country side + 0.30).
(7) Design head (stability uplift) = 1:20 year HWL in July - (ground el. c/s + 0.30 m)
(8) Ht. of the gate = El. of bottom head wall - sill level (R/S)
(9) Pool size and slots: variable depending on type of river/streams
(10) Baffle No. $= \frac{\text{Designhead}}{\text{Headrop}} = \frac{4.00}{0.3} = 13.30$
(11) Maximum Permissible velocity = 1.50 m/sec.

2.4 Design of fish pass/fish ladders

2.4.1 Design parameters

One important biological parameter in the design of fish pass structure is that the facility must accommodate the weakest fish within the weakest species requiring passage. A further requirement is that the size of the facility should be based on the expected numbers of fish which need passage and the expected hourly or daily rate of ascending migrants.

Information needed for design of fish pass structures includes site specific data such as tail water rating curves, local topography, magnitude of flow and velocities and water surface profile along each bank upstream and downstream of the proposed fish pass location. Combined with biological requirement and hydraulics these physical parameters will determine the type of fish pass facility which will suit a specific flood control regulator.

Actual site observations and possibly modelling will be required to locate fish pass entrance and exits and determine the scale of the facilities and passage flow in combination with biological requirement. Observing the behavior of fish and the flow pattern downstream of existing structure are often the best method of locating a successful fish entrance to a by pass. Fish entrances based on theoretical hydraulic consideration alone often need modifications after construction. Model studies can be a valuable tool in helping the designer understand the full scale fish pass and fish entrance setting. There should be no excessive turbulence in the outflow from the first entrance and an adequate depth for fish to readily enter. Higher velocity sluice or hydraulic Jumps adjacent to fish entrance make fish seek the acceptable velocities through a by pass.

2.4.2 Conceptual Layout of Fish Pass Facilities

Fish passes or fishways are channels or series of pools installed to aid fish in over coming natural or artificial obstacles to migration. A small amount of water is diverted from the river or forebay of a dam upstream of obstacle to migration. The diverted flow is controlled throughout the length of the fish pass by means of baffles, weirs orifices so as to reduce velocity to the point. where the fish in the upstream migration can swim without to much exertion. Resting spaces between baffles and weirs are provided so that fish can recover after darting or bursting from pool to pool.

The main concern in the hydraulic design of fish passes is to determine the best way to control the water flowing through the structure so as to dissipate its energy most efficiently without hindering the swimming ability of fish. Apart from acceptable hydraulics, other general requirements are:

- sediment load, debris and polluted water must not interfere with the flow;
- the fish pass should be designed so that the least amount or at best no manual control would be required for maintenance of flow through in structure;
- the operating water level range must satisfy fluctuation in head water and tail water;
- the flow through the fish pass mush be adequate to attract fish at the downstream end (fish entrance);
- the upstream and of the fish pass (fish exit) must be located so that fish leaving will not be swept down over obstruction or dams; and
- the size of the fish pass much be based of numbers of fish expected to use the facility.

The last and probably most important aspect of fish design is the location of fish entrance. Other than adequate attraction flow, the entrance should be located and aligned so that migrating fish will not be delayed unduly by turbulence which confuse direction and cause traffic jam.

Selection of site is very important for effectiveness of the fish pass structure. Principal criterion to be followed for site selection of fish pass are as follows:

- there must be evidence (local people opinion/studies) that FCDI project has had negative impacts on fisheries, specially that fish migration has been disrupted (usually manifested as low abundance or absence of some species of big fish;
- reliable and abundant population of migratory fish should occur in the river;
- the FCDI project area should be medium to large (in order to minimize the opposition from farmer to release of water through the fish pass into the project area);
- the river channel opposite the fish pass should be preferably perennial;
- a number of beels inside the FCDI project area should be perennial; and
- there should be no cross dam in the channel which connects to the fish pass.

At embankments and regulators in the Northeast east region the forebay levels normally vary independently of tail water (Haor side) during the premonsoon period. Under these conditions a vertical slot fish way appears to be a better option. Sizing of vertical slot fish way is normally based on hydraulic consideration from model test and by the required capacity for moving fish over an obstruction.

Fish passes to be planned for at regulators between rivers and Haors would have to accommodate fluctuation in head water levels of upto 3-3.5 during premonsoon period. Fish migrating from the haor to river (out migration) would ascends from low to high water levels whereas in migrating fish would move downstream in the opposite direction from river to Haor.

Out migration (upstream moving fish) can be accommodated by a vertical slot fishway which operates at variable water depth. However downstream passage of fish (in migration) at the same time is questionable. It is suggested that fish migrating from the river to the Haor be provided an alternate by pass through a fish friendly under flow sluice way structure. Vertical slot fish ways and sluice way passage facilities will be assessed and in corporated in the same layout.

Upstream (and downstream) passage of migrant fish through the fishway depend on adequate depth of water over the forebay and fishway invert level. Adequate passage is expected with submergence of one meter.

Ideally for a vertical slot fish way which is self regulating the forebay (fish exit) and tail water (fish entrance) level changes by equal amounts and water depths and flow are the same at each baffle slot. However at regulator dams for flood protection around Haors the forebay in the initial flood stages rises faster than the tail water. To prevent hydraulic drawdown in the upper pools when water starts flowing through the fishway the water levels at the fish entrance needs to be adjusted.

The stream channels (*khals*) downstream of fish entrance might have to be trenched and or provided with berm weirs to facilitate a channel with adequate depth of water for fish to swim to or from the fishway.

2.4.3 Hydraulic Design of Fish Pass

The consideration adopted in the hydraulic design of fish pass structure as the same as regulators (Hossain 1993). These are briefly described below

- Invert level determination
- design head
- scour depth and cutoffwall
- loose protective work
- exit gradient, floor length & thickness

Invert Level: The invert level of fish pass structure should be selected in such a way mat the minimum water depth in the structure is about 1 meter for the movement of carp fish. Fish passes are 100% functional if the water depth at the fish exit end (river side) and fish entrance side (Haor side) and between the baffles are equal or nearly equal if all stages As for example if the average premonsoon water level at the r/s is 6.00 m pwd and 3 7m pwd as the Haor side during the harvest of boro paddy then the invert level for the fish pass structure may be set at 5.00m pwd in the fish exit end (river side). This invert level at the Haor side goes down to elevation +2.7m pwd to ensure minimum depth of flow of 1.00m throughout the entire length of the structure.

Design Head: Estimation of design head is important in checking the stability of the structure and in calculating the uplift pressure and floor thickness downstream. The design head should be expected maximum head during the premonsoon & monsoon period. Based on the water levels of R/S and c/s fish structures stability is checked for the required design head. This head is also considered in checking the exit gradient, up lift pressure and floor thickness.

Scour Depth (Garg 1983)
Depth of scour is determined by Lacey's regime formula
$R = 1.35\ (q^2/f)^{1/3}$; where f is Lacey's silt factor and R is the normal depth of scour below H.W.L. in meter and q is discharge/unit width in m3/sec.

Silt factor: Laceys formula may be used to determine scour depth
According to Lacey
$f \propto V_0^2/R$
V_0 = regime velocity
R = hydraulic mean depth

A qualitative formula for determining "f" for the predominant type of silt transported, is $f = 1.76\ (dm)^{1/2}$, where dm is the mean dia of silt in mm corresponding to maximum size of silt from 0.01m to 0.257 millimeter.

The total depth a scour below H.W.L. at the downstream and upstream structure and sluices is taken X-times R where R is Laceys normal scour depth and the values of X (safety factor) for different classes of scour are given below:

Table:

Scour type	Reach	mean value of X	D=XR-water depth(y)
A	straight	1.25	1.25 R-y
B	moderate bend	1.50	1.50 R-y
C	severe bend	1.75	1.75 R-y
D	Bend	2.0	2.00R-y

A value of X is taken as 1.25 on upstream and 1.50 on downstream side of the structure. The depth of cut of wall, is calculated from scour depth formula and then checked against exit gradient. If exit gradient criteria is not satisfied adjustment is made between length of floor and depth of cut off wall.

Protective Block works (Hosain 1993)
Protective works are required on the upstream and downstream of the hydraulic structure in order of alleviate the possibility of scour hole travelling close to the concrete floor of the structure and to relieve any residual uplift pressure through the filter. The normal arrangement consists of (i) Inverted filter (ii) Launching apron.

Inverted filter (river side):
At the end of a concrete floor, an "inverted filter" of length 1.5D to 2.00 times D is generally recommended where D is the depth of scour below original bed. The following limits are recommended to satisfy filter stability criterion and to provide ample increase in permeability between base and filter. To prevent filter from dislocation under surface flow, concrete or masonry blocks are laid over the filter material.

$$\text{(i)} \quad \frac{D15 \text{ or filter}}{D_{15} \text{ of base material}} \geq 5$$

Provided that the filter does not contain more than 5% of material finer than 0.074 mm after compaction (USBR 1987).

$$\text{(ii)} \quad \frac{D15 \text{ of filter}}{D85 \text{ of base material}} \leq 5$$

Where D_{15} is the size at which 15% of the total soil particles are smaller; the percentage is by wt. as determined by mechanical analysis. The D_{85} size is that at which 85% of the total soil particles are smaller.

The size of block can be determined from well known formula of California Highway practice (CHP). The recommended block size depends an flow velocity at the exit.

$$w = \frac{0.00002\, V^6 \text{ sgr } \operatorname{cosec}^3 (\phi-\theta)}{(\text{sgr}-1)^3}$$

where

W	= wt. of stone in lbs. (two third of stone should be heavier)
ϕ	= 70 degree constant for broken stone
sgr	= sp. gr. of hard material
θ	= slope of material measured from horizontal face slope
V	= mean velocity in ft/sec

Launching apron: At the end of inverted filter, a loose apron is provided for a length generally 1.5* D where Dis the depth of scour from original bed. The apron generally launches to e slope 2:1 and if t is thickness of apron in the launched position, the design thickness of the launched apron shall be equal to:

$$(2^2+1^2)^{1/2}\ t/1.5 = (2.24t/1.5) = 1.5t.$$

An empirical formula for the thickness of the stone pitching suggested by Inglish is:

$t = 0.06\, Q^{1/3}$
Q = discharge in cubic feet/sec
t = thickness of stone in ft.

Dimension of Baffle, Baffle slot and pilaster:
The dimension of baffle, baffle slot and pilaster are selected based on the ratio for pool length to width as determined by model studies in Australia for carp fish migration. The dimension of vertical slot fish ways for south eastern Australia are given in Fig. (2.17).

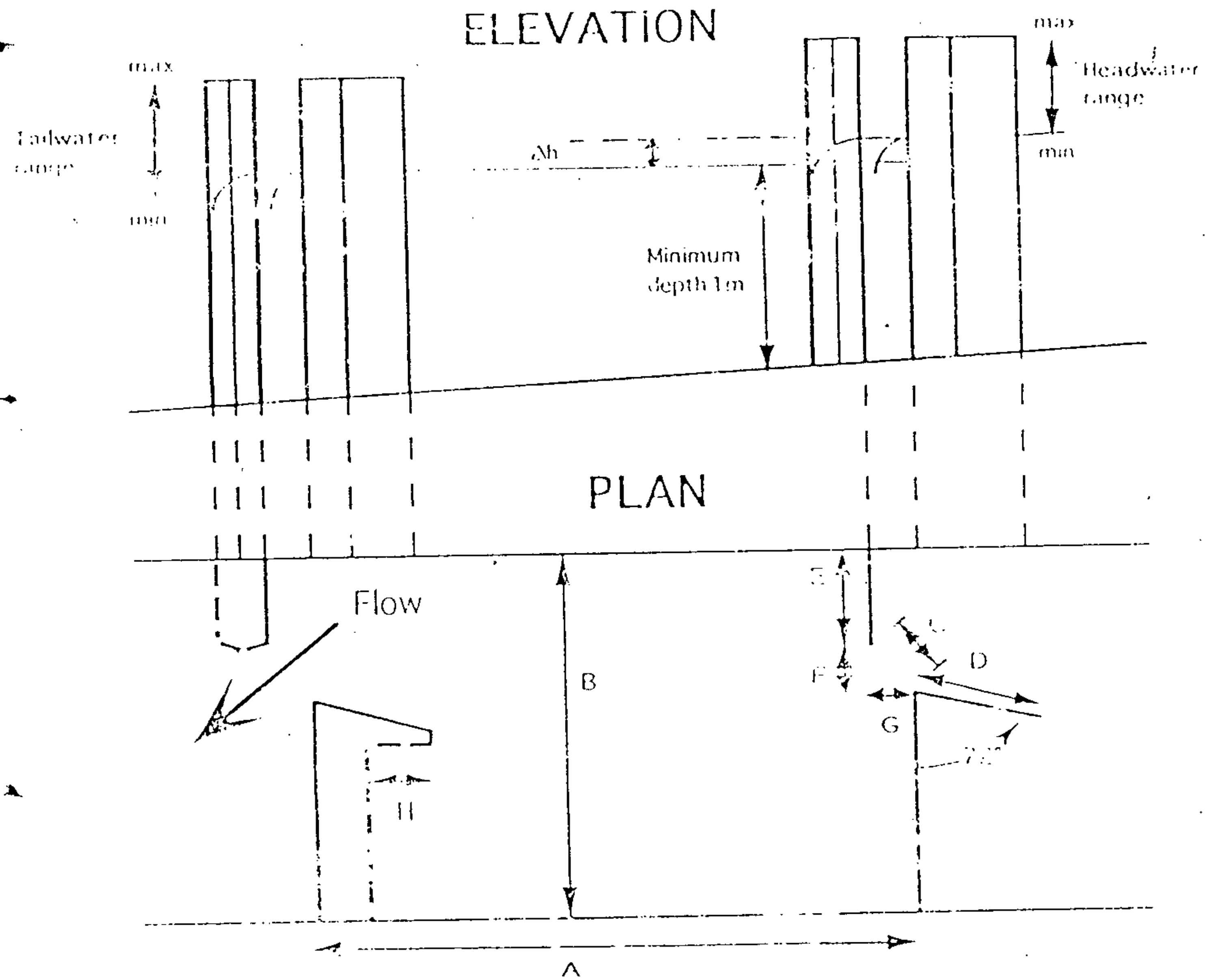


Fig. 2.17 Dimensioning vertical slot fish pass

Cell ratios
A:B (Min. 'A' = 1.5 m in coastal streams)
1.0:.6 or greater = 2.5 m in tributaries of Murrya darling rivers
= 3.00 m in Murray darling rivers)

C : A
0.1 : 1.0 or greater ("C" = 0.15 m in coastal streams
= 0.25 m in tributaries of Murray darling rivers
= 0.30 m in Murray Darling river)

A : D	: E	: F	: G	: H
1.0: 0.2	: 0.16 :	0.071:	0.071:	0.1

Δh = 50 mm in coastal streams with tidal influence
= 100 mm in coastal streams above tidal influence
= [illegible] mm in Murray darling stream

2.4.4 Structural Design:

General Design requirement

Any structure should be designed so that it remain stable against external loads and pressure and all members of the structures are strong enough to resist external loads and internal stresses.

Fish pass structure elements

The elements of the components of fish pass structure are the.

- The U type trough
- The Baffles and pilaster
- operating deck slab
- miscellaneous structural details and
- Gates

The following design steps are considered in the structural design of fish pass structure

- Design criteria
- Stability analysis
- Design of U trough
- Design of Baffles and, pilaster
- operating deck slabs
- Miscellaneous details

Design criteria

The working stress design method is usually adopted in the structural design of fish pass structure

External loads/unit or of material

Reinforcement cement conc. = 23.6 kn/m3
moist soil 17.3 kn/m3
saturated soil 18.90 kn/m3
water 9.80 kn/m3
Truck load H 40 (100kn truck)
Imposed load 7.20 kn/m^2 (on operating deck)
Gates and hoist = 10 kn (on operating deck)

Back fill soil parameters

(Angle of internal friction) = 30^0 (for back fill soil)
Allowable stress and design constant
fc = 7.2N/mm (fc = 18.0 N/mm2)
Vc = .387 N/m^2
n = 10, k=.357, J = .881
R = 1.1 N/m^2

2.4.5 Stability analysis:

The stability analysis of a structure should fulfil the requirement that it must be:

- safe against over turning at any horizontal plane;
- stable against sliding on any horizontal plane, including planes in foundation material;
- stable against water uplift; and
- that it shall not overstress the underlying foundation material or soil

CHAPTER-III

METHODOLOGY

3.1 General

FCDI interventions inevitably change the aquatic environment particularly detriment of open water capture fishery. Mitigation plan in the form of fish pass structure to prevent the decline of fishery resource is indispensable.

This study aims to establish the design parameter for Bangladesh condition of a fish pass based on available data and information. Then these parameters would be applied in remodelling on existing regulator. Accordingly a through study of available literatures and a study on performance of existing fish friendly structure in the country have been considered essential elements of the methodology of this study.

3.2 Determination of Design Parameter of Fish Friendly Structure

The parameters needs to be determined to make the structure fish friendly. These would be based on the following.

- (a) Available literature;
- (b) Design report of fish pass structures;
- (c) Implementation of similar structure in the country or else where;
- (d) The performance evaluation of similar structure in home and abroad;
- (e) Biological concept of fish pass and fish behavior;
- (f) Field trip to already constructed structure and discussion with field officials and fish biologist.

Important parameters to be fixed are the following:

- (i) Site specific data such as tail water rating curve, local topography, magnitude of flow and velocities and water surface profile.
- (ii) Biological requirement such as behavior of fish which is often a function of individual species.
- (iii) Other important parameter which influence the design are the shore and depth orientation of fish during migration, where they rest, how they respond to barrier such as gated control structure and associated hydraulics.
- (iv) Physical and chemical factors:- physical factors such as depth of water, bottom material, pressure, temperature, intensity of light photo period, nature of water current, and turbidity pH of water concerned, taste and smell of water, salinity are important chemical factors.
- (v) Distribution of migratory fish within the rivers and Haors system.
- (vi) Location of excess channels to and from the fish pass
- (vii) Date of opening of gate for agriculture and opening gate for migration of fish
- (viii) Invert level
- (ix) Slot width.
- (x) Size of pool
- (xi) Structural stability

Among these parameters, the exit velocity and water depth very important. The parameters are to be selected first and will be checked with the existing regulator so as to evaluate the changes necessary to make it fish friendly

3.3 Site Selection Strategy

The regulator to be selected for modification will have enough back ground information regarding hydrological, topographical, hydraulic consideration in the design of the sluice. The biological information regarding fishery resource, fish habitat, fish migration period, fish species to be available. In the side to be selected previously there ought to have been enough flow and a fish migratory route.

As the route will be known to the fish and if fish pass facilities are provided there, fish will be attracted easily. The structure will represent the very typical characteristics of the hydraulic structures in Haor area. The result of the study can be extended to other similar structures of the Haor area which will help to restore the mother fishery of many Haor and prevent the decline in abundance of fresh water fish. These will help to increase the annual protein intake of its population, help countries economy, generate employment opportunities for fisherman community.

3.4 Selection of Regulator for Modification

To investigate the possibility of modification of design of existing regulator to make it fish friendly, some typical nontidal regulators specially in the Sylhet areas may be selected. In selecting the regulator the following consideration need to be made.

- (i) The area should be nontidal area and there should be evidence of obstruction of migratory routes of fishes.
- (ii) The area should be have enough potential for fishery resource development.
- (iii) The areas should have enough perennial source and beels and duars for overwintering.
- (iv) The FCDI projects area should be medium to large (in order to minimize opposition from farmer to release of water through the fish pass the project area).
- (v) The river channel opposite the fish pass should be perennial.
- (vi) Reliable and abundant populations of migratory fish should occur in the river.
- (vii) A number of beel inside FCDI project should be perennial
- (viii) During the time of pre-monsoon there should be no open embankment breaches or public cut.
- (ix) There should be no cross dam in the khal which connects the fish pass.
- (x) There should be enough topographical and hydrological information. Topographical maps are needed to determine basin area and elevation relationship. Hydrological data such as rainfall water level needs to be available for drainage analysis and also determine 80% dependable water level at the early period from April to July. Frequency of water level (M PWD) help in fixing invert level to ensure minimum 1.00 m depth of water in the month of April-June for movement of carp fish. The fish passes are 100% functional if the water depths at the fish entrance end (R/S) and the fish exit end (country side) and between the baffles are equal at all stages.

Keeping in mind these criteria the Gilutia regulator under "Udghal Beel Project" in the District of Sunamgonj has been selected for study for modification to make it fish friendly. Field visit was also made and discussions were held with local people, BWDB field official and fish biologist of the project

To make the regulator fish friendly following consideration has to be made.

(i) Time of movement of brood fish, hatchling, fish fry/fish spawning from R/s to c/s during pre-monsoon. Also movement of fish from c/s to r/s during post monsoon.

(ii) Exit velocity required to help the fish swim without injury.

(iii) Minimum depth of water required for passage of fish.

(iv) Atleast 80% dependable water level at the early period of April-May June. In case the water level does not permit the period may be considered upto June-July for easy passage of fish spawn and fry from external river to ward the project area.

3.5 Concept for Modification:

Concept of modification will be in the light of suggestion given in FAP13 for modified sluice/ regulator to permit the passage of fish spawn and fry. The concept had been:

- To permit managed migration of fish both new operation rules, modification of structures would be required.
- To permit spawning migration of fish, the regulator gates would need to be wide open in April-May when mature fish swim out against the first inflow of rising monsoon water; they are not strong swimmers and so could not escape against a strong current or a head of water.
- When the mature fish release spawn in the river, the spawn and fry generally move in the sub surface water (2"-4" below the surface) and would normally float into the flood plain during June-August. As regulators vents are open from bottom the fish spawn fry which are floating near the water surface can not enter the FCDI project. To solve this problem one or two vents (depending on the size of the regulator and the intake channel can be modified to allow passage for the fish spawn/fry fingerlings into the project areas.
- A suitable slope (perhaps 1:2) should be provided on the c/s of this passage with a dividing wall to protect the delicate spawn from being damaged by water turbulence. The vertical gate for this passage would be rested below the floor of the passage so that the flow could be adjusted by raising the top of gate to allow only 15 cm depth a water over it.
- The floor level of the spawn passage would have to be fixed by careful examination of the lowest water level of the river at the spot for the months from late June to mid august to allow sufficient flow during a dry year. Operation of the new spawn and fry passage gate would thus aim at keeping the top of the gate about 15 cm below the outside water surface. Guide bunds on the R/S might be needed to help direct spawn and fry into the regulator and it should be located at sites adjacent to areas where spawn are known to concentrate.

Based on this concept the two outer ventages of the sluice, will be modified to act as fish passage. The invert level will be fixed based on the lowest water level at the spot for the month from April to June extending upto mid August to allow sufficient flow during a dry year.

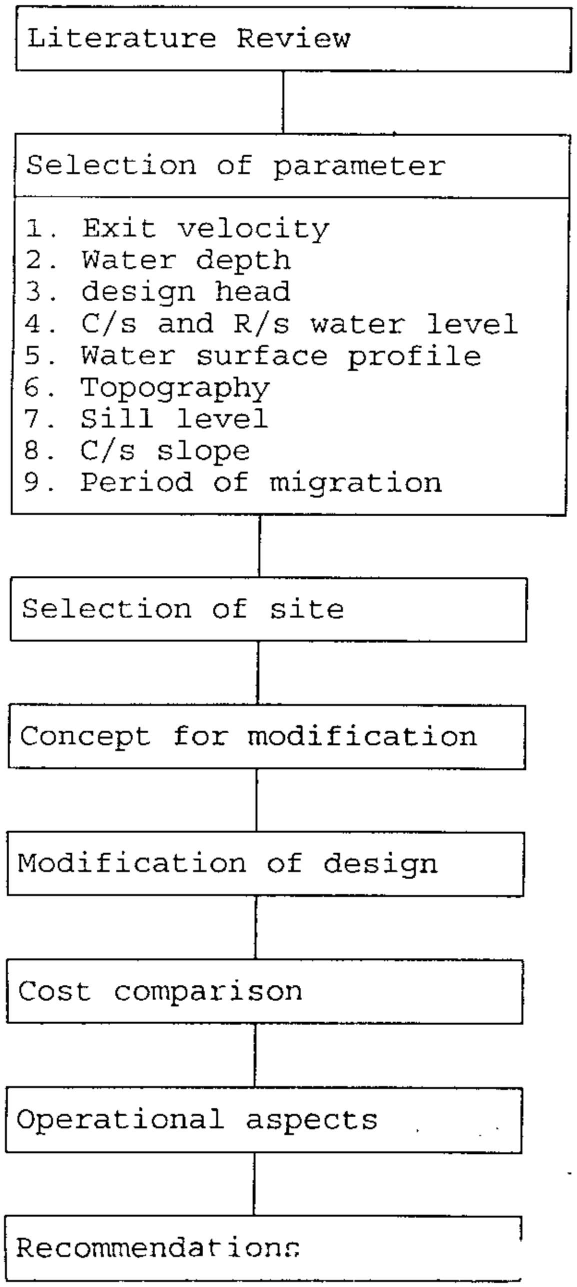
3.6 Approximate Cost Evaluation:

Based on the above discussion the selected structure will be modified to make it fish friendly. An approximate cost for the modification will be evaluated from which % increase in cost will be determined.

3.7 Operational Aspect of Regulator:

The operational aspect of the regulator for the possible modification will be evaluated and suggestion made for possible improvement. Sluice operation aspect for other structure for fish migration without injury will also be studied in brief and suggestion made accordingly.

The schematic diagram of the methodology can be represented by a block diagram as follows:



CHAPTER IV

PERFORMANCE EVALUATION OF FISH FRIENDLY STRUCTURES IN BANGLADESH

4.1 General

So far two fish pass structures have been constructed in Bangladesh. One is the Kashimpur fish pass structure for revival of the old status of Kawadighi Haor where construction of Manu River Project (MRP) has ruined the mother fishery. The other is the Jugini Main Inlet under Compartmentalization Pilot Project, Tangail (FAP20).

Another structure is the Marichar Danra Regulator (9-1.52x1.82) under Marichar Danra Subproject of Nawabgonj district which is under construction, where two vintages will act as a fish passage. As a mitigation measure against the negative impact of FCDI project some fish pass structures will be constructed. Design of the structures have been completed but construction is yet to start.

4.2 Kashimpur Fish Pass Structure of MRP:

In Chapter II some details of this project has already been given. Further to these the following information are given here. This fish pass was designed to facilitate migration of fish in the pre-monsoon and monsoon season (April-October) from the river to shallow areas inside the MRIP. The site of the fish pass was selected after analyzing migratory routes of fish in the Kushiyara river over a period of 3 years. The fish pass was built on the embankment in village Kashimpur of Rajnagar Thana in Moulvibazar district. The structures has been functioning since 1995 immediately after construction.

This is a single jet vertical slot structure 2.5 meters wide and 62 meters long. It has 17 pools and 16 baffles. The structures has the maximum flow velocity of 1.3 meters/sec. through vertical slot. It is a simple structure and easy to operate.

The project staff have been monitoring the functions of the fish pass since may 1995 by taking samples of fish passing through the structure regularly and recording the species passing through the structure. The monitoring phase ended in Dec. 1997.

4.2.1 Performance of Kashimpur Fish Pass

Detailed discussions were held with concerned officials about the background of this fish structures, fish behavior, performance of the structure, constraint with the operation of the structure, measures to improve the performance and preservation of fishery resource. Due to the construction of MRIP the mother fishery of *Kawadighi Haor* was ruined as it was cut off from *Kushiyara* river by the MRIP embankment. This resulted in loss of fishery and consequent impoverishment of several thousand fishing family. The fish pass structure was an attempt to revive the old status of *Kawadighi Haor*. A prefeasibility study was done with the frame work of NERP, and the fish pass pilot project was an innovative project, an out come of this study.

Before the construction of the embankment, the early flood season i.e. April, May and June was the breeding time and fish favoured to move to shallow areas in the *Haor*. The *Haor* environment was very favourable for breeding and feeding. Juvenile and brood fish entered the project area from may, the period might be extended further. During monsoon big fish entered the project area. During post-monsoon fish came of out *Haor* to river for over wintering. It may be noted that though in general fish likes to migrate against current but it is not mandatory. Fish due to its necessity during breeding and for feeding may go in favour of current also. The fish likes light and cold atmosphere that is why water hyacinth is favorable. Regarding characteristics of fish it is said that there are some bottom feeder and some are surface feeder. Regarding present location of fish pass it may be mentioned that as previously there had been a migratory route here and there is the existence of pump house, it was attractive for fish movement. Further there was permanent water body like *Kawadighi Haor* which was very resourceful. Thus the selection of the site was very reasonable.

Monitoring of fish movement:

(a) First operation: The fish pass began operation on May 24, 1995. This coincided with the first major pre-monsoon surge in Kushiyara river for 1995. River level began rising sharply from 4.69 m on the evening of May 18, 1995 peaked at 7.54 m on May 23,95 and declined to a low of 5.95 m on June 3, 1995. First operation of the fish pass thus coincided with the declining water level phase of the first pre-monsoon flood surge. When the r/s gate was opened for the first time at 1000 hr. on May 24, 1995, the W.L. at the river was 7.37 m (i.e. 1.91 meter above the river side invert elevation of 5.46m).

(b) Sampling Period: Sampling was done to estimate fish traffic through the fish pass. From May 24,1995 to October 26, 1995 a total of 104 samples were obtained from the observation chamber. Sampling hours were 10.8% of the total number elapsed hours. Only 7.7% of the samples were taken at time and the total number of night time sampling hrs was 19.3% of the total. Night time sampling was hampered by the lack of electricity for lights above the observation chamber. Total elapsed time since opening of the fish pass was 3744 hrs., the gate of the fish pass was closed for 907 hrs. Total closure time is a significant fraction (24.2%) of the total elapsed from. It seems the potential impact of the structure on fish production in the Haor could have been reduced by about one quarter because or the closure (FAP 6, Fish pass pilot project Interim report, 1995.

(c) Estimate of fish traffic through the fish pass:

The results of the first five months of the operation of the fish pass were extremely encouraging. Some of the results had never been reported any where and were a worlds first. The most general results were as follows:

- All 104 samples taken during the 1st five months trapped fish. The 100% success rate suggested that there was a continuous traffic of fish through the fish pass whenever there was sufficient water flow inside the structure. In contrast conventional fish pass applications elsewhere usually cater for seasonally migrating species, and water flow in the structure tropically carried fish traffic for only part of the operational year.
- Fish traffic moved simultaneously bidirectionally in the fish pass. Conventional fish pass applications usually cater for fish traffic moving unidirectionally.
- Fish traffic moved both counter current and concurrent conventional fish pass applications are usually designed only for counter current fish traffics.
- Fish traffic responded positively to flow reversal inside the structure. Conventional fish pass usually operate under conditions of unidirectional water flow

The presence of fish in concurrent samples interpreted passive drift. Consistent presence of fish of all sizes in counter current indicates active entry and migration.

Results of the fish migrations showed that 44 species entered the Haor areas in 1995. In 1996, about 62 species entered the Haor area out of which 16 were new species.

(d) Structural function:

The design head for the structure is 4.00 m and the head difference is reduced to 0.00 at the last pool. Usually there is a head drop from .15-.25 meter in each pool. The slot width is 0.41 meter and height of the baffle is 4.5 m. The chamber dimension is 2.5 m x 2.9m. Bed slopes 5%. There are two observation chambers on the two sides. There are two gates at different elevations. This has been done depending on the characteristics of fish whether they are bottom feeder or surface feeder.

The allowable velocity was 1.5 meter/sec. During observation it was found that in some pool the velocity was as high as 2.25 m/sec. This velocity posed a greater impediment to migration. The amount of turbulence in the fish pass increase with increasing velocity. Pool no.1 had been the one most likely to exhibit potentially problematic levels of turbulence, as slot no. 1 consistently showed the highest velocities in the structure in either flow direction.

In counter current movement there had been more turbulence in the exit compared to concurrent movement. It was observed that for a difference of 1 m head difference there had been more turbulence in the exit in comparison with concurrent flow.

4.2.2 Suggestion for improvement

(a) Redimensioning of structure

- To minimize the adverse effect of higher velocity the slope should be made flatter or, the pool dimension to be refixed and also the number of pools to be increased.
- The reduce too much turbulence at the exit during counter current movement the slope of the structure may be made flatter. Further sill level may be lowered down. If the sill level is lowered there may be more discharge. To compensate this the structure to be kept open for smaller time. If 2/3 days during peak water level the gate is kept open maximum benefit can be derived.

(b) Community participation:

It is observed that the 3 vent drainage regulator (3-1.32mx1.82m) near the fish pass structure is very detrimental for the preservation of fishery resource inside the project area. The sill level being to low excessive drainage reducing the water area and lessee catches all the fishes. It doesn't give sufficient time for the growth of fish and no residual fish remains for reproduction. This excessive drainage should be stopped by proper regulations so that additional area is created. There should be reserve sanctuary Lease should be for at least 3 years and fish catching should be stopped for 1-2 years so that enough time is available for growth of fish. Complete drying of the beels should be stopped so that residual resource remains for reproduction.

It is also observed that lease is given by land ministry and there is no co-ordination between land ministry and fishery directorate. So there should be co-ordination between land ministry and fishery directorate for proper management of fishery. It is found community has not been involved indifferent stages of project planing, implementation for which the concept of the fish pass structure has not been clear to the farmer and they have created hindrance to operation of the structure. To make the project socially meaningful and acceptable the concept of the project to be explained to public from the very beginning of the project planning and their participation needs to be assured. This will help O&M of the structure effectively. Again there should be good correlation between agriculture crop requirement and fish migration requirement so that agriculture is protected and at the sometime migration also takes place. This can be possible by institutional development and suitable gate operation strategy. There should be regular meeting of the local consultative committee, at least once in a month and any problem regarding operation of the structure can be resolved amicably.

4.3 Jugini Main Inlet of CPP, Tangail

4.3.1 Structural function

The main inlet structure in the Lohajong River i.e. Jugini main inlet which is said to be designed fish friendly. The structure has three double gated inlets and two smaller slide gates (single gate). These slide gates were constructed to allow hatchling migration (of which concentration are highest at the banks and the top layer) during the first peak. The main gates can be closed and the smaller slide gates remain open. Sill level of these slide gates are however relatively high 10.7 m PWD in place of 9.20 m of sill level of the middle opening. This relatively higher sill level may prevent early low flood water levels from entering. The slide gates are therefore likely to be less fish friendly then the main gates when fully retracted. The control gates can be operated in overshot mood. This should be preferred if full retraction is not possible.

The Jugini main inlet has been visited and had a discussion with Project Director CPP, Tangail and local fishermen.

The structures has got the flushing purpose and it has no drainage purpose. When the river water level rises with onrush of flood, water enters into the project area. The project has been devided into 15 sub compartments. In each sub compartment there is water management committee and they operates the gate, operator belongs to the committee and not WDB. Project authority has got the authority to open the gate on special cases for water management. It is observed that:

(i) Smaller gates always remain open. The central gates are opened and closed depending on circumstance. During early flood when the area behind the project area inundates the gates are opened.

(ii) The velocity in the two end slide gated opening are comparatively less.

(iii) In the central openings there has been much turbulence and it extends to the end gates also.

(iv) During early flood hatchling enters the project area and along with the hatchling Juvenile also enters. The hatchling which enters along the central opening gets damaged.

(v) Fish inside the project area adjacent to the structure are less than the fish in falar river outside the project area.

(vi) During post monsoon some fishes migrates from project area to the outside river.

It is also observed that when the head of water in the end ventages increases and the c/s water level is low there is too much turbulence and it is likely that hatchling gets damaged and fish friendliness of the structure becomes questionable.

Upto 15th July there is eggs/hatchling migration and it generally takes place through the slide gate opening where there is less turbulence.

Adult reverine fish in the upper catchment of the Jamuna river respond immediately on a rise in water level. They spawn and consequently egg/hatchling in the river water increases. The major peak of hatchling is found in the first flood peak and timing for the intake of water is essential.

The period in which carp respond to a rise of water level is limited and reproduction ended in mid August. Consequently no carp hatchlings are found after that date.

4.3.2 Hatching movement monitoring

Hatchling migration monitoring was done during monsoon of 1995. Observation on the effects of regulators on hatchlings were unclear. Rapid fluctuations of hydrostatic pressure might have negative effects though large kills so far not been reported (FAP 17). This was the basis of experiments which were conducted in the early monsoon at CPP main regulator (1995) and Binnafair inlet 1996.

The monitoring was carried out in the early monsoon during the first 1.5 month after water entered the Lohajong river and Binnafair khal. The concentration of carp hatchling is the highest at this time (special fisheries studies 1994).

Two bags nets were placed simultaneously downstream and upstream from the structures. They had a removable cod-end to make collection easier without damaging the hatchling. The nets were placed near the banks, at the top layer of the water because hatchling concentrations are the highest there (SFS 1994). The nets were placed at such a distance from the regulator that downstream turbulence and eddies did not affect the collection. The duration of the sampling was chosen in such a way that a minimum of 100 hatchling were collected. Collection was on daily basis except on Friday and Saturday.

After collection, the hatchlings were collected in two bucket (1 upstream, 1 downstream) and brought to the laboratory where dead and alive larvae were counted. Hatchlings were than reared for 3 days in plastic jar in the laboratory. After these 3 days again the survivals and dead hatchling were counted. In this way effects on the survival on a longer term could be assessed. Hatchlings were reared on Artemia according to method earlier used in the fish section.

Results:

The results of the hatchling mortality monitoring in 1995 have been shown in the table 4.1. Survival rates in both u/s and downstream nets were very low which can be explained by the large number of non carp hatchlings in the samples. These non carps are very vulnerable and therefore can not be caught alive. Carps however are stronger and can be caught alive. The inflow on carp hatchling are concentrated in the beginning of the monsoon period The sample of carp hatchling could not be collected because water started to flow only in the middle of

July at which time the concentration of carp hatchling had already reduced. From the 1st experiment no conclusion could be drawn.

In 1996 no carp hatchling could be collected downstream of these structures. Because of construction activities, gates were more or less closed and no hatchling could enter. Further monitoring is therefore necessary to draw a conclusion.

Table 4.1: Hatchling survival at the main regulator during monsoon 1995

	Inside inlet				Outside inlet			
	alive	death	total	% survival	alive	death	total	% survival
18.7	0	12	12	0.00	6	31	37	16.22
19-7	-0	11	11	0.0	-2	23	25	8.00
28-7	-0	38	38	0.00	0	111	111	0.00
26-7	-1	30	31	3.23	0	125	125	0.00
22-7	-1	24	25	4.00	.3	76	79	3.80
23-7	-0	19	19	0.00	1	45	46	2.17
Total	2	134	136	1.47	12	411	423	2.84

4.3.3 Suggestion for improvement

1. The blockage of intake of Lohajong river by a sand rim might have obstructed entry of hatchling through the main inlet. The rims need to be removed and widen the mouth.

2. To prevent the interference of turbulence from the central opening of the regulator to the end opening meant for hatchling passage, a divide wall to be constructed.

3. To prevent excessive turbulence in the end ventage at high head difference when country side water level is low, there should be a suitable slope in the country side apron preferably 1:2 to prevent the delicate spawn being damaged by water turbulence. The apron may be modified accordingly.

4. Hatchling movement needs to be monitored in each season.

CHAPTER V

MODIFICATION OF DESIGN OF THE EXISTING REGULATOR TO MAKE IT FISH FRIENDLY

5.1 Introduction

In several locations in the country during the last decade natural migratory patterns of fishes have been interrupted by construction of dykes and regulators. These hydraulic structures completely ignored the fishery aspect during planning & design which has resulted decline of open water fishery, both in terms of catch and biodiversity. Only recently the FAP studies have given due importance to this very important aspect of national economy and also important factor from environment point of view. To offset the negative effects of FCDI project, structures must be designed to assist the fish to pass them. Further as there exists hundred of structures without fish passage facilities attempt needed remodel some of the structures to make them fish friendly if it is technically viable and economically feasible. As a test case a structure has been selected in the District of Sunamgonj in the north eastern region of Bangladesh for modification to make it fish friendly.

5.2 Particulars of the structure

1. Name of the project: Udghal Beel Project
2. Gross area of the project = 5900 ha = 14579 acre
   = 22.78 sq.mile = 59.00 sq.km
3. Benefitted area = 4800 ha
4. Location of the structure - at Gilutia in the District or Sunamgong
5. Type of the structure = Drainage cum flushing
6. Purpose of the structure

   (a) Prevention of early flood
   (b) Post monsoon drainage
   (c) Inflooding after harvesting

(7) Frequency of flood considered = 10 years
(8) Cropping intensity = 100%
(9) No. of vents and vent size (4-1.98x2.29m)
(10) Location of gauge station from structure site

There are two gauge stations namely Sunamgonj - 50 miles upstream and Azmirigonj, 20 miles downstream which provide with water level data.

(11) HFL ever experienced = 8.23 mPWD.
(12) Existing Embankment top elevation = 7.30 mPWD
(13) Drainage required level +2.00 mPWD
(14) Invert level = +2.00 mPWD

The plan and section of the sluice is given in Fig. 5.1 and 5.2.

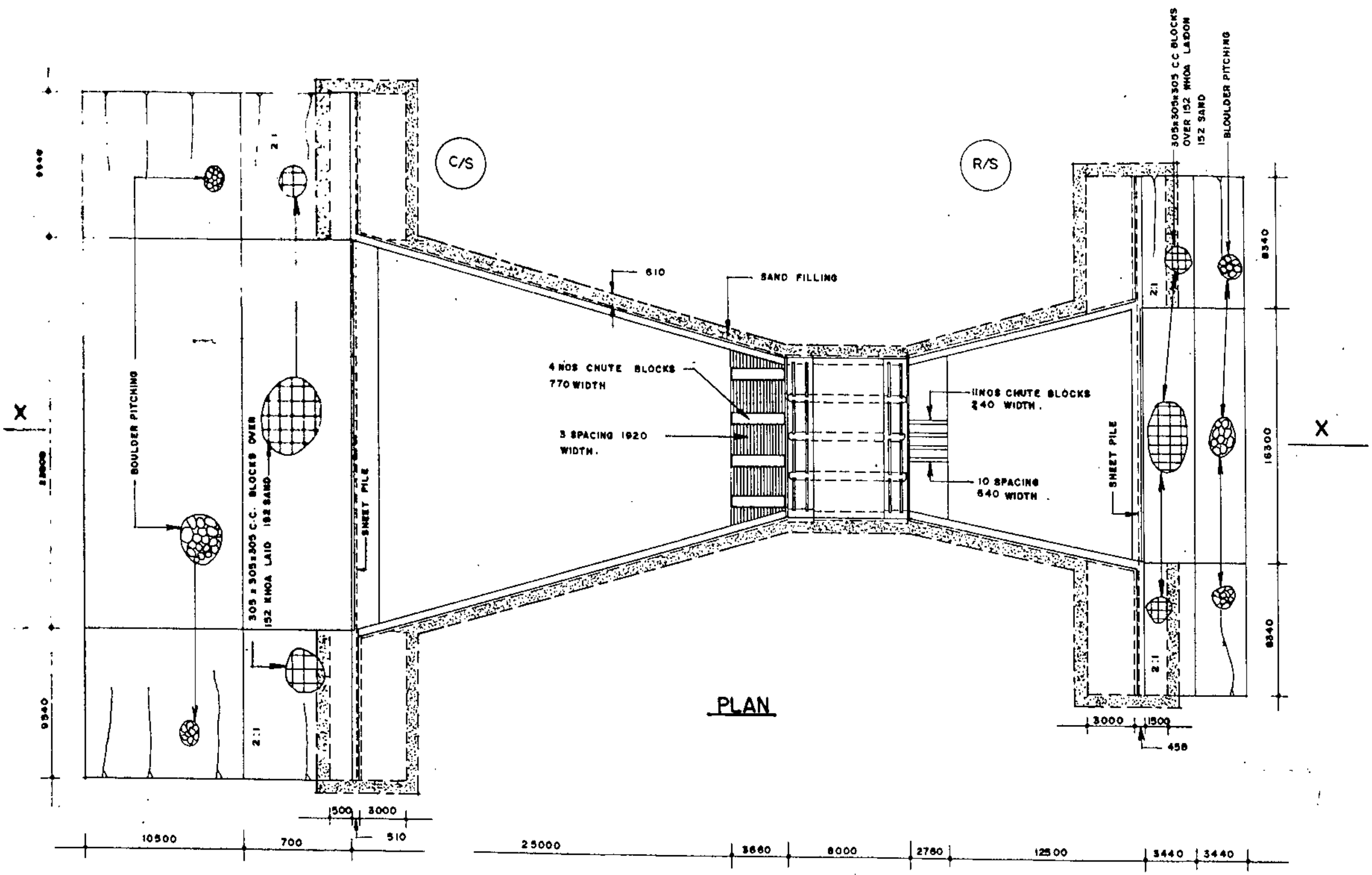


FIGURE - 5.1

Fig. 5.1 Plan of Udghal Beel regulator

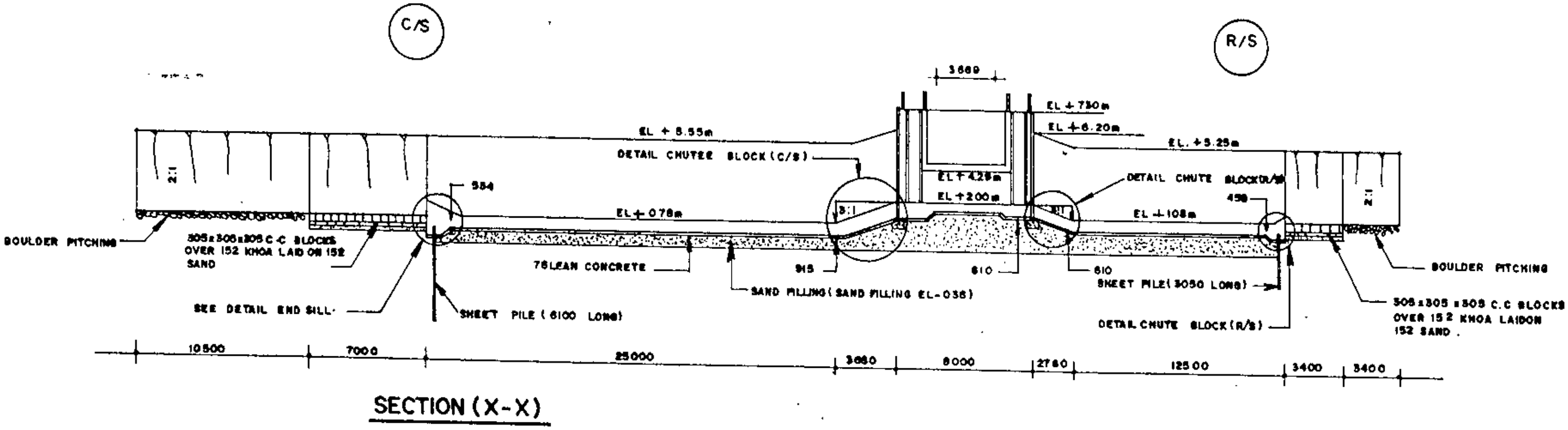


Fig. 5.2 Section of Udghal Beel Regulator

5.3 Fisheries of the project area:

The project area has been protected by submersible embankment to protect Boro rice crop from early flooding. Ninety percent of the project area are available for cultivation. Homestead, village, orchard road etc. occupy small portion of the project area at higher elevation and there are some permanent water bodies including beels and khal at lower elevation. During the dry season the fishing area within the sub project is reduced to only few beels and khals. About 10-15% of subproject population depend on fishery.

There are a number of Jalmahals : Some are below 10 hectares and some above 10 hectares in size. The Upazila Parishad is empowered to lease out the smaller fishery (upto 10 hectare). Most of the smaller Jalmahals managed by Upazila parishad are getting silted up rapidly and are losing there potential as fisheries.

Due to increased sedimentation many of the fisheries managed by Upazila parishad can't be leased out be cause they are not longer suitable for fish habitation in the dry season. Immediate re-excavation possibly through food for works is necessary to revitalize the fishery.

In the preproject condition the beels in the project area remain connected with the rivers through small khals or channels. These channels usually go dry during the dry season. During the late February to April when water level rises these channels receive water and the connection between the beels and rivers restored. In this situation brood stock fish migrate from the beels to the rivers for breeding. On the other hand brood stock from perennial beels within submersible embankment would not be able to breed in the flood plain which remain dry until the end of may. Inhibition of natural breeding with in the river flood plain ecosystem will thus reduce the fish biomass and high valued fishery will be reduced by low valued small miscellaneous fish. Before the construction of submersible embankment, fish catch in the Haor areas used to be dominated by high valued major carp like Rohu, cattle, mrigel etc.

Opening of gates of conventional hydraulic regulators results in velocities through the regulator between 6.5 m/sec to 9 m/sec under different head across the regulator of 3 - 4.00 meters. This likely exceeds the swimming performance of all fish species (except perhaps the target chital).

5.4 Design of Fish Passage

(a) Area Capacity Computation: The area under different elevation has been given in Table 5.1. Computation of area capacity has been presented in Table 5.2.

(b) Fixation of Design R/S Water Level by Flood Frequency Analysis:

The structure site is located 50 miles D/S from Sunamgong gauge station #269 and 22 miles u/s from Azmirigong gauge station #271 Water level data of these stations are collected for 9 years and interpolated the water level near the structure site by slope method. The Table 5.3 gives the water level data at the two station and also at the structure site for a particular year with respective date.

From Gumble Method 10 years flood frequency at structure site is +5.81. So Design River side water level is taken as +5.81 m PWD

Table 5.1 Area elevation

Elevation in RL (SOB)	Area in sq.mile
Below 6.00	3.720
6.00-8.00	0.854
8.00-10.00	2.490
10.00-12.00	3.442
12.00-14.00	2.84
16.00-18.00	2.949
18.00-20.00	1.232
20.00-22.00	0.846

Table 5.2 Area capacity computation

Ground elevation	Area in hac.	Cum. area in hac.	Avg. cum. area between two contour	Storage in hac.m	Cum. storage in hac. m.
2	0	0	0	0	0
2.29	963.5	963.49	481.75	139.71	139.71
2.9	221.2	1184.68	1074.09	655.19	794.9
3.51	644.9	1829.6	1507.14	919.36	1714.25
4.12	891.5	2721.09	2275.35	1387.96	3102.21
4.73	735.6	3456.66	3088.88	1884.21	4986.43
5.34	733	4189.64	3823.15	2332.12	7318.55
5.94	763.8	4953.44	4571.54	2788.64	10107.19
6.55	391.1	5344.53	5148.99	3140.88	13248.07
7.16	291.1	5635.64	5490.09	3348.95	16597.02

Table 5.3 Water Level Data

Year	Date	#269	#271	At Structure Site
1990-91	29th April	7.44	4.91	5.68
1989-90	5th May	7.30	4.81	5.57
1988-89	14th May	7.05	4.78	5.47
1987-88	14th April	6.08	4.46	4.95
1986-87	20th April	6.65	4.02	4.82
1985-86	28th April	6.80	4.10	4.92
1984-85	15th April	6.10	4.65	5.09
1983-84	11th May	7.05	5.05	5.66
1982-83	12th May	6.55	4.03	4.80

Table 5.4 Determination of 10 Years Highest Water Level

Year	HWL(m)	No year	HWL (Avg.)	Standard Deviation	k	Cv	H_{10}
1991	5.68	9	5.2177	0.3506	1.703	0.067	5.814
1990	5.57						
1989	5.47						
1988	4.95						
1987	4.82						
1986	4.92						
1985	5.09						
1984	5.66						
1983	4.80						

Table 5.5: Runoff Calculation For Paddy Land

Month	Monthly rainfall (mm)	Monthly evaporation (mm)	Initial soil moisture (mm)	Depression storage (mm)	percolation loss (mm)	Run off (mm)	Run off volume (Ha-m)
January	4.60	80	-	100	0	0	
February	15.00	103	-	100	0	0	
March	67.00	146	-	100	0	0	
April	340.00	146	-	100	0	94.00	555
May	318.00	71	-	100	0	147.0	867
							1422 (Ha-m)

(c) Fixation of Design Country side water level:

Design Country side water level can be obtained by calculating the internal storage and the corresponding level can be found out by using storage elevation curve (Fig. 5.3, 5.4). Monthly rainfall data is taken from design calculation file a Baram Haor Project of Sylhet District.

$$\text{Runoff Volume} = \frac{5900 \text{xRunoff}}{1000} = \text{Ha-m}$$

C/s water level can be calculated from storage elevation curve
From curve for storage 1422 corresponding el. 3.35 m
Daily internal storage 867/15 Ha-m per day
= 57.8/4 Ha-m per 6 hr
= 14.45 Ha-m

So the design country side water level is +3.35 m PWD.

(d) Fixation of sill level of the fish pass structure = It is seen from the flood frequency studies vide table 5.3 that R/S water level at the structure site varies from 4.80 m PWD to 5.68 PWD during the period from April to May for the study year 1982-83 to 1990-91 and the design R/S water level from Gumbles method 10 year flood frequency analysis is +5.81 PWD. So in consideration of flushing of water in the pre-monsoon and also after harvesting of Boro crop the sill level of the fish pass structure has been fixed at +4.59 MPWD so that during the leanest water level of 4.80 also there is a water depth of 0.21 m of water in the fish passage. The sill level of fish passes will be 2.59 m above the sill level of the original sluice. Plan and section of the modified regulator is given in Fig. 5.5, 5.6, 5.7.

(e) Exit velocity

The exit velocity should be less than be swimming speed of fish species. If the critical velocity if less than 1.5 m/s the structure will act as fish friendly structure.

The gate over which flow will take place will act as a sharp crested weir. The head over the weir will be 0.15 m. The critical velocity and exit velocity is calculated as follows:
$q = C_d \times H^{3/2}$
$= 2.68 \times 0.15^{3/2}$ where value of C_d has been considered to be 2.68 for sharp crested weir
= 0.16 cumec.
The critical depth $y_c = (q^2/g)^{1/3} = 0.14$ m/s
Critical velocity $v_c = q/y_c = 0.16/0.14 = 1.14$ m/s
Using Barnaulis equation the velocity v1 can be found out as follows:
$y_c + v_c^2/2g + z = y_1 + v_1^2/2g$
or $y_c + 0.5\ y_c + 0 = y_1 + V_1^2/2g$
or $1.5\ yc = y_1 + (0.16/y_1)^2/2g$
or $1.5 \times 0.14 = y_1 + (0.16/y_1)^2/(2 \times 9.81)$
or $0.21 = y_1 + 0.001529/y_1^2$

This is quadratic equation and trial value y1 can be found out and it came as 0.145m
So $V_1 = q/y_1 = 0.16/0.145 = 1.1$m/s less than 1.5 m/s and hence o.k.

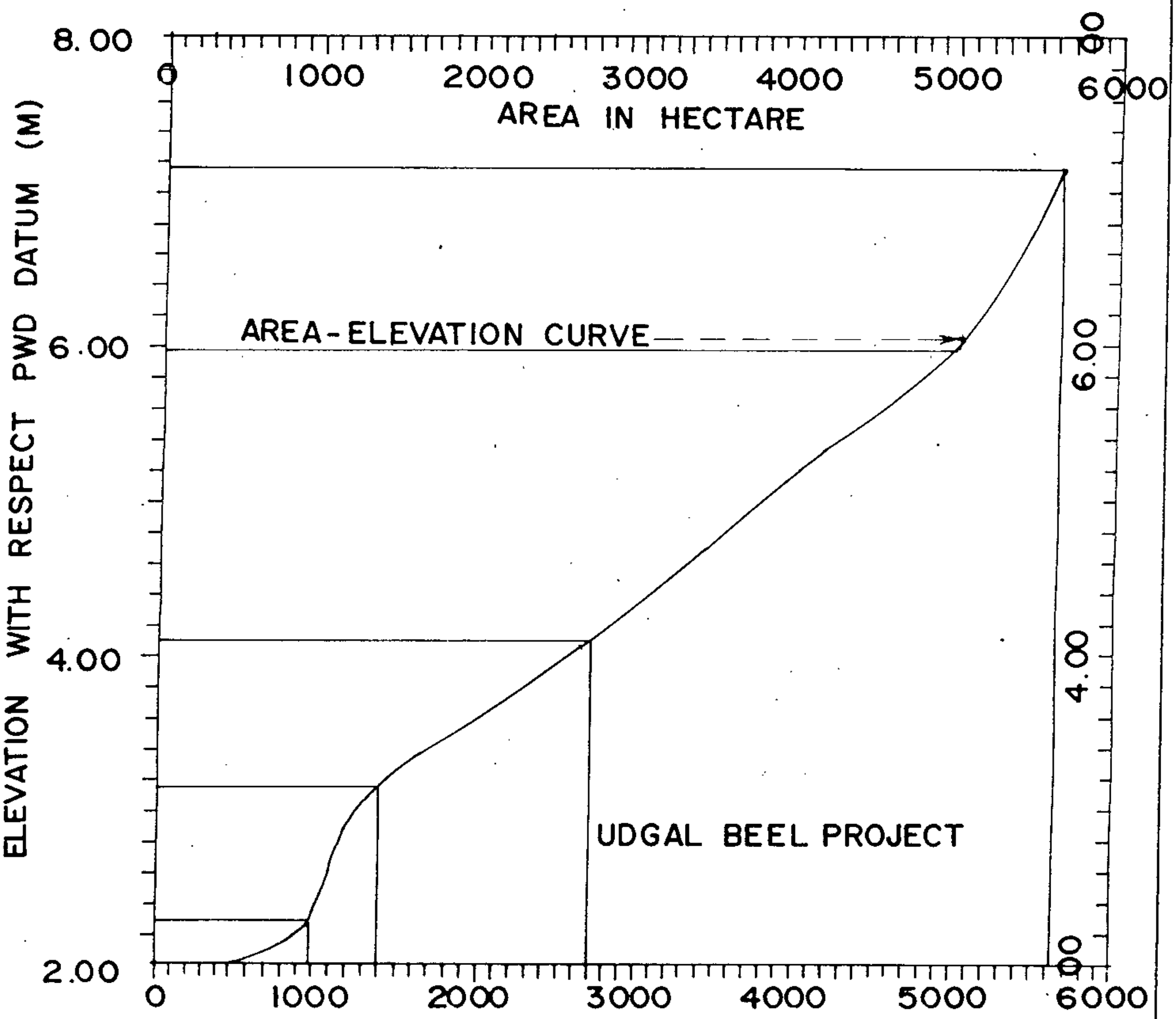


Fig. 5.3 Area elevation curve of Udgal Beel project area

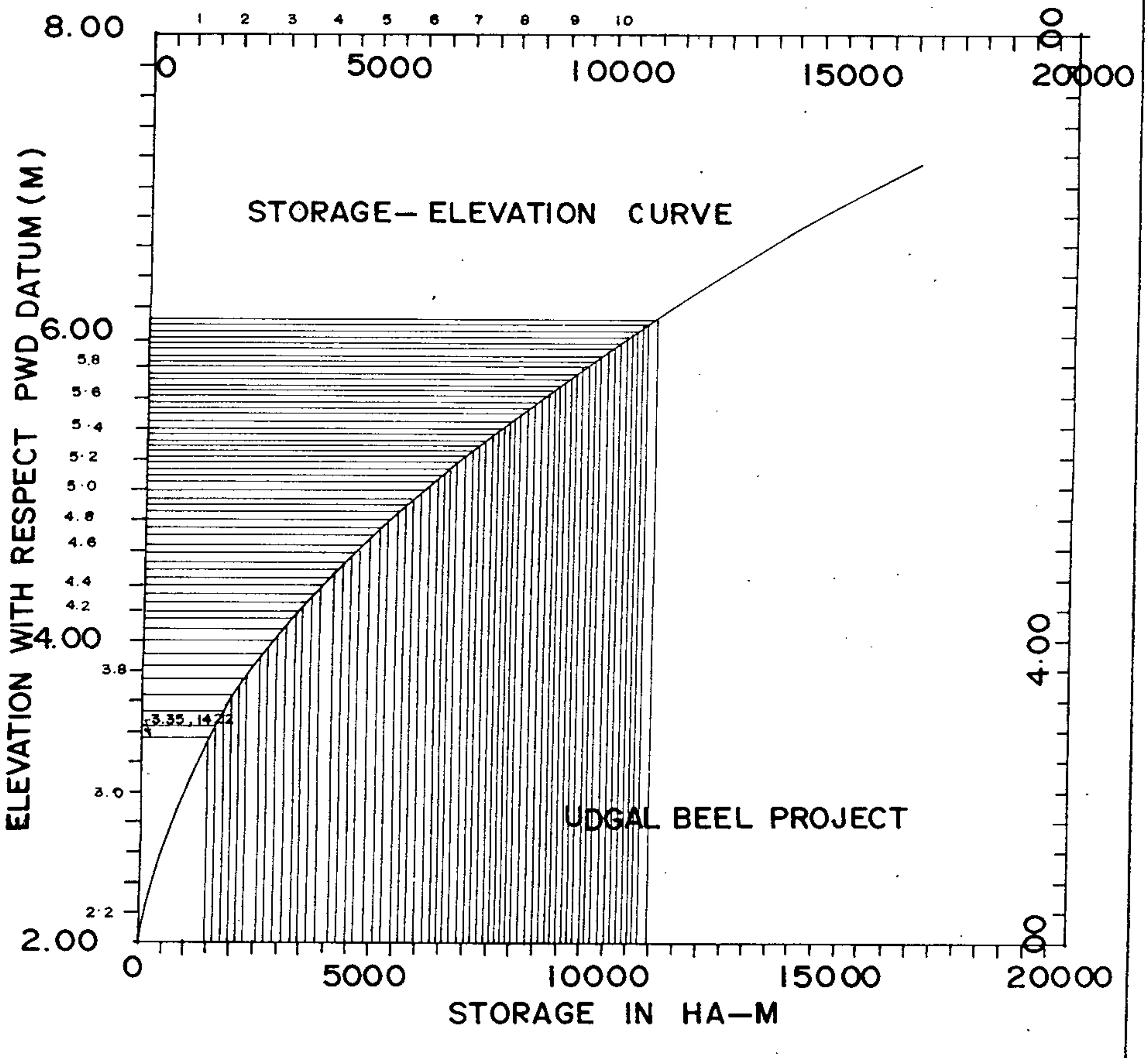


Fig. 5.4 Storage elevation curve of Udgal Beel project area

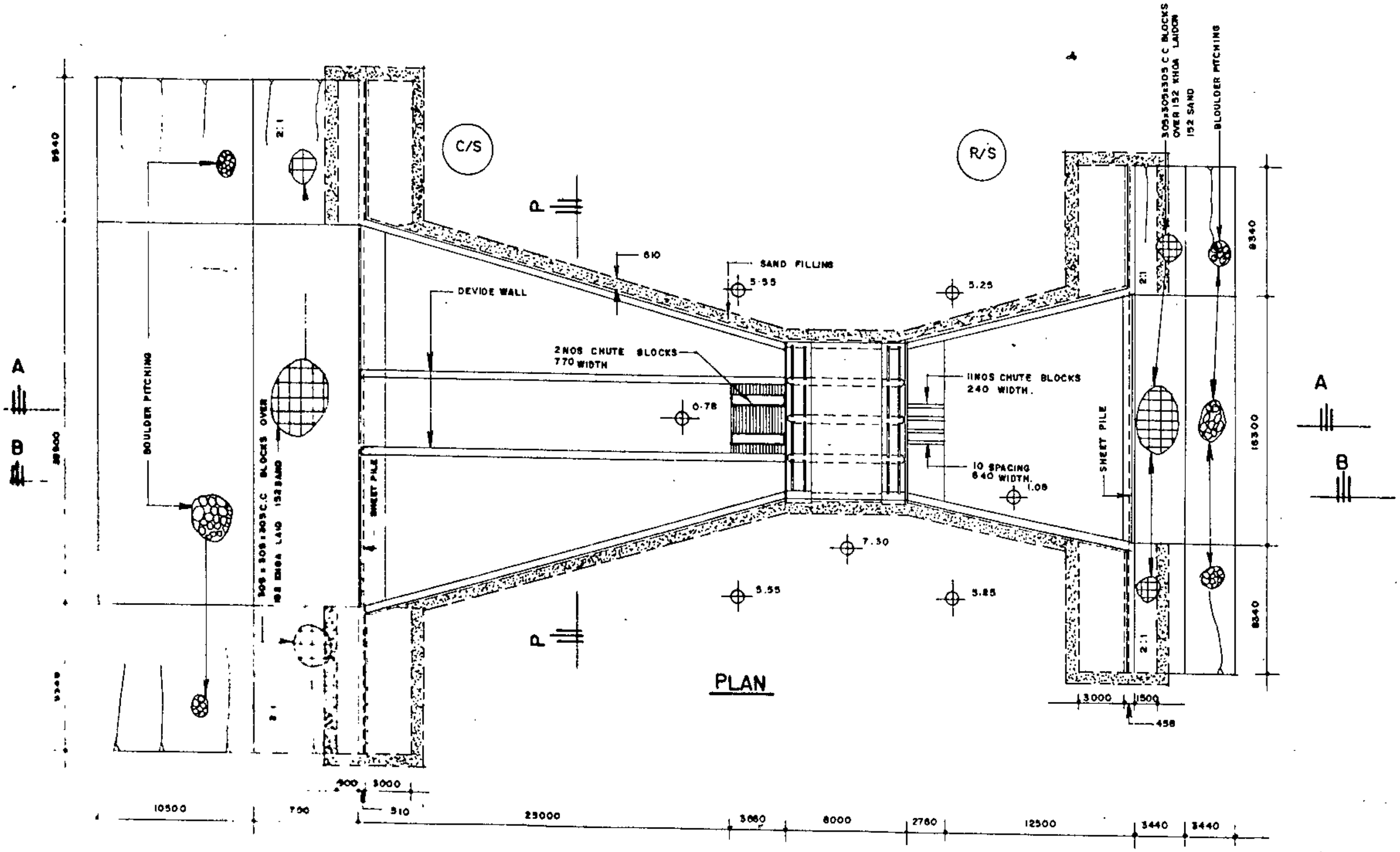


Fig. 5.5 Plan of modified Udghal Beel Regulator cum fish pass

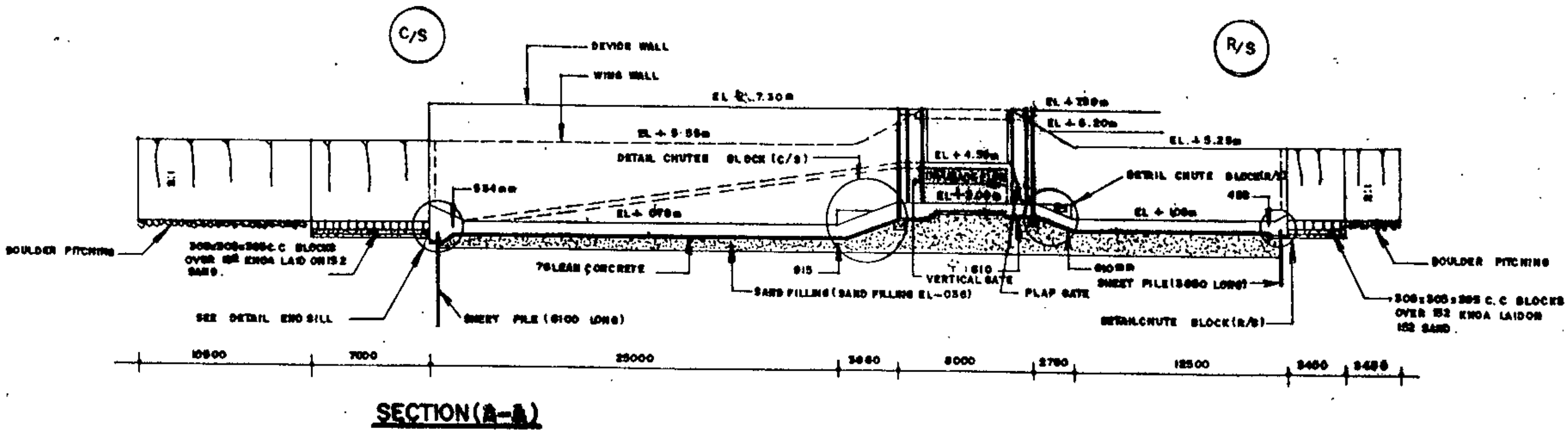


Fig. 5.6 Modified Udghal Beel Regulator cum fish pass section (A-A)

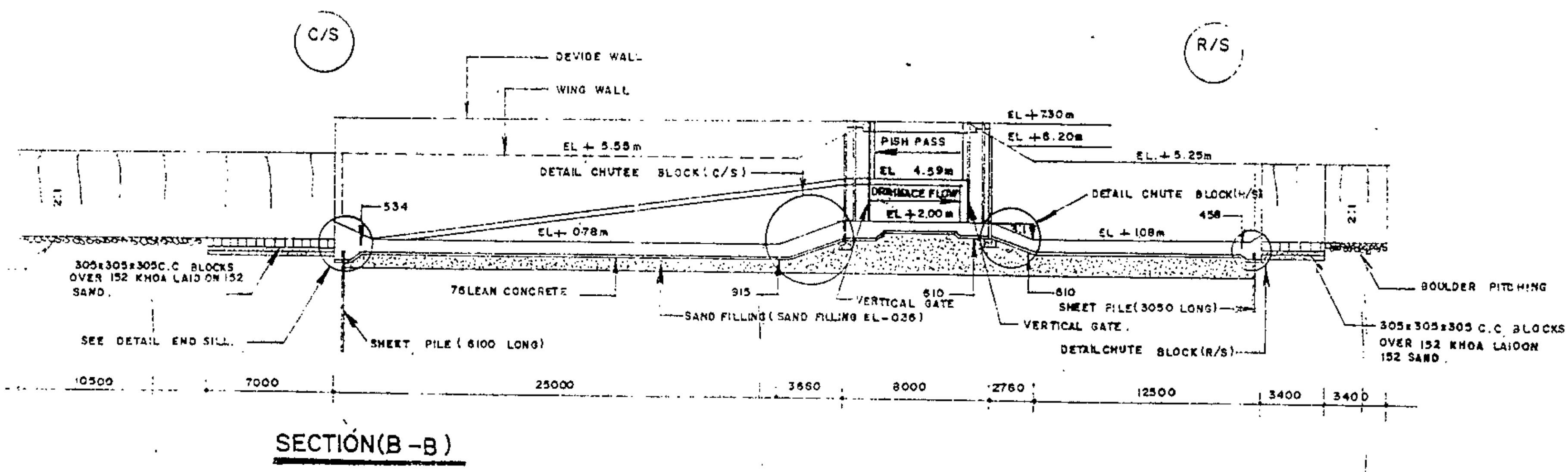


Fig. 5.7 Modified Udghal Beel Regulator cum fish pass Section B-B

(f) Slope in the C/S apron: A suitable slope (1:2) has been provided on the c/s of this passage with a dividing wall to protect the delicate spawn from being damaged by water turbulence. A vertical RCC 300 mm wall will be constructed at the junction of floor and apron upto sill level or fish passage el. 4.59 and sloping c/s apron 300 mm thickness will be made. The gap between the newly formed c/s apron for fish passage and origin c/s apron of the original drainage cum flushing structure will be filled up with compacted sand. The sketch of the c/s slope with tentative reinforcement is given in Fig. 5.8.

The floor to be dismantled at the junction of barrel and c/s apron, at the end of apron near the sheet pile to connect reinforcement with the existing one.

Devide wall: A devide wall has to be constructed over the c/s apron extending the pier to protect the delicate spawn from being damages by water turbulence. Devide wall will be a RCC wall resting on the c/s apron of the fish passage. The portion of the apron to be dismantled and reinforcement of the devide wall to be welded to the reinforcement of the c/s apron of the original sluice. The top of the devide wall to be at par with the top slab of the fish passage. The typical devide wall with possible reinforcement is shown in Fig.5.9.

Fish passage bottom slab: The existing top slab of the original sluice ventage to be extended upto the end of the pier and reconstructed. The head wall of the original sluice over the barrel in the fish passage portion to be dismantled.

Fish pass top slab: Top slab to be constructed. The top slab coincides with the operation deck slab level. The slab will be like deck slab, its thickness will be more and there will be no necessities of backfilling over it.

Gate: In the R/S, vertical lift gate will have to be fitted. For this a vertical wall will be constructed in the original sluice opening and gate will slide along the wall. The vertical gate for this passage would be rested below the floor of the fish passage so that the flow can be adjusted by raising the top of the gate to allow only about 15 cm depth of water of it. For the operation of the vertical gate there should be operation platform and suitable lifting device for smooth operation of the gate (Fig. 5.10).

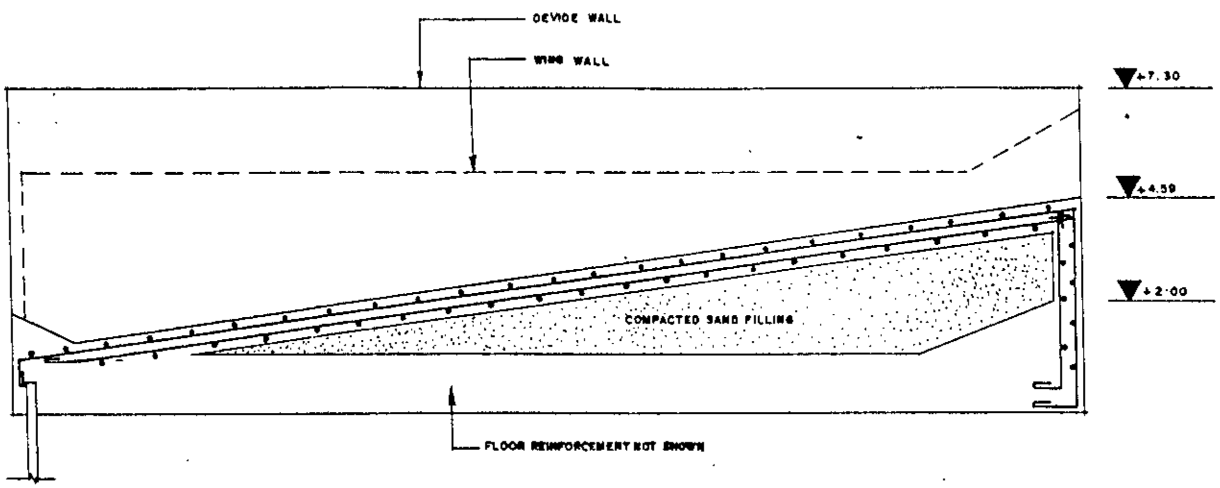
For the other opening excluding fish passage there should be flap gate in the r/s and vertical gate in the c/s.

Construction of cross dam: To facilitate remodelling of the sluice to make it fish friendly cross dams will have to be constructed on both c/s and r/s and the water from the trench to be bailed out.

5.5 Cost estimate

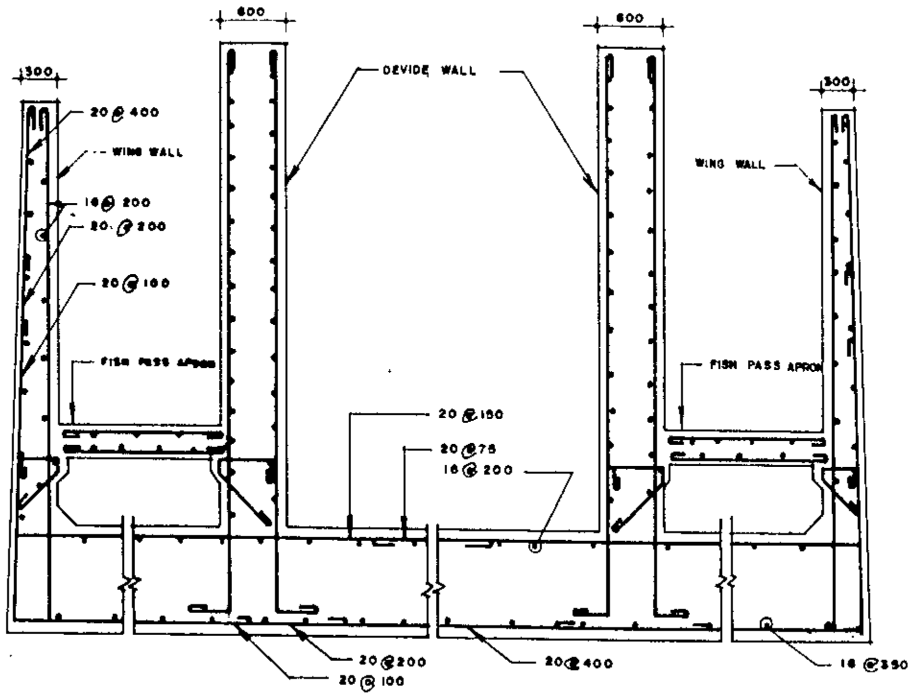
5.5.1 Approximate cost of original regulator

The approximate cost of the original regulator as per present schedule of rate can be summarized as follows based on the approximate bill of quantities of similar structure. Only the major items have been considered.



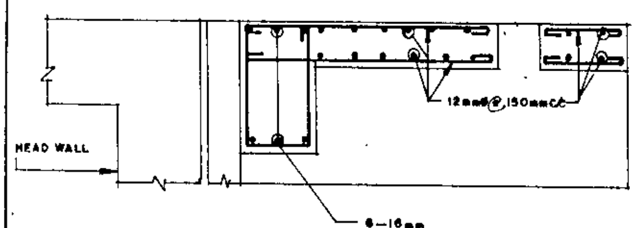
REINF. DETAIL OF FISH PASS SLOPE (PROVISIONAL)

Fig. 5.8 Modified Udghal Beel Regulator cum fish pass slope



DEVIDE WLL DETAIL SECTION (P-P)

THE REINFORCEMENT IS PROVISINAL



OPERATION DECKREINF(PROVISIONAL)

Fig. 5.9 Dévide wall detail section (P-P)

Fig. 5.10 Modified Udghal Beel Regulator cum fish pass devide wall, operation deck detail.

5.5.2 Approximate Cost of Modification:

Approximate cost of construction has been calculated on the basis of the present approved schedule of rates of BWDB and the analysis are shown in Table 5.7. Summary of figure is given Table 5.8.

5.6 Changes in Operation Pattern

For the passage of fish spawn and fry the vertical gate on r/s of the fish passage needs to be operated carefully and constant monitoring of operation during fish migration is necessary. The vertical gate for this passages is rested below the floor of the passage so that flow could be adjusted by raising the top of the gate to allow only 15 cm(6") depth of water over it. Operation of the new spawn and fry passage gate would thus aim at keeping the top of the gate about 15 cm below the out side water surface. First two to three days of peak water level is very much important for fish migration. Care should be taken during these period so that gate is operated as per optimal condition to derive maximum benefit.

For other opening also care to be taken so that incoming migration and out going migration of fish, migration of hatchling can be helped by operation of the sluice in such a way that it causes less injury to the migrant. This can be achieved by over shot regulation with sufficient back water depth to create a smooth flow which may help concurrent fish migration and drifting of hatchling. Attempt to be taken so that head difference between r/s and c/s water level reduces to 300 mm with in 2/3 days and in that case turbulence is reduced and fish, spawn, fry, Juvenile is not hurt.

By gate operation only the flow condition cannot be made fish friendly. When head differences are 3 meters or more flood control schemes are likely to interfere with migration route and in that case installation of fish pass is necessary. When head difference is less than 1 meter adjustment of operation can cause least damage to fishes and to allow passage of fish at the time of upstream, downstream or river to flood plain movements. Mode of operation of gate has some influence on flow characteristics. Free surface flow through regulator gate (over shot flow) is preferable to under shot flow to facilitate fish passage through a regulating structure. For fish friendliness gates need to be wide open. Again to meet the requirement of fish passage regulator need to be opened fully over a period of hours rather than days.

For sustainability of water resources project integrated water management is essential to serve its multidisciplinary functions. Its main function at present is to support the agriculture. However at the sametime management of the fishery and environmental aspect must be taken up in due earnestness. In flood control projects where, normally no water is allowed to move inside before 15th May, which is the cutoff date for harvesting of Boro, it may be necessary to permits development of a connection between flood plain/beel and the main river for, facilitating movement of fish fingerlings during the initial days of monsoon i.e. in the later part of April. If it is possible to keep the gate open for short periods and then close it without any appreciable damage to the agriculture, then it should be done. For this integrated management approach is necessary. Peoples participation and institutional development is necessary to ensure such management practice. For integrated water management sluice operation manual is necessary and it is to be followed strictly. Legislation may also be necessary to enforce it. For integrated water management, interdepartmental coordination is necessary. For preservation of fishery resource there should be national fishery policy and there should be a provision of leasing out of fishery for 3-5 years in the policy. Catching of fish may be restricted within initial 2 years to give enough time for the growth of the fish and complete drying of the fishery should be restricted for reproduction of the resource.

Table 5.6 Approximate Cost of Original Regulator

Sl. No.	Item of work	Bill of quantities (approximate)	Approximate cost (lac)
1	Mobilization	L.S.	1.00
2	·Excavation of foundation with all additional lead and lift	10,500m3	2.00
3	Construction of cross bund/ring bund/embankment for approach etc.	18,530m3	3.00
4	Backfilling of hydraulic structure with sand of specific F.M. in 150 mm layer	1220m3	2.50
5	Excavation of diversion channel	12340m3	2.00
6	Lean conc 1:3:6	20m3	0.50
7	RCC work of 1:2:4 will 25 mm down graded coarse aggregate and sand of Fm 2.5 and crushing strength 18 N/m^2	485m3	16.00
8	Form work for centering, shuttering as per drawing with 30 mm thick wooden plank with batten strut	1305m2	3.00
9	MS. work for reinforcement with plain ms bar fy=276 N/mm^2 including bending binding including the cost of material	55000kg	16.00
10	Supply of sheet pile including labour charge for driving	12.50MT	9.00
11	Manufacturing and supplying of cc block of proportion 1:3:6 with cement, sand FM>1.5 and Jhama chips with strength of 9.00 N/m2 including the habor charge for placing	1660Nos.	3.00
12	Supplying and laying dry 1st class picked jhama chips as filter in two layers compacting each layer with supply of all materials, well graded between 50 mm to 20 mm and 20 mm to 5 mm	170m3	1.50
13	Supplying and laying of sand of required FM as filter material	80m3	0.50
14	Dewatering by shallow tube well	L.S.	4.80
15	Bailing out of water	L.S.	0.30
16	Manufacturing supplying and installation of pedastal type lifting device for slide gate	4 Nos.	1.60
17	Manufacturing supplying installation and fitting fixing vertical lift gate/flap gate as per design and specification	4 Nos vertical gate 4 Nos. flap gate	2.40 1.40
18	Manufacturing supplying and installation of MS embedded parts for flap/vertical gate including fabricating bending welding forging drilling holes etc.	L.S	1.00
19	Fundation treatment	Provisional	8.00
20	P.V.C. water stop	L.S.	0.50

Total [illegible] Lac
(Eighty lac)

Table 5.7 Cost of modification

Sl. No.	Items of work	Approximate bill quantities	Approximate cost (lac)
1	Construction of ring bund including closing of r/s & c/s channels	9264m3	2.00
2	Compacted sand filling	196.95 m3	0.35
3	RCC work in leanest mix 1:2:4	236 m^3	8.00
4	Form work for centering shuttering 25 mm thick wooden plank and pattern and structs and props etc. complete (a) upto 3.5 m.Hl (b) above 3.5 to 6.5 meter ht.	(a) 406 sqm. (b) 288 sqm.	0.75 0.90
5	MS. work in reinforcement with plain bar fy 276 N/mm^2 (made of billet) in rcc work including bending, binding and cost of material	17000 kg	5.00
6	Manufacturing supplying and installation of padestal type lifting device for slide gate with all accessories complete including the cost all materials	2 no	1.00
7	Manufacturing and supplying and installation and fitting fixing of vertical steel lift gate	2 Nos.	1.20
8	Manufacturing supplying and installation of embedded ms parts for flap/vertical gate	L.S.	0.30
9	Dismantling of construction works including removing debris within 60 m as per direction of engineering rcc work	25.76 m^3	0.20
10	Bailing out of water with all leads and lift by mannual labour or pump	L.S.	0.30

Total: 20.00 lac

Table 5.8 Summary of cost

Sl. No.	Approximate original cost of the regulator	Cost of remodelling	Total cost	% increase
1	80.00	20.00	100.00	25%

CHAPTER VI

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

6.1 Summary

The open water fishery is a natural and uncultivated fish production system in open bodies. It is also known as capture fisheires. Fish populations, inhabiting rivers, beels and flood plains are self producing and self sustaining provided that there is no intervention of the water regime and there is no over exploitation of the resource.

A host of human activities in the form of different intervention had left a trail of devastating effects on fish stock. Development of FCDI facilities inevitably change the aquatic environment particularly to the detriment of open water capture fisheries. Apart from steady decline in the total catch, there is an alarming level of adverse effect on bio-diversity.

As our economy is agro-based, FCDI interventions are necessary for food grain production. On the otherhand in a country like us where fish is the main source of animal proteins, prevention and mitigation of fishery losses and enhancement of fish production measures are not only important but indispensable. Among the prospective mitigation measures fish pass is important one and other may be classified as development work. Apart from going for a new fish structure it is also possible to modify some of existing structures to make it fish friendly. Review of the available literature, performance of the existing structures, engineering skill, mode of operation of the gates, institutional development may be important tool to achieve the objective. There may be some increase in cost for modification but this may be offset by possible benifits to be derived. The concept of modification can be incorporated in the design of new structure and one or two ventages may be added for fish passage. Further to match the operational patterns of the flow regulatory structures with the behavioural characteristics of fish community , new operating rules for the structures can be formulated.

6.2 Conclusions

Based on the study following conclusions are drawn.

1. Existing appurtenent structures can be modified to make it fish friendly. If the capacity of the existing structure does not permit, then one will have to go for new fish pass structure.
2. In selecting sites of structure the original migratory routes to be given due weightage so that fish are attracted to use them. Presently this factor is not given any consideration in locating a hydraulic structure and as such improper locations are often selected.
3. For the specific project studied during this study, it was found that there would be an approximate increase of cost by 25% to make it fish friendly.
4. Parameters to be considered in design are: exit velocity, river side and country side water level data, water surface profile, sill elevation, water depth, period of migration, type of species etc.

Values for the various parameters recommended are as follows.

- exit velocity - This should be about 1.5 meter/sec.
- period of migration: This should be in premonsoon (April-May). when brood stock will move from the river to the floodplain for breeding. At that time there may be migration of hatchling. The period may be extended to July-August for the passage of fish, fish spawn and fry from the external rivers to the project beel areas.
- Water level - water level to be considered during flushing will be after 15th May. R/S water level to be considered from 10 years flood frequency analysis and c/s water level to be considered from calculation of internal storage vs corresponding level from storage elevation curve.
- water depth - A minimum water depth of 1.00 m is to be available in the exit channels for the fish to readily, enter.
- Invert level - The invert or floor level of the fish passage would have to be fixed based on the lowest water level during the period of migration in thè premonsoon to allow sufficient flow during a dry year.
- The vertical gate of the fish passage should be rested below the floor of the fish pass so that flow can be adjusted by raising the top of the gate to allow only 15 cm. depth of water over it.
- A suitable slope preferably 1:2 should be provided in the c/s with a deviding wall to protect the delicate spawn from being damaged by water turbulance.

6.3 Recommendation for Further Study

The structure in question has been modified based on the performance of the existing structure, information and guide line available in FAP-13, FAP-17, FAP-6 studies and other literature. As the river water level vary independently of country side water level, a vertical slot fish pass appears to be a logical option for Bangladesh. In the modification of existing structure as fish friendly, the possibility may be explored to fit the vertical Slot Fish Pass with the existing structure. As head is dropped by about .25m in each baffle. for a drop of 4m-5m about 16-20 baffles with 17-21 pools will be required and in that case a larger length of fish pass will be necessary. To accommodate this length the structure needs to be extended beyond the block protective work in both c/s and r/s. Again with sill level at lower elevation, there is a possibility of larger discharge. It needs to be investigated whether it is possible to pass fish with such a larger discharge and for this a more detail hydraulic analysis is necessary. Study may be done to come with a suitable proposition for the modification in the light of a vertical slot fish pass.

The main and important biological parameter in the design of fish pass is that the facilities must accommodate the weakest fish within the weakest species requiring passage. Further the size of the facilities should be based on the expected number of fish which need passage and the expected hourly or daily rate of migrants In the present study size of the passage determined arbitrarily. Facility is different for different species. Further study needed to specify requirement for individual species. Again there is bottom feeder and top feeders. In the present study there was no scope for considering bottom feeder and top feeder separately and gate operation is same for both the categories.

The facilities have been considered for entry of fry/spawn, brood fish in early monsoon. Further studies needed to generalize facilities for both in migration and out migration in the same ventage throughout the whole year. In the present case migration has been considered through the end ventages. Practically there may be migration through other ventages also. Study needed to see how gate operation mode e.g. undershot, overshot or retracted regulation can make the structure fish friendly.

There is a standard instruction from BWDB to keep the gate closed up to 15th may for harvesting but there is no guide line/regulation for subsequent opening of gate, there should be legislation regarding operation of gate so that conflict among various interest group can be resolved.

One important thing is the location of the migrating path of the fish. If the location is not in line with migration route the construction will be useless. Therefore random construction of fish pass without adequate knowledge of migrating path will be fruitless.

Design consideration for fish pass structure in north east region will be different from other regions. N.E.Z. may need special consideration due to assumed nature of carp breeding behaviour, S.W. Region may necessiate inclusion of regulators designed for opening and closing with rising and falling water level due to tidal influence. So study may be under taken for modification fo sluice in coastal areas.

The purpose of the fish pass whether for migrating fish or hatchling needs to be identified. Further study needed to fit movement of hatchling. spawn fry and adult fish for both in migration out migration.

Seasonal variation is also important for fish migration. Study needed to see which type of fish is suitable for which season.

In Bangladesh, at present, there is no rational approach to the problem of energy dissipation in a fish pass and sizing of the fish pass. In dimensioning the fish pass structure the hydraulic model studies for carp fish migration in Australia is followed. In reality Bangladesh situation may be different and behaviour of various local fish species may be different. So to establish Bangladesh situation we need to have model studies of our own. Further the locations of a structure with proper fish entrance and exit setting is very important to attract fish because wrong location and alignment might delay movement for fish and cause traffic jam. In these consideration physical modelling can be done with prototype condition in the laboratory where flow pattern, energy dissipation and surface profile can be observed with live fish and design the structure accordingly.

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