

## **IMPACT OF KUKULE GANGA HYDRO POWER PROJECT ON AQUATIC FAUNA**

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*Received on: 05.01.1997*

*Accepted on: 07.07.1997*

### ***Abstract***

Results of the study indicated that Pelang Ganga and its tributaries carry less water. Some tributaries near water outfall are almost dry (eg. Dangolla Ela, near water outfall). Therefore, addition of 48m<sup>3</sup>/sec of water will increase erosion, sediment load of water. The aquatic faunal composition will be disturbed. It is necessary to construct re-regulation ponds and flood protection facility there. Water in Kukule Ganga is slow moving and carries mote water. The river morphology does not show the need to have a re-regulation ponds. The river morphology and the volume of water carried in the river will buffer the addition of 46 m<sup>3</sup>/ sec of water during plant operation.

Fauna of Kukula Ganga is less affected compaired to that of Pelang Ganga. Both rivers sustain endemic (to Sri Lanka) and threatened species of fish and other fauna. These are also present in other river basins of the wet zone. There are migratory fish and prawn species in both rivers. Therefore, a fish pass will help them in their annual migration. Thus., they will sustain in Kukule Ganga basin. However, in the absense of this facility, migratory species will eliminate from the region and not from the wet zone.

Out of the six alternative routes studied, Kukule-Kule Run of River (R-K ROR) has the least impact on the aquatic fauna. Under a weir any excess water over 46 m<sup>3</sup>/sec, will be naturally released. But no water at all will be released under low and high dam. Further, more tributaries will be innundated under low and high dam. This badly affects riverine species of fish and other fauna.

Therefore, Kukule-Kukule weir and its reservoirs has the least impact on aquatic fauna. Therefore, it is the most appropriate out of six project alternatives. In view of the above it is recomended to be implemented.

**Key Words:- Kukule Ganga, Hydro Power, Run on River, Fauna.**

## 1. Introduction

The Island Sri Lanka has a central hill country surrounded by three plains, namely; southwestern plain, southeastern plain and northern plain. The southwestern plain receives the highest annual rainfall for the island. Therefore, it is also called as wet zone.

The entire Island sustains 64 species of true freshwater fishes (Senanayake and Moyle, 1982). They are distributed in the rivers and their tributaries. The rivers and tributaries of the wet zone have water throughout the year. Therefore, it is the most important ichthyological province for endemic fishes. It already contains 67% of the endemic fishes of Sri Lanka.

"Kalu Ganga is one of the rivers in the wet zone. Its basin has 47 species of fish, which is about 75% of the true freshwater fishes of the Island. Fifteen of the above 47 species are common but restricted in distribution. Three species are rare and one is rare and vulnerable. Two of the fish species listed for Kalu Ganga are rare and endangered (Pethiyagoda, 1991). Therefore, Kalu Ganga basin is an ichthyologically important region.

### Results of previous studies

There are 64 species of true freshwater fishes in Sri Lanka, of which 24% are endemic to the island (Senanayake and Moyle, 1982). The distribution pattern of fishes in Sri Lanka suggests that there are three distinct ichthyological provinces there.

There are 18 endemic fish species in Sri Lanka, of which 16 are only found in the wet zone. Further, 13 of the above 18 species are found in the lowland rain forest, belt, particularly in the Kalu Ganga basin. Nine of the above 18 are listed as either threatened or vulnerable species (Evens, 1981). Seven of the above endemic species are present in the Kalu Ganga basin. They are Combtail (*Belontia signata*). Ornate Paradise fish (*Malpulutta kretseri*). Two Banded barb (*Barbus cuminqi*), Black Ruby barb (*Barbus nigrofasciatus*). Side Stripped barb (*Barbus pleurotaenia*), Cherry barb (*B. titteya*) and Vetria Flower Rasbora (*Rasbora veterifloris*). They are also listed in the IUCN Red data Book (1988), (TEAMS, 1989).

The common fish species of Kalu Ganga estuary are the Mullet *Mugil cephalus*, Green Chromide (*Etiopius suratensis*), Slip Mouth (*Leiognathus splendens*), Glass fish (*Ambassis sp.*), Carangids (*Caranx sp.*) and Gobies (TEAMS, 1989).

Some of the endemic and threatened species such as *R. veterifloris* is found in small schools, confined to clear water streams under the shade of forest cover. The Red tailed *Sicydium halei* is found in freshwater streams of the project area near Atweltota (TEAMS, 1989). Species such as *B. cuminqi*, *B. nigrofasciatus*, *B. pleurotaenia*, *B. titteya*, *Belontia signata*, *M. kretseri* and *R. veterifloris* prefer clear shallow waters of the wet zone.

Aquaculture in Sri Lanka is in its infancy. However, the proposed reservoir should be able to sustain a fishery for *Oreochromis mossambicus*, *O. niloticus* Labeo rohita and *Cyprinus carpio* (TEAMS, 1989).

Migratory fresh water prawns such as *Macrobrachium rosenbergii*, *M. australe*, *M. latimanus*, *M. idella* and *M. scabrcum* have been reported from Kalu Ganga basin and its estuary (Costa, 1979).

**Objective:**

To assess the impact of the diversion of Kukule Ganga on aquatic fauna.

**2. Material and Methods**

Tributeries of Peleng Ganga (Fig 1), Maguru Ganga, Delgoda Ganga, Koskulana Ganga, Kosweti Ganga and Kukule Ganga have been studied on the whole, samples were collected in 24 stations at the above mentioned rivers. Further, major tributaries draining into Kukule Ganga between diversion structure and water outfall have been studied. The Kalu Ganga estuary has also been studied for fauna, water quality, water regime and sediment load. The study period extended from October 1991 to Sept 1992.

Six project alternatives, namely Kukule-Kule route, Kukule-Peleng route with three types of dams weir low dam and high dam. in each of the routes were studied within this period .

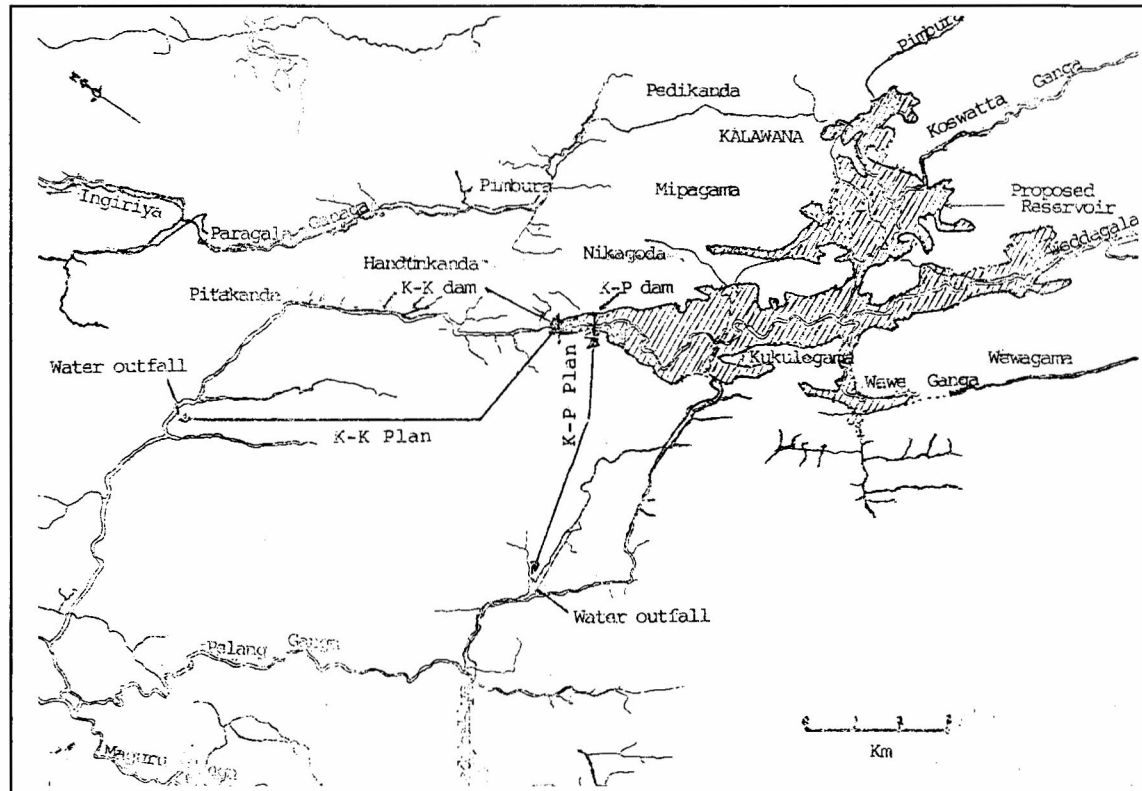


**Fig 1.** Map of kukule reservoir area, K-K and K-P are two proposed diversion routes.

**Sampling methods**

In each station, samples of fish were collected within a stretch of 25 m using cast nets in the middle of the river and scoop nets along the edges. Molluscs were hand picked inside 1 m<sup>2</sup> quadrat on the river bed. At each station five random sample plots from the bottom from each station were studied.

Benthos under boulders was sampled using a benthic sampler according to Lagler (1956). The area of the underside of boulders sampled was calculated using 1 mm graph papers in order to calculate the number of insect nymphs/m<sup>2</sup>.

The larvae of prawns were collected using lures made out of paddy hay. These lures were suspended for one week and the accumulated larvae were collected using scoop nets. Gut contents of fish and freshwater prawns were analyzed for quality and quantity of diet according to De Groot (1971).

Sediment load, namely, the amount of solid matter suspended in the water was estimated by filtering 100 ml of water through Whatman filter paper. The dry weight of sediment was obtained by oven drying the sediment at 100 °C for one day in the laboratories of the University of Sri Jayewardenapura. The depth of water at sampling stations was measured using a lead weight tied onto a nylon line. The speed of water at the surface was measured by timing a 9 cm<sup>2</sup> large piece of regiform over a distance of 5 m. Water temperature and Secchi disc readings were also taken in all sampling stations twice a month.

The impact of the six project alternatives on the environment was assessed using 26 project elements taking into account the environmental aspects at the same time. Ranks used were 1 to 6 (Tables 1,iv, Significant aspects to the aquatic fauna was exerted by the project elements, weir, low dam, high dam, reservoir and reservoir operation. Therefore, the above elements will be dealt in detail. (Table V-VII).

**3. Results**

Physico-chemical parameters are important for the sustenance of aquatic life. Therefore, those factors are considered first.

The mean sediment load in Peleng Ganga gradually increased from Dangolla Ela (4.6 mg/100 ml) to its confluence with Kukule Ganga (9.3 mg/100ml) (Table 1). The sediment load of Kukule Ganga also increased downstream from its tributary, Delgoda Ganga (8.6 mg/ 100ml) to the point of confluence with Pelang Ganga (21.3 mg/100ml).

The current speed gradually declined from the above regions down stream in both rivers. But the current speed of Pelang Ganga was generally higher than that of Kukule Ganga (Table 1).

**Table I** Sediment load (mg /100ml), current speed (m/s), conductivity (us/cm), dissolved oxygen (mg/l), secchi disc reading (cm) and depth of water (cm) of selected stations of Kukule Ganga and Pelang Ganga

|                     | Station   |           | properties |         |        |        |       |
|---------------------|-----------|-----------|------------|---------|--------|--------|-------|
|                     | Sedi Load | Cur speed | Temp       | Conduct | Diss O | Secchi | Depth |
| <b>PELENG GANGA</b> |           |           |            |         |        |        |       |
| Dangolla Ela        | 4.6       | 1.0       | 27.0       | 24      | 5.9    | -      | 20    |
| Delvitiya Dola      | 7.4       | 0.71      | 26.6       | 24      | 7.0    | -      | 40    |
| Above water         |           |           |            |         |        |        |       |
| -outfall            | 8.3       | 0.79      | 27.0       | 23      | 6.3    | 41     | 110   |
| Rapids              | 9.1       | 1.3       | 27.0       | 22      | 6.7    | -      | -     |
| Peleng-Kukule       |           |           |            |         |        |        |       |
| - confluence        | 8.6       | 0.83      | 27.2       | 22      | 6.1    | 38     | 140   |
| <b>KUKULE GANGA</b> |           |           |            |         |        |        |       |
| Above tail end      |           |           |            |         |        |        |       |
| of reservoir        | 8.6       | 0.6       | 26.8       | 21      | 5.8    | 120    | 70    |
| Rapids              | 8.9       | 1.2       | 27.0       | 23      | 6.8    | -      | -     |
| Reservoir region    | 18.6      | 0.7       | 27.0       | 29      | 6.5    | 69     | 150   |
| Down stream of      |           |           |            |         |        |        |       |
| weir/dam            | 21.5      | 1.1       | 27.2       | 25      | 6.1    | 24     | 78    |
| Kalutara estuary    | 18.7      | 0.75      | 27.5       | 310     | 5.4    | 64     | 130   |

The conductivity of Pelang Ganga was almost same from its upper reaches to the confluence with Kukule Ganga. In the Kukule Ganga however, the conductivity slightly increased along its course.

The dissolved oxygen content ranged from 5.9 mg/l to 7.0 mg/l in Pelang Ganga (Table 1). It varied considerably from rapids (7.1 mg/l) to pools (5.8 mg/l). Both levels are suitable for aquatic life. However, rapids sustain fauna with high oxygen demand. It also varied from upstream of proposed water outfall downstream, to the confluence with Pelang Ganga. The dissolved oxygen content of Kukule Ganga varied in the same manner, but with a smaller magnitude (Table 1).

The transparency was expressed using secchi disc readings. It declined from the point of water outfall to the confluence with Pelang Ganga (Table 1). The depth of water in the two rivers fluctuated considerably among stations. The lowest and the highest values recorded downstream of weir/low dam site were 30 cm during droughts and 6.00 cm during wet weather.

The water temperature of the two rivers fluctuate between 26.7 to 27.5 C. The highest values for Kukule Ganga were recorded from the lower part, near the confluence with Pelang Ganga (27.3 C). The lowest value for Pelang Ganga was recorded from station G (26.7 C) and the lowest near its confluence with Kukule Ganga (27.4 C).

### Aquatic fauna

Fifteen species of fish have recorded from Pelang Ganga and its tributaries. These tributaries drain into Pelang Ganga in the vicinity to proposed water outfall (Table 2). Three of the above fifteen species, namely; *G. ceylonensis*, *P. nigrofasciatus* (= *Barbus nigrofasciatus* of Pethiyagoda, 1991) and *Neomacheilus botia* are endemic to Sri Lanka. *P. nigrofasciatus* is listed in the Red Data Book (1988) and TEAMS (1989). It was also found that mature *P. nigrofasciatus* (anterior half of mature males are red) at the head end of Delvitiya Dola.

Pelang Ganga also sustain a number of crustacea, namely; *Caridina nilotica*, *Atya. typus*, *M. rosenbergii*, *M. australe* and *Paratelphusa ceylonensis* (Table 2). There are two species of gastropods in the above region, namely; *Paludomus loricatus*, which is endemic to Sri Lanka.

**Table II** Fauna density in Pelang Ganga and its tributaries in October and November 1991 (N/m<sup>2</sup>)

| Species                         | Delvitiya<br>Dola | Dangolla<br>Ela | Pelang<br>Ganga | Parapelalla<br>Dola |
|---------------------------------|-------------------|-----------------|-----------------|---------------------|
| Fish                            |                   |                 |                 |                     |
| <i>Clarias brachysoma</i>       | 0.003             | 0.05            | -               | -                   |
| <i>Danio aequipinnatus</i>      | 0.006             | -               | 0.01            | -                   |
| <i>Garra ceylonensis</i> *      | 0.034             | -               | 0.001           | 0.002               |
| <i>Heteropneustus</i>           |                   |                 |                 |                     |
| <i>fossilis</i>                 | -                 |                 | -               | 0.004 -             |
| <i>Glossogobius giuris</i>      | 0.034             | -               | 0.05            | -                   |
| <i>Mastacembelus</i>            |                   |                 |                 |                     |
| <i>armatus</i>                  | 0.006             | -               | 0.04            | -                   |
| <i>Macrones keletius</i>        | -                 | 0.05            | -               | -                   |
| <i>Ophiocephalus</i>            |                   |                 |                 |                     |
| <i>punctatus</i>                | -                 | -               | 0.04            | -                   |
| <i>Ompok bimaculatus</i>        | -                 | -               | 0.04            | -                   |
| <i>Puntius nigrofasciatus</i> * | 0.01              | -               | +               | +                   |
| <i>P. filamentosus</i>          | 0.006             | -               | -               | -                   |
| <i>Rasbora daniconius</i>       | 0.006             | -               | 0.02            | -                   |

|                              |       |      |       |       |
|------------------------------|-------|------|-------|-------|
| <i>Anguilla bicolor</i>      |       |      |       |       |
| <i>bicolor</i>               | 0.002 | -    | +     | -     |
| <i>Noemacheilus botia</i> *  | 0.002 | 0.05 | -     | 0.002 |
| <i>Tor khudree</i>           |       |      |       |       |
| <i>longispinis</i>           | +     | -    | ++    | -     |
| Molluscs                     |       |      |       |       |
| <i>Paludomus loricatus</i> * | 6.0   | -    | 4.0   | -     |
| <i>Pila globosa</i>          | 0.5   | -    | 0.75  | -     |
| Crustacea                    |       |      |       |       |
| <i>Caridina nilotica</i>     | 2.0   | 0.8  | 9.0   | 0.004 |
| <i>Atya typus</i>            | 0.012 | 0.17 | 2.0   | 0.002 |
| <i>Atya</i> sp               | -     | -    | -     | 0.002 |
| <i>M. rosenbergii</i>        | +     | -    | -     | -     |
| <i>Paratelpusa</i>           |       |      |       |       |
| <i>ceylonensis</i>           | +     | 0.05 | +     | -     |
| Insects                      |       |      |       |       |
| <i>C. productus</i>          | -     | -    | 0.25  | -     |
| Dragonfly nymph              | -     | -    | 5.6   | -     |
| Limnotrephes                 |       |      |       |       |
| <i>campbelli</i>             | -     | -    | 5.4   | -     |
| Stonefly cages               | 800.0 | -    | 480.0 | -     |
| Stonefly nymph               | 4.0   | -    | 2.0   | -     |
| Damselfly nymph              | 0.04  | -    | 0.7   | 0.006 |
| Mayfly nymph                 | 120.0 | -    | 32.0  | -     |
| Caddisfly nymph              | 240.0 | 1.0  | 178.0 | -     |

\* endemic and threatend is sri Lanka.

*Pila globosa* which is commonly found in stagnant pools (Table 1)

There are about 8 species of nymphs of aquatic insects in Peleng Ganga (Table 2). They live under boulders in rapids. These larvae have been reported from many parts of wet zone (Fernando and Mendis, 1962). There are migratory fish and prawns in the above region. Three known migratory species are: *A. bicolor bicolor*, *H. fossilis* and *G. aiuris* (Fernando and Mendis, 1962; Pathiyagoda, 1991; Jinadasa 1985). Mature eels migrate to the sea for spawning and their larvae, elvers, migrate upstream and grow in streams and lakes to feed and grow (pethiyegoda, 1991 and Jinadasa, 1985) Different crustaceans specially *Macrobrachium* sp. are also migratory. The mature adults migrate to the estuaries for spawning. Their larvae then migrate again upstream to rivers, streams and paddy fields. They grow their and migrate once again once they are mature. This is an annual event (Kurian and Sebastian, 1976 and Jinadasa, 1985).

**Table III** Aquatic fauna in the three proposed reservoir regions of Kukule Ganga

|                          | Nos/ m3 |                       |          |   |
|--------------------------|---------|-----------------------|----------|---|
| Name of species          | FOR     | Low dam<br>reservoirs | High dam |   |
| Fish                     |         |                       |          |   |
| Tor khudree longispinis  | 0.006   | 0.048                 | 0.016    |   |
| Macropodus copanus       | -       | 0.007                 | -        |   |
| Rasbora daniconius       | -       | 0.024                 | -        |   |
| P. pleurotaenia          | -       | 0.036                 | -        |   |
| P. nigrofasciatus        | 0.048   | 0.024                 | 2.4      | T |
| P. filamentosus          | -       | 0.007                 | 0.021    | E |
| P. chola                 | -       | 0.003                 | -        |   |
| P. vittatus              | -       | 0.005                 | -        |   |
| D. aequipinnatus         | 0.006   | 0.018                 | +        | E |
| G. ceylonensis           | 0.023   | 0.047                 | 0.032    | E |
| Anabas tes tudineus      | +       | 0.003                 | -        |   |
| Anguilla bicolor bicolor | +       | +                     | -        | E |
| A. nebulosa nebulosa     | 0.001   | +                     | +        |   |
| Malpulutta kretseri      | -       | -                     | 0.002    | T |
| Balantia signata         | 0.008   | 0.009                 | 0.009    | V |
| Crustacea                |         |                       |          |   |
| Caridina nilotica        | 0.200   | 0.046                 | 0.032    |   |
| Atya typus               | 0.090   | 0.015                 | 0.90     |   |
| Macrobrachium sp I       | 0.020   | 0.020                 | 0.020    |   |
| do sp II                 | +       | +                     | +        |   |
| Paratelphusa ceylonensis | 0.001   | 0.015                 | -        |   |
| Molluscs                 |         |                       |          |   |
| Paludomus loricatus      | 0.020   | 0.130                 | 0.180    |   |
| Pila globosa             | 0.001   | 0.001                 | +        |   |
| Insect nymphs            |         |                       |          |   |
| Dragonfly nymph          | 0.003   | -                     | -        |   |
| Damselfly nymph          | 9.0     | 83.0                  | 63.0     |   |
| Mayfly nymph             | -       | 13.0                  | 17.0     |   |
| Stonefly nymph           | 30.0    | 86.0                  | 111.0    |   |
| Caddisfly nymph          | 11.0    | 110.0                 | 34.0     |   |

E, endemic to Sri Lanka, T, threatened, V, vulnerable

There are 16 species of Fish in Kukule Ganga (Table III) Their distribution pattern varied according to stations. Thirteen species have been reported from the area that would be inundated by the low dam. Four of the species found are endemic to Sri Lanka. It should be noted that *P. nigrofasciatus*, *M. kretseri*, two threatened species are also found there.

Similarly, there are migratory crustacea and insect nymphs confined to Kukule Ganga (Table 3). However, most of these species are also found elsewhere in the wet zone, A significance difference between Pelang Ganga and Kukule Ganga was noted in the distribution of nymphs of aquatic insects. Their numbers rapidly increased upstream from weir, low down stream (Table IV).

The diet of *Tor Khudree longispinis*, *Ompok bimaculatus*, *P. nigrofasciatus* contained remnants of Juvenile fish, molluscs and crustacea. The diet of *D. aequipinnatus*, *R. danicormius*, *P. darsalis*, *P. nigrofasciatus* contained large proportions of (45% by numbers) of insect larvae. The diet of *Macrobrachium* sp. contained high percentage of (58%) digested insects. The above results indicated that there is an ecological balance in the above area.

### Evaluation of project alternatives

The impact of the six project alternative, K-K ROR, K-K LD; K-K HD; K-P ROR, K-PLD, K-P HD, on the environment was assessed using 26 project elements Significant impacts to the aquatic fauna are exerted by the project elements, weir/dam, reservoir and reservoir operation. Therefore, the above elements have been dealt in detail.

Results in the above tables indicated weir/dam and the reservoir, tunnel and the operation of the plant exert major impacts on aquatic fauna. Because the riverine environment of the area changes into a reservoir environment. Temporary structures like temporary roads, camps etc. also exert an impact at lower magnitude.

#### Weir/low dam and high dam

The proposed weir is the smallest and the high dam is the highest proposed construction facility across Kukule Ganga. These facilities will lead reservoirs with surface areas of 0.6, 1.0 and 20.8 km<sup>2</sup> at full supply level. The gross volume of the water in the small, medium and large reservoirs will be approximately 1.5, 151 and 400 (mio m<sup>3</sup>) respectively. The smallest reservoir will practically inundate about six small tributaries above the weir. These sustain *P. nigrofasciatus*, *G. ceylonensis*, *P. sarana*, *Tor Khudree longispinis*, *D. aequipinnatus* and *A. nebulosa*.

*A. nebulosa nebulosa*, *P. loricatus*, *C. nilotica*, *Macrobrachium* sp., *P. ceylonensis* and a large number of insect nymphs (Table 4-3). Mature *P. nigrofasciatus* have been present in the tributaries of the affected region. It is known that *P. nigrofasciatus* is a threatened species in Sri Lanka. *G. ceylonensis* on the other hand is endemic to Sri Lanka.

The Low Dam and its reservoir have a surface area of 9.9 km<sup>2</sup> with a volume of 151 (miom<sup>3</sup>). Therefore, the reservoir inundates head ends of about 18 tributaries. These tributaries sustain about 14 species of fish, molluscs, crustacea and insect nymphs. Some of which are endemic and still some are threatened (Table IV - III). Different species are migratory, notably, *A. bicolor bicolor*, *A. nebulosa nebulosa*, *Macrobrachium* sp. are migratory. Further, most species of barbs (species of *Puntius*) are also migratory and show annual migration to tail ends of tributaries for spawning (TEAMS, 1989). Some species such as *G. ceylonensis* are confined to shallow pools in streams and rivers. *P. nigrofasciatus* similarly is confined to small tributaries. *P. loricatus* similarly is confined to small tributaries. *P. loricatus* confine themselves to beds of tributaries. Therefore, their survival could be ensured only under a weir. Under a low dam will retreat to tail ends of tributaries outside the boundaries of the reservoirs, where they they will survive.

As for quality of water, the weir the smallest impact, where as low and high dam reservoirs will change the quality of water significantly. It has been demonstrated for Victoria, Randenigala and Kotmale reservoirs that thermal, oxygen, nutrients and biological stratification take place (Piyasiri, 1991 ; Piyasiri and Jayakody, 1991).

Based on the above results, weir and its reservoir has the lowest impact on aquatic fauna and water quality.

### **Flood protection works**

In case of Kukule-Peleng water scheme water outfall into Pelang Ganga is located near Dangolla Ela.

The annual stream flow in Dangolla Ela amounts to 3 m<sup>3</sup>/s. Addition of further 48, 61, 85 m<sup>3</sup>/s due to plant operation would flood the area and inundate erosion. Therefore, re-regulation ponds, major erosion and flood protection measures are planned there. Aquatic fauna in Pelang Ganga will be displaced, riverine species, namely; *P. nigrofasciatus*, *D. aequipinnatus*, *G. giuris* and *N. botia* (refer Table 4) will disappear from the region.

Water outfall to Kukule is near Makeliya Oya. The volume of water carried there is about 30 m<sup>3</sup>/s. Further, the river is about 35 m wide there and its banks are high. During the rainy seasons the water level rises by as much as 5 m. Therefore, the planned plant discharges of 48, 61 and 85 m<sup>3</sup>/s respectively will not require major flood and erosion protection measures to protect the aquatic fauna.

### **Reservoir operation**

The volumes of water discharged during peak plant operation will be 48, 61 and 85 m<sup>3</sup>/s under weir, low dam and high dam. When the above volumes of water are added either in to Kukule Ganga or Pelang Ganga the following changes will occur:

- a. daily and seasonal water regime downstream of water outfall in KK and KP schemes
- b. daily and seasonal water regime between diver diversion facility and water outfall
- a. Daily and seasonal water regime downstream of water outfall in KK and KP schemes:

The bed of the Kukule Ganga is much wider (about 35 m) than that of Pelang Ganga (about 25 m) near the water outfall. Therefore, the rise in water level in the former river is in the region of 1.0 to 1.8 m, where as in the latter one it is in the region of 1.5 to 2.6 m. The lowest rise will be under a of weir. Pelang Ganga has more rapids and carries less water under normal condition. It is associated with its ecological balance. Addition of further water would therefore disturb its balance. The situation in Kukule Ganga is quite different in that it carries more water. Therefore, plant operation will not change its ecological balance.

- b. Daily and seasonal water regime between diversion facility and water outfall:

Weir show no effect on seasonal water regime. dams will considerably alter the water regimes.

#### **Kukule Ganga upstream of dam/weir**

The lowest number of aquatic fauna will be affected by weir (Table -III) and the highest by dam scheme.

Migratory species such as *A. bicolor bicolor* *A. nebulosa nebulosa* and endemic fish species such as barbs (*B. nigrofasciatus*). Freshwater prawns such as *M. rosenberquii*, *M. malcomsoni*, *M. australe* and *M. scabriculum* are present upstream of weir and low dam.

These species make annual migrations downstream into estuary at Kalutara for spawning. Construction of high dams of the Kukule Ganga will prevent these migrations which in turn will result in their disappearance from the river basin. But all the above species are also present in most of the other rivers and tributaries of the wet zone (Pethiyagoda, 1991; Costa 1969). Therefore, they will not be eliminated from Sri Lanka. However, their elimination from Kukule Ganga basin will disturb the ecological balance in the region and may eventually eliminate many more other species. The details of such ecological interactions among species of the Kukule Ganga are not yet known. However, the diet of some fish species have been stated earlier, therefore, the above fish and insect nymph interaction will be disturbed in the above area. The magnitude of the damage is proportional to the height of the dam and the volume of water in the reservoirs. Because more tributaries are inundated under dams and reduce the available space for insect nymphs. The least damage will be done by the weir.

### **Kukule Ganga down stream to outfall**

Severe reduction of stream flow between diversion facility and water outfall (i. e. 9 km) in KK scheme. Severe reduction of stream flow in the Kukule Ganga between diversion facility and confluence with Pelang Ganga (i. e. 16 km) in KP scheme.

The above stretch of river will be completely dry under a low and high dam. But any excess water over 45 m<sup>3</sup>/s will be released under a weir. There are about 12 fish species, two molluscs species, four freshwater prawn species and two insect nymph species are present in the above region (Table IV). There are no new species in the region. All the reported species are present in Pelang Ganga and also above the dam. Even if these species are destroyed in the above region, due to complete drying up of the river bed, they will survive below water outfall.

Pelang Ganga downstream of water outfall will be flooded due to the addition of 48, 61 and 85 m<sup>3</sup>/s of extra water. This is much more than the mean volume of water carried daily. Therefore, riverine fauna will be affected. Species such as *G. ceylonensis*, *P. nigrofasciatus* and *N. botia* will be disappeared from downstream of water outfall.

Other project elements such as quarries and borrow spoil area, water ways, switch yard, access road, transmission lines, switch yard, access road, transmission lines, re-settlement host areas, construction camps will probably have no significant impact on the aquatic fauna.

Dry up source, scale land slide and dam/weir failure would have drastic impacts on aquatic on aquatic fauna.

Re-settlement of 3500 or 10,000 people (low dam and high dam) will definitely affect the water quality and thus aquatic fauna in the rivers in the re-settlement host areas.

K-K and K-P routes with three types of dams in each of the route were compared using pros and cons with respect to selected characters (Table V -VII). Marks 1 to 6 were assigned and the overall results showed K-K weir has the least impact on aquatic fauna (Table. VII).

**Table IV** Species composition of fauna in Kukule Ganga down stream of dam to water outfall

| species            | abundance |
|--------------------|-----------|
| A. bicolor bicolor | +         |
| P. nigrofasciatus  | +         |
| P. sarana          | +         |
| R. daniconius      | ++        |
| G. ceylonensis     | ++        |
| P. amphibious      | +         |
| P. melanymphyx     | +         |
| P. dorsalis        | +         |
| O. bimaculatus     | +         |
| C. brachysoma      | +         |
| W. attu            | +         |
| H. fossilis        | +         |
| Molluscs           |           |
| P. lor icatus      | ++        |
| P. globosa         | ++        |
| Crustacea          |           |
| C. nilotica        | +++       |
| A. typus           | +         |
| M. malcomsoni      | ++        |
| M. sp.             | +         |
| P. ceylonensis     | +         |
| Insects            |           |
| Dragonfly nymph    | ++        |
| Stonefly nymph     | +++       |
| Damselfly nymph    | +         |

+ 25% of the sample, ++ 50% of the sample, +++ all samples

**Table V** Comparision of the two water way schemes

| K-K Scheme                                   |                                                                      |
|----------------------------------------------|----------------------------------------------------------------------|
| Pros                                         | Cons                                                                 |
| * High mean water flow, 30 m <sup>3</sup> /s | -                                                                    |
| * Fauna affected less                        | -                                                                    |
| * -                                          | * Animal pass needed                                                 |
| * Erosion of river banks low                 | * Dam to water outfall (9 km) dry of some water needed to be let out |
| * River morphology buffers additional water  | -                                                                    |
| * Innundation of banks less                  | -                                                                    |
| * Less sediment is carried                   | -                                                                    |
| * No flood protection work needed            | -                                                                    |

| K-P Scheme |                                                               |
|------------|---------------------------------------------------------------|
| -          | * Stream flow less                                            |
| -          | 3.5 m <sup>3</sup> /s                                         |
| -          | * Fauna are highly affected due to added 30 m <sup>3</sup> /s |
| -          | * Erosion of river banks and beds high                        |
| -          | * Sediment load in the water due to erosion is high           |
| -          | * Flood protection work needed                                |

## Overall assessment of K-K and K-P at ROR level

|              | K-K | K-P |
|--------------|-----|-----|
| Pros         | 6   | -   |
| Cons         | -2  | -5  |
| Total points | 4   | -5  |
| Rank         | 1   | 2   |

All the other levels have more cons. Therefore, K-K scheme is more suitable at all levels.

**Table VI** Comparison of the KK - ROR Low Dam and High Dam

## ROR

## Pros

1. Reservoir is shallow. Therefore, riverine species such as *G. Ceylonsis*, *B. Signata* will survive.
2. Length and the area of the reservoir is very small (0.6- 1.0 kms). Therefore, very few tributaries are inundated. Therefore, relatively more fauna are conserved.
3. Re-regulation ponds and flood protection if needed at low phase.
4. Excess water over 48 m<sup>3</sup>/s will be released. Therefore, less damage is caused to the rivers.
5. Least erosion down stream of weir as volume of water is least.
6. Least number of people (3600) are needed to be re-settled. Therefore, disturbances to water ways are minimal.

## Cons

1. Least sediment is retained in the reservoir, that could affect the riverine fauna down stream of water outfall.

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Overall assessment : Pros and Cons

|              |    |
|--------------|----|
| Pros         | +6 |
| Cons         | -1 |
| Total points | +5 |

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## LOW DAM

## Pros

1. Surface area is small (9.9 km<sup>2</sup>). Therefore, less land is inundated.

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Cons

1. More tributaries and rivers are inundated.
2. More riverline species are affected.
3. No water is released so fauna down stream are affected.
4. More flood protection measures are needed.
5. More people will be re-settled (10,000). Therefore, more disturbance to near areas affecting aquatic fauna.

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Overall assessment of Pros and Cons

|              |    |
|--------------|----|
| Pros         | +1 |
| Cons         | -5 |
| Total points | -4 |

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## HIGH DAM

|      |     |
|------|-----|
| Pros | Nil |
|------|-----|

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## Cons

1. Larger reservoir (volume 400 miom3). Therefore, largest number of riverine aquatic fauna are affected.
2. No water is released down stream of dam. Therefore, aquatic fauna are highly affected.
3. Deepest narrow reservoir, bottom water would not be suitable for aquatic fauna.
4. Largest number of people will be re-settled. Therefore, largest area including water ways are affected.
5. Highest volume of water outfall. Therefore, flood protection envisaged.

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| Overall assessment of Pros and Cons |    |
|-------------------------------------|----|
| Pros                                | 0  |
| Cons                                | -5 |
| Total points                        | -5 |

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| Overall Points |     |         |          |
|----------------|-----|---------|----------|
|                | ROR | LAW DAM | HIGH DAM |
| Points         | +5  | +1      | -5       |
| Rank           | 1   | 2       | 3        |

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**Table VII.** Overall assessment of project impact on aquatic fauna and hydrobiology

| Evaluation   | K-K ROR | K-K LD | K-K HD | K-P FOR | K-PLD | K-P HD |
|--------------|---------|--------|--------|---------|-------|--------|
| Unweighted   | 30      | 63     | 94     | 37      | 79    | 110    |
| Weighted     | 93      | 224    | 354    | 132     | 233   | 378    |
| Improvement  | 30      | 62     | 97     | 39      | 83    | 113    |
| Unweighted   |         |        |        |         |       |        |
| Improvements | 90      | 153    | 251    | 110     | 187   | 292    |
| Weighted     |         |        |        |         |       |        |
| Total        | 249     | 502    | 797    | 309     | 582   | 893    |
| Overall      | 1       | 3      | 5      | 2       | 4     | 6      |
| Rank         |         |        |        |         |       |        |

## ASSESSMENT OF THE RELIABILITY OF THE RESULTS

The above was based on the following;

1. Project elements with and without weights were used to assess the project alternatives.
2. Pros and Cons approach was also used to assess the project alternatives.
3. Published literature on the importance of large dams on the environment (Piyasiri, 1991a, b; Jinadasa, 1985; Neives, 1977)
4. Life cycles of known species such as eels, freshwater prawns and barbs indicated that they migrate.
5. Present study was carried out according to standard methods available for environmental impact assessment.

All the above approaches indicated identical results.

K-K- Kukule- Kukule.

K-P- Kukule - Peleug.

ROR - Run on River, LD - Low Dam, HD - High Dam

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Figure 1 . . . Map of Kukule reservoir area, K-K and K-P are two proposed diversion routes studied. I Indicate sampling stations.