Chapter 9

# SUMMARY AND RECOMMENDATIONS

Throughout the developing world, river sand and gravel are widely exploited as aggregates for building constructions. As transportation and construction infrastructure expanded during the Post Independence Era, demands for construction grade sand also increased. Among the various sources, the river channels and its floodplains are major contributors of the construction grade sand. Sand is a non-renewable resource in human life scale and when extracted from river channels requires almost no processing other than size selection. Depending on the geological setting, this surface or subaqueous type of mining can cause serious environmental impacts, particularly if the river being mined is erosional. The in-channel or near channel extraction of sand inevitably alters the sediment budget and may substantially change channel hydraulics and ecosystem functioning. The impact of sand mining on the various environmental components such as land, water, biotic and social characteristics are typically severe and need indepth analysis for better conservation and management of the river ecosystem. Despite the importance of river sand mining in the construction sector, the details of its economic and environmental aspects and the impact of mining are not yet fully understood and do not adequately inform the decision makers and / or the authorities concerned with its regulation and environmental protection.

Kerala State, in the southwest coast of India, is characterised by fast pace of urbanisation and associated developmental activities, since early 1970's. This, in turn, led to the rise in demand for construction grade sand and gravel. Unfortunately, the 44 rivers in the State are small in size and sand resource capability, compared to neighbouring States. At the same time, indiscriminate mining of sand is booming in the State to meet its ever-increasing demand in the construction sector. Due to the extensive mining, the environmental problems associated with this are also emerging in the State. Now a stage has reached that the Kerala rivers are no longer able to assimilate the human interventions; instead the rivers need immediate attention and corrective measures. As rivers are the first to negatively affect to all developmental stressors, their monitoring and scientific recommendations based on systematic studies are very essential for tuning the activities within sustainable limits. In view of the above factors and also considering its likely impact in the sustainable development of the State, an attempt is made in this study to analyse the problems related to indiscriminate sand mining and to assess its environmental impacts taking the rivers draining the Vembanad lake catchments as a case study site.

The Vembanad lake and its hinterland areas (15100 $km^2$) drained by Achankovil, Pamba, Manimala, Meenachil, Muvattupuzha, Periyar and Chalakudy rivers occupies about 39% of the total area of Kerala State. The area is located between north latitudes $9^0 0'$ – $10^0 35'$ and east longitudes $76^0 05'$ - $77^0 25'$. The study area is known for its increased pace of urban and industrial developments. The coastal lands have the highest density of population (Population density of Kochi Corporation as per 2001 census = 6277 $inh.km^{-2}$). This region includes all the three major physiographic provinces of Kerala such as highlands (8625 $km^2$), midlands (4534 $km^2$) and lowlands (1941 $km^2$). The land use and settlement pattern varies considerably within the study area in tune of the physiographic settings.

The rivers in the study area reveal wide variations in their nature and characteristics. The segments in the main channel of Muvattupuzha river exhibit maximum average sinuosity index (1.71). Among the individual segments, Pamba (1.95) and Manimala (1.82) rivers exhibit high sinuosity index in the highlands whereas Achankovil (1.74), Meenachil (1.44), Muvattupuzha (1.9), Periyar and Chalakudy (1.59) rivers in the midlands. The majority of the river channel segments in the study area fall under the category of irregular meanders. Straight channel pattern is observed only in Periyar river that drains through Munnar-Peermedu plateau in the highland region. The average annual water and sediment discharges for the period 1987/88 to 1996/97 is highest in Periyar river (Water discharge: 83344 cumecs; Sediment discharge: 354870 tonnes), which has a greater basin area compared to other rivers in the study area. The analysis of sediment characteristics of the seven rivers reveals that, in general, there is a progressive decrease in grain size downstream. Sandy gravel dominates in the highlands and gravelly sand in the midlands and slightly gravelly sand or sand in the lowlands. An inter-comparison of all dissolved nutrient species reveals wide seasonal concentration differences. The rates of flux of nutrients like nitrate and phosphate through all rivers are considerably high during monsoon period compared to non-monsoon. Generally, rivers from the southern region reveal high seasonal difference of $NO_3$-N flux rate compared to the northern rivers of the study area.

Generally, two types of instream sand mining are practiced in the area - pit excavation and bar skimming. Deep pit excavation is widespread and is a common practice of sand mining in many parts of the river systems in the study area. The detailed examination on the extent of instream sand mining shows that the intensity of mining is high in the alluvial reaches. A physiography-wise analysis of sand mining reveals that in the highlands, the maximum quantity of sand is being mined from the Periyar river (0.667 x $10^6$ $ty^{-1}$; 41.49%) followed by Pamba (0.374 x $10^6$ $ty^{-1}$; 23.28%) and Achankovil (0.270 x $10^6$ $ty^{-1}$; 16.82%) rivers. The main channel and tributaries of the entire rivers in the highlands are widely exploited for sand and gravel. A detailed examination of the extent of sand mining shows that river channels in the midlands are extensively mined for construction grade sand than the other two physiographic zones. The Periyar river holds a share of about 55% of the total quantity of sand extraction in the midlands followed by Muvattupuzha (15%) and Manimala (9%) rivers. Similarly in the lowlands, Periyar (40%) and Muvattupuzha (27%) rivers ranks the first and second positions in the total quantity of sand extraction. If one considers the study area as a whole, out of the total quantity of sand extraction, 50% is from the Periyar river, which flows through the most urbanized and industrialized areas. An overall analysis reveals that about 75% of the quantity of sand extraction is from the midlands. Also, rivers in the northern part of the study area (Muvattupuzha and Periyar rivers) close to the major developmental centres, like Kochi City, ranks top in the case of sand extraction. The sand mining locations are also higher in numbers in midlands than in the highland and lowland counterparts.

In addition to instream mining, floodplain mining is also widespread in the study area, especially in lowlands. Among the river basins, the downstream reach of Muvattupuzha river basin is widely exploited for floodplain sands often using diesel powered engines. In the Periyar river basin, land sand mining is widespread in the plateau region in the highlands. Mining of sands from these areas impose severe environmental problems to the river basin environment.

An apparent assessment of the quantity of sand extraction with respect to the sand input (replenishment) shows that mining in the river reaches down the gauging stations is of the order of 40 times higher than the input. The storage zones of the rivers are now transformed into deep pools due to pit excavation. The river segments at many places are devoid of mineable quantities of sand. This, in turn, has aggravated mining of sands from floodplain and over bank areas of river channels. Therefore, the quantity of sand allocated to mining should be strictly reduced in a phased manner (after normalizing the mechanism of mining), so that, over a period of time, the quantity of mining can be made in tune with natural replenishment.

The physical adverse effects of sand mining in the study area are numerous and need careful examination / analysis. The rivers in the Vembanad lake catchments exhibit marked 'human imposed' modifications in their bed profiles over the years consequent to sand mining and construction of embankments or dams upstream. The river cross sections over the years show that the channel beds are subjected to incision at faster rates (4.44 $cmy^{-1}$ to 16.19 $cmy^{-1}$) due to indiscriminate sand mining. The present level of bed degradation in the rivers in the area can be attributed to sand mining activities because the scale of extraction of river sand exceeds the natural replenishment. Furthermore, the strong positive correlation existing between the quantity of sand mining and channel incision reiterates this view. Although timely interventions of Hon'ble Court and Government could yield positive results for short-term periods (which in turn, reflected well in the slow pace of channel incision at certain periods) the efforts could not sustain long due to illicit sand mining to meet the ever increasing demands in the construction sector.

Removal of sand by manual as well as mechanical means results in the generation of large pits in the river channels, which in turn, act as trap for sediments rich in nutrient elements. In addition, the pits trap much of the bedload sediment and sediment starved water (hungry water) that passes downstream of such pits not only aggravates erosion of river bed and banks with great vigour, but also undermines bridges and other engineering structures built in the river channel. Bank failure incidents are common in the midlands and lowlands and downstream areas of highlands of the entire rivers close to indiscriminate sand mining. The problem is very severe in the high flow periods of the monsoon season. The river stretch experiences marked changes in river bed configuration, damage to engineering structures constructed along and across the river channel, widening of river channel due to mining of sand close to river banks and adjoining areas, etc. Uprooting of trees is noticed at some places. Riparian vegetation is very scanty or totally absent on the banks in some areas.

The physical composition and stability of substrates are altered as a result of instream sand mining and most of these physical effects may exacerbate sediment entrainment in the channel. A comparative evaluation of the present study of changes in grain size characteristics in the Muvattupuzha river with the database of the year 1988, reveals that Very Coarse Sand (VCS) and Coarse Sand (CS) fractions are higher in majority of the samples in the upstream reaches. Indiscriminate extraction of sand from the lower reaches of the river has imposed marked changes in the sediment distribution pattern. Sand extraction has resulted in the imposed bed coarsening in the upstream areas by selective removal and transportation (entrainment) of medium to very fine sands from the upstream stations and their deposition in the subsequent stations downstream reaches. The surface and core sediments collected from the Valanchuzhi point bar of the Achankovil river reiterates the fact that bed coarsening phenomenon is also taking place in point bar deposits that are used for holding religious / cultural congregations. The variation of VCS, CS, Medium Sand (MS), Fine Sand (FS) and Very Fine Sand (VFS) shows a deviation from the gravel entity by exhibiting a general increase towards the downstream part of the river channel. Removal of sand and gravel taking place in the sand mining location (Vyazhi *kadavu*) situated downstream, as well as winnowing of gravels and sands from the incising river bed, has resulted in a kind of armouring (the development of a lag concentrates of pebbles) in the upstream side of the Valanchuzhi point bar.

The analysis of Total Suspended Sediments (TSS) in Manimala river reveals that during intense sand mining periods, the overlying waters close to mining centres are loaded heavily with TSS contents than sand mining prohibition periods. In addition, the positive correlation existing between TSS and quantity of sand extraction reiterates that the mining is one of the major causative factors in raising the suspended particulate contents in river environments. It can be noticed from the study that the lowering of water table in the wells constructed in the floodplains / older river terraces, especially during summer season, is in consonance with channel incision consequent to indiscriminate sand mining.

Sand mining from rivers has resulted in habitat destruction, which in turn, imposes negative effects on the fishes and benthic fauna that inhabit the sandy substratum. The elimination of benthic fauna consequent to indiscriminate sand mining can adversely affect the survival of carnivorous and omnivorous fishes. Examination of freshwater fish fauna from different parts of the study area indicates that most fauna are in serious decline and in need of immediate conservation measures. Sand mining also has deleterious effects on the riparian vegetation along the banks of the rivers.

Social effects are complex and cannot be considered separately from environmental effects. The potential socio-economic impacts of river sand mining inferred from this study are largely negative. Besides for its potential for employment creation, sand mining is also related to the livelihood issues of local people in the form of resource availability. The costs to repair or replacement of engineering structures damaged by channel incision consequent to sand mining account for a huge amount and are far higher than the revenue generated from the mining activities. At many places, people have to bear the cost of lowering the wells for correction of channel incision and thereby maintaining water availability, loss of productive lands, loss of access to clean water and increase in the risks of accidents and diseases. The deep pits created in the river channel now act as death traps for a number of people residing along the banks of the rivers. In highlands and midlands, alterations by extraction to the hydrological environment increase the risk of diseases, especially during summer where low flow exists. The excavations associated with river mining create stagnant waters that may favour the multiplication of vectors such as flies, mosquitoes and other parasites.

Environmental Impact Assessment (EIA) was carried out for instream mining to examine the magnitude of impacts in the three different physiographic settings. The impact magnitude and impacting actions of mining activities in the three physiographic zones - the highland, the midland and the lowland - are different. The EIA exposes the negative impacts of sand mining on various environmental components of the study area. Land, one of the major life-supporting components in the environment is affected adversely by mining. The effects of mining such as bank slumping, channel incision etc., cause physical disturbances on the land stability triggering bank erosion in previously stable areas. The transport of vehicles cause negative impacts on air quality and enhance the noise level. The after-effects of sand mining activities such as siltation and turbidity, creation of deep pits in the channel, transportation of vehicles into the riverbed for easy loading of the mined material etc., create negative impacts on surface water quality. Lowering of water table in the wells adjacent to the mining sites is also noted in the study area. The negative effects of mining impose severe stress on the biological communities as well. Through mining activities, jobs and opportunities are generated, and significant contributions are made to the State's economy. Despite its positive phase, negative impacts dominate in the aesthetics, hazards, land holdings, etc. In many circumstances, the poor riparian land holders are forced to sell their property at throwaway prices. EIA carried out for floodplain mining of sand reveals that the wet pit mining using diesel powered engines (i.e., mechanical mining) is most disastrous and cause land instability problem in the area. In addition to this, groundwater, surface water, flora and fauna and sustainable livelihoods are also adversely affected. Moreover, manual extraction of floodplain sands by creating wet pits is dangerous to humans.

A management plan is prepared to mitigate the impacts of mining. Among the various management alternatives of sand mining – no mining scenario, bar skimming, floodplain mining and pit excavation – no mining scenario may be opted for the river stretches in the lowlands and midlands. At the same time controlled bar skimming may be allowed in the river reaches of the highlands and upper part of midlands at places where sand bars are exposed. A share of the revenue collected from sand mining should be used for river restoration since the well being of a society is essentially a function of the environment.

Recommendations / suggestions

The following are the major recommendations / suggestions drawn from the present study.

- Aggregate management should be considered separately from river management. The present practice of combining these two should be stopped with immediate effect.
- An integrated environmental assessment, management and monitoring program should be part of the sand extraction processes. Individual extraction operations should be evaluated from a perspective that includes their potential secondary and cumulative impacts.
- Evaluate physical, chemical and biological effects of instream mining on a river basin scale, so that cumulative effects of sand extraction on the aquatic and riparian resources can be recognized.
- Mechanical forms of sand extraction are to be discouraged and manual removal of sand is strongly recommended subject to environmental safeguards.
- Incorporate costs of environmental impacts (to bridges and other resources) into price of instream sand and gravel.
- There is an urgent need for strengthening multidisciplinary studies on the rivers for providing adequate scientific information to river restoration and management activities.
- Examine and encourage alternatives to river sand for construction purposes. Import sand from areas where there is surplus availability.
- Immediate steps to be taken to intensify research activities leading to the finding of suitable, low cost and easily available alternatives to river sand. Simultaneously, alternative building technologies with low sand / no sand content to be developed and promoted to rescue the rivers of the study area from further deterioration.

- The abandoned pits left after floodplain mining of sand should be reclaimed by land filling using proper scientific methods.
- The top soil shall be stripped off and kept separately for replacement to a similar depth in the rehabilitated or landscaped area. Correspondingly, the natural vegetation and land use practices that existed before the mining shall be reintroduced.
- Prohibit mining in such areas where small landholders are settled.
- Regulate random mining and allow only location specific extraction of the floodplain sand under strict guidelines.
- Avoid mining below the level of depth of water table (with respect to the water table conditions of summer season) of adjacent areas.
- Awareness campaign should be conducted at various scales and levels about river sand mining, present state of environment of rivers, finite character of river sand, immediate need for control measures etc.
- Continued funding for R & D activities for updating the database, technologies and management.
- Enforce strictly the 'Kerala River Bank Protection and Regulation of Removal of Sand Act', 2001.

These suggestions / recommendations are to be taken into consideration while formulating strategies for the conservation and management of the fast degrading river ecosystems of Kerala.