# River sand mining and associated environmental problems in Sri Lanka

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**Abstract** The demand for sand for construction purposes has increased significantly in Sri Lanka in recent years, particularly due to the tsunami disaster that occurred in December 2004. This high demand led to a major increase in sand mining in many areas. Extraction of sand from river bed and river bank sand deposits has increased greatly. The current demand for sand for building construction within the country is approximately 7–7.5 million cubic metres per year. River sand mining activities have disrupted the natural equilibrium and have caused adverse affects on the environment. The Nilwala and Ginganga rivers are the main rivers in southern Sri Lanka that are suffering from both illegal and excessive sand mining. However, other rivers in the southern part of the island have also been affected by this problem at different scales. It is estimated that mining of sand from the Nilwala River has increased by three times compared to 1997. Excessive extraction of sand from river channels results in wide ranging impacts, including the intrusion of sea water into the river, collapse of river bank, and loss of riparian land. Recognising the need for scientific assessments of the extent of environmental degradation caused by indiscriminate sand mining, an attempt has been made to study the environmental impacts of such sand mining in the Nilwala River basin of southern Sri Lanka and to propose corrective measures. The objective of the study reported in this contribution focused on changes in groundwater quality resulting from sand mining in the Nilwala River basin area. River sand mining has reduced significantly in recent years due to people participation, integrating research findings, imposition of legal regulatory frameworks, and networking of community-based organizations.

**Key words** sand mining; salinity; pH; electrical conductivity; groundwater; seawater intrusion; Sri Lanka

## INTRODUCTION

Sri Lanka is blessed by well developed river systems that comprise 103 river basins. Since pre-history, the inhabitants of the Island have benefited greatly from the resources provided by rivers. From the establishment of ancient settlements in Sri Lanka to the present, human advancement has depended heavily on its rivers from many perspectives. However, such human advancement has resulted in many serious negative impacts on the environment. River sand mining is one such activity that has resulted in both direct and indirect impacts on the physical, natural and social environments. The direct impact of river sand mining can be readily discerned within rivers through changes in the movement of water and sediment, channel geometry, bed elevations, substrate composition, in-stream roughness and the stability of the river bed, banks and riparian zone. Indirect impacts can be linked to associated changes within the drainage basin that cause impacts on runoff, water quality and sediment yields. When subject to limited and ineffective regulatory control, this form of resource exploitation can produce extremely serious environmental impacts (Taglia-Vini, 1978; Larinier, 1980; Kondolf, 1994, 1997). Furthermore, although the impacts of sand mining on the channel and riparian environments of larger rivers are relatively well documented, little information is available for smaller streams, and only limited attention has been given to the relationships between sand mining, streambed sediment deficits, and the sediment balance of coastal zones (Inman, 1985).

In Sri Lanka, the sand required for construction purposes has traditionally been obtained by mining sand deposits in rivers. Increasing use of mechanized extraction in the late 1990s has resulted in heavy localized turbidity, lowering of water tables, bank erosion, land degradation and salinity intrusion resulting in hardship, both to agriculture and food security. Such demand for sand has increased greatly in recent years, particularly as a result of the widespread damage caused by the tsunami disaster that occurred in December 2004 and the subsequent reconstruction programmes (Piyadasa *et al*., 2007). The current demand for sand for building construction within the country is approximately 7–7.5 million cubic metres per year. High demand for sand has led to a major increase in sand extraction in many areas, with sand sources including both sedimentary deposits and sand associated with river beds and flood plain deposits. River sand mining directly affects the natural equilibrium of river systems. The rapid expansion of the mining of river bed and river bank sand have caused widespread environmental, social and economic problems linked to the livelihoods of people, agriculture, health, land and air pollution, inflow of sea water into the rivers, causing droughts and flooding, and depletion of coastal sand barriers and beaches that provide important protection against sea surges and tsunamis.

The Nilwala River is the main river in southern Sri Lanka that is suffering from illegal and rapidly increasing sand mining (Fig. 1). However, many other rivers in southern Sri Lanka also face similar problems to varying degrees. It is estimated that extraction of sand from the Nilwala River has increased by three times since 1997 and the lower river reaches extending 50 km inland from the sea have been badly affected by extensive sand mining. Over-extraction of sand from the Nilwala River has caused numerous problems, including salinization of the drinking water supply to the city of Matara due to intrusion of seawater into the river, collapse of river banks, and loss of valuable riparian land. It is important that the extent of such environmental degradation resulting from unregulated sand mining should be monitored and assessed and this contribution focuses on the changes in groundwater quality that are occurring in the lower Nilwala River basin due to sand mining activity.

## METHODOLOGY

A number of existing dug wells on the right bank of the Nilwala River were selected for continuous monitoring to document the spatial variation of groundwater levels and groundwater quality, as reflected by variations in salinity. The locations of these wells (latitudes and longitudes) were established using a GPS and their elevations were determined from the 1:10 000 contour map. Water levels in the wells were continuously recorded and the quality of the well water, as represented by Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity and pH was measured at monthly intervals using an EC/pH meter. The water level data obtained from the wells were used to establish the hydrogeological features in the unconfined sandy/sandstone aquifer. The ArcView GIS package was used to plot the hydrogeological map and the maps of the spatial distribution of Electrical Conductivity and Salinity presented later in this communication.

## STUDY AREA

The Nilwala River basin falls mainly within the wet zone of the southern Province of Sri Lanka and originates from the Sinharage Highland Natural Forest (Fig. 1). The river is the largest in the southern province of Sri Lanka and has a length of ~72 km. Nearly 90% of the catchment of the Nilwala River is located in the Matera District.

The study area is located within the WL2 agro-ecological region. The mean annual rainfall ranges between 1875 and 2500 mm and the mean temperature is 25°C. The relative humidity is 75–80%. The catchment covers approximately 971.0 km$^2$ and is located between latitude 5°55′ and 6°13′ and longitude 80°25 and 80°38′. From a hydraulic perspective, the course of the Nilwala River consists of two very different parts. The upstream part has a steep longitudinal slope, where the river bed is rocky, and flow velocities are fairly high. The valley floor is well defined and floods are constrained and do not cause widespread inundation. The downstream lowland part of the catchment constitutes the main study area. The southern lowlands of the basin extending inland up to about 12 km from the coastline are subject to severe flooding during the southwest monsoon rains as a result of both conventional rainfall and cyclones. Approximately 70% of the Nilwala River basin is used to grow paddy rice, tea, coconuts, cinnamon, citronella and rubber. The paddy area covers approximately 18 000 ha, including 9000 ha in the lower part of the basin subject to seasonal flooding. A wetland called the “Kirelakele Marsh” is located near the Indian Ocean outfall of the Nilwala River. The population density of Matera District in 1990 was about 596 per km$^2$.

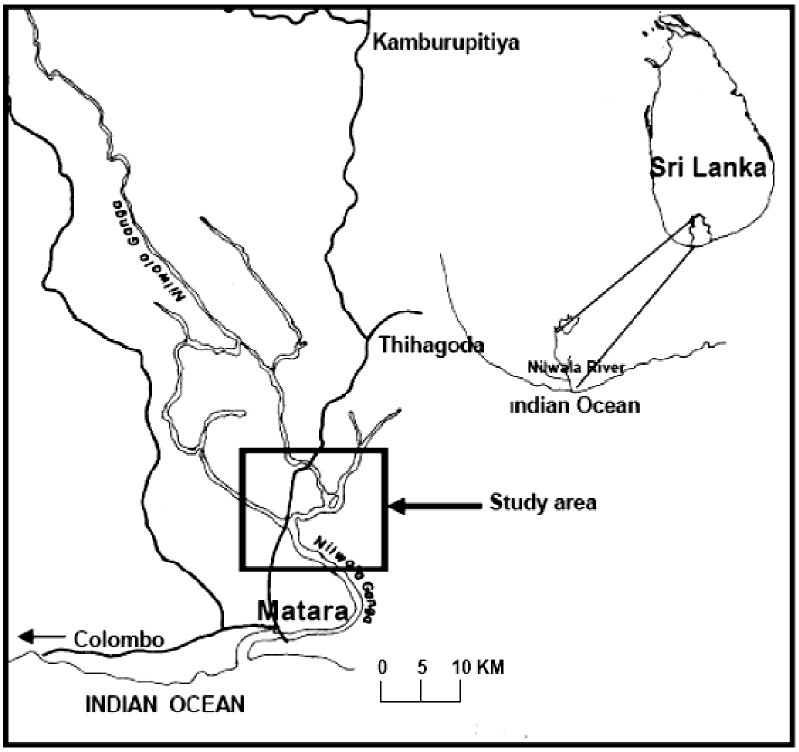


**Fig. 1** The Nilwala River basin and the location of the study area.

## THE GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The study area is dominated by Precambrian metamorphic hard rocks overlain by Quaternary sedimentary deposits (Cooray, 1983). The Precambrian basement comprises rocks of the so-called Highland Complex which consists of granite silimants with-biotitic gneiss. The soils are mainly sandy clay in texture. The isolated lateritic hills found in the flood plain are of the same geology as the inland land mass. The upper unconfined alluvial aquifer is distributed across the Nilwala River basin and along the coast (Panabokke & Perera, 2005). The water-bearing sand in the top section is commonly fine, whereas the lower sections usually comprise coarse sand with small amounts of gravel.

The upper Quaternary sandy aquifer and the surface soils of the coastal margin of the Matara area are highly permeable. The hydrogeological conditions are therefore very favourable for saltwater intrusion. Along the coastal belt, alluvial and coastal sand deposits are dominant and form higher-yielding local aquifers.

## RESULTS AND DISCUSSION

### Groundwater salinity

During the wet period, the upper catchment area feeds the river with fresh water which flows towards the sea. During the dry periods river flow decreases and sea water intrusion take place, due to seasonal tidal waves. As a result, saline river water easily infiltrates into the permeable aquifers in the river banks.

The study conducted on the right bank of the Nilwala River aimed to document the changes in groundwater quality caused by seawater intrusion resulting from sand mining in the lower reaches of the Nilwala River. Groundwater levels in the unconfined aquifer range from 5 to 45 m above MSL. Recharge and discharge zones in the study area can be readily identified when the groundwater contour map (hydro-isograph) (Fig. 2) is examined. It is evident that the central part of the study area receives water from the upper catchment areas (Fig. 2). In the northern part of the

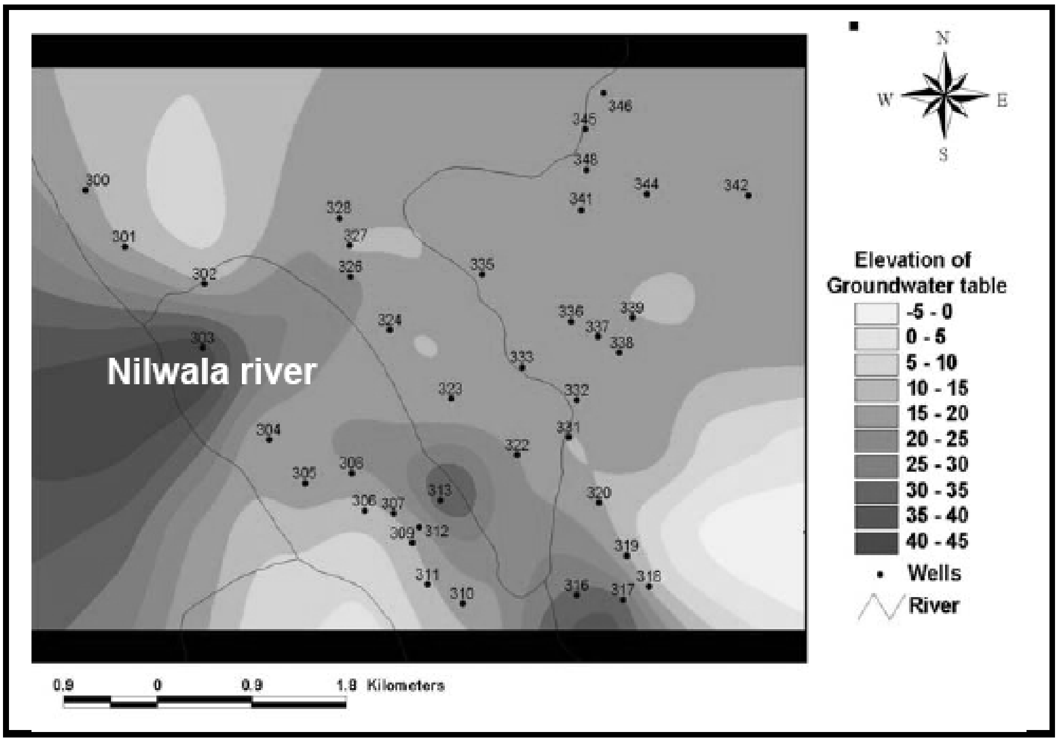


**Fig. 2** Groundwater levels (Hydro-isograph) in the study area.

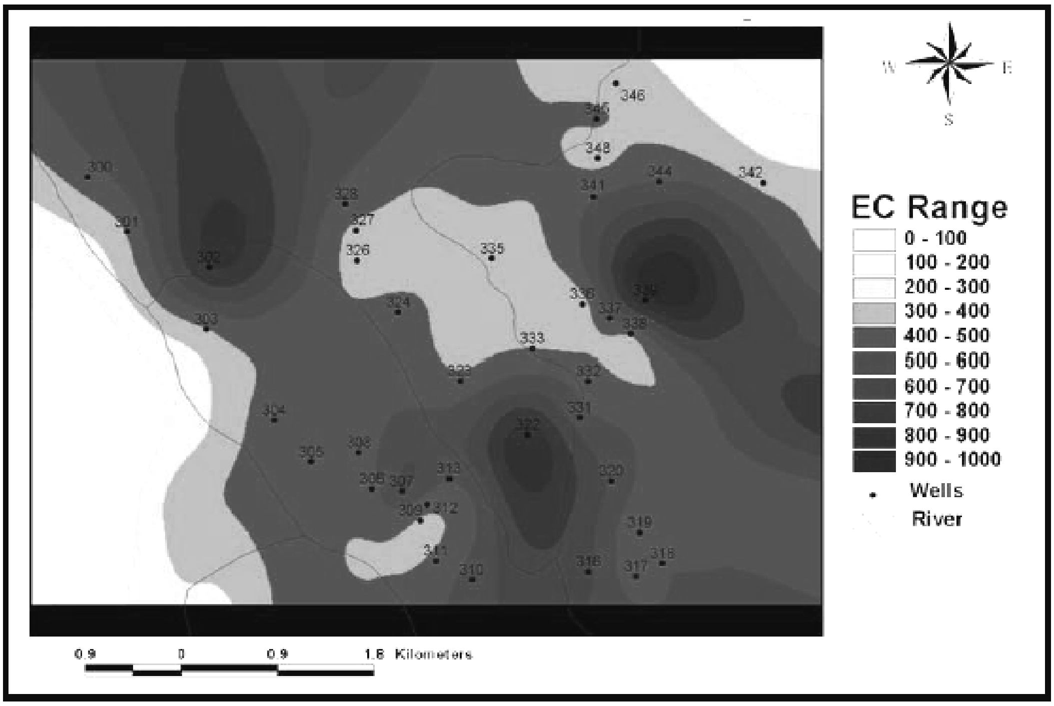


**Fig. 3** The spatial variation of the electrical conductivity (μS/cm) in the groundwater..

study area, groundwater levels fluctuate between 10 m and 12 m. The central area also seems to provide a significant contribution of water to the Kirama Ara stream. However, the hydraulic gradient is very low (0.0001) at this location. In the northern part of the area, the hydraulic gradient varies from 0.001 to 0.0001 and recharge rates are quite considerable. The central part of the area collects water from the surrounding recharge areas and discharges to the Nilwala River.

Groundwater level monitoring during the study period demonstrated the flow characteristics of groundwater in the Nilwala River basin. Hydro-isograph and topographic maps demonstrate a close relationship. In the case of unconfined aquifers, this relationship is an important feature to describe the groundwater distribution of the area. It is clear that groundwater levels are high in higher elevation areas whilst they are low in low-lying areas.

Electrical conductivity (EC) values measured in the groundwater of the Nilwala River basin range from 38.48 to 1100 μS/cm (Fig. 3). Due to seawater intrusion via the river, electrical conductivity values exceed 1000 μS/cm in the southern part of the area. Most of the Nilwala basin area remains within the accepted Sri Lankan standards for drinking purposes (1500 μS/cm). Groundwater flows from the river to the surrounding area. Here soil acts as a filter by binding ions. Therefore EC is high near the river and it reduces with increasing distance from the river (Fig. 3).

The distribution of salinity in the groundwater of the Nilwala River basin closely follows that of EC. Salinity values range from 0 to 0.5% across the study area (Fig. 4). Increases in salinity reflect both seawater intrusion as well as water logged conditions.

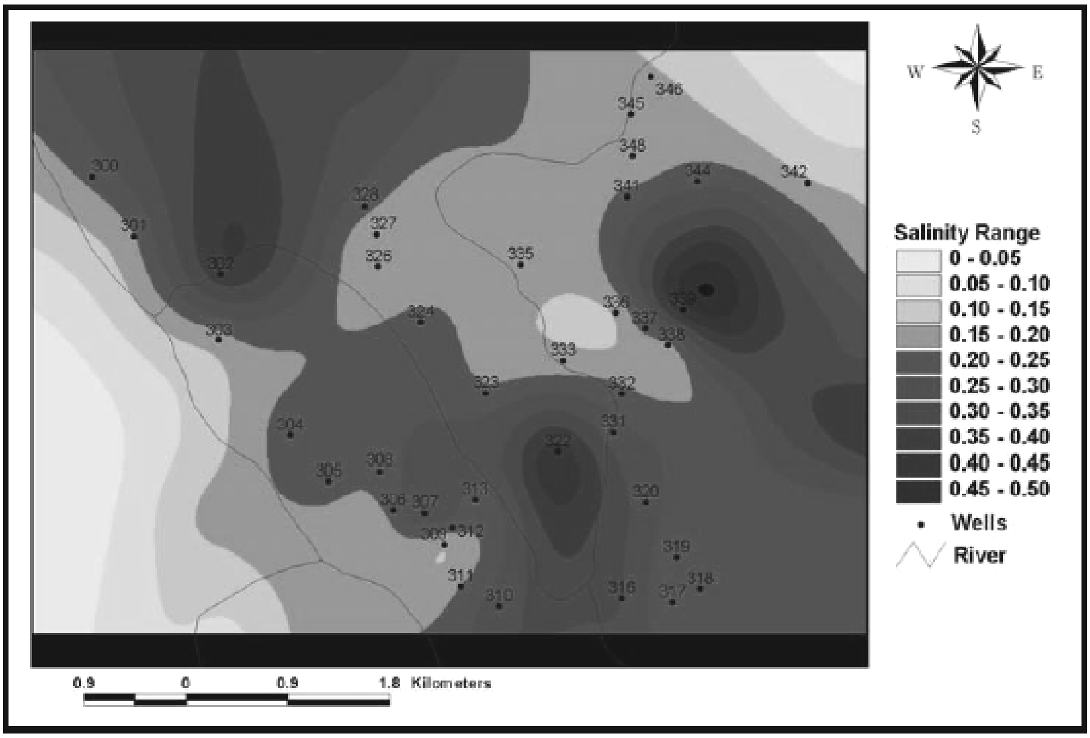


**Fig. 4** The spatial variation of salinity in the groundwater of the study area.

## CONCLUSIONS

The electrical conductivity and salinity of the groundwater resources have been shown to still fall within the Sri Lankan standards for drinking water, and they represent a reliable source to meet the water demands of the population.

In the past decades, rivers in the densely populated areas of the world have been subjected to immense pressures, due to various kinds of human activity. The indiscriminate mining of construction grade sand from alluvial reaches causes major impacts. This is primarily because river sand mining needs to be controlled and regulated through people participation and integration of research outputs with policy development linked to legal frameworks.

## RECOMMENDATIONS

An integrated environmental assessment, management and monitoring programme should form the basis of any extension of sand extraction activities. There is also an urgent need to develop multidisciplinary studies of human-induced degradation of the small rivers on the southwest coast of Sri Lanka. The physical, chemical and biological effects of in-stream sand mining should be investigated at the river basin scale, so that the cumulative effects of extraction on the aquatic and natural resources can be recognized and addressed at various levels, to provide effective remedial measures. Alternatives to river sand for construction purposes should be investigated and promoted.

**Acknowledgement** The author would like to thank Mrs C. M. Vithanage, Department of Geography, University of Colombo, for preparing all the graphics in the paper.

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