British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

DFID
Department For
International Development

River Mining

SUMMARY

Sand and gravel is an essential source of aggregate for the construction industry. In developing countries it is often exploited directly from the active channels of river systems, where it is easily extracted and usually requires almost no processing other than size selection. It is often considered a renewable resource. However, in-channel or near-channel mining of sand and gravel inevitably alters the sediment budget of a river system, and may substantially alter channel hydraulics. The impacts of such mining on farmland, river stability, flood risk, road and bridge structures and ecology are typically severe.

An understanding of aggregate resources, supply and economics, and of the impacts of aggregate extraction is essential if river sand and gravel resources are to be managed effectively. This report summarises our study of river mining in developing countries and illustrates how an improved understanding can be used to provide an effective mechanism for the control of river mining operations; to protect local communities, to reduce environmental degradation and to facilitate sustainable use of the natural resource base.

With a better knowledge of available resources, supply options, market and production issues, of the physical, biological and social impacts of extraction, and of best practice legislative and planning guidelines, we suggest solutions for reducing the problems associated with river mining of sand and gravel. A Code of Practice is recommended, based on best practice guidance, which regulators can develop to work within their preferred strategic framework for examining and reconciling the conflicting claims of mineral extraction and the environment.

The project has involved a multidisciplinary team of researchers who have carried out field investigations on selected river systems in Jamaica and Costa Rica. The British Geological Survey has led the project activities with specialist input from the Camborne School of Mines (University of Exeter), the Corporate Citizenship Unit at the University of Warwick, Alliance Environment and Planning Ltd, Guildford, UK and the National Centre for Environmental Toxicology, Marlow, UK, a component body of the WRc-NSF Ltd. Overseas partners are principally, the Mines and Geology Division of the Ministry of Land and Environment in Jamaica and the Instituto Costarricense de Electricidad in Costa Rica.

Details of the project work and research results are given in seven project technical reports and are summarised in this report. The reports cover:

- aggregate production and supply in developing countries
- sand and gravel resources in Jamaica
- alternative aggregate resources
- alluvial mining in Costa Rica
- environmental and social impacts of river mining
- ecological effects of river mining
- planning guidelines for management of river mining.

River aggregate processing plant, Yallahs, Jamaica.

River terrace sand and gravel, Rio Minho, Jamaica.

Yallahs River, Jamaica.

River Mining
Project Summary Report

Commissioned Report CR/03/198N
D J Harrison[1], M MacFarlane[2], P Mitchell[2], S Fidgett[3], P W Scott[4], J M Eyre[4], S J Mathers[1], and J M Weeks[5]

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DFID Department for International Development

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INTRODUCTION

Sustainable river mining

Throughout the developing world river sand and gravel is widely exploited as aggregate for construction. Aggregate is often mined directly from the river channel as well as from floodplain and adjacent river terrace deposits. Depending on the geological setting, in-stream mining can create serious environmental impacts, particularly if the river being mined is erosional. The impacts of such mining on farmland, river stability, flood risk, road and bridge structures and ecology are typically severe. The environmental degradation may make it difficult to provide for the basic needs (water, food, fuelwood, communications) of communities naturally located beside the river.

Despite the importance of this extractive industry in most developing countries, the details of its economic and environmental geology are not fully understood and therefore do not adequately inform existing regulatory strategies. The main problem is therefore a need to strengthen the general approach to planning and managing these resources. Compounding the problem is the upsurge of illegal extractions along many river systems. There is therefore a need to foster public awareness and community stewardship of the resource.

The project 'Effective development of river mining' aims to provide effective mechanisms for the control of sand and gravel mining operations in order to protect local communities, to reduce environmental degradation and to facilitate long-term rational and sustainable use of the natural resource base. This project (Project R7814) has been funded by the UK's Department for International Development (DFID) as part of their Knowledge and Research (KAR) programme. This programme constitutes a key element in the UK's provision of aid and assistance to less developed nations. The project started in October 2000 and terminates late in 2004.

Specific objectives of the project include:

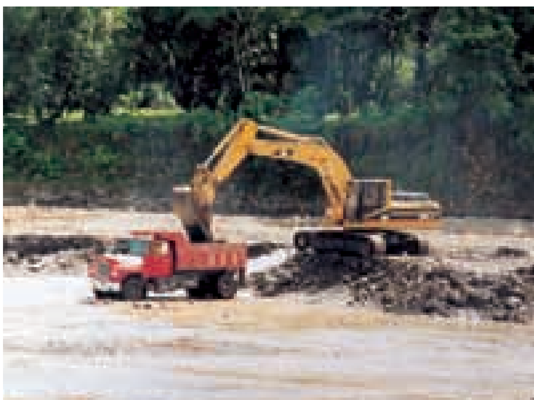
- resource exploration and resource mapping at the project's field study sites (Rio Minho and Yallahs rivers in Jamaica)
- analysis of technical and economic issues in aggregate mining, particularly river mining
- determination and evaluation of the environmental impacts of river mining
- evaluation of social/community issues in the context of river mining
- investigation of alternative land and marine aggregate resources
- review of the regulatory and management framework dealing with river mining; establishment of guidelines for managing these resources and development of a Code of Practice for sustainable river sand and gravel mining.

The 'Effective development of river mining' project is multidisciplinary, involving a team of UK specialists. It has been led by a team at the British Geological Survey comprising David Harrison,

Extraction of river sand, Costa Rica.

Erosion of Yallahs ford, Jamaica.

Instream aggregate mining, Costa Rica.



INTRODUCTION

Andrew Bloodworth, Ellie Steadman, Steven Mathers and Andrew Farrant. The other UK-based collaborators are Professor Peter Scott and John Eyre from the Camborne School of Mines (University of Exeter), Dr Magnus Macfarlane and Dr Paul Mitchell from the Corporate Citizenship Unit at the University of Warwick, Steven Fidgett from Alliance Environment and Planning Ltd and Dr Jason Weeks from WRc-NSF Ltd. The research project is generic and applicable to developing countries worldwide, but field studies of selected river systems have been carried out in Jamaica and review studies have been undertaken in Costa Rica. Key participants in these countries have included Carlton Baxter, Coy Roache and Larry Henry (Mines and Geology Division, Ministry of Land and Environment, Jamaica), Paul Manning (formerly Mines and Geology Division, Ministry of Land and Environment, Jamaica) and Fernando Alvarado (Instituto Costariccense de Electricidad, Costa Rica).

The authors would like to thank the many organisations in Jamaica and Costa Rica who have contributed to the project. In addition to the collection of data, many individuals have freely given their time and advice and provided the local knowledge so important to the field investigations. This report is the project Summary Report based on the technical project output reports listed below:

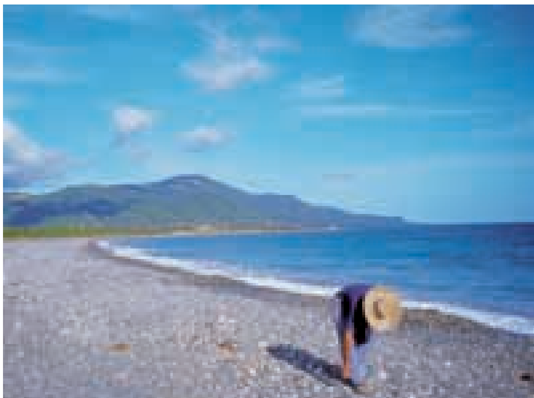
- Geology and resources of the lower Rio Minho and Yallahs Fan-delta, Jamaica, 2003. A R Farrant, S J Mathers and D J Harrison, British Geological Survey
- Aggregate production and supply in developing countries with particular reference to Jamaica, 2003. P W Scott, J M Eyre (Camborne School of Mines, University of Exeter), D J Harrison and E J Steadman, British Geological Survey
- Assessment of the ecological effects of river mining in the Rio Minho and Yallahs rivers, Jamaica, 2003. J Weeks, WRc-NSF Ltd and D J Harrison, British Geological Survey
- Scoping and assessment of the environmental and social impacts of river mining in Jamaica, 2003. M Macfarlane and P Mitchell, Warwick Business School, University of Warwick
- Alternative sources of aggregates, 2003. DJ Harrison, British Geological Survey
- Alluvial mining of aggregates in Costa Rica, 2003. Fernando Alvarado Villalón (Costa Rican Institute of Electricity), D J Harrison and E J Steadman, British Geological Survey
- Planning guidelines for management of river mining, 2003. S Fidgett, Alliance Environment and Planning Ltd

Details of how to obtain these reports and more information about the 'Effective development of river mining' project can be obtained by contacting the Project Manager, David Harrison at the British Geological Survey, Keyworth, Nottingham, UK, email: djha@bgs.ac.uk. Summaries of these technical reports, including the key research findings, are given in the following pages. Aggregate resources, economics and supply issues are dealt with first, and following sections of the report describe socio-environmental impact assessment methods, procedures and results. Strategies for more effective management of river sand and gravel mining are given in the planning guidelines and Code of Practice.

River mining, Yallahs River, Jamaica.

Crushed limestone sand — an alternative resource.

Marine aggregates — a viable option?



Aggregates supply

Primary aggregates are made either from crushed rock or naturally occurring sand and gravel. Sources of crushed rock are numerous and may include many different rock types (limestone, sandstone, basalt, dolerite, etc). In developing countries, sand and gravel is often exploited from the active channels of river systems. They are easily extracted, and often require almost no processing other than size selection. They are often considered a renewable resource.

In developing countries, production is often on a small scale, with many small quarries operated by different companies or informal groups. The granting of permissions to extract is less formal, or even non-existent, with illegal mining commonplace. The supply of aggregates is inconsistent and the quality of products may be extremely variable.

Aggregates must be fit for the purpose for which they are used. Their properties (physical, mechanical and chemical) vary according to their composition, origin and degree or type of processing. The properties required of aggregates if they are to be accepted for use are often defined by national standards.

Aggregates in Jamaica

There are two main sources of aggregates in Jamaica. These are sand and gravel from alluvium found in and adjacent to the present rivers, especially the active stream channels, and limestone. Limestones in Jamaica are located throughout the island, extraction being mainly in the north and west of the island. Resources of sand and gravel are located mainly in rivers flowing to the south coast, principally the Rio Minho and Yallahs rivers. Other rocks, which might appear initially to be good resources of aggregates, are either deeply weathered or remote from the major centres of population. Annual aggregate production is around 4 million tonnes, made up approximately half from limestone and half from river sand and gravel. There is additional production of marl (a softer limestone) used for fill purposes.

The extraction of sand and gravel in Jamaica is directly from the active stream channel. Extraction from riverbanks, floodplains and older fluvial terrace deposits does not usually occur. The processing varies from a simple screen on an A-shaped frame to remove oversize particles, to processing plants in which coarse gravel is processed by crushing, washing and screening to make a range of products. Limestone is extracted mostly by ripping, blasting not commonly being used, and processed by crushing and screening to produce crushed rock aggregate.

The prices of aggregates in Jamaica, excluding transport costs, are similar throughout the country. River sand is a premium product, because of its relative scarcity. Further sand is made by crushing gravel and as a by-product of crushing limestone, when it is known as 'stone dust'.

River mining, Pakistan.

Limestone aggregate quarry, Jamaica.

River mining, Yallahs, Jamaica.

River aggregate processing plant, Jamaica.

Limestone aggregate production, Jamaica.

Illegal sand and gravel mining, Jamaica.

With few exceptions the mobile and fixed plant used in aggregate production in Jamaica are very old, breakdowns are frequent with consequent loss of production. Considerable overmanning and spare mobile plant capacity is one strategy used to overcome these problems. Finance is available through investment banks for renewal of plant, but the provision of extraction licences for only a short period of time (1–2 years) is a disincentive to re-finance and re-equip.

Production costs for aggregates in Jamaica are very low and a small-scale sand and gravel unit with simple processing is likely to be very profitable. Successful development of an aggregate operation which requires external finance for a new processing plant would, however, need a sustained market over a long period of time. If blasting is required to extract limestone aggregate, accompanied by repayment of capital on new plant, it is unlikely that a profit could be achieved at present sale prices.

Conclusions

- Aggregate supply is dictated by the geology but may be restricted by the lack of suitable materials near to the consumer or near the surface due to deep tropical weathering.
- Jamaica has enormous resources of limestone for crushed rock aggregate production and substantial resources of alluvial sand and gravel. Natural sand is a premium product and is often in short supply. It commands a higher price compared with gravel or limestone products.
- Reduction of instream mining of sand and gravel would have a severe effect on the supply and economics of aggregates in Jamaica, unless similar material was available from alternative sources.
- Aggregates need to be produced to acceptable quality standards. Although some standards exist in some developing countries, there is often little attention paid to them in the production of aggregates, and aggregate products, such as concrete blocks. The development and implementation of a building code that only allows aggregates which meet specifications to be used, would encourage the aggregate industry to adhere to quality standards. In addition, contracts for work should include requirements for regular testing of aggregates and specifications of quality.
- Aggregate production plants in developing countries are usually very old and there are frequent breakdowns. Investment in new plant is generally lacking. Overmanning is endemic, but it enables repairs to plant to be undertaken quickly.
- The provision of extraction licences only for short periods is a disincentive to the producers to re-finance and re-equip their activities, and to take a long-term view of their property. Long term licences and available finance at preferential rates of interest are important if aggregate producers are to modernise and be efficient.
- Illegal sand and gravel extraction is common, and the penalties provided in mining or environmental legislation preventing this activity may not be effective. If quality requirements were specified and maintained then the market for products from the illegal producers would be significantly reduced.

Sand and gravel resources

Purpose and scope

River channels are the principal source of sand and gravel in many developing countries. In Jamaica, aggregates are extracted directly from the channels of many of the major rivers, but little is known about deposit volume or geometry, size distribution of the material in the deposits, physical characteristics of the material or the volumes extracted in each river system. In order to determine the quantity and quality of sand and gravel available in the rivers chosen as trial sites for the River Mining Project, resource mapping studies were undertaken. The geological-geomorphological units in the lower Rio Minho and Yallahs fan-delta were divided into areas of relative suitability for aggregate exploration.

Overview of methods

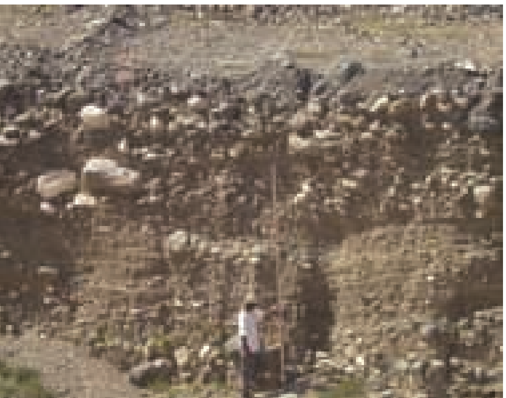
Stratigraphical and sedimentary features of sand and gravel deposits beneath the floodplain and river terraces were mapped and described from the mapping of geomorphological features and from the examination of natural outcrops and exposures at the many gravel pits in the river valleys. Several suites of aerial photographs were used to map major depositional landforms, to refine resource boundaries and to record river movements over time. Some subsurface information (well and borehole logs) was used to provide reconnaissance data on sediment composition and thickness. Samples for measurements of particle size and physical quality were collected from a series of vertical trenches dug by backhoe and taken at 52 localities in the lower Rio Minho. The survey methodology also aimed to review the scale of aggregate extraction in the Rio Minho and Yallahs rivers by mapping the depth and boundaries of extraction and by determining extraction rates. Estimates were then made of the volumes extracted in recent years.

Resources in the Rio Minho valley

Two principal levels of Quaternary alluvial sand and gravel-bearing deposits have been recognised in the lower Rio Minho valley: those forming the broad coastal plain, classified as the Second Terrace, and those related to the meander belt of the Rio Minho incised into the coastal plain and termed the First (floodplain) Terrace. In the more upstream areas, a third unit is recognised, termed the High Level Gravels. These are perched on the shoulder of the Rio Minho valley 20–25 m above the present floodplain, but are small and do not constitute a significant aggregate resource.

The First Terrace deposits mostly form a significant bluff feature, about 6–8 m above the active channel. Sections in the riverbanks and trial pits show around 2 m of silt overlying up to 3 m of sand and gravel. This is the classic fining upward sequence of a meandering river. The First Terrace deposits therefore form a major sand and gravel resource, adjacent to the river channel deposits. The Second

Coarse river gravels, Yallahs, Jamaica.



Undercutting of the Yallahs ford, Jamaica.

Heavily mined area, Yallahs, Jamaica.

River terrace sand and gravel, Rio Minho, Jamaica.

Digging terrace deposits, Rio Minho, Jamaica.

Simple processing of sand and gravel, Jamaica.

Terrace deposits occur at elevations up to 15 m above the floodplain and natural sections in these deposits, confirmed by trial pitting, show up to 15 m of silt and clay with subordinate sand beds. They are not considered to be a resource of sand and gravel.

Resource mapping has identified a series of river terrace deposits of varying potential. Large amounts of sand and gravel have been extracted from the Rio Minho and almost all extraction has been by instream (river channel) mining. Total production since 1980 when extraction started, is estimated to be about 5.25 million tonnes. Significant sand and gravel resources have been shown to be present within the First Terrace deposits and these should be considered as alternative resources of good quality sand and gravel.

Resources in the Yallahs River

The Yallahs River drains the southern flank of the Blue Mountains and the river sediments form a lobate fan-delta covering over 10 square kilometres. The delta sediments are composed of coarse sandy gravels, ranging in size from small pebbles and cobbles to large boulders 2 m in diameter. The sediments thicken rapidly downstream and are over 150 m thick near the coast. Coarse poorly sorted sand and gravel resources are inferred to be present throughout the fan-delta.

Large amounts of sand and gravel have been extracted from the fan-delta in recent years. It is estimated that about 4.4 million tonnes of aggregate have been produced since 1990. Extraction is concentrated in the main channel which is now incised up to 6 m below the level of the fan-delta surface.

Conclusions

A combination of walk-over geological surveys and studies of aerial photographs were used to produce aggregate resource maps, showing the distribution and relationships of the major sand and gravel bodies in the lower Rio Minho valley and Yallahs fan-delta. The maps form an essential starting point for planning the future supply of aggregates in Jamaica, particularly for sourcing supplies of fine aggregate (sand).

Large amounts of sand and gravel have been extracted from these rivers in recent years and almost all extraction has been by instream mining. Large resources of good quality sand and gravel have been shown to exist in adjacent river terrace deposits and these deposits should be considered as alternative resources for aggregate exploration. This is one of the principal alternatives to river mining and can lead to effective restoration to nature conservation, tourism or agriculture.

Alternative resources

In most countries aggregates are produced from the crushing and processing of hard rocks or from the digging and screening of unconsolidated deposits of sand and gravel. In Jamaica, there are two main sources of aggregates; sand and gravel from alluvial deposits, especially from the active river channels, and crushed limestone. River sand is often in short supply and is generally the only available source of natural fine aggregate, an essential component of concrete and other building products. There is particular concern about the environmental and social effects of in-stream sand and gravel mining and thus there is a need to know to what extent alternative materials can augment or replace natural sand and gravel from this source. In Jamaica, these alternative sources include marine sand and gravel, manufactured sand, river terrace deposits and recycled aggregates.

Marine sand and gravel

In many countries marine dredged sand and gravel make important contributions to aggregates supply. There is currently no production of marine aggregates in Jamaica but the environmental and social concerns of onshore extraction and pressures on land-based development require any marine sources to be seriously investigated.

The Yallahs fan-delta, which forms a major resource of sand and gravel onshore, extends offshore for a further 2 km. The onshore deposits are a thick, interbedded succession of coarse gravel and sand and it is likely that the sediments offshore are similar in lithology and thickness to the land-based deposits currently extracted at Yallahs. Offshore sands and gravels may, therefore, offer a realistic alternative to the onshore deposits at Yallahs and, currently, there is interest in dredging marine aggregates from off the mouth of the Yallahs River.

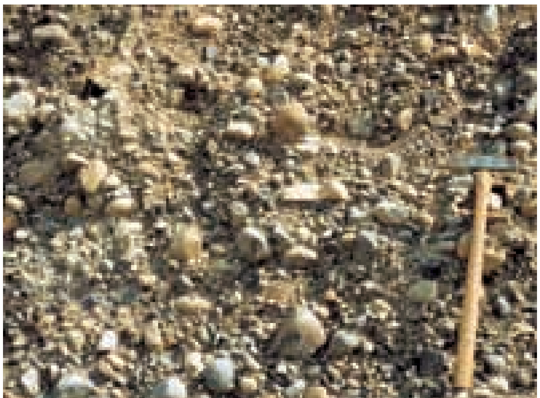
If adequate aggregate resources are proved, and if sufficient financial investment is available, then it is likely that extraction of marine aggregate resources at Yallahs will be viable, provided all environmental and development issues are identified and managed effectively.

Manufactured sand

Sand can be manufactured by the crushing and screening of solid rocks to produce fine-grained material known as 'manufactured sand' or 'crushed rock sand', and quarry fines are often sold as fine aggregate for the construction industry. Such materials are a major source of fine aggregate in many countries. In Jamaica, 'stone dust' is produced during limestone quarrying and is sold as 'sand' for use in concrete and asphalt. Manufactured sand is also produced by crushing river gravel at several of the larger river mining sites. Such crushed rock sands are largely at the limits, or fall outside the specifications of fine aggregates for concrete manufacture, and poor quality blocks and other products result. The grading and particle shape of the manufactured sand could be greatly improved by investment in new processing plant, such as 'Barmac' impactor rock crushers and washing plants.

Dredging marine sand and gravel.

River terrace deposits.



Working river terrace deposits, Jamaica.

Recycled aggregates.

Manufactured sand.

Yallahs fan-delta, Jamaica.

Jamaica has large resources of rocks that can be crushed to produce manufactured sand, but improvements in quarry crushing and processing plant is required to consistently produce manufactured sand of acceptable quality.

River terrace deposits

Substantial resources of sand and gravel are likely to occur within the fluvial terrace deposits of major river valleys. In many countries such alluvial deposits are the preferred source of sand and gravel aggregates as in-stream mining is restricted by environmental concerns and legislation. Resource mapping (see previous pages) of alluvial deposits in the lower Rio Minho and Yallahs fan-delta has shown that thick sequences of sand and gravel are developed beneath the agricultural lands bordering the active channels. These deposits are not currently worked for sand and gravel; extraction is largely restricted to the river channel deposits. Development of the terrace deposits in Jamaica will ease the pressure on in-stream mining, reducing the impacts arising from river extraction. Nevertheless, there are environmental and social impacts associated with the working of river terrace deposits and any extraction will need to be carefully managed, to prevent or reduce unacceptable impacts. If properly managed and controlled it can be less environmentally damaging and can lead to effective restoration to nature conservation, tourism or agriculture.

Secondary aggregates

Many mineral wastes fulfil the technical requirements to substitute for primary aggregates and many governments are now encouraging greater use of mineral wastes as aggregates. Concrete, bricks and asphalt, for example, may be crushed and screened to produce secondary aggregates that can be used in construction. Recycling concrete rubble not only reduces the environmental and social impacts of new aggregate production, but also avoids impacts associated with disposal. In Jamaica, the degree of recycling of mineral waste materials into secondary aggregates is currently very small, although some construction and demolition waste is used as fill.

The scope for secondary aggregates is often small in developing countries, as regeneration may not produce much useful material and development is mainly on new land.

Conclusions

In Jamaica there are large resources of river channel sand and gravel deposits and of limestone bedrock deposits. However, their extraction creates considerable environmental and social problems. There are several potential sources of alternative aggregate materials, the viability, benefit and impacts of which should be assessed in aggregate resource management plans to ensure that all possible sources are properly considered.

Environmental impacts

The extraction of sand and gravel from rivers in the absence of appropriate planning and management, can have significant physical and biological effects on the river and floodplain environment. The significance and extent of the environmental effects will depend upon a range of factors including the location of the extraction site, the nature of the sediments and the sediment budget, fluvial processes, flood risk, the design, method, rate, amount and intensity of extraction, and the sensitivity of habitats and assorted biodiversity, and other river users in the locality.

The River Mining Project has reviewed the potential impacts relating to in-stream extraction of sand and gravel and has carried out fieldwork to identify the significance of the potential impacts in the specific environmental context of Jamaica. The fieldwork included the identification of significant environmental impacts at all phases of development, positive as well as negative, direct, indirect, and cumulative, permanent and temporary as well as the identification of appropriate technical and strategic mitigation measures to address these impacts. Results are used in the development of a 'Code of Practice' that, if adopted, would assist in the prevention or mitigation of the major environmental impacts of river mining activities in Jamaica and elsewhere.

Environmental impact assessment (EIA)

To enable the organisations responsible for authorising extraction to evaluate the nature and scale of the effects and in order to decide whether a proposal can proceed, it is necessary that an adequate assessment of the environmental effects be carried out.

A typical EIA will include the following stages:

- initial environmental evaluation and screening to determine if a formal EIA is required
- definition of environmental issues (the scope of the EIA)
- identification of potential impacts
- assessment of impacts
- prediction of impacts
- identification of mitigation or compensation measures and monitoring requirements
- consideration of residual impacts and overall conclusions (whether it is acceptable)
- monitoring
- auditing and review.

Within the context of the River Mining Project the first four stages were undertaken by desktop review and via direct observations and interviews in Jamaica. The final four stages are represented by the Code of Practice developed during the project. A formal EIA for the field study sites in Jamaica is outside the scope of the project's objectives.

Illegal sand and gravel mining, Jamaica.

Asphalt plant, Jamaica.

Unrestored workings, Yallahs, Jamaica.

Scour hollows in riverbed, Rio Minho, Jamaica.

Yallahs ford, (2001), Jamaica.

Bailey Bridge, Yallahs, (2002), after flood damage.

Impact review

The principal activities that comprise the process of river mining are:

- extraction of raw material (including overburden and waste)
- processing (including screening, crushing and washing)
- transport (including products and wastes).

This categorisation is a useful means of breaking the overall river mining lifecycle into smaller parts that aid the assessment of environmental impacts, and their causes. In addition, there are three major environmental impact groups:

- physical impacts
- water impacts
- biological impacts (including ecosystem health).

This approach, describing impacts according to the three principal activities and the three impact groups, has been used to categorise the environmental impacts and their sources. Social impacts are closely interlinked and are an integral part of impact assessment (see below). Details of the review of the potential impacts of river mining are given in the accompanying Project Technical Report (Macfarlane and Mitchell, 2003). In some cases, restoration of the river environment (bank structure, river bed floodplain) is recommended or is undertaken and this is an additional activity that follows from consideration of the environmental and other consequences of mining activity.

Field studies in Jamaica

Site visits were made to the areas affected by river mining operations in the Yallahs fan-delta and in the lower Rio Minho river basin. Interviews were held with both local stakeholders and strategic project stakeholders in Kingston.

Details of the causes and effects of environmental (and social) impacts seen firsthand and inferred from interviews are given in the Technical Report. However, the most important environmental impacts are considered to be:

- physical: dust arising from extraction and processing, riverbank erosion, shifting of river course, flooding and damage to infrastructure such as roads and bridges
- water: contamination with suspended solids and flooding.

Biological and ecological impacts are detailed in the next section.

Conclusions

As might be expected, the two principal impacts of river mining activities are physical and aquatic — the remaining impacts are largely secondary ones that arise from these impacts. Ultimately, the ability of mine operators and government agencies to identify, generate, implement and enforce appropriate technical and strategic mitigation and enhancement measures will be affected by a number of factors. The critical factors observed include; the legal status of the mine operators; regulatory development and synthesis; government agency co-ordination; agency funding and corruption. These interrelated factors are in no way unique to the Jamaican context and are typical of the mining sector and regulatory environment of many developing countries. However, Jamaica's present legislative framework is relatively comprehensive overall and it is weakness with regard to information availability, implementation of controls, monitoring and enforcement that remain the overriding concerns.

Ecological impacts

Sand and gravel extraction in rivers will impact on the aquatic ecosystem and it is important to understand the disturbance resulting from such activity which may lead directly to impacts on organisms and indirectly to impacts on their habitat.

The effects of sand and gravel mining activity at the trial sites (the rivers Yallahs and Rio Minho) in Jamaica were investigated using indices of biological diversity obtained by biological monitoring of each river. Four points were sampled for biological assessment along the Yallahs river and seven along the Rio Minho; sites were selected upstream and downstream of mining activity. The aim of the biological assessment was to indicate general changes in biodiversity at each locality (ie. to indicate which taxonomic groups/families/species were missing downstream, compared to the upstream locations).

Materials and methods

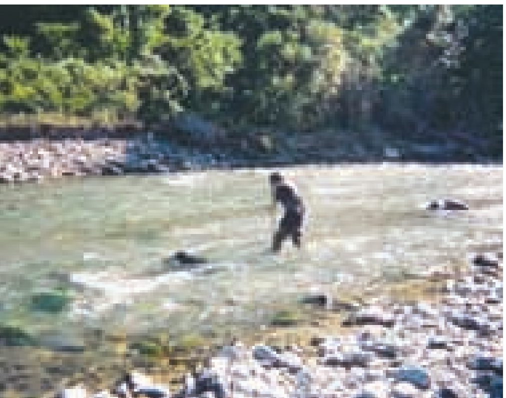
In order to determine the chemistry of the river waters, samples of water were collected at each site and analysed for selected heavy metals (copper, zinc, arsenic, cadmium and lead) and for other contaminants such as organic compounds. Samples of the benthic fauna at each site were taken with a standard long-handled pond-net using a standard three-minute kick sample procedure. Specimens from three searches were pooled and stored in water-filled containers prior to sorting and preserving in alcohol. Samples were then separated into their representative taxonomic groups and identified. A range of biodiversity measurements, or indices were then calculated for each of the samples from each river system. These biodiversity statistics were used to assess species richness or diversity within or between samples.

Results

The chemical data suggest that there is little elevation of heavy metals at any of the sites investigated and polycyclic aromatic hydrocarbons (PAHs) or polychlorinated biphenyls (PCBs) were not found. This shows that river mining at these sites has not resulted in any contamination of the river waters, due to disturbance of bottom sediments or pollution during extraction.

There is, however, considerable biological diversity between the sampled sites in the two rivers. The Rio Minho is meandering and depositional in nature and has a far greater biodiversity and abundance than the Yallahs, which is a much faster-flowing braided river. In the Rio Minho, large-scale sand and gravel extraction coincides with an observed decline in biodiversity. The Yallahs river also shows higher diversity and higher total individual species numbers at the sites upstream of river channel extraction, compared to the sites in the heavily excavated delta. Statistical analysis of the results is, however,

Biological sampling, Yallahs River.



Biological sampling, Rio Minho.

Rio Minho near WaterLane, Jamaica.

Rio Minho south of Maypen, Jamaica.

Rio Minho north of Maypen, Jamaica.

Sampling on the Yallahs River.

problematic, due to the changing nature of the river, the intermittent effect of mining activities and the short term and limited nature of this study.

Conclusions

The limited findings from this research show major disturbances to the overall biodiversity of the benthic macroinvertebrate fauna at both Jamaican rivers as one moves downstream along the watercourses sampled. The greatest change in faunal assemblage occurs in the immediate vicinity and immediately downstream of sand and gravel mining operations. Biological recovery from these activities is likely to be slow following the removal of the riverbed which results in massive habitat loss for the benthic fauna. It is anticipated that recolonisation of these habitats will be slow, resulting in areas of lowered biodiversity.

Further longer term studies, more data collection and enhanced dialogue with both stakeholders and decision makers are needed to demonstrate the extent and longer term aquatic impacts of river mining activities.

Impacts of river mining and processing, Rio Minho, Jamaica.

Social impacts

It is recognised that sand and gravel extraction from rivers may cause significant harm to the environment. What is not as widely understood is the effect river mining may have on communities and river users in the locality. Social impact assessment (SIA) complements the environmental impact assessment (EIA) process and is used to promote such understanding. In recent years, recognition of the potential of SIA to contribute to the planning of mining projects has grown considerably. This has been reinforced by the mounting social activism of affected communities and pressure from other key stakeholders such as government, employees and NGOs. As a result many countries now require EIAs to address social issues, and impact assessments are now commonly integrated, bringing together environmental and social issues.

Their respective approaches are sometimes difficult to combine, as data collection methods, stakeholder groups and assessment time frames often differ. Within this project, however, separate (but overlapping) environmental and social impact assessments were conducted at the same time, using the same sites and through interviews with identical stakeholder groups, because to a large extent, social impacts result directly or indirectly from impacts of river mining on the environment. Analysis of environmental and social issues has therefore been combined in the Technical Report (Macfarlane and Mitchell, 2003).

SIA and social impacts

The SIA process is designed to inform project planning, decision-making and ongoing management. At the most fundamental level, the SIA process can provide direction in:

- identifying social impacts
- projecting and predicting social impacts
- mitigating negative social impacts, and
- enhancing positive social impacts.

Social impacts may be positive or negative in nature. For example, activities or policies that enhance quality-of-life and that make people feel better about themselves and where they live have a positive impact. In contrast, activities or policies that debilitate the vitality of a community, or make people feel worse about themselves and where they live, have a negative impact.

There are four principal social 'impact groups':

- socio-health impacts
- socio-cultural impacts
- socio-economic impacts
- socio-livelihood impacts.

Illegal extraction of sand and gravel, Jamaica.

River mining, Yallahs, Jamaica.

Limestone quarrying, Jamaica.

Water for drinking and washing, Rio Minho.

Washing clothes, Rio Minho.

Sand and gravel pit, Rio Minho.

Many impacts are secondary impacts that arise from impacts on the physical and water environment. However, others are a hybrid of environmental, social and economic parameters that can improve social conditions (such as income and local revenue generation) or can reduce it (such as loss of access to clean water).

The key potential social impacts of river mining are documented in detail in the accompanying Technical Report.

Field studies in Jamaica

The assessment of social impacts at the local level involved investigating the impacts of river mining activity (in the Yallahs fan-delta and lower Rio Minho river basin) and the response of affected stakeholders, including quarry managers and their employees, local residents, health and police officials, council officials, customers, suppliers and local businesses. In addition, an assessment at the strategic level, was obtained through semi-structured interviews with strategic project stakeholders in Kingston, including representatives of the Water Resources Authority, the National Environment and Planning Agency, the Mines and Geology Division, the Quarry Advisory Committee, the National Works Agency and the Department of Tourism.

Details of the causes and effects of social impacts seen firsthand and inferred from interviews are given in the Technical Report. However, the most important impacts are considered to be:

- socio-health — worker, vehicle and pedestrian accidents
- socio-cultural — corruption, political collusion
- socio-economic — negative–road congestion, road degradation, bridge failure; positive - enhanced services, employment and infrastructure
- socio-livelihoods — reduced fishing stocks, loss of land.

Conclusions

Management of sand and gravel resources in a more sustainable way should ensure that any extraction minimises the adverse effects on the physical and water environment and local community. The production of an 'Environmental/Social Statement', developed along the lines suggested in the accompanying Technical Report and formulated into the project's Code of Practice, should provide a basis for determining the potential effects of river mining and identifying possible mitigating measures.

There will be cases where the social and biophysical environment are too sensitive to disturbance to justify the extraction of aggregate, and unless the environmental and social issues can be satisfactorily resolved, extraction should not normally be allowed. However, the extent to which environmental and social impacts are acceptable is, relative, and in part depends on the wealth of the country. In less economically developed countries there may be less funding and little political will available to address such impacts.

Planning guidelines

It is important to ensure an effective and consistent supply of aggregates to meet the needs of developing economies in order to support economic activity and the level of investment in the physical infrastructure, utilities and buildings required to raise living standards. At the same time it is equally essential to ensure that the provision of such minerals does not result in undue environmental or social degradation, such that harm to the population or the environment outweighs benefits derived from such development. The proper control of the environmental and other effects of river mining and other quarrying activity is important in achieving improvements in living standards and quality of life.

The River Mining Project examined the regulatory infrastructure controlling the effects of sand and gravel mining in Jamaica with the aim of establishing guidelines for managing these natural resources and developing a Code of Practice for a more sustainable approach to river mining. Although the study looks in detail at practice in Jamaica it also seeks to establish principles that can be more widely applied.

The most appropriate forms of regulation are those that allow the operators of mines and quarries to invest in operations on a reasonably secure basis, to put in place proper operational and environmental infrastructure, and over a period of time that reflects the ability to make a reasonable return on the investment. This generally means granting permits or licences for longer periods, but equally means that the level of control exercised by the regulators needs to be carefully considered and individual sites monitored, with effective enforcement of permit or licence conditions to prevent or, when it fails, to remedy harm to the environment. It is clear that at present in Jamaica, in spite of very clear efforts to do so by some highly motivated staff, neither of these basic requirements are met. The project considers some of the basic measures that will enable progress towards this objective to be made.

Policy and administration

In order to achieve adequate control of river mining the basic requirement of a system of control needs to be in place. These include:

- an effective legislative framework that allows the exercise of control over river mining and other forms of quarrying activities
- an administrative structure that gives clear responsibility and authority to the respective agencies involved in such regulation
- well informed policies and proposals for the development and control of river mining and other forms of land use as part of an integrated approach to land use and the environment
- a shared commitment to the effective operation of the system by government, industry and other stakeholders.

Damage to bridge structures, Jamaica.

Rivers and eco-tourism.

Visual impact of limestone quarrying, Jamaica.

Communities maybe affected by river mining.

Unlicensed (illegal) river mining, Jamaica.

Mountain and coastal terrain, Jamaica.

Planning and land use

Effective control of river mining and other forms of quarrying should be based on a planning system that provides:

- a clear and consistent form of forward planning, reconciling policies and proposals for the existing and future use of land determined with reference to carefully considered social, economic and environmental priorities and objectives
- a system of licensing or permitting that requires a consistent level of information to be provided prior to individual decisions on applications to mine or quarry, measured against the policies and proposals set out in the forward planning context. To help with this process a typical licence application is recommended in the accompanying Technical Report (Fidgett, 2003) that helps indicate a level of information that is the minimum reasonably necessary to help assess an individual application to develop a sand and gravel quarry
- a commitment to effective monitoring and enforcement that is adequately resourced and based on clear information on licence/permit requirements and on the occurrence of illegal mining or of activity inconsistent with a licence or permit.

Technical solutions to river mining activities

In addition to the policy and legislative framework that will help shape the future pattern of mining activity, actions on the ground that help address the environmental and social impacts of river mining can be broken down into:

- proactive technical solutions — these deal with the determination of the best practicable means of undertaking the extraction, processing and restoration of mining or quarrying operations and are focused at the planning stage, prior to the granting of a licence or permit
- reactive technical solutions — these deal with the determination of the best practicable means of mitigating existing quarrying operations, addressing extraction, processing and restoration. They are focused at the operational stage and during the review or reissue of any licence or permit.

These factors have been used in framing the recommendations of this research which are given in detail in the accompanying Technical Report. At each stage of activity affecting the control of river mining an awareness and understanding of the environmental, social and economic effects is essential.

At a practical level, to support this approach, the research work has led to the development of a Code of Practice that is intended as a guide to each of the potential practical issues raised by river mining, summarising its key characteristics and setting an objective and performance indicator to help guide the actions of both quarry operators and regulators on the ground.

Code of Practice

In order to promote the sound management of river sand and gravel resources and to ensure that the mining industry operates in harmony with other users of the river and adjacent lands a Code of Practice for sustainable river mining has been developed. These guidelines are intended to provide a flexible framework that any country can adopt within its own regulatory system.

The Code of Practice (Macfarlane and Mitchell, 2003; Fidgett, 2003) takes the assessment of environmental and social issues identified in the accompanying technical reports, summarises the key characteristics of each potential issue raised by river mining activities, sets an objective and a series of performance indicators to help guide the actions of both quarry operators and regulators on the ground. It is intended to be of practical application to both existing situations, where quarries exist already, and in the planning and consideration of proposals for either new quarry operations or the renewal or extension of existing operations. The Code of Practice is not set in stone and forms a basis that can be adapted and used in different circumstances over time. It is, however, intended as a starting point for the consideration of a range of issues affecting the environmental effects and future of river mining.

The recommended mitigation and enhancement measures within the Code of Practice are based on the results of literature review and observation of best practice in river mining and the mining industry generally. The result is an issue led systematised Code of Practice for the mitigation and enhancement of the respective negative and positive impacts of river mining.

A total of 26 key issues are categorised according to the type of river mining activity they are associated with, and the impact group they belong to. The intervention level for each issue is defined as either principally strategic (policy level) or technical (operational level) and best practice mitigation or enhancement measures are suggested. Full details are given in the accompanying technical reports (Macfarlane and Mitchell, 2003; Fidgett, 2003).

Key Issues

The 26 key issues of river mining activity covered in the Code of Practice are:

1. Physical contamination — avoidance of impacts on river quality
2. Chemical contamination — avoidance of contamination of the water environment
3. Water supply — avoidance of loss or reduction of water resources
4. Boreholes — prevention of groundwater depression
5. Release of wastes — prevention of the release of polluting wastes
6. Flooding — avoidance of flooding, reduction of flood risk
7. Waste management — minimise waste production, responsible waste disposal
8. Dust — dust control and reduction
9. Fumes — minimise impacts of vehicle fumes
10. Noise — minimise noise and vibration
11. Incision — minimise incision of the river channel

Sand processing, Rio Minho, Jamaica.

New Bailey Bridge, following flood damage, Jamaica.

River mining, WaterLane, Rio Minho, Jamaica.

Avoid riverbank erosion.

Minimise channel erosion.

Avoid loss of agricultural land.

12. Bank erosion — prevention of erosion of the river bank
13. Livestock — minimise loss of livestock during mining operations
14. Cultivated land — avoidance of loss of agricultural land
15. Fishing stock — avoidance of adverse impacts on river ecology
16. Employment displacement — avoidance of displacement of economic activity
17. Housing — avoidance of adverse impacts on housing and housing land
18. Sustainable transport — minimise impacts of traffic
19. Workplace accidents — minimise worker accidents
20. Plant and buildings — avoidance of poorly maintained, dangerous sites
21. External appearance — avoidance of obtrusive operations
22. Natural resources — avoidance of harm to important nature or environment
23. Restoration and after-use — promote land restoration to beneficial after-use
24. Community liaison — promote effective dialogue between operators and communities
25. Quarry plans — provision of quarry plans for effective resource development
26. License/permit — avoidance of illegal operations, full compliance with license conditions

The Code of Practice provides step-by-step guidance on how river mining should be conducted in order to minimise conflicts with other river and land users and optimise the use of natural resources. These guidelines are also intended to provide a basis for assessment to help ensure that sufficient information is produced to enable an EIA/SIA to be carried out, and within a strategic framework which provides a system for examining and reconciling the conflicting claims on land and river.

Example from Code of Practice

Issue Number:23
Objective: **Restoration and after-use** — to ensure that the land is restored to an appropriate condition that enables its beneficial after-use.

Performance indicator:
Is restoration proceeding according to the operational plan and the requirements of the planning permission?·
Has an after care scheme been prepared and submitted to the government where appropriate?·
Where appropriate, is the restoration phased with the mineral extraction?
Are topsoils, subsoils and overburden stored separately?
Have soils been handled only when in a dry and friable condition?
Have recommended machinery and soil handling methods to minimise solid compaction been followed in solid stripping, storage and placement operations?
Does the restored area appear cared for and well managed?
Has action been taken to deal with problems of discolouration, dieback, waster-logging or settlement in the restored areas?
Are detailed restoration and farming management records being maintained?
Has land drainage been installed where appropriate?
Has tree and hedge planting been undertaken?
Have conservation areas been developed?
Does restoration blend with the surrounding landscape and land uses?
Have the banks of any restored lakes and/or of the river channel been designed and protected against water erosion?

Relevant activity or location: Extraction and closure

Impact group: Physical, quality of life, livelihoods, economic

Issue description:
Visual impact of river mining and the associated plant, equipment, physical disturbance and quarry areas can be significant and degrade the landscape or visual quality of significant areas, an issue important to quality of life and tourism. This often combines with noise or dust to create a significant overall impact.

Intervention level: Policy, planning & land use and technical.

Minimum acceptable standard: Provision of land restoration to beneficial after-use.

Best practice guidance: Operations should be planned with restoration and after-use in mind. This can be to ensure the continued integrity of the river and its channel or where working involves the floodplain for the plant site or for mining or quarrying can be for agriculture, tourism, lakes, fishing or nature conservation/wildlife. Where working is of the river terrace, operations should follow the quarry plan and be in phases so that progressive restoration of worked out areas can take place. Where working the floodplain, soils should be removed carefully before sand and gravel is extracted and the soil should be stored in earth bunds or mounds for reuse in restoration. Soils can form useful screen bunds to help visually screen mining operations. As part of restoration soils should be replaced where restoration is dry (i.e. above the groundwater level) or can form gently graded margins to lakes where extraction is below the water level. The aim should be to provide an ongoing use for the land or for the long term integrity of the river, once mining has ceased.

Conclusion

In many countries sand and gravel from mining river channels makes an important contribution to the national demand for aggregates. A reduction of instream mining could therefore potentially have a severe effect on the supply and economics of aggregates unless similar material is available from alternative sources. Therefore, the suitability and economic viability of alternatives must be carefully examined, along with an assessment of the environmental, biological and social impacts associated with their production.

Instream mining reduces the pressure to work floodplain deposits of sand and gravel and avoids conflicts of land use (eg agriculture and housing). Other benefits include local production of aggregates and reduction in long distance road transportation from more remote deposits. However, these benefits need to be balanced against the negative impacts of river mining, which may be severe. Aggregate extraction from river channels, if not carefully controlled, can cause significant damage to the river and its associated biota, and to the adjacent land, as well creating conflict with other users of the river. There will be cases where the social and biophysical environment are too sensitive to disturbance to justify the extraction of aggregate and unless these issues can be satisfactorily resolved, extraction should not normally be allowed.

A consideration of all factors associated with river mining has resulted in the development of a methodology for effective control of sand and gravel mining operations. Although this has been developed on field data from Jamaica and Costa Rica, it is intended to be applicable to developing countries worldwide.

As a general guide, it is likely that the following topics considered below will need to be addressed.

Description of the physical setting

The proposed extraction area will display a number of inherent and pre-existing characteristics that will influence sand and gravel extraction, including:

- location and topography
- extent and volume of the deposit and overburden
- sites available for waste disposal
- sediment type and particle size distribution
- source of the material and sediment budget
- average rainfall/storm frequency
- flood risk
- river stability and sediment dynamics.

Penas Blancos, Costa Rica.

River mining site, Rio Minho, Jamaica.

Offshore Yallahs delta, Jamaica.

River mining, Rio Minho, Jamaica.

Processing plant, Rio Minho, Jamaica.

Water spraying to reduce dust, Rio Minho, Jamaica.

Description of river mining activities

In general terms, river mining consists of three major activities: extraction, processing and transport. The assessment of these activities should include information on:

- total volume to be extracted, expected lifetime of the resource
- opportunities/constraints to site expansion
- proposed maximum annual extraction rates
- extraction and processing methods
- age, reliability and suitability of equipment/plant used
- transport planning and routing, number of trucks, truck loading controls
- restoration plans
- project-related employment.

Information required for physical impact assessment

To assess the physical impacts, the following should be considered:

- predicted changes to the river bed and river bank topography
- implications of extraction for changes to sediment supply and transport
- exposure of different substrates
- transport and settlement of fine sediment disturbed by aggregate extraction
- effects on water quality
- time scale for recovery of the river.

Information required for biological impact assessment

The potential for biological impacts will vary according to the nature of the habitat and the varying effects of river mining activities, in particular those arising directly or indirectly from extraction and processing. To assess ecological impacts, the following should be considered:

- changes to the benthic community structure
- habitat sensitivity
- effects on fishery resources, including spawning areas
- effects on flora and fauna including birds and mammals
- effects on any sites designated under local, national or international regulation
- predicted rate and mode of recolonisation by flora and fauna.

Interference with users of the river and adjacent lands

The indirect effects of river mining are less well recognised than the more obvious physical and environmental impacts, which are typically their source. The assessment should consider the following:

- adjacent agricultural land
- road and bridge structures, including river-based and transport-based degradation
- local communities use of river waters (fresh water, washing etc)
- recreational uses
- location in relation to existing or proposed aggregate extraction areas
- potential for nuisance from windblown dusts
- potential conflicting uses of local roads and access.

Mitigation measures

Ultimately, the ability of mine operators and government agencies to identify, generate, implement and enforce appropriate technical and strategic mitigation and enhancement measures will be affected by a number of factors, including the legal status of the mine operators; regulatory development and synthesis; government agency co-ordination; agency funding and corruption. Within this overall context, the assessment should include consideration of the steps that might be taken to mitigate the effects of river mining activity. These may include:

- modification of the depth and design of extraction operations to limit changes to hydrodynamics, sediment transport, incision and risk of flooding
- zoning of the area to protect sensitive fisheries, species or habitats
- consideration of alternative resources
- planning for prevention of impacts as a priority
- use of settlement ponds to control impacts arising from the release of sediments
- watering of roads and use of screening vegetation to reduce windblown dusts.

Extraction licence

From a producer's perspective, the provision of short-term extraction licences is a disincentive when considering re-financing and re-equipping their activities, and does not encourage them to take a long-term view of their property. Long-term licences and finance at preferential rates of interest are important if aggregate producers are to modernise (and also integrate environmental restoration into their operational strategy). From a regulatory and community perspective, authorisation conditions should be drafted in plain and unambiguous language to ensure that:

- material is only extracted from within the licensed site
- mitigation requirements are complied with
- monitoring requirements are fulfilled
- company employees are familiar with all relevant provisions
- conflicts with other local and regional land use requirements are minimised
- conditions for termination of authorisation are clearly demarcated.

Penas Blancos, Costa Rica.

River mining, Yallahs River, Jamaica.

Yallahs River, Jamaica.

Project outputs

Geology and sand and gravel resources of the lower Rio Minho valley and Yallahs fan-delta, Jamaica. Farrant, A R, Mathers, S J and Harrison, D J, 2003. BGS Commissioned Report CR/03/161N.

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Dissemination workshops

1. San Jose, Costa Rica, 8–9 December, 2003.
2. Kingston, Jamaica, 10–11 December, 2003.
3. Southern Africa, January, 2004.
4. Tirana, Albania, 29–30, March, 2004
5. Sri Lanka, September, 2004.

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