Manufactured Sand Potential and Status in Karnataka

Center for Study of Science Technology and Policy
Bangalore

Manufactured Sand Potential and Status in Karnataka

P. Shyam Sunder
Jai Asundi

Center for Study of Science Technology and Policy
Bangalore

Center for Study of Science, Technology and Policy (CSTEP) is a private, not-for-profit (Section 25) Research Corporation registered in 2005.

Designing and Editing by CSTEP

Cover Image Courtesy: www.shutterstock.com

This report should be cited as: Shyam Sunder, P., and Asundi, J.(2015). *Manufactured Sand Potential and Status in Karnataka*, (CSTEP-Report-2015-02).

April, 2015

Center for Study of Science, Technology and Policy

18, 10th Cross, Mayura Street,

Papanna Layout, Nagashettyhalli, RMV II Stage,

Bangalore-560094 Karnataka, INDIA

Tel.: +91 (80) 6690-2500

Fax: +91 (80) 2351-4269

Email: cpe@cstep.in

Website: www.cstep.in

Acknowledgements

The authors would like to thank Shri. Tushar Girinath, Secretary, Ministry of Mines and Geology, Government of Karnataka for giving us an opportunity to take up this study. Mr. Harish and his team of geologists and other experts from the Ministry provided their support, suggestions and vital information. The authors also appreciate the efforts of the field executives for the site verification exercise.

At CSTEP, Pareexit Chauhan, GIS Analyst conducted the GIS analysis. Advisors Shri S.V. Ranganath (Retd. IAS), Dr. V.S. Chandrasekaran, and Dr. Ramakrishnan N. provided valuable insights, comments and guidance to our study. We thank Nihit Goyal, Research Scientist for his assistance in structuring the report and providing critiques and suggestions for improving the analysis.

The personnel at *Robo Silicon Pvt. Ltd.* and *M/s Mines and Rocks* provided useful information regarding the manufacture of sand that has provided clarity for the study.

Executive Summary

Sand is an essential element in concrete and hence plays an important part in the construction and infrastructure industry in a modern economy. Sand is used primarily in concrete and is typically sourced from riverbeds, which are located in ecologically sensitive areas. Hence excessive mining leads to the degradation of riverbeds, which affects the local groundwater system, potential biodiversity and the recreational potential of these places.

Karnataka officially produces 9 Million Tonnes (Mt) of sand per year, and a large part of this quantity is currently sourced from riverbed mining. Some sand is also imported from neighbouring states. This study estimates the current demand for sand in Karnataka to be 26 Mt (in 2014) and the future demand to grow between 56 and 81 Mt per year. Due to the high demand for sand (as compared to supply), the state has observed high sand prices leading to an increase in construction costs and a slowdown in infrastructure development. The high demand for sand has also led to environmental concerns, hence there is a need to reduce dependency of riverbed sand. Thus, a search for alternate materials such as sand made by crushing sedimentary rocks can be considered as a viable alternative to meet the demand. Crushed-stone sand or 'manufactured sand' is produced by crushing rocks to a grade comparable to that of natural sand. The current production and use of manufactured sand is estimated to be 3Mt/year.

This study examined the potential for manufacturing sand from existing mines with expired leases, existing mines given area extensions as well as unexploited open rock formations (using satellite maps and GIS). After excluding ecologically sensitive areas and areas close to human built environments, the study estimates that there are adequate rock resources available to meet the growing demand for sand.

Based on superior technical performance and availability of manufactured sand, the following recommendations are proposed:

i. Publicise and promote manufactured sand by highlighting the salient features from the Indian Institute of Science (IISc) study on the properties of manufactured sand.
ii. Mandate the use of manufactured sand by the Public Works Department (PWD), Irrigation Department, and Urban and Rural Development Departments.
iii. Revisit the existing tendered quarries to encourage the production of manufactured sand.
iv. Identify and demarcate zones for new stone quarries and crushing areas before auctioning and leasing parcels. Provide access and associated infrastructure such as roads, electricity, etc. to these zones.
v. Provide structural and financial incentives for stone crushers to engage in the production of manufactured sand.
vi. As a the long-term plan, the Government should explore the potential of utilising building debris or new building materials to produce sand and adopt innovative architecture.

The Government, through its forward looking policies, can make a significant impact in creating a "re-use, recycle and reduce" based ecologically conscious and environmentally sustainable society.

Table of Contents

List of Figures

List of Tables

1. Introduction

Sand is an essential element in concrete and hence plays an important part in the construction and infrastructure industry in a modern economy. It is an abundantly available mineral, classified based on physical appearance (by size) and physical texture [1]. Sand is also used in metal casting, reclamation of land and other civil and military applications. Different applications require different types of sand, which is typically sourced from riverbeds and sea shores. These sources are usually located in ecologically sensitive areas. Hence excessive mining leads to the degradation of riverbeds, and affects the local groundwater system, potential biodiversity and recreational potential of these places [2].

Karnataka officially produces 9 Million tonnes (Mt) per year. A majority of this quantity is currently sourced from riverbed mining. The total demand for sand in Karnataka was estimated to be approximately 26 Mt as of 2014 [3]. Due to the high demand of sand (as compared to supply), the state has observed an escalation of sand prices [4] [5] as well as proliferation of unauthorised sand mining, which has been difficult to monitor. Some sand is also imported from neighbouring states such as Tamil Nadu. The cost of sand factors in transportation distance. This has led to an increase in construction costs and a slowdown in infrastructure development[3].

The construction sector in India contributes to over 7% of the GDP [6] and it is estimated that more than 70% of India's infrastructure (for 2030) is yet to be built [7]. An increasing urban population will drive the demand for newly built environments, and hence for sand as part of concrete, in the coming years. Low availability of sand is driving the examination of alternate materials, which have similar characteristics, for use in construction-related applications. Sand made from crushing sedimentary rocks is perceived as one such alternative. Crushed-stone sand or 'manufactured sand' is produced by crushing rocks to a grade comparable to natural sand. The properties of sand from crushed rock is said to be similar (or often better) to riverbed sand. The current production and use of manufactured sand is estimated to be approximately 3 Mt.

This study examined the potential and scope for manufacturing sand in Karnataka and its role in meeting the demand for sand till 2030. The methodology used for this study includes:

1. Use of analytical models to estimate the increase in demand for sand till 2030.
2. Examine the potential of existing locations for sand manufacture.
3. Use Geographic Information Systems (GIS) and satellite maps to identify new potential areas for supply.
4. Engage in expert consultations to validate the assumptions used in analytical models and gain insights for policy recommendations.

The following section calculates the estimated demand and supply for sand in Karnataka. Section 3 describes the production process of manufactured sand and the technical viability of the same. Section 4 explores the plausible locations for rock mining for sand production and estimated quantities. The report concludes with policy recommendations based on the findings of this study.

2. Demand and Supply of Sand in Karnataka

A. Demand for Sand in Karnataka

The demand for sand in Karnataka is estimated based on its primary use in concrete. According to technical specifications, concrete is a mixture of cement, sand and aggregates mixed in a ratio of 1:2:4 (respectively) by weight [8][1].Every tonne of cement used requires two tonnes of sand in a concrete mixture. Estimating the consumption of cement in the state is the first step towards calculating the demand for sand.

India's cement production (and consumption) in 2012 was observed to be 248 Mt, and the per capita cement consumption in India in in the same year was about 202 kg [9]. Assuming a growth rate of 7.7%, the national cement production in 2014 is estimated to be 287 Mt. Assuming a similar (to national average) per capita consumption of cement in Karnataka, the consumption of cement is estimated to be 13 Mt in 2014. Using the standard sand to cement ratio in concrete (cement:sand=1:2) to estimate the quantity of sand required, the total demand for sand in 2014 is estimated to be 26 Mt[2].

Assuming that the consumption of cement grows similar to the Gross State Domestic Product (GSDP), which will be between 5.02% and 7.5% per year [10] for the next few years, the estimated demand for sand will grow between 56 Mt and 81 Mt till 2030.(Figure 1)

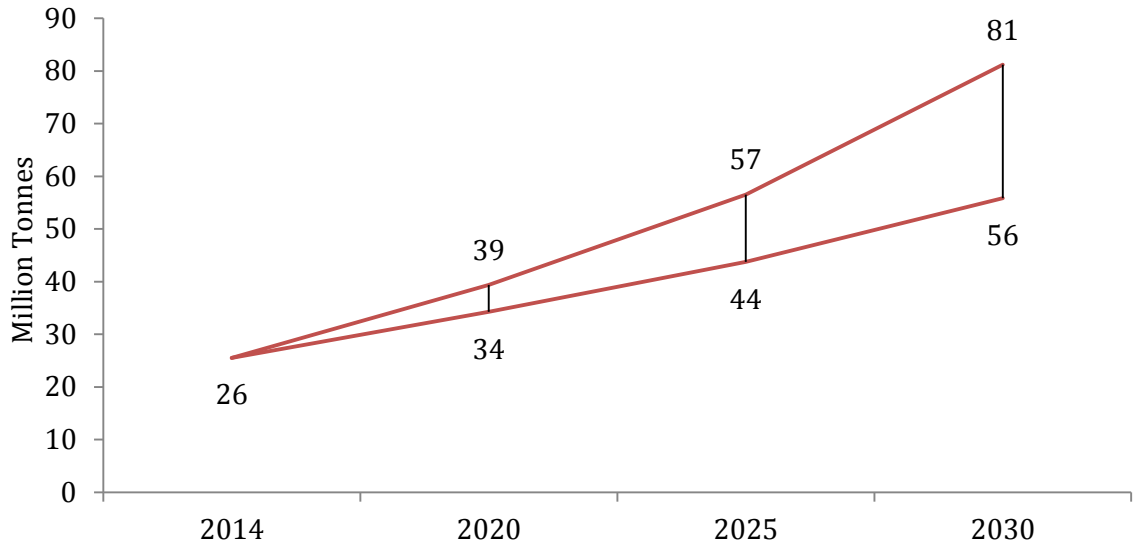

Figure 1: Sand Demand Estimate up to 2030 (in Mt)

Thus, the cumulative sand requirement in Karnataka till 2030 will be between 661 Mt to 823 Mt depending on the growth in demand for sand in the next few years.

The current patterns of urbanisation and population density suggest that the demand for sand from Bangalore, Belgaum, Mysore, Tumkur and Gulbarga will be relatively higher than other

[1]The brick masonry and plastering aggregate mix ratio is about 1:4 or 1:6. The overall, sand requirement in plastering is significantly lower than that required when used in concrete.
[2]Other estimates claim that the total sand demand is 23-26 Mt

districts in the next few years. Figure 2 spatially illustrates the estimated demand for sand in 2014 based on the population in the various districts.

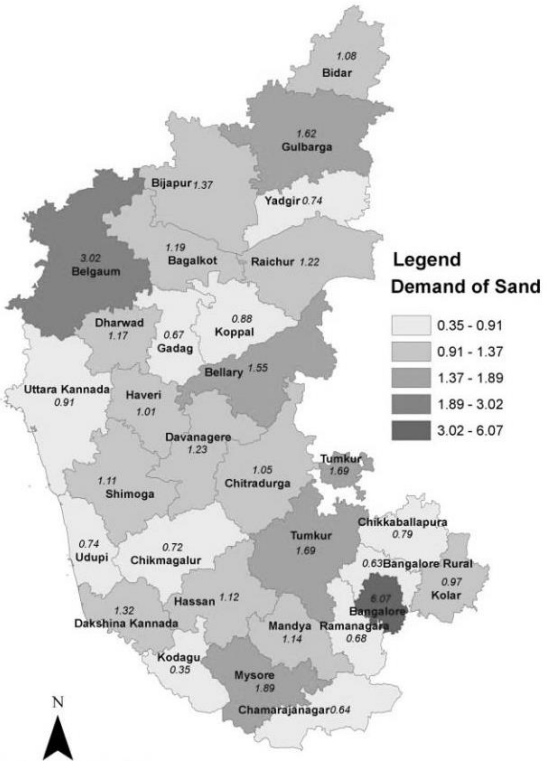

Figure 2: District-wise Demand for Sand (Mt)

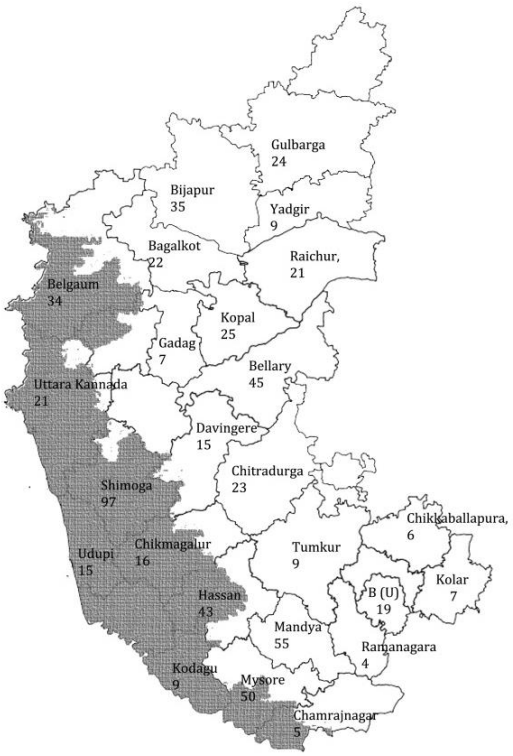

Figure 3: Number of Sand Blocks (as of 2013) and Eco-sensitive Zones

B. Supply of Sand in Karnataka

As of 2013, there were 613 allocated sand blocks for mining natural riverbed sand in Karnataka. The quantum of sand obtained from each sand block is estimated to be 7 Mt. The total estimated supply of sand in Karnataka in 2014 was 9-10 Mt (including approximately 3 Mt from manufactured sand).

Figure 3 spatially illustrates the location of sand blocks in each district. According to a recent report by the Ministry of Environment and Forests [11], parts of Belgaum, Uttara Kannada, Shimoga, Udupi, Chikmagalur, Dakshin Kannada, Hassan, Kodagu, Mysore and Chamarajnagar have been identified as eco-sensitive districts of the Western Ghats. These districts account for 290 out of the 613 allocated sand blocks. There is a concerted effort in protecting these eco-sensitive areas from heavy industrial activity, which includes mining.

In 2014, manufactured sand accounted for 3 Mt of the total sand available. Another 16 manufacturing units, with a total capacity of 3 Mt, are expected to commence operations in 2015. With the auctioning of additional (stone quarry) leases, the Government expects manufactured sand capacity to reach 10 Mt by 2016. The gap in demand and supply of sand is being met by imports from other states, and possibly unauthorised mining of riverbeds in the state. This may be reduced in the future by examining alternatives to riverbed sand mining and mining in eco-sensitive areas.

3. Manufactured Sand

Crushed-stone sand or manufactured sand is the fine aggregates obtained by crushing rocks (predominantly open rocks). The production usually involves a series of stone crushers and screeners to filter the crushed aggregates to an accepted size. It is to be noted that dust from the crushers do not qualify as manufacturd sand. Minerals such as quartzite and sedimentary rocks are suitable for producing manufactured sand [12]. The suitability of manufactured sand for the purpose of construction should be assessed before the state encourages its use and production on a large-scale.

A. Manufacturing Process for Sand

The process for manufacturing sand commences with quarrying for rocks, which involves blasting and drilling. The process produces rocks of smaller sizes, which are then transported to the crushing plants. Sand is produced using a three stage crushing process:

1. In the first stage,the rocks are crushed and downsized from 500 mm to 150 mm by using Jaw Crushers.
2. In the second stage, the 150 mm sized rock is fed into a Cone Crusher to produce a 40 mm sized aggregate.
3. In the third and final stage, the aggregates are passed through a Vertical Shaft Impactor to produce sand (fine aggregates) of the required gradation and shape (as per the IS 383 Standard).

Figure 4 illustrates the process of producing manufactured sand.

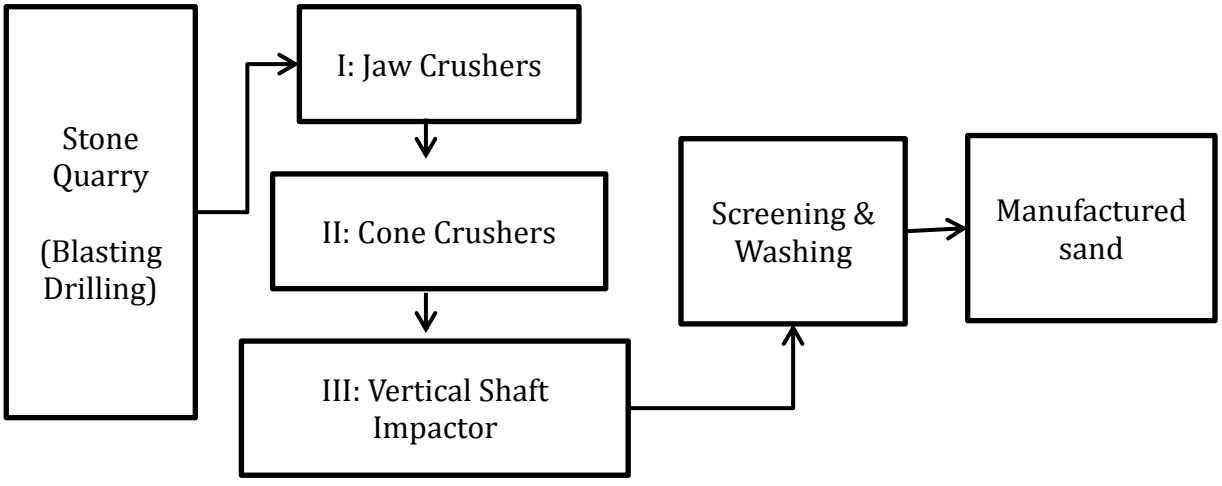

Figure 4: Manufacturing Process (Manufactured Sand)

The IS 383 Standard specifies the required size and shape of fine aggregates to qualify as manufactured sand suitable for concrete mixture. There are four grading zones, starting with Zone I to Zone IV, i.e., coarser to finer grade. The quality of concrete depends on a number of factors including the proportion of fine and coarse aggregates used in the concrete mixture.

B. Technical Analysis of Manufactured Sand

The suitability of crushed-stone sand in various applications depends on the technical and physical characteristics of the materials used. A study was conducted by the Department of Civil Engineering, Indian Institute of Science, Bangalore to examine the suitability of manufactured sand as fine aggregates in mortars and concrete [13].The study compared manufactured sand (Grade II- provided by the Department of Mines and Geology, Government of Karnataka) and riverbed sand. The key results of the study include (from [13]):

A. In mortar:
   1. Physical characteristics - shape, size, bulk density and specific gravity of manufactured sand particles are similar to those of riverbed sand.
   2. The imporved workability of mortar with manufactured sand requires lower water to cement ratio to achieve specific flow values.
   3. The water retentivity value (which governs the strength and bond development) for mortar with manufactured sand is higher than mortar with riverbed sand.
   4. The compressive strength of mortar with manufactured sand is higher (almost double) than that of mortar with riverbed sand.
   5. The flexure bond strength of masonry using manufactured sand mortar is significantly higher (almost 150% increase) as compared to mortar using riverbed sand.
   6. The compressive strength and modulus for masonry with manufactured sand is higher (almost 30% increase) as compared to mortar with riverbed sand.

B. In concrete:
   1. Concrete with manufactured sand possesses higher compressive strength (6-9% increase) as compared to concrete with riverbed sand.
   2. Flexure strength of manufactured sand concrete is higher (by 12-15%) than riverbed sand concrete.
   3. Manufactured sand-based concrete provides marginally higher bond strength as compared to concrete with riverbed sand.
   4. The stress-strain behaviour (load-bearing ability) of concrete composed of manufactured sand and riverbed sand is similar.

Based on the technical analysis, it is evident that manufactured sand shows properties suitable for application in mixtures such as mortar and concrete, and performs better than riverbed sand. Crushed-stone sand is thus a suitable material to replace riverbed sand.

4. Manufactured Sand Potential Assessment

Mining of rock reserves for the purpose of manufacturing sand should be conducted in a safe and ecologically sustainable manner. The quantity of manufactured sand that may be produced is dependent on the availability of suitable rock reserves. This section examines the areas within the state that have a potential for producing manufactured sand.

A. Manufacturing Sand from Inactive Mines and Quarries with Expired Leases

According to the Ministry of Mines and Geology, Government of Karnataka, there are 215 stone-crushing units (and quarries), each more than 5 acre in size, whose lease has expired. The total area is known to be 1801 acres. These locations have been mined to a depth of 8m. For the purpose of manufacturing sand, these quarries could be mined further up to a depth of 14m. After eliminating the quarries which fall within eco-sensitive districts (38 quarries with an area of 447 acres), the total potential for manufactured sand from the remaining units (177, with an area of 1354 acres) is estimated to be 40 Mt of sand, assuming an yield of 60% conversion of stone to sand. Figure 5 provides a geographic representation of the different districts in Karnataka and their respective crushed-sand potential from existing mines. A further examination of these existing quarries must be conducted to ensure that the land does come under the safe zone for crushing activities.

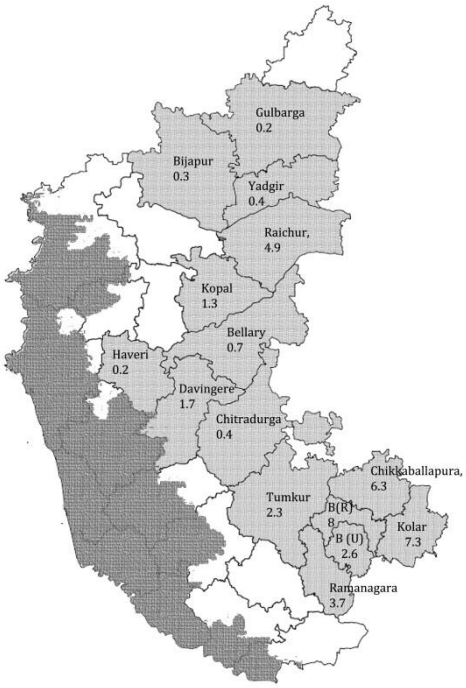

Figure 5: Crushed-stone Potential from Inactive Mines (Mt)

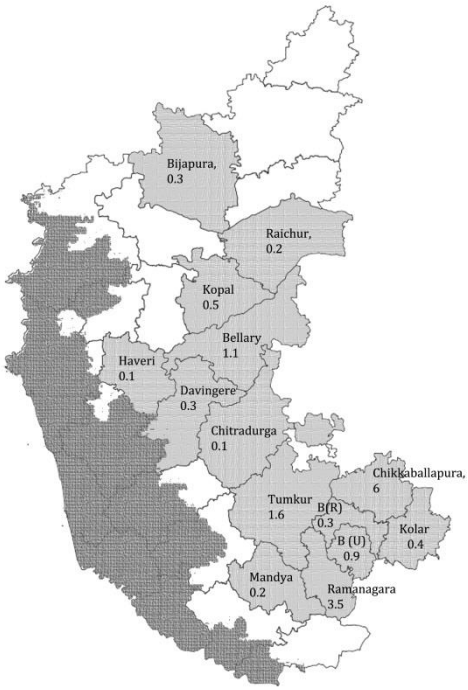

Figure 6: Crushed-stone Potential from Extended Areas of Active Leases (Mt)

B. Manufacturing Sand from Quarries and Mines with Extended Leases

In recent years, the Department of Mines and Geology, Government of Karnataka has provided additional land to quarries of existing lease holders. The total area provided through this

extension is 840 acres. If the yield of manufactured sand from this extended area is considered to be 60%, then the amount of sand produced from these extended leases would be about 25 Mt (about 21 Mt of this capacity falls in non-eco sensitive areas), as can be seen from Figure 6.

C. Manufacturing Sand from New Potential Areas

The geographical map of Karnataka (Figure 7) shows that there is a wide variety of rock minerals available abundantly. There are sources of igneous rocks, which are hard to crush and hence used to produce coarse aggregates. Other types of rocks such as egresses, slates and marbles can also be crushed (to an appropriate size) to produce satisfactory sand substitutes.

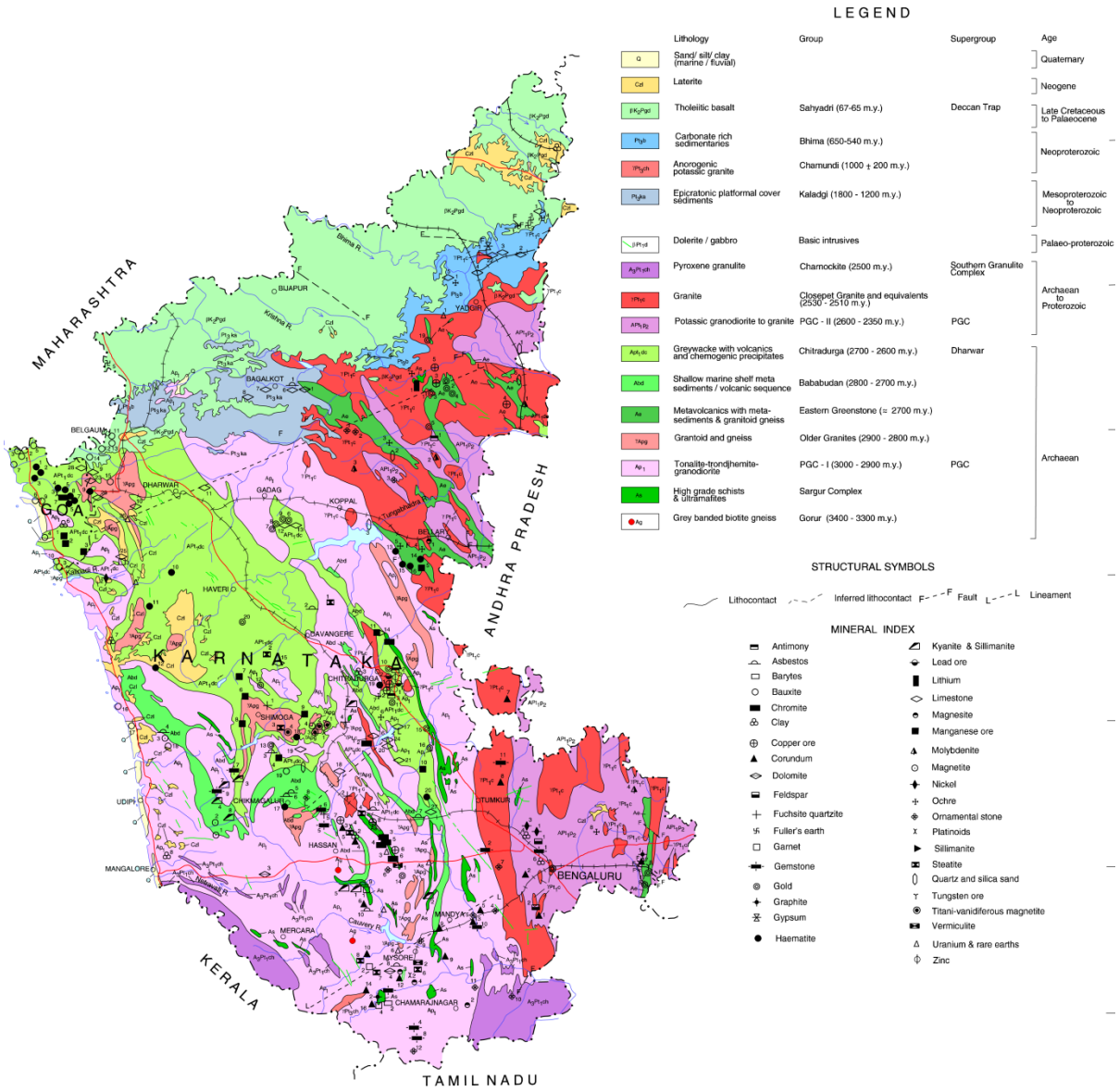

Figure 7: Geological Map of Karnataka [14]

The aspects considered in this study while identifying potential areas for manufacturing sand were:

1. Proximity to rock reserves (raw material).
2. Relative distance from human settlements and built areas (more than 200 m).
3. Avoiding identified eco-sensitive areas (as defined by the Kasturirangan Report) [11].
4. Within identified wastelands (as per land classification data on land-use).

While this is a preliminary assessment conducted at a macro level, the production areas must comply with the Karnataka Minor Mineral Concession Rules (KMMRC) and Stone Crushing Act 2013.

The detailed steps for our assessment of rock resources for manufacturing sand are as follows:

1. Tracing open-rock resources identified on a satellite map (Google Satellite Map) and creating a rock resource digital layer.
2. Superimposing the rock resource layer on a wasteland map layer.
3. Eliminating areas/districts considered to be eco-sensitive.
4. Using a GIS software to identify overlaps between the two layers (open rock and wastelands).
5. Eliminating land parcels below 10 acres (which has been assumed to be the minimum amount of land required for a mining and crushing facility).
6. Estimating the quantity of rock that could be mined from suitable areas that have been identified (based on a square or rectangular profile).
7. Calculating the total potential of manufactured sand quantity for each district.

The assessment should not be considered as comprehensive or detailed, and is a proof-of-concept technique developed to identify (at a preliminary level) areas suitable for the production of manufactured sand. Ground assessments of the potential areas identified is the next step so as to verify their suitability.

Examining the case of Chikkaballapur, our methodology identified 83 parcels of land with crushed-stone sand potential. The estimated quantity of sand from this district, assuming an yield of 60% (stone to sand) and 6 m mining depth, is 316 Mt As can be seen in Table 1. The actual (more accurate) capacity would require a detailed ground assessment on suitability for mining as per KMMRC and the Stone Crushing Act.

Table 1: Estimated Sand Extraction from a Sample District (Chikkaballapur)

District	Taluk	Acres	Number of Parcels of Land Identified	Potential quantity of Sand Manufacturing (MT)	
				6m depth	12m Depth
Chikkaballapur	Bagepalli	4363	21	130	221
	Chikkaballapur	1055	16	31	54
	Chintamani	2724	32	81	138
	Gauribidanur	930	5	28	47
	Sidlaghatta	1545	9	46	78

Note: The capacity estimation is based on a methodology detailed in the annexure. The size of the area may be subject to change based on on-site examination, clearance of land, and other site conditions.

Based on a geospatial assessment, it was found that regions in northern Karnataka have traces of rocky minerals while there are a number of rocky areas in most of the south-eastern districts. Districts such as Chikaballapura, Kolar, Tumkur, Mandya and others show greater potential and scope for producing manufactured sand than other districts.

Applying a similar methodology, the total capacity for manufacturing sand in each district was calculated (Table 2).

Table 2: District-wise Potential Estimate of Manufactured Sand from Unexploited Rock

District	Number of land parcels	Total Area (acres)	Potential quantity of manufactured sand (Mt)	
			6m depth	12m depth
Bangalore Rural	59	3138	93	159
Bangalore Urban	16	2706	80	137
Bellary	88	5088	151	257
Bidar	1	12	0	1
Chikkaballapur	83	10617	314	536
Chitradurga	54	4007	119	202
Davanagere	10	1426	42	72
Haveri	2	81	2	4
Kolar	96	10901	323	551
Koppal	13	980	29	50
Mandya	68	4227	125	214
Raichur	2	70	2	4
Ramnagaram	42	2657	79	134
Tumkur	225	14951	443	755

Table 6 in the annexure provides a similar taluk-level potential assessment for sand manufacturing across all districts known to be rich in rock resources. A map of the same is shown in Figure 8. The map also demarcates the eco-sensitive districts, which have been excluded in our assessment.

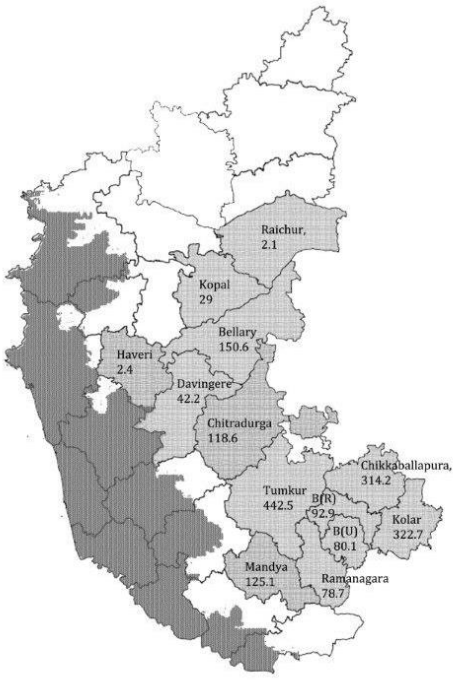

Figure 8: Districts with Potential for Manufacturing Sand (in Mt) at 6m Depth

Figure 9 illustrates the areas identified in Chikkaballapur taluk on a satellite map which have open rock formations suitable for mining.

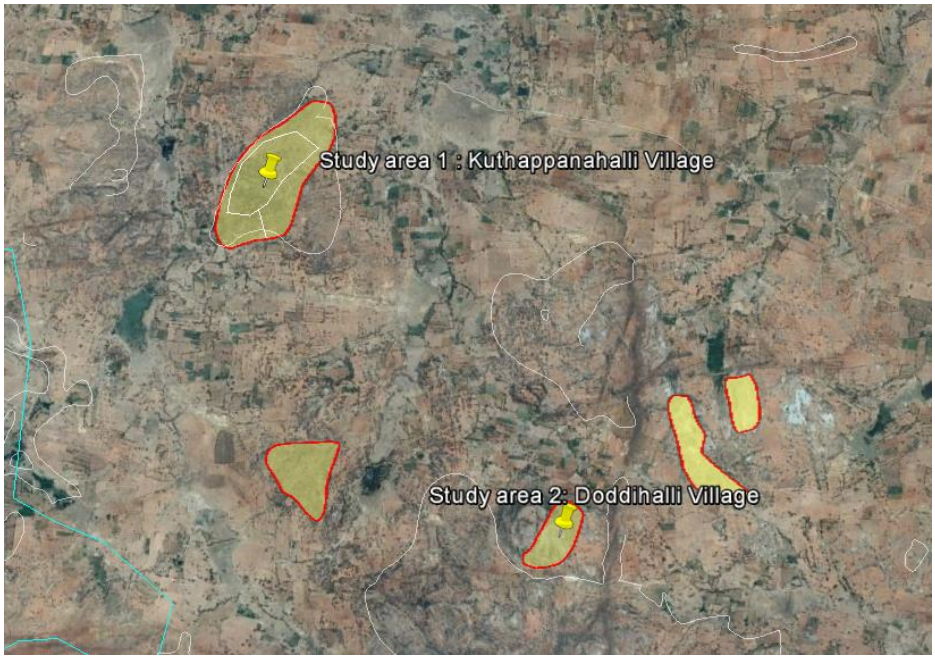

Figure 9: Identified and Examined Land Parcels from Satellite Image

Site Verification

Though the potential assessment in identified locations is based on spatial evidence, for actual estimation, a ground verification of these sites will be required. Using this study's methodology, four random locations were selected that were considered to be suitable for sand production. These locations were examined by field officers[3] and have been reported to have no evidence of call for mining in the past and meet the requisite conditions of KMMCR 1994 Rule 6(2) [15]. The field officers have thus affirmed that the sites are suitable for manufacturing sand.

For any site identified using this study's methodology, the following issues must be resolved through site analysis before further activities can be carried out:

- Area confined to the KMMCR 1994, Rule 6(2) [15] and Stone Crushing Act, which explains the distance criteria from schools, villages, temples, etc.
- Clearance from Revenue and Forest Departments.
- Access to mining areas and planning of utility services.
- Control of emissions and particulate matters from mining and transportation.
- Occupational health and safety.

D. Addressing Eco-sensitive Zones and Respective Districts

Given the presence of eco-sensitive zones within Karnataka, it was believed that a number of districts will not be suitable for facilities to manufacture sand. Hence, neighbouring districts will have to meet the demands of the districts with eco-sensitive zones.

Table 3 shows the districts with eco-sensitive areas and the ideal/nearest source district/s for sand.

[3]Field survey report, Ministry of Mines and Geology, Government of Karnataka

Table 3: Eco-sensitive Districts and Plausible Supply Districts

	Plausible supply districts									
Eco Sensitive Districts	**Tumkur**	**Bijapur**	**Davanagere**	**Bagalkot**	**Dharwad**	**Mandya**	**Chitradurga**	**Haveri**	**Gadag**	**Bangalore Rural**
Dakshina Kannada	1		1				1			
Hassan	1					1	1			
Shimoga			1					1		
Uttara Kannada					1			1		
Udupi			1					1		
Chikmagalur	1		1				1			
Chamarajanagar						1				1
Kodagu	1					1	1			
Belgaum		1		1	1				1	
Mysore						1				
Total	**4**	**1**	**4**	**1**	**2**	**4**	**4**	**3**	**1**	**1**

E. Summary of Potential Assessment

The potential of manufacturing sand from three distinct sources was examined in this study. The estimated amount of sand that could be produced from each source is shown in

Table 4.

Table 4: Total Potential of Manufactured Sand

Resource	**Total area (acres)**	**Potential capacity in Mt**	
		6m depth	**12m/14m depth**
Inactive mines – revisited for mining from 8 to 14mts (60%)	1354	-	40
Existing expanded quarries (60%)	840	25	42
Un-exploited sand stones (60%)	60862	1801	3075

Note: The estimates mentioned above are based on square shape mining and are subject to ground conditions.

The projected demand for sand from 2014 to 2030 is cumulatively estimated to be around 660 to 823 Mt. The potential assessment indicates that the stone reserves available in Karnataka are sufficient to cater the demand for sand for several decades. Suitable policy instruments and safeguards are needed to ensure efficient functioning of the market and adequate availability of sand for various applications.

F. Market for Manufactured Sand

The current sale price of manufactured sand (at plant) is estimated to be between Rs. 500 and Rs. 600 per tonne. Transportation costs amount to a further Rs. 300-400 per tonne, depending on the distance travelled, resulting in a total cost of Rs. 800-1000 per tonne. In comparison, riverbed sand is priced at Rs. 1500-2000 per tonne (including transportation). Given that the technical performance of manufactured sand is better than that of riverbed sand, increasing its availability will play a significant role in reducing the demand as well as the market price of sand.

5. Conclusion and Policy Recommendations

The study examined the potential for manufacturing sand in Karnataka. Currently, there seems to be a severe shortfall of sand in the state. A study conducted by Prof. B.V.V. Reddy at the Indian Institute of Science, Bengaluru, shows that manufactured sand (from stone) performs better than riverbed sand in the application of mortar and concrete – the two principal uses of sand.

This study also explored the possibility of manufacturing sand from sources such as expired quarry leases, extended leases as well as new sites identified through satellite maps and GIS layers of land classification. In four sample cases, ground assessments were carried out to validate the results obtained from the desk assessment. It is evident from this study that there are adequate rock resources to meet the demand for sand in Karnataka in the decades to come.

Based on the analysis conducted and consultation with experts, certain policy recommendations emerge. Following are some suggestions:

1. **Publicise and promote manufactured sand highlighting its salient features from the IISc study**
   The IISc study clearly shows that for the application of sand in mortar and concrete, manufactured sand performs better than riverbed sand. It will be in the interest of the Government to publicise this fact through advertisements and special promotional materials to the construction industry as well as the mining and crushing industry. In addition, the public at large could be informed about the benefits of manufactured sand through newspaper articles and op-eds written by experts. Given the ecological damage associated with riverbed sand mining, it will be in the interest of the State to assist the transition towards manufactured sand for construction.

2. **Mandate the use of manufactured sand by Public Works Department (PWD), Irrigation Department, Urban and Rural Development Department**
   The current policy of the PWD is to mandate the use of manufactured sand for projects above Rs. 10 crore. This might not be adequate and to further popularise manufactured sand, the PWD, Irrigation, Urban and Rural Development departments should be mandated to use manufactured sand for ALL projects, irrespective of size. This measure will establish the demand for manufactured sand, and thus encourage current lease holders and stone crushers to invest in the necessary equipment to increase their production of manufactured sand.

3. **Revisit the existing tendered quarries to encourage production of manufactured sand**
   This option may be considered to immediately add supply to the market as existing quarries will have the necessary clearances and infrastructure to commence manufacture. The total supply expected from this measure is 65-82 Mt of sand, which will be sufficient to cater to the sand demand of the state for the next 4-5 years.

4. **Identify and demarcate zones for new stone quarries and crushing areas before auctioning and leasing parcels. Provide access and associated infrastructure such as roads, electricity,etc. to these zones**
   Significant uncertainty is faced by manufacturers in obtaining environmental and other Governmental clearances for stone quarries and crushing units. This leads to a considerable delay and increase in costs, which are passed on to the consumer. If the Ministry of Mines and Geology along with other concerned government departments identify and demarcate zones for such activities, and provide the necessary basic infrastructure (which could be recovered via royalties), it will accelerate the uptake and investment in the production of manufactured sand – leading to lower market prices.

5. **Provide structural and financial incentives for stone crushers to engage in production of manufactured sand**
   There are a number of stone crushers in the state that produce aggregates from stone for construction. The operators of these units are best placed to quickly upgrade their equipment to produce manufactured sand. The state might consider (continuing) incentives, for those willing to take up sand manufacture as an activity, such as i) Longer lease periods (upto 20 years), ii) Larger mining areas (upto 50 acres per lease) and iii) Lower interest loans (5% subsidy on loans for equipment for a period of 5 years).

6. **For the next few decades, the Government should explore the potential of utilising building debris to produce sand or explore new building materials and adopt innovative architecture**
   Given the environmental concerns associated with riverbed sand mining as well as stone quarrying, the Government must explore the potential of reducing mining in these areas. With ageing infrastructure, the disposal of debris from the same will become an important issue. Use of debris for manufacturing sand is a technology that warrants examination. The Government may consider involving the Municipal Corporations of large cities like Bengaluru and Hubli-Dharwad to establish pilot plants for converting building debris to sand and provide the necessary impetus to this aspect of recycling. In addition, the Government could also explore the possibility of encouraging alternative designs and/or new building materials that use lesser amounts of sand for construction. This will play a significant role in reducing the demand for sand in the long-term.

The ability to re-use, recycle and reduce construction material is the hallmark of an ecologically conscious and environmentally sustainable society. The Government, through its forward looking policies, can make a significant impact in this direction.

6. Bibliography

[1] Department of Agriculture, "Glossary of terms in Soil Science," 1976. [Online].

[2] San Diego State University -The Ojos Negros Research Group, "Sand Mining Facts," [Online]. Available: http://threeissues.sdsu.edu/three_issues_sandminingfacts01.html.

[3] The Hindu, "PWD can only use manufactured sand," 17 September 2013. [Online]. Available: http://www.thehindu.com/news/national/karnataka/pwd-can-only-use-manufactured-sand/article5135846.ece.

[4] The Times of India, "Sand shortage hits construction work in Heritage City," 21 September 2014. [Online]. Available: http://timesofindia.indiatimes.com/city/mysuru/Sand-shortage-hits-construction-work-in-Heritage-City/articleshow/43062179.cms.

[5] Bangalore Mirror, "Sand prices quadruple, hit Rs 1 lakh per load," January 2014. [Online]. Available: http://www.bangaloremirror.com/bangalore/others/Sand-prices-quadruple-hit-Rs-1-lakh-per-load/articleshow/28445637.cms.

[6] Cement Manufacturing Association, "Indian Economy," 2014. [Online]. Available: http://www.cmaindia.org/indian-economy.php.

[7] McKinsey Global Institute, "India's urban awakening: Building inclusive cities, sustaining economic growth," 2010.

[8] Canadian Center for Architecture, "Atlas Concrete Handbook," 88-B11001 ed., Atlas Portland Cement Company, 1972.

[9] Cement manufacturing Association, "Annual report," 2012-13.

[10] Indiaonline pages, "Population of India," [Online]. Available: http://www.indiaonlinepages.com/population/index.html. [Accessed 7 December 2014].

[11] Ministry of Environment and Forests, "Report of the high level working group on western ghats," 2013.

[12] Ministry of Micro, Small and Medium Enterprises, "Granite Sand Manufatcure," [Online]. Available: http://www.dcmsme.gov.in/reports/projectprofileonsandmanufacture.html.

[13] P. B. V. V. Reddy, "Rocks Suitable for sand manufacturing Rocks Suitable for sand manufacturing," Indian Institute of Science, Bangalore, 2012.

[14] Geological Survey of India, "State Geology and Mineral Maps published along with Miscellaneous Publication No. 30," [Online]. Available: http://www.portal.gsi.gov.in/portal/page?_pageid=127,603606&_dad=portal&_schema=PORTAL.

[15] Govenment of Karnataka, "Karnataka Minor Mineral Concession rules," 2014. [Online].

[16] SINTEF, "Production and Utilization of Manufactured Sand," SINTEF Building and Infrastructure, OSLO, 2009.

[17] Karnataka Public WorksDepartment, "Roads in Karnataka," Bangalore, 2013.

[18] Global Cement, [Online]. Available: http://www.globalcement.com/news/item/3271-indian-cement-market-expected-to-grow-at-9-cagr-in-2014-2019.

7. Annexure

A. Method for Estimating the Quantity of Sand Produced from a Stone Quarry

Shown below is the cross-sectional sketch of a square plot of 10 acres (200 X 200mts). A 7.5m clearance is provided on all four sides for safety and access. It is necessary to approach the site at 45^0 from all four sides. The same methodology is applied for mining at further depths. Figure 10 illustrates the profile of a typical quarrying site and the calculation for quantity of manufactured sand, assuming 6 m mining depth followed by further mining up to 12 m.

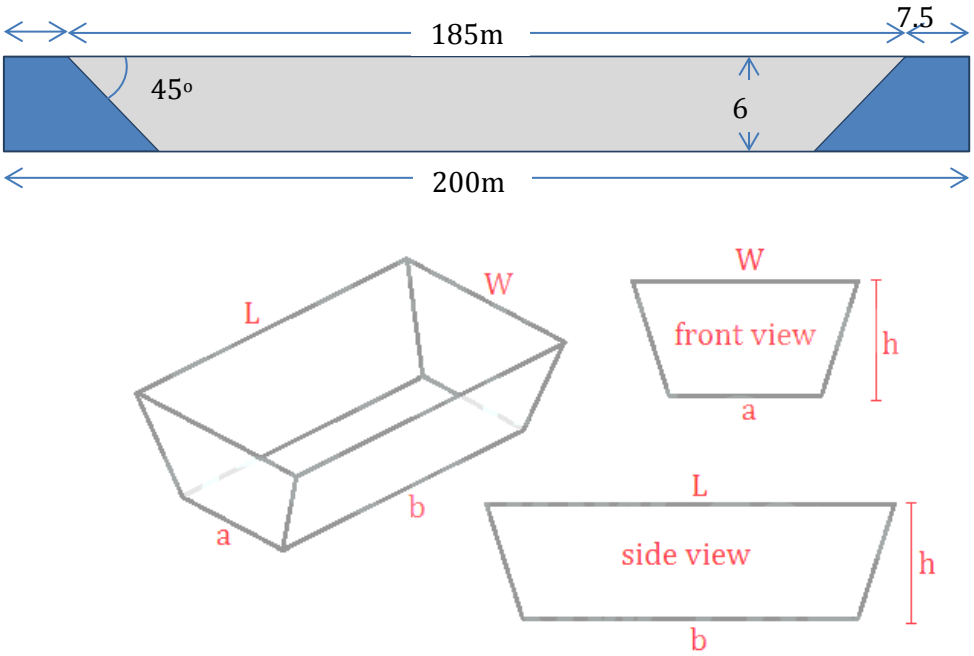

Figure 10: Profile of a Rectangular Quarrying Site

Volume of trough of material mined = $\frac{h}{6} \times (WL + (W + a)(L + b) + ab)$

Where W=L and a=b (square trough) Volume = $\frac{h}{3} \times \left((L^2 + a^2) + L \times a\right)$

Total Quantity mined = Volume x specific gravity

Net Saleable Tonnage= Total mined – losses

Proportion for manufactured sand =60% of Net saleable tonnage

Table 5 below shows the estimated quantity of manufactured sand that could be produced from two mining designs (square and rectangular).

Table 5: Estimated Quantity of Sand from Different Types of Mining Design

Mining Shape	Volume	Conversion factor	Total quantity mined	Saleable (95%)	Manufactured Sand (60%)
	Cu-m	tonne/m³	Tonnes	Tonnes	Tonnes
Square	192318	2.7	519259	493295.7	295977
Rectangular	179718	2.7	485239	460976.7	276586

**Calculation for Mining depth for 6mts, Quantity of materials mined in 10 acres land (4.047 Hectare)*

B. Unexploited Rock Resource Potential Assessment

Table 6: Taluk-wise Potential from Unexploited Rock Resource

District	Taluk	Number of parcels	Total Acre	Estimated saleable materials extracted (60% of the total crushed to m-sand), Mt	
				Mining Depth, 6m	Mining Depth, 12m
Bangalore Rural	Devanhalli	17	703	20.8	35.5
	DodBallapur	10	1176	34.8	59.4
	Hoskote	3	114	3.4	5.8
	Kanakapura	8	430	12.7	21.7
	Magadi	21	715	21.2	36.1
Bangalore Urban	Anekal	5	822	24.3	41.6
	Bangalore North	6	1000	29.6	50.5
	Bangalore South	5	884	26.2	44.7
Bellary	Kudligi	43	3332	98.6	168.4
	Sandur	45	1757	52.0	88.8
Bidar	Aurad	1	12	0.4	0.6
Chamrajnagar	Gundlupet	1	66	2.0	3.4
Chikkaballapur	Bagepalli	21	4363	129.1	220.4
	Chikkaballapur	16	1055	31.2	53.3
	Chintamani	32	2724	80.6	137.6
	Gauribidanur	5	930	27.5	47.0
	Sidlaghatta	9	1545	45.7	78.1
Chitradurga	Challakere	2	25	0.7	1.3
	Hiriyur	9	1030	30.5	52.0
	Molakalmuru	43	2952	87.4	149.2
Davanagere	Harpanahalli	10	1426	42.2	72.0
Haveri	Ranibennur	2	81	2.4	4.1
Kolar	Bangarapet	7	2527	74.8	127.7
	Gudibanda	4	284	8.4	14.4
	Kolar	28	3792	112.2	191.6
	Malur	10	1608	47.6	81.3

District	Taluk	Number of parcels	Total Acre	Estimated saleable materials extracted (60% of the total crushed to m-sand), Mt	
				Mining Depth, 6m	Mining Depth, 12m
	Mulbagal	38	2016	59.7	101.9
	Srinivaspur	9	674	20.0	34.1
Koppal	Koppal	13	980	29.0	49.5
Mandya	Krishnarajpet	9	907	26.8	45.8
	Malavalli	1	297	8.8	15.0
	Nagamangala	56	2986	88.4	150.9
	Pandavapura	2	37	1.1	1.9
Raichur	Lingsugur	2	70	2.1	3.5
Ramnagaram	Ramanagaram	37	2395	70.9	121.0
	Channapatna	5	263	7.8	13.3
Tumkur	Chiknayakanhalli	3	127	3.8	6.4
	Gubbi	3	63	1.9	3.2
	Koratagere	51	2620	77.6	132.4
	Kunigal	14	727	21.5	36.7
	Madhugiri	60	4874	144.3	246.3
	Pavagada	60	4119	121.9	208.1
	Sira	2	178	5.3	9.0
	Tiptur	7	296	8.8	14.9
	Tumkur	20	1316	39.0	66.5
	Turuvekere	5	631	18.7	31.9
Total		**760**	**60928**	**1803.0**	**3079.0**

C. Economics of a Typical Manufactured Sand Plant

Investments in the manufacture of sand are primarily towards operating equipment, working capital, land and other in-house infrastructure. The size of a plant depends on the area and capacity of equipment (tonnage per day). Figure 11 shows the typical cost-share for a 27,000 tonne plant [12].

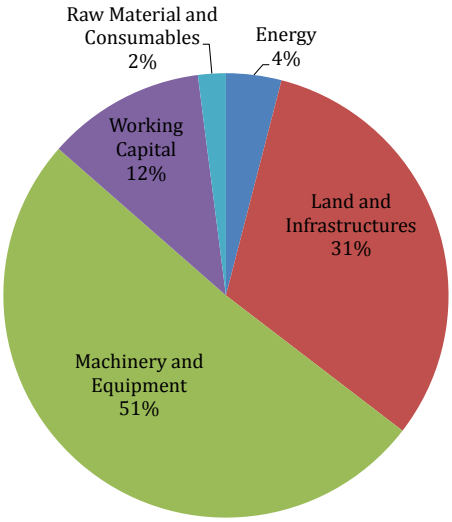

Figure 11: Cost-share of a Typical Manufactured Sand Plant [12]

Table 7: Financial Analysis of a Sand Manufacturing Unit [12]

I	Fixed Capital Costs	39,15,000
a	Land and Buildings	14,15,000
b	Machinery	20,00,000
c	Office Equipment	3,00,000
d	Pre-operation Expenses	1,85,000
II	Working Capital	
e	Staff and Labour	5,19,000
f	Raw Material and Consumables	91,000
g	Utilities	1,81,000
h	Other Contingencies (three months)	10,08,000
III	Total Capital Investment = Fixed Costs + Contingency Costs	49,23,000
	Financial Analysis	
	Annual recurring cost (h *3)	40,32,000
	Depreciation on building @ 5%	45,750
	Depreciation on machinery and equipment @ 10%	2,00,000
	Depreciation on office furniture and equipment @ 20%	60,000
	Interest on Capital Investment	8,86,140
IV	Production (tonnes)	27,000
	Sale Price (Rs/tonne)	225
	Total Sale (Rs)	60,75,000
V	Profit per annum	8,51,110
VI	Net Profit Ratio	14.01%
VII	Rate of Return	17.29%

Table 7 provides details on investment and expenditures required for operating a small-scale plant. The calculation is based on the assumption that the plant runs at its full capacity; the unit will operate in a single shift for 25 days a month. Figure 12 shows a graphical representation of the cash flow for a manufactured sand facility.

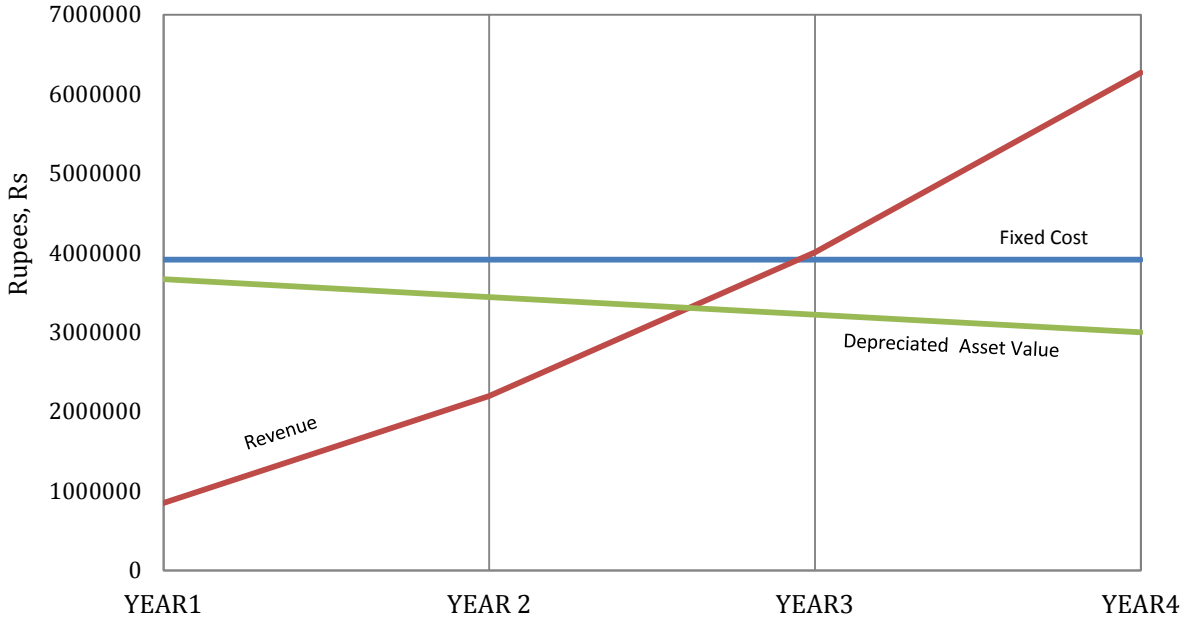

Figure 12: Cash Flow for a Typical Manufactured Sand Facility

CSTEP
CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

18, 10th Cross, Papanna Layout, Mayura Street, Nagashettyhalli
RMV II Stage, Bangalore-560094, Karnataka, INDIA
Phone:+91(80) 66902500
Fax: +91 (80) 23514269

www.cstep.in