Reducing the impact on sand mining of Kosrae and the provision of a long-term supply of sand aggregate for construction: A proposed way forward.

Draft for consultation

Development Review Commission
January 2000
Updated 2002 to include 2000 census data

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Executive Summary

Current sand mining practices are continuing to exacerbate coastal erosion problems on parts of the Kosrae coastline. This study looks to assess:

- The efforts to tackle sand mining on other small islands
- The changing pattern of construction on Kosrae
- Attempts to assess Kosrae's current annual sand aggregate demands
- Assesses existing sand aggregate resources on Kosrae
- Identifies and assesses potential sand aggregate resources
- Assesses the various options for tackling the sand mining and limited aggregate sources on Kosrae.
- Provides a proposed way forward to addressing Kosrae's sand resource and sand mining problems.

From the study the main key issues have been identified and the following conclusions recommendations have been drawn:

1. There are no case examples of developing small islands where regulating the removal of sand from beaches has been successful without other supporting activities. From over twenty years of experience in attempting to tackle the problems in the Caribbean islands, the following criteria has been deemed necessary to successfully control sand mining activities:

   - Complete political support to stopping sand mining practices
   - Existence of a good and affordable alternative source of aggregate
   - Continued education campaigns
   - Tackling special interests groups with sand mining interests, e.g. contractors
   - Perseverance – the problem will not be solved overnight, month or year, it is a problem that needs to be continually addressed.

2. The removal of sand and coral rubble from the coastline has been a major cause of coastal erosion on Kosrae. Although large scale (mechanical) removal of sand has now ceased, small scale, localized, sand mining by hand is continuing to exacerbate the significant coastal erosion problems that have previously occurred.

3. The import of cement (and other construction material) has quadrupled (in value) between 1993 and 1998. It can be assumed that a similar increase in the amount of aggregates (sand and gravel) used has also occurred. It can also be assumed that this increase will continue, at least in the short term

4. Future Kosrae Government sand aggregate demands are likely to be highly dependant on the outcome of the financial agreements reached as part of the Compact Negotiations with the US.

Future demands may also be reduced due to an increasing amount of Government construction projects being contracted to the private sector.

5. Existing and future permitted potential sand mining sites in the coastal hinterland are limited and can only be considered a short-term solution. The potential is summarized below:

   - ***Lelu****:* Virtually no potential sites where any significant future permitted sand mining sites should be allowed. Some small scale sites could be permitted on the landward side of the circumferential road in the Finfokoa area.

   - ***Malem****:* Virtually no potential sites where any significant future permitted sand mining sites should be allowed.

   - ***Utwe:*** Few potential sites. Some small scale sites could be permitted on the landward side of the circumferential road to the east of the road to Finsrem.

   - ***Tafunsak:*** Substantial deposits are located in the Sialat, Finfukul and Finfoko areas of Tafunsak. However, these have been extensively exploited over the last five or so years. There is still potential suitable sand mining sites along the Tafunsak coastline, situated well back from the coastline, inland from the road. However, as these are the only substantial deposits on Kosrae they can only realistically meet Kosraes sand aggregate demands for the near future. Considerable sand mining has been conducted in the Fintukaa area of Tafunsak. No further mining should be permitted in this area apart from small scale sites landward of the access track.

6. With an increasing population and increasing development and construction demands, Kosrae is facing a serious aggregate shortage which will:

   - Restrict construction activities in the near future (unlikely),
   - Result in an increase in un-permitted sand removal from the beach or coastal hinterland.
   - Increase pressure on the Development Review Commission to permit sand extraction from unsuitable sites.

7. Furthermore such pits often become a breeding ground for mosquitoes, dumping sites, and may well lead to coastal erosion problems in the future.

8. Kosrae has no offshore deposits of sand, beyond the coral reef, that are accessible to current dredging technology. There is also no potential for reef flat mining as is conducted on Pohnpei or the Marshall Island (which in itself causes significant further problems as seen at Tafunsak).

9. The carbonate sands used for construction on Kosrae are a very poor construction material, leading to high maintenance costs and short building lifespan.

10. It is vital that education on the impacts of sand mining be continued.

11. At present regulating sand mining should be limited to regulation through the Housing Renovation Loan Fund regulation which can be enforced easily and does not result in an onerous financial constraint on the individual.

12. Adopting a full sand mining regulation is not considered a practical or effective solution to the sand mining problems being experienced on Kosrae at present. There is little point in punishing people who have currently few practical (or affordable) alternatives. However, such regulation will be an integral part of tackling sand mining activities on Kosrae in the future but will first require:

    - The development of a good quality, inexpensive alternative sand source
    - The provision of the infrastructure to allow people to access this supply in each of the Municipalities.
    - The development of incentive measures for low volume users or people on subsistence incomes.

13. Adopting a full sand mining regulation at present will:

    - Impact most on low income households.
    - Not solve the problem of where people get construction sand from.
    - Lead to pressure on the DRC to permit sand mining from unsuitable locations.
    - Be difficult to enforce effectively on an island such as Kosrae.

14. It is recommended that crushed volcanic rock be developed as an alternative sand source. Careful consideration needs to be given as to how this alternative sand source is developed, and in the use of economic incentives for low income and low volume users.

15. Sand sources in Lelu and Okat Harbour should also be investigated further with the assistance of the South Pacific Applied Geoscience Commission when they carry out survey mapping of these harbours in 2000.

16. An assessment should be made of the economic potential for exporting volcanic sand aggregate to neighbouring island states such as the Marshall Islands and Kiribati.

17. Even with an integrated approach through education, development of accessible and economical alternative sand sources, and regulation, there is no guarantee that this will effectively stop all sand mining. However, if alternative sand sources are developed before full regulation is introduced, the penalties, and hence the deterrent can be more severe.

1. Introduction

Sand mining from the beaches of Kosrae has been, and still is, a major cause of much of the coastal erosion that has occurred on Kosrae over the past 30 or so years. Much of the erosion stems back to the removal of much larger quantities of coral rubble and sand from the reef flat during the period when the circumferential road was being upgraded and other large scale development projects were being constructed.

At present most Government and major construction projects use sand and aggregates from licensed sand mining sites and not from the beach. As a result of this the erosion rate is slowing down as the beaches and reef flat gradually recover from such activities.

Most sand and coral rubble removal from the beach is due to local people, primarily within the subsistence economy, removing the material for house construction, landscaping or landfill. This is generally conducted by hand, often just a few bags at a time (when a bag of cement can be bought). However, with a rapidly increasing population, increasing development, and the current extent of erosion on Kosrae's coastline, these sand mining practices are still significantly exacerbating coastal erosion.



Figure 1: Typical sand mining practices on Kosrae

There is considerable pressure to introduce legislation to regulate the removal of sand from the beaches of Kosrae. However, experience on other small islands, notably the Caribbean, suggests that regulation on its own, is rarely effective in preventing this small scale sand mining activity. On Kosrae, as with virtually every other small island the most significant issue is not one of controlling sand mining, it is the lack of a readily available and affordable alternative to beach sand. This is by far the main problem and one which it is necessary to tackle if a long term approach is to be adopted to tackling Kosrae's future aggregate supply and sand mining problems.

This report presents a suggested way forward for Kosrae to address:

- The long term and sustainable provision of sand aggregate for construction purposes on Kosrae.
- The long term approach to reducing sand removal from Kosrae's beaches.

2. A global perspective of beach sand mining on small islands

Erosion caused by the removal of sand, gravel and cobbles from beaches is not just a problem on Kosrae. It is a problem in many parts of the world. Most documented case studies of beach sand removal are from islands in the Caribbean where the pressures of tourism development have been much greater over the past 20 or so years, (Cambers, 1997), with other recent examples from Sao Tome and Principe off the African Coast.

There are also many examples of reef dredging for aggregate, which often has vastly greater environmental impact. Dredging of reef flats on Pohnpei and the Marshall Islands is the principal source of construction aggregates in these islands, and also in many other Pacific Islands. Such activity is also widespread in Indonesia, the Philippines and islands in the Indian Ocean, with efforts to reduce the problem in Sri Lanka, well documented (Clark, 1996).

Most of the Caribbean islands have had laws banning sand mining, or making it a controlled activity through a permitting process since the 1970's. Such laws were rarely enforced, either due to:

- A lack of enforcement on the enforcing authority's part (police, environment agency).
- The actual logistical difficulty in controlling the practice (for example at night), where enforcement was practiced.
- Local magistrates who tended to take a lenient view of the activity.
- A summary of some of the case studies from the Caribbean is provided in Appendix 1.

Such sand mining regulation, where it has been applied, has followed the traditional format of environmental policy, laws and institutions on tackling environmental effects. This is characterized by an "effects-orientated" approach, which has predominated in most areas of environmental policy, having developed from concerns over the decline in environmental quality in industrial nations during the 1950's and 1960's. The experience of regulating sand mining in the Caribbean has indicated that such an approach is rarely effective in tackling this type of problem. Instead focus is now shifting to regulation that concentrates on policies geared towards the sources of these effects, which is a distinctly different view of both the issues and the organizations managing them. Furthermore, the experience in the Caribbean has highlighted that enforcement through regulation is more difficult the second time around where a law has previously been unsuccessful in controlling sand mining activity.

Many of the examples from the Caribbean also failed due to the lack of political support, often due to politicians themselves having a direct vested interest in sand mining operations or due to the political power of the groups controlling the sand mining (e.g. truckers).

Based on this experience, the following key factors emerge as being vital for success:

- Complete political support to stopping sand mining practices
- Existence of a good and affordable alternative source of aggregate
- Continued education campaigns
- Tackling special interests groups with sand mining interests, e.g. contractors
- Perseverance – the problem will not be solved overnight, month or year, it is a problem that needs to be continually addressed.

3. The present situation

3.1 Current regulatory framework

There is no current legislation that specifically addresses the removal of sand and coral rubble from the beach or reef flat. However, the removal of sand is addressed within Title 7, Chapter 4 of the Kosrae Code.

Within the Regulations for Development Projects, a development project is defined as:

> *"Development Project" means the construction, alteration, movement, fill, removal, disposal or any modification to the land or coastal areas. A development project can include, but is not limited to the installation, placing or building of surface structures, land reclamation, navigational channels, harbors, utility lines, piers, shopping centers, clearing land, causeways, golf courses, apartment complexes, hotels, schools, roads, parking areas, or any other similar activities."*

The DRC Permit Process states that a Development Review Permit is required for development projects that fall within the parameters of Section 7.402 of Title 7 of the Kosrae Code or for development projects that satisfy six criteria. Of relevance to sand and coral removal from the beaches or the reef flat are conditions a, b and d:

a) involve any earthmoving activities

Where earthmoving is defined in the regulation as:

> *"Earthmoving" means any construction or other activity which disturbs or alters the surface of the land, a coral reef or bottom of a lagoon, including, but not limited to excavations, dredging, embankments, land reclamation in a lagoon, land development, sub-division development, mineral extraction, ocean disposal, and the moving, deposition of soil, rock, coral or earth."*

b) located below the mean high water mark

d) disposal or removal of dredged materials, including all sand mining operations.

"Dredged materials" or "sand mining operations" are not defined in the regulations.

3.2 Changing characteristics of construction on Kosrae

3.2.1 Major infrastructure development

The use of beach and reef deposits has been a traditional practice on Kosrae for many years. For example, much of Lelu island is reclaimed land, in-filled with reef flat deposits. This reclamation was conducted during the development of the neolithic site at Lelu between AD 1100 and AD1400. The reclaimed area during this time is estimated to be approximately 27 hectares (an earlier estimate was 40 hectares) with a depth of between 0.6 m and 1m of fill (Athens, 1995). This provides a volume of material removed from the reef flat of Lelu lagoon of between 162,000 m^3 to 270,000 m^3 (211,530 to 352,550 cubic yards) or approximately 62,300 tonnes to 103,850 tonnes of reef material, an enormous volume to have been moved by hand. This may be the reason why there are no vegetated storm deposits along the outer reef flat of Lelu lagoon, as is found all along other sections of the easterly facing Kosrae coastline.

Between 1851 and 1945, the arrival of the Missionaries, and an increase in shipping to the islands during the German and Japanese periods resulted in imported timber and cement beginning to be used for building construction. The German administration were the first to construct a causeway between Lelu island and the main island of Kosrae, in 1910, using coral blocks and fill from the reef flat of Lelu lagoon.

Major development projects after the war involved the construction of five large churches, which, until the construction of the gymnasium, were the largest buildings on Kosrae. The construction of these will have utilized beach sediments. Development of the circumferential road also utilized large quantities of beach sands as fill and surfacing material between the 1960's and 1980's. Associated with this was the widening of the causeway (1960's) to Lelu to accommodate vehicles, again using fill obtained from the reef flat. The causeway was further widened in the 1980's.

From 1980 onwards, the US Trust Territory Administration began funding major infrastructure projects, which continued with Compact Funding after 1986. A summary of major development projects that utilized significant quantities of beach sands or reef flat deposits as a construction aggregate is provided below:

- Airport & Harbor complex
- Fill and surfacing material for the further development of the circumferential road
- Kosrae State Government offices in Tofol
- Construction of the Power plant

- School construction (Tafunsak, Lelu, Malem & Utwe Elementary Schools and Kosrae High School)
- Public Market, Aquaculture and Marine Resources complex
- Municipal offices in each Municipality
- Gymnasium

Since the formation of the Development Review Commission in 1992, the Government and large construction projects have ceased using sand mined directly from the beach, instead obtaining construction sand from permitted sand mining sites in the coastal hinterland.

3.2.2 Changes in housing construction

Traditional housing on Kosrae, as in most small islands, utilized the native materials with mangrove timber the main material used in house construction. Timber from the species *Bruguiera gymnorhiza* and *Lumintzera littorea* were commonly used for house posts due to their resistance to rotting. *Rhizophora mucronata* and *Rhizophora apiculata* was generally used for rafters and beams, with *Sonneratia Alba*, a common floor timber. *Terminalia carolinensis* and *Horsfieldia nunu* were also important traditional construction materials. The palm fronds of the nipa palm *Nypa fruticans* were favoured as thatching material as they lasted longer than thatch made from coconut palm.

At the turn of the 20th century, three typhoons affected Kosrae over the space of about 15 years destroyed a high percentage of housing each time. The demise in the use of traditional materials in housing construction on Kosrae is attributed to the effects of these events and the extent of damage that occurred. It is also around this time that the German and subsequently Japanese influence began to increase with more regular imports to the island, including construction material.

More recent changes in the housing characteristics on Kosrae can be identified by comparing the 2000 and 1994 FSM Census of Kosrae (Kosrae State Government, 2002, 1996) with the Trust Territory of the Pacific Island (TTPI) census of Kosrae in 1980. Over this period the population on Kosrae increased from 6,607 inhabitants in 1980 to 7687 in 2000. The corresponding number of housing units also increased from 615 occupied housing units in 1980 to 1087 occupied units in 2000. Over this period mean household income increased from $9,686 to $12,407. Two effects of this can be seen:

- A decrease in the average number of people per household from 7.5 in 1980, to 7.1 in 2000.
- An increase in the number of rooms per house from a median on 2.5 in 1980 to 3.8 in 2000. Figure 2.

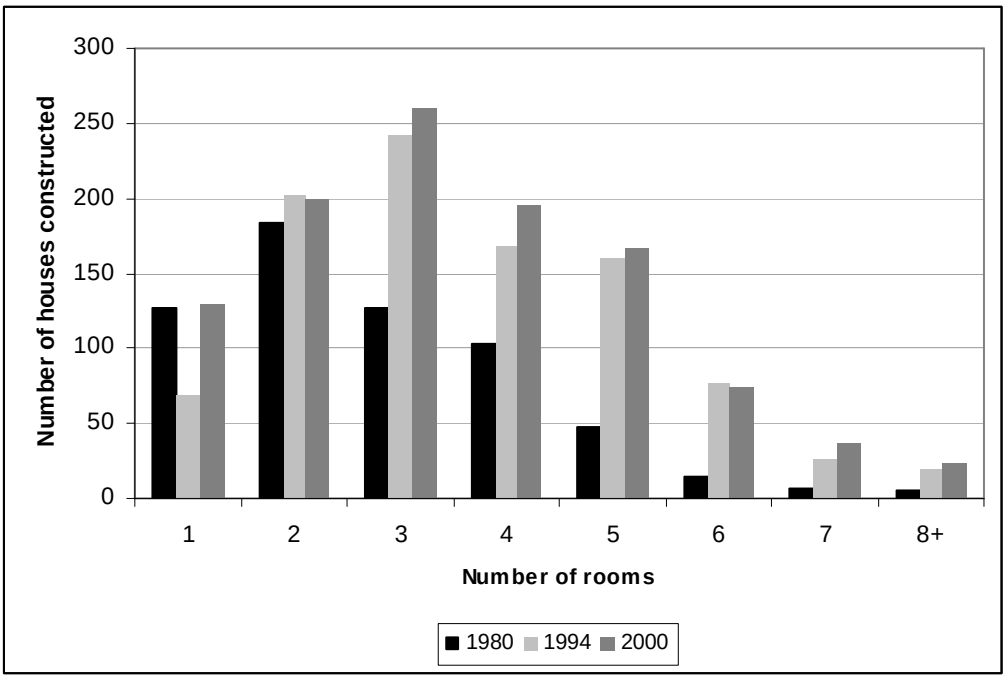


Figure 2: Changes in the numbers of rooms per house between 1980 and 2000.

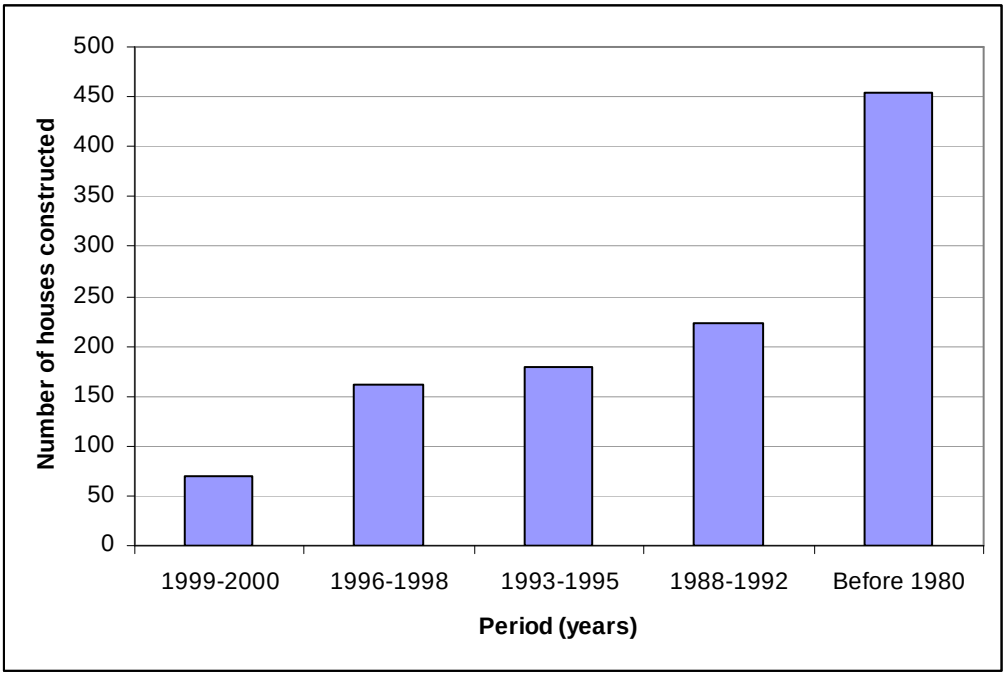


Figure 3: Dates of existing house construction.

Figure 3 presents the year of construction of housing on Kosrae and also a measure of the disappearance of old housing from the inventory. In both the 1994 and 2000

census, one in every three housing units on Kosrae had been constructed within the previous five years.

The most significant change in housing characteristics on Kosrae is in the materials used for construction with an almost total move away from traditional forms. In 1980 the roofing of all houses were made of corrugated iron or metal (78%) or thatch (21%). In 2000, the proportion of corrugated iron or metal roofing material had increased to 78% with poured concrete roofing accounting for 18%, Figure 4. A similar pattern is evident in the materials used for outside walls. In 1980, three out of every four housing units were constructed with wooden walls. By 2000, 68% of walls were either poured concrete or concrete block, with 30% wooden, Figure 5. There is no information on foundation / floor materials in the 1980 census, but in 2000, virtually all housing (94%) had concrete floors and foundations.

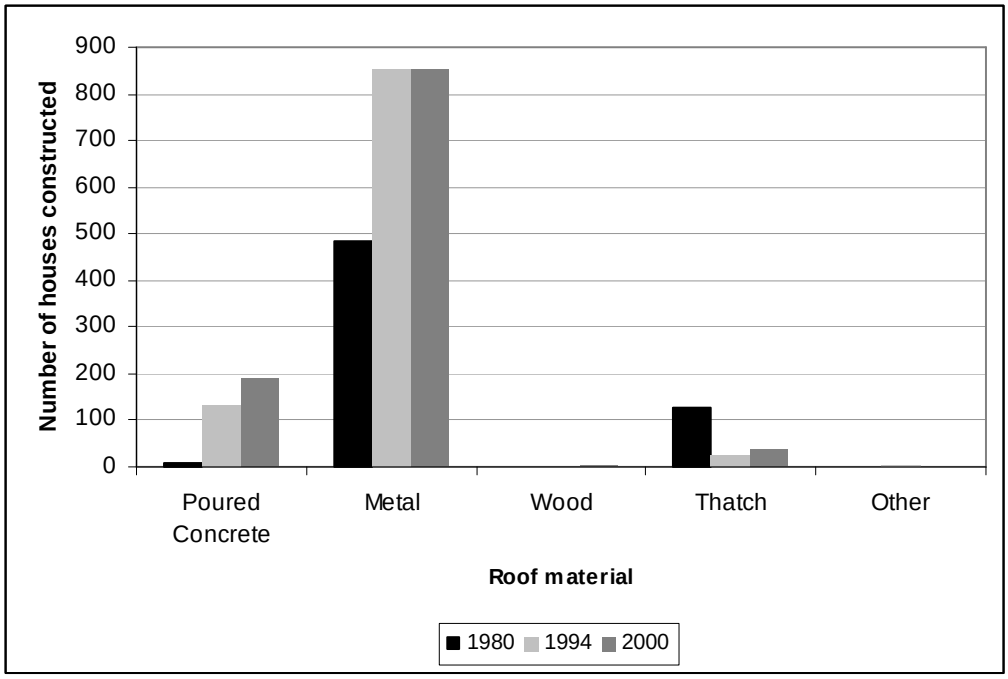


Figure 4: Changes in the roof material used for housing construction between 1980 and 2000.

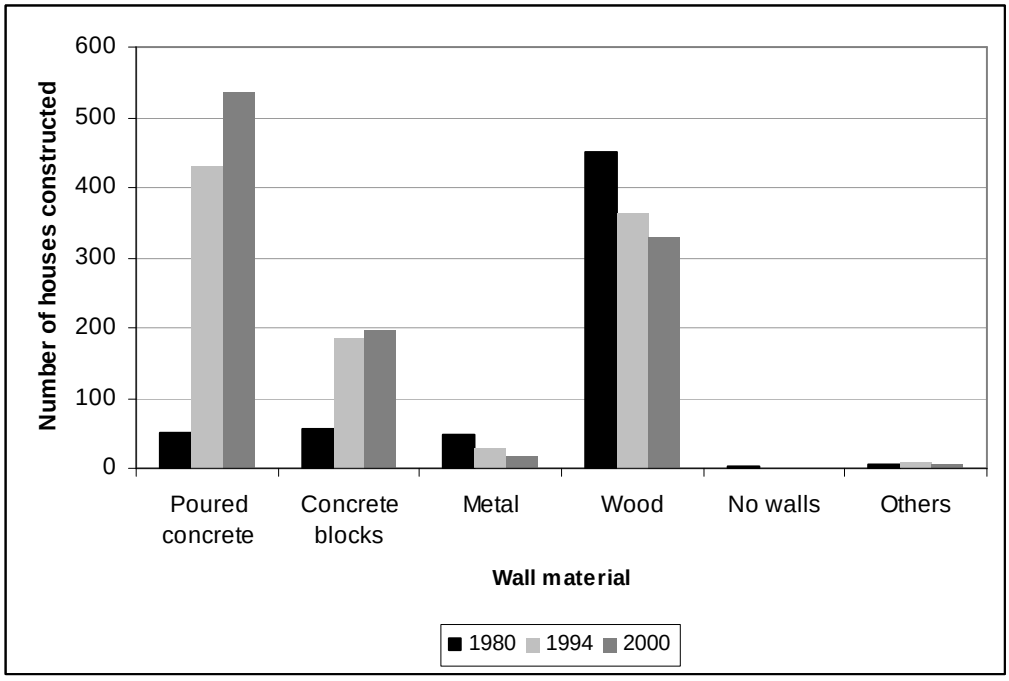


Figure 5: Changes in the wall material used for housing construction between 1980 and 2000.

3.3 Current sources of sand for construction

Existing sources of construction sand are summarized below:

- DRC licensed sand mining sites
- Importation from Pohnpei
- Un-licensed sites

3.3.1 DRC licensed permit sites

The most common permitted source of construction sand is from a Development Review Commission permitted site. All permitted sand mining sites are in the coastal hinterland with no sand extraction allowed from the beach or directly behind the beach. A permit is issued for one year, whereupon it needs to be renewed, with a number of conditions, most commonly specification of the area that can be mined and restoration requirements to the site once mining has ceased. The location of all permitted sand mining sites since 1993 are shown in Figure 6, with Figures 7 and 8 show the total number of permitted sites each year between 1993 and 2000 and the breakdown for each municipality.

All permitted sand mining sites are located in the immediate coastal hinterland, with sand aggregate dominated by marine carbonate sediments, see sections 3.4 and 4.2 for more information.

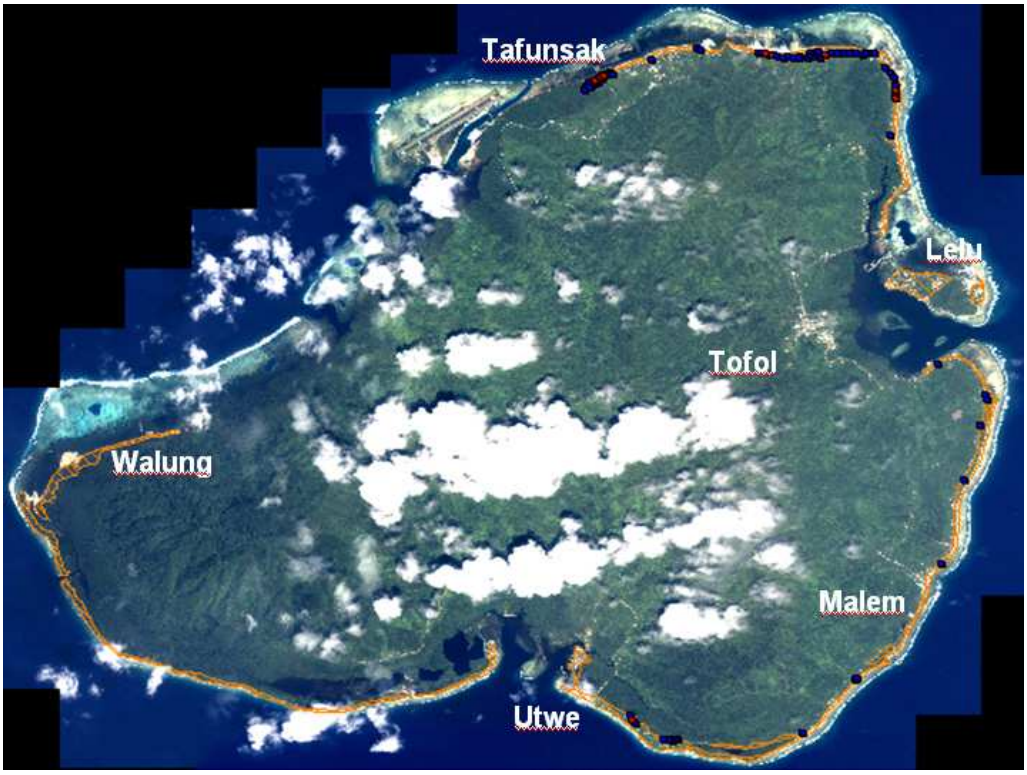


Figure 6: Locations of all permitted sand mining sites between 1993 and 2000 (blue dots). Existing permit sites (2000) are shown by red dots. The orange areas show the extent of the existing coastal sand deposits.

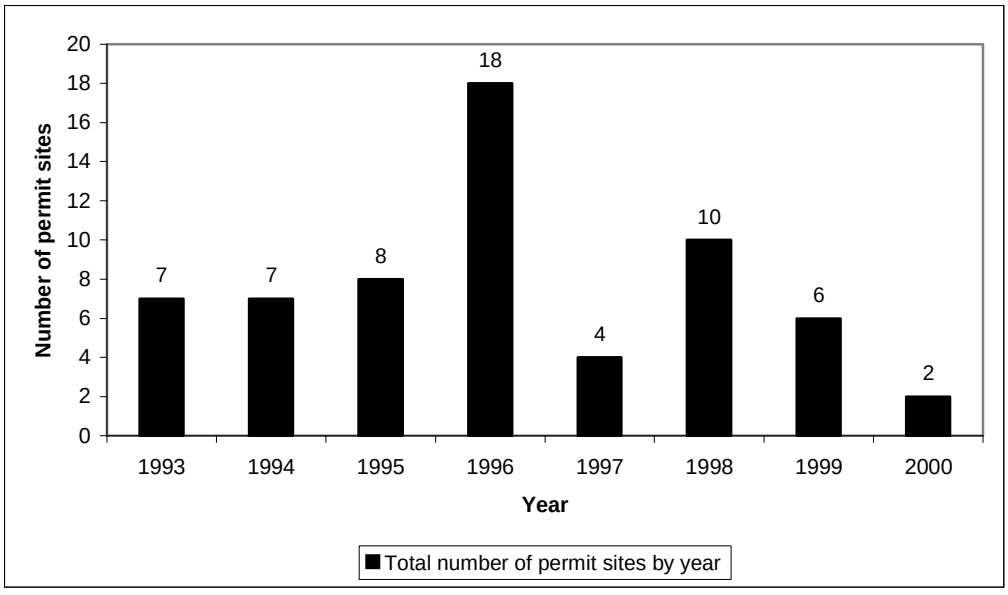


Figure 7: Total number of permitted sand mining sites by year (1993 – January 2000).

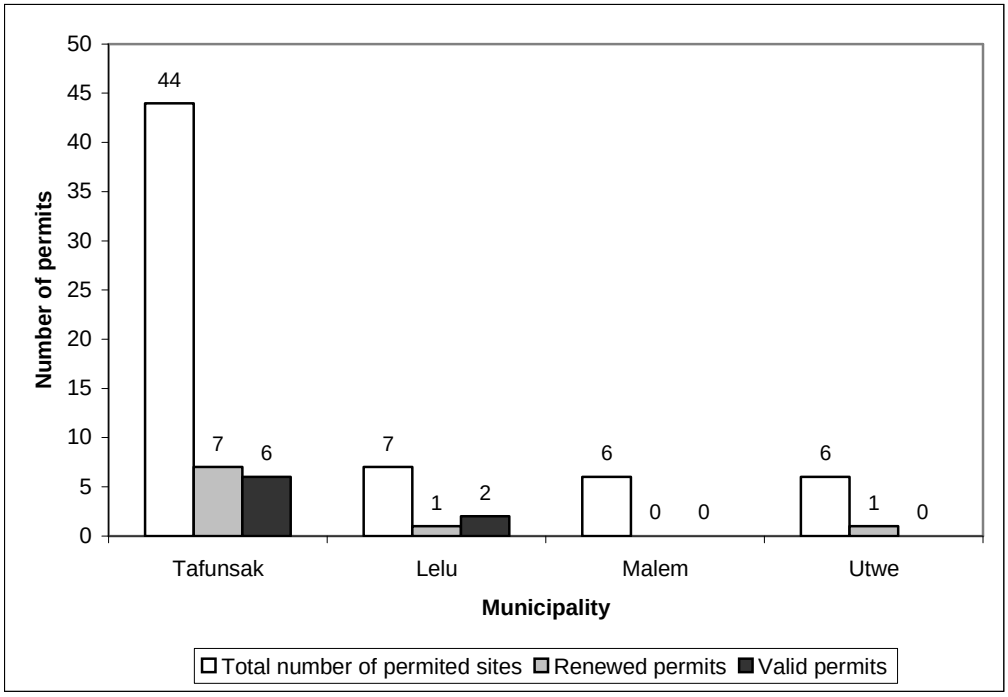


Figure 8: Permitted sand mining sites in each Municipality (1993 – January 2000).

It is difficult to obtain an accurate assessment of the volume of sand extracted from permitted sites. Most permits rarely specify the actual dimensions or volumes to be extracted and in many cases actual excavation rarely relates to the permit details. Assessing actual excavated volumes has proved to be difficult without detailed surveying and due to many of the pits being backfilled (a condition of their permit).



Figure 9: Typical small scale permitted sand mining site (left) and larger scale government site supplying sand for the hard sealing of the road between Okat and Walung.

3.3.2 Importation from Pohnpei

Sand imported from Pohnpei is a relatively recently occurrence, starting in the later part of 1999. The sand is sourced from reef flat dredging operations on Pohnpei's reef flat. However, the Pohnpei EPA are keen to see the export of sand to Kosrae from this source stopped and such dredging practices limited and

Kosrae White Sands, who are responsible for importing from Pohnpei estimate that up until January 2000 ??? cubic yards of sand was imported.



Figure 10: Imported sand from Pohnpei at Lelu (right), and an old reef dredge pit on Pohnpei (right).

3.3.3 Un-permitted sites

The other major sources of sand aggregates come form un-permitted sites. These are either:

- Sand and coral aggregates removed from the beach or reef flat areas
- Sand or coral obtained from small pits in the immediate coastal hinterland on the landowners property, usually close to the particular construction project.

Removal of sand from small pits in the coastal hinterland is preferable to the removal of beach material from the beach of reef flat areas. However, this can only provide a sufficient volume of sand aggregate for relatively minor construction projects. Indeed in almost every yard can be seen indentations where small amounts of sand has been excavated.

The main beach mining locations are generally those with easy access to the circumferential road, with some of the most regular locations listed below:

- Walung coastline
- Pukusruk, Finfokoa & Finaunpes
- Muntunlik and Sansrick

- Pilyuul to Malem Municipal dump, particularly Malem village and Kotfwa to Fukrin coast
- Utwe / Malem Municipal Boundary to Utwe village

Unfortunately most of these stretches of coastline are also the some of the most heavily eroded areas.

3.3.4 Current sand resource demand for construction

There are no accurate figures available for the amount of sand used for construction on Kosrae. An estimate can be made based on the amount of cement imported from the Kosrae Statistical Yearbooks. The value of cement imported between 1991 and 1998 is summarized in the table below. From this an estimate of the volume of sand utilized for cement and concrete construction has been made based on an average aggregate to cement ration of 4:1, with the assumption that a 50kg bag of cement costs $8.50 (no account has been made for inflationary changes).

Table 1: Value of cement imported and estimate of construction sand demand

Year	Value of Cement Imported ($)	Tonnes of cement (tonnes)	Est. tonnes of sand used (tonnes)	Est. volume of sand used (cubic metres)	(cubic yards)
1991					
1992					
1993	108,464	638	2552	982	1284
1994	146,486	862	3447	1326	1734
1995	174,831	1028	4114	1582	2069
1996	78,407	461	1845	710	928
1997	258821	1522	6090	2342	3064
1998	409494	2409	9635	3706	4847

Kosrae aggregate demand for concrete and cement construction in 1998 was approximately 10,000 tonnes (or about 1000 truck loads). This value of cement imported (and presumably volume of sand aggregate utilized) has quadrupled since 1994, with a particularly large increase from 1996 to 1998. A similar increase is seen in the value of other construction material imported, such as timber, plyboard and corrugated iron. However, it can be assumed that actual sand aggregate demand may be considerably greater as sand is also used for landscaping, a surfacing for tracks and a sub-base for paved road.

An assessment was made of records held by the Department of Public Works of the volume of sand used in Government construction projects, Table 2, between 1989 and 1998 (this does not include sand used in contracts let to private contractors).

The Department of Public Works sand requirements are extremely variable, depending on major capital construction projects. Increasingly more projects are now being contracted out to the private sector. Furthermore, future demand for infrastructure development is likely to be heavily dependent on the outcome of the current Compact Negotiations with the US.

Table 2: Sand usage by the Department of Public Works since 1989

Year	Volume of sand Yds^3 (m^3)	Equivalent tonnes of sand (metric tonnes)	Percentage of annual total estimated from cement imports
1989	580 (443)	1153	
1990	280 (214)	557	
1991	32 (24)	64	
1992	1420 (1086)	2823	
1993	503 (385)	1000	39
1994	917 (701)	1823	53
1995	54 (41)	107	3
1996	622 (476)	1236	67
1997	972 (743)	1932	32
1998	184 (141)	366	4
Average annual usage (since 1993)	542 (414)	1077	23

Note: A number of projects were conducted over more than a year. The sand quantities have been included in the year of completion.

Black Construction, the largest private construction company indicated that they required approximately 500 cubic yards for the Malem Wastewater Project in 1999 and require 4000 cubic yards for sub-base for current upgrading of the circumferential road between Okat and Tofol which is being obtained from a permitted sand mining site at Sialat in Tafunsak.

3.4 Engineering properties of beach sand as a construction material

Virtually all of the sand found on the reef flat, beaches and hinterland deposits on Kosrae is derived from the physical and biological production and breakdown of carbonate skeletal remains of corals, mollusks, sea urchins and other echinoderms, sea cucumbers, forminafera (mainly *Baculogypsia sphaerulata*), crustose coralline algae, and sand producing green algae (*Halimeda sp.*). Only a very small percentage of sand sized material, found in these coastal deposits, has derived from terrestrial sources.

Construction aggregate with a high calcium carbonate content generally has poor engineering properties when compared to terrestrial derived sediments. Specifically, such aggregates are of low unit weight and have low crushing / compressive strength. They also contain harmful chloride and sulphate ions and are of low abrasion qualities.

Carbonate sands bonds poorly in concrete, deteriorates in concrete-aggregate mixtures, and is porous and can easily crumble. Furthermore, in Kosrae, the sand is rarely washed in fresh water before use as a construction material. This causes the reinforcement in the concrete to corrode and causes paint to peel easily from the walls.

These inherent properties render these materials generally of low quality, with structures built using such material having a much shorter life than buildings constructed with terrestrial derived sediments. These factors all lead to much higher maintenance costs, and can be seen in Figure 2 in Section 3.2.2 where the average Kosraean residence has a life-span of fifteen to twenty years.

4. Future construction aggregate sources on Kosrae

4.1 Introduction

Virtually all of Kosrae's constructions sand comes from marine derived sources in the coastal zone. However, this is a limited resource. The following chapter assesses the future sources of construction aggregates on Kosrae

4.2 Existing hinterland deposits

Kosrae's land based sand resources are extremely limited. A major assessment of Kosrae's soil types was conducted by the US Department of Agriculture in 1979 and 1980, with a report containing soil type maps produced in 1983 (USDA, 1983). This report detailed the suitability of Kosrae's soils for a wide range of land use activities and management practices. The suitability of soils for construction aggregates was assessed within this report and potential land based sand and gravel sources mapped. The report indicated that there were two main identifiable soil types that may be potential construction sand sources:

- ***Ngedebus loamy Sand:*** Sand derived from coral and other carbonate sediments derived from marine sources found in narrow strips of 2 to 10 hectares in size along the coastline. The elevation of the deposits is usually less than 2m above sea level. The surface layer is typically dark greyish brown loamy sand, 10 centimeters (4 inches) thick, with a 40cm thick (16 inches) subsoil of pale brown sand and a substratum of very pale brown sand of 150 cm (5 feet) or more.

  Figure 7 shows the sediment grading curve limits for the substratum (the surface layer is normally removed as it has a higher percentage of fines and organic material). A typical sediment grading curve of construction sand is shown in Figure 11 from Livingstone Anton's permitted site in Sialat, Tafunsak.

- ***Ngedebus-Urban land:*** This sand is similar to the above, consisting of 50% Ngedebus loamy sand and 40% Urban land. The sand and gravel is derived from coral and other marine carbonate sediments. The elevation of such sources are generally less than 2m above sea level. The soil description and sediment gradings are similar to that of the Ngedebus loamy sands.

There are another two soil types that have less potential for construction aggregates but may have small deposits of suitable construction sands:

- ***Ngedebus variant:*** This soil type is derived dominantly from coral but with fine sands from other carbonate marine sources. Elevation of such deposits are less than 2m above sea level. The surface layer is typically dark brown very cobbly loamy sand, 10cm thick. The subsoil is pale brown very cobbly sand 40cm thick, with the substratum very pale brown very gravelly sand to a depth of 150cm or more. The potential for construction aggregates is much reduced due to the high percentage of cobbles and gravel.

- ***Ngerungor mucky peat:*** This soil is unsuitable for construction aggregates, formed from mainly organic material and is mainly swamp forest. There are small deposits of marine sands around the edges of this soil type, typically buried at depths of less than 150cm. However, this is unlikely to be a productive source of construction sands.

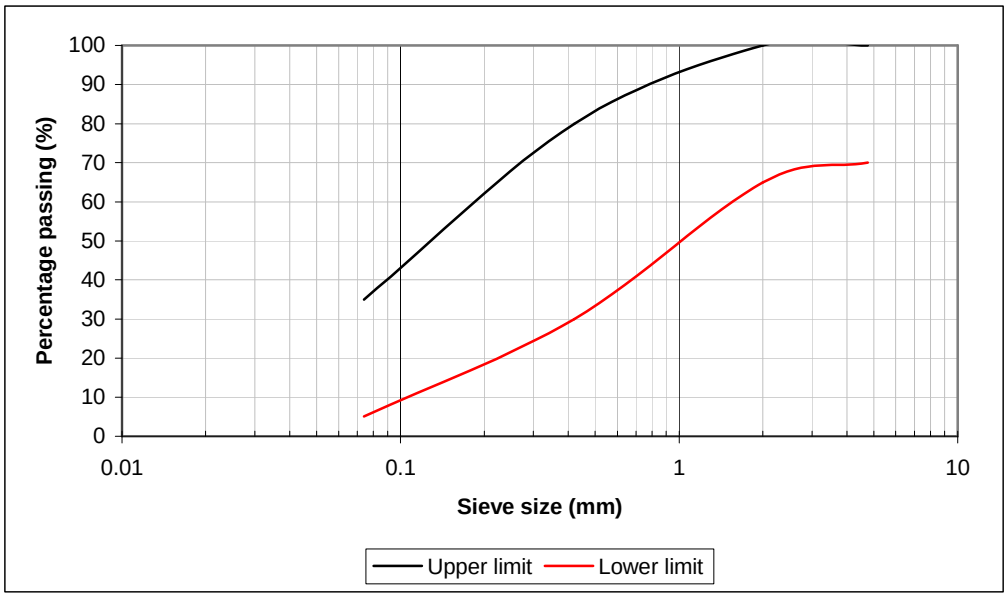


Figure 11: Sediment size range of Ngedebus loamy Sand (10-150cm depth).

As would be expected almost all of Kosrae's potential aggregate resources are derived from marine sources (see Section 3.4), with deposits occurring in narrow wave deposited locations around the coastline of Kosrae (see Figure 6). Virtually all existing permitted sand mining sites are located in areas of Ngedebus loamy sands. All other soil types identified on Kosrae are unsuitable as a source of construction aggregates, largely due to the high percentage of clay or silt.

The soil types with potential to provide construction sands are also the location where virtually all residential property and infrastructure is situated around the island. From the assessment of USDS mapping and from site visits to most of the permit sites on Kosrae the following summary of the future potential in each of the Municipalities has been developed

- ***Lelu:*** Virtually no potential sites where any significant future permitted sand mining sites should be allowed. Some small scale sites could be permitted on the landward side of the circumferential road in the Finfokoa area.

- ***Malem:*** Virtually no potential sites where any significant future permitted sand mining sites should be allowed.

- ***Utwe:*** Few potential sites. Some small scale sites could be permitted on the landward side of the circumferential road to the east of the road to Finsrem.

- ***Tafunsak:*** Substantial deposits are located in the Sialat, Finfukul and Finfoko areas of Tafunsak. However, these have been extensively exploited over the last five or so years. There is still potential suitable sand mining sites along the Tafunsak coastline, situated well back from the coastline, inland from the road. However, as these are the only substantial deposits on Kosrae they can only realistically meet Kosraes sand aggregate demands for the near future. Considerable sand mining has been conducted in the Fintukaa area of Tafunsak. No further mining should be permitted in this area apart from small scale sites landward of the access track.

4.3 Crushed volcanic deposits

The crushing of various volcanic rocks is a major source of construction aggregate throughout the world. For example, the US currently produces approximately 2.3 billion tons of construction aggregate from such sources.

Crushed volcanic rock is used on Kosrae to produce 3/8" ½" and ¾" chips for concrete and other construction, Figure 12. Black Micro have a crushing plant located at Inlas quarry in Sansrick. Rock is blasted or dug from the quarry face and crushed into the three aggregate sizes.



Figure 12: The crushing plant and quarry at Sansrick, and the ½" chips produced.

A waste material is produced from the existing crushing operation (black sand). Some concrete tests have been conducted by Public Works, which have found that the mix does not bind well. This is primarily due to the high percentage of aggregate above 2.38mm (8 mesh) and below 0.074mm (200 mesh), Figure 13. To use this material as a sand aggregate source would require screening to remove the fine and course particle with such equipment not available on Kosrae at present. However, virtually all of the stockpile that has accumulated is now being used as part of the sub-base for the road upgrading project between Okat and Tofol. Furthermore the quantity of waste material produced is insufficient to meet Kosrae's long term demands.

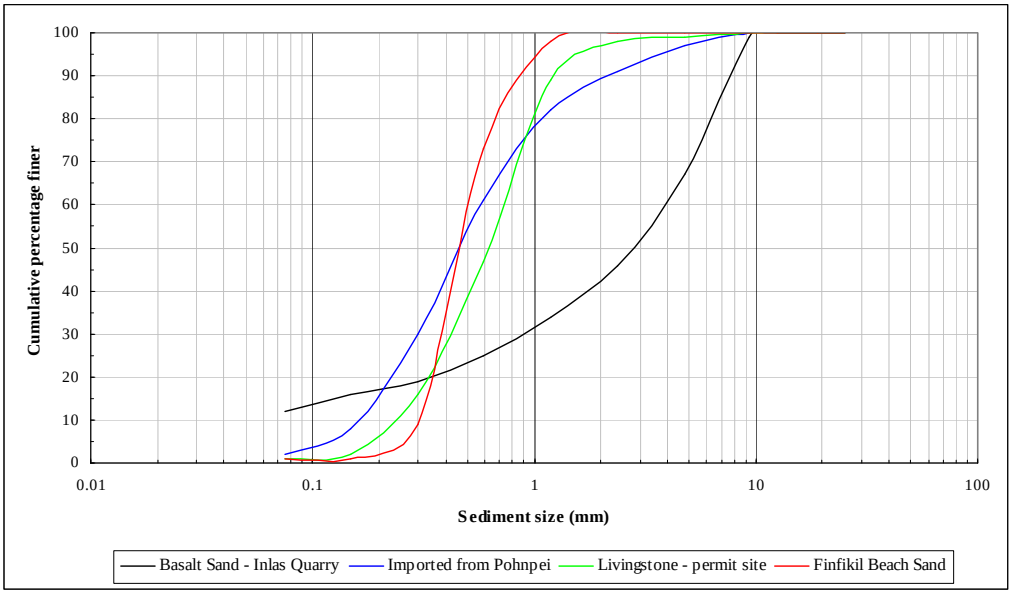


Figure 13: Typical sand gradings from various sources on Kosrae.

A study was conducted by SOPAC (Maharaj, 1999) in Pohnpei to assess the suitability of the rock for construction sand. As the volcanic rock on Kosrae is very similar to that on Pohnpei it can be expected that it will also be suitable for such a purpose. Rock

samples have been sent to SOPAC in Fiji for testing to assess their suitability for producing sand aggregate.

To develop sand sized aggregate would require the purchase of a new crusher and screening equipment which has a considerable capital cost attached to it. The operation of the plant may also be reliant on Black Micro, which may limit the flexibility the Government has in introducing this alternative. This is discussed more fully in Chapter 5. A summary of the advantages and disadvantages of developing this option are listed below.

Table 3: Advantage and disadvantages on developing crushed volcanic rock as an aggregate source.

Advantages	Disadvantages
• Potentially new, very large source • Likely to have good engineering properties • Production costs low once equipment is set up • Potential to also crush glass and certain plastics in some uses (e.g. road sub-base) – help waste management problem • In the longer term, potential for economic income from exporting to the Marshalls and Kiribati.	• High initial start up costs. • May be reliant on Black Construction to supply • People may still prefer to continue to use beach sand due to convenience or economic factors

4.4 Deposits in Lelu & Okat Harbours

There may well be significant and accessible sand deposits within both Lelu and Okat Harbours that could be exploited as a sand source.

To assess this source an assessment of sediments within these two harbors will be conducted by the South Pacific Applied Geoscience Commission (SOPAC) sometime in 1999. SOPAC have been requested by the FSM National Government to carry out bathymetric mapping of all of the navigational ports in the FSM (Lelu & Okat in Kosrae) and sediment analysis of both these harbours will be conducted at the same time.

Sand material in both harbours may well be of a poorer quality than existing beach sands. Sand is likely to be dominated by *Halimeda* fragments. Such sediment tends to be highly friable, with a high percentage of fines and usually unsuitable for use in cement or concrete mixes. However, the source may be suitable for surfacing of farm tracks, and other landscaping.

To extract this sediment, the procurement of standard dredging equipment is unlikely to be economically feasible. However, there are suction pumps available that can work to depths of 10m (30ft). One such pump is now being used in Kiribati to extract sand from the lagoon.

Table 4: Advantages on developing sand sources in Lelu and Okat Harbours

Advantages	Disadvantages
• Potentially new, large source • Relatively inexpensive suction pumps (in relation to dredging equipment) are capable of operating in up to 10m (30ft) water depth. • May be suitable for surfacing of farm tracks and un-paved roads	• May be poorer quality sediment than existing beach sources • Difficulty in extracting sediment in depths deeper than 10m • May need barge or similar to transport sediment to shore and offloading facilities. • Expensive capital costs • People may continue to prefer to use beach sand due to convenience or economic issues

4.5 Importation from Pohnpei

Sand from Pohnpei is currently being imported to Kosrae by Kosrae White Sands. This sand is dredged from the reef on Pohnpei and there is considerable pressure by the Pohnpei EPA to reduce this practice. A number of geological studies have recently been conducted on Pohnpei (Smith et al, 1998, Marahaj, 1999) which have recommended that reef flat dredging be reduced and that the emphasis be placed on crushed volcanic aggregates for construction material. A typical sediment grading curve for sand aggregate imported from Pohnpei is shown in Figure 13.

Table 5: Advantages and disadvantages of importing sand from Pohnpei.

Advantages	Disadvantages
• Larger source • Already occurring on a small scale • Potential for improving construction materials if Pohnpei begin to produce sand aggregate from crushed volcanic rock	• Higher than existing market cost • Existing sediment is still a poor construction material. • People may prefer to continue to use sand from the beach due to convenience or economic issues. • Shipments at present are irregular • May simply increase problems for another FSM State. • Likely to be some time before Pohnpei is able to supply crushed volcanic aggregate for export to Kosrae.

4.6 Offshore deposits

There are no sand deposits on the outer coral reef slopes around Kosrae that are likely to be accessible to current dredging technology.

4.7 River deposits

There are no significant river deposits of sand sized material on Kosrae to meet the demand of construction aggregates. The use of such sources often cause significant environmental damage.

4.8 Further dredging at Semo ship repair facility

The ship repair facility at Okat Harbor was constructed on reclaimed land using dredged reef material from around the vicinity of the facility. Through the latter part of 1998 and 1999, dredging of the reef flat continued with the dredged material available for purchase. Semo estimate that approximately ??? tonnes were supplied during this time.

The dredged reef material is mainly used in landscaping, road sub-base or farm road paving. The quality is not suitable for use in cement or concrete. Since the latter part of 1999, no further dredging has occurred. From discussions with the US Forest Service Experts (Allan, Kraus, Pers. Comm.) there is no current evidence that dredging activities at Semo have had an impact on the health of the mangroves in the area. However, it was stated that it could be a number of years before any impacts are evident. Whilst a silt barrier is supposed to be in place during dredging activities, it is not known whether sedimentation effects from the dredging activities are having an impact on the marine ecology. Hence, it is recommended that no further dredging of the reef flat be permitted until a fuller understanding of the impacts that this activity could cause be developed.

5. A proposed way forward

5.1 Introduction

From the preceding discussion it is considered that to adequately meet Kosrae's future sand aggregate demands and to reduce the current extent of un-permitted sand removal from the beaches around Kosrae that the following key issues need to be fully considered:

- The removal of sand and coral rubble from the coastline has been a major cause of coastal erosion on Kosrae. Although large scale (mechanical) removal of sand has now ceased, small scale, localized, sand mining by hand is continuing to exacerbate the significant coastal erosion problems that have previously occurred.

- Sand mining legislation has been largely ineffective in other small islands (in many cases increased the problem) without the prior introduction of affordable alternative sand sources, full support from the political leaders and continual perseverance.

- The import of cement (and other construction material) has quadrupled (in value) between 1993 and 1998. It can be assumed that a similar increase in the amount of aggregates (sand and gravel) used has also occurred. It can also be assumed that this increase will continue, at least in the short term

- Future Kosrae Government Sand demands are likely to be highly dependant on the outcome of the financial agreements reached as part of the Compact Negotiations with the US. Future demands may also be reduced due to an increasing amount of Government construction projects being contracted to the private sector.

- With an increasing population and increasing development and construction demands, Kosrae is facing a serious aggregate shortage which will:

    - Restrict construction activities in the near future (unlikely),
    - Result in an increase in un-permitted sand removal from the beach or coastal hinterland.
    - Increase pressure on the Development Review Commission to permit sand extraction from unsuitable sites.

- Existing and future permitted potential sand mining sites in the coastal hinterland are limited and can only be considered a short-term solution. Furthermore such pits often become a breeding ground for mosquitoes, dumping sites, and may well lead to coastal erosion problems in the future.

- Kosrae has no offshore deposits of sand, beyond the coral reef, that are accessible to current dredging technology.

- As Kosrae has only a fringing reef surrounding it, there is no potential for reef flat mining as is conducted on Pohnpei or the Marshall Island (which in itself causes significant further problems as seen at Tafunsak).

- The carbonate sands used for construction on Kosrae are a very poor construction material, leading to high maintenance costs and short building lifespans.

To establish a way forward to tackle these key issues there are three main process that can be adopted:

1. Education on the impacts of removing sand from the coastline
2. Regulate the removal of sand and cobbles from the coastline and reef flat
3. Develop alternative low-cost sources of construction aggregate

5.2 Education

During 1999, the Development Review Commission has conducted a number of educational activities concerning the impacts of sand mining. This included an initial awareness poster and radio broadcasts on the subject. A further factsheet has been developed which goes in to more detail on the impacts of sand mining, how it affects people in the community and what people can do to help reduce these impacts.

The objective of the education program is to increase awareness amongst the communities of the effects of sand mining in exacerbating coastal erosion. The cost if this is relatively minimal but ongoing. In terms of effectiveness, the advantages and disadvantages are summarized in Table 6.

Towards the end of 1999 there was some concern that sand mining from the beaches was on the increase, with it being postulated that the education campaign had led people to believe that a sand mining law banning the practice was about to be introduced. However, there is no evidence of stockpiling of sand around the island, all

sand taken from the beaches appears to be used in ongoing construction projects. This apparent increase is more likely to be attributed to an ongoing increase in the rate of private sector and housing development (see Section 3.2.2).

Table 6: Advantages and disadvantages of an educational campaign.

Advantages	Disadvantages
• Increases awareness of the problem • Low cost • Is a necessary precursor to other methods of tackling the problem	• Doesn't solve the problem – people have to get construction aggregate from somewhere. • People are aware of the problem but are unwilling to use other sources due to cost and inconvenience. • Doesn't address the poor quality of construction material used on Kosrae.

5.3 Regulation

There is considerable pressure from many parts of the Government, and many local people, to completely ban the removal of sand from the beaches. Two approaches have been considered to control the removal of sand and other aggregates from un-permitted sites on the reef flat and beach areas:

- Changes to Housing Renovation Loan Fund regulations
- Development of a full sand mining regulation

5.3.1 Housing Renovation Loan fund

The Housing Renovation Loan Fund (HRLF) was established by the Kosraean Government to provide loans of up to $20,000 for the construction or renovation of a residential property. A high percentage of new residential dwellings on the Island are financed by the HRLF scheme. In-addition most residential housing construction does not require a DRC permit, and most sand removed from un-permitted site is for house construction, renovation or landscaping Recommendations have been made to the regulations to ensure that recipients of a Housing Renovation Loan use sand and aggregate from permitted sites on Kosrae, or imported sand:

> *"No loan application will be considered proposes the removal of sand or coral aggregate from the beach, reef flat, or other non-permitted site for construction or other activities associated with the loan".*

It is intended that this requirement be enforced by ensuring that the bill of quantities for HRLF applications identifies a legitimate source for the sand, and the budget

accounts for this cost. The addition of construction aggregates generally adds little to the overall construction budget.

The major benefits of introducing this addition to the HRLF is that:

- It is both easily enforced through the existing Housing Department monitoring process,
- It does not introduce an onerous financial commitment on the applicant as the sand component is a relatively small part of most loans.

5.3.2 Sand mining regulation

A further measure is to completely ban the removal of sand and coral aggregates from the reef flat and beach areas. Currently a regulation has been drafted but as yet is on hold.

The perceived view is that the introduction of such a regulation will be effective in controlling the removal of beach sands and other aggregates from un-permitted sites. However, experience from other small islands, See Chapter 2, suggests that this is rarely the case unless a number of other factors are also addressed.

One of the main questions with the regulation of sand removal from the beach is: where will people get construction sand from? It has already been discussed in Section 4.2 that the potential for future DRC permits in Lelu, Malem and Utwe is extremely limited and that although Tafunsak has more substantial deposits, these have been actively exploited over the last ten years.

There is no point in punishing people who have no practical (or affordable) alternatives. If such regulation is to be applied, it is vital that the appropriate infrastructure be developed to provide feasible alternatives. Furthermore one of the major criticisms of environmental regulation such as this, is that it is socially regressive (the financial impacts increase as personal income decreases).

It is foreseeable that the Development Review Commission would be responsible for enforcing such regulation. Enforcement of such laws are often problematic. In essence they work by either deterring the removal of sand due to the threat of criminal action or by applying criminal sanctions if caught removing sand from the beach. However, the DRC can only act on cases that they know about:

- By the time that the DRC is made aware of the activity, the sand has been removed from the beach. In some cases the sand could be returned to the beach but in others it may already have been used.

- There is likely to be many cases that the DRC is unaware of (such as mining under the cover of darkness etc) – hence the impacts, exacerbating coastal erosion, will still occur.

The DRC permitting process is also likely to come under increasing pressure to permit sand mining sites that are unsuitable as the demand for sand from permitted sites increases and the available sand resources and suitable sites decreases.

Table 7 below summarizes the relative advantages and disadvantages of introducing regulation to ban sand mining.

Table 7: Advantages and disadvantages of adopting sand mining regulation

Advantages	Disadvantages
• Provides a legalized course for controlling the mining of sand and coral rubble. • Will be most effective when applied in conjunction with the introduction of alternative sand sources.	• Doesn't solve the problem – people have to get construction aggregate from somewhere. • Impacts most significant on low income households • Doesn't address the poor quality of construction material used on Kosrae. • Will lead to pressure on the DRC to permit sand mining from unsuitable sites. • Difficult to enforce on an island like Kosrae. • No examples of small island states where regulation, on its own, has been effective in controlling sand mining (see Appendix 1).

5.4 Developing alternative sand aggregate sources

5.4.1 Introduction

Chapter 4 assessed the future sand aggregate options for Kosrae. Out of these, the most feasible solution to meeting Kosrae's future aggregate demands is considered to be the development of sand from crushed aggregate. This could be supported with sand won from shallow deposits in Lelu and Okat Harbours should future planned surveys indicate suitable potential. At present

Currently geological tests are being conducted to assess the potential for producing sand from Kosrae's volcanic rock. Six suppliers of rock crushing equipment have also been contacted, with three having responded. From initial discussions with these suppliers the following aspects are important:

- The cost of such equipment (crusher and screening equipment) is likely to range from about $35,000 to $100,000 for second hand equipment and about $100,000 to $200,000 for new equipment.
- These crushers have the capacity to produce between about 15 and 100 tons per hour, a vastly greater capacity than Kosrae requires to meet existing sand demands
- Some equipment has a limit as to the size of rock that can be crushed which may result in a reliance on Black Micro to first produce chipped size material as an input to the sand production process.
- It is likely that the sand material produced will need to be washed and sieved which will require such facilities at the Inlas Quarry site.

5.4.2 Some considerations for the development of this source

There are a number ways that the development of a sand supply from volcanic sources could be developed. The options are introduced here, but will require substantial further discussion and economic assessment to develop this further and decide on the most appropriate way forward. The various ways that such equipment could be sourced are summarized below.

Table 8: Options for the development of volcanic sand source on Kosrae

Purchase of equipment	Equipment owner	Equipment operator
Aid funded, or FSM National Government, or Kosrae State Government	Kosrae Government	Kosrae Government
Aid funded, or FSM National Government, or Kosrae State Government	Kosrae Government	Private Sector
Private Sector	Private Sector	Private Sector

The various costs, advantages and disadvantages of each option needs to be assessed carefully. For example, allowing the private sector provide the capability relieves the Government of any financial commitments in terms of the capital purchase and maintenance but results in the sand aggregate being offered at current market costs. On the other hand, if the process is wholly controlled by the Government a mechanism will need to be put in place to ensure some income is programmed for maintenance and replacement of equipment in the future. However, the Government can control the costs and develop economic incentives (see next section) to persuade people to switch to the alternative source.

5.4.3 Economic measures in introducing an alternative sand source

Experience from the introduction of alternative aggregate sources in other small islands has suggested that offering alternatives at the market rate is not the most effective method, in terms of persuading people to switch from the use of beach sand to the alternative.

On Kosrae, sand is expensive, reflecting that relatively few landowners control the areas with suitable sand resources. Sand for construction purposes costs approximately $30 per cubic yard. At such rates there is considerable scope, given the current relative requirements between Government / contractor requirements and individual or household requirements, and the production potential, to develop and introduce a economic incentive scheme for low volume users or low income or subsistence communities. For example:

- All Government contracts and private contractors purchase the sand at the market rate.
- Individuals with development grants or housing loans purchase the sand at the market rate
- Individuals without Government jobs can claim a certain volume of free or reduced cost sand per week or month.

Finally, there could be considerable potential for the export of high quality construction sand, such as could be produced from volcanic sources. The Marshall Islands and Kiribati are less than one day's sailing from Kosrae. Both these islands have a vastly greater aggregate demand and have no good quality sand sources. Current sand aggregate activities on these islands largely consists of reef dredging which is causing substantial environmental damage. Any economic assessment into the development of volcanic sand aggregate sources on Kosrae should investigate the feasibility of this.

5.5 The way forward - conclusions and recommendations

To effectively tackle the sand mining problem, Kosrae must learn from the experiences of other island states. None of the three methods detailed above will solve the sand mining problem alone. Nor will the problem be solved overnight. It is going to take perseverance over a long period of time to effectively tackle the problem. Education, regulation and the development of alternatives all need to be carried out together if an effective solution to Kosrae's future sand aggregate and beach sand mining problems are to be tackled:

1. It is vital that education on the impacts of sand mining is continued. If alternative sand sources are developed, the community must be made fully

aware of the availability, why the source has been developed and why it should be used.

2. The alteration to the HRLF is currently under consideration. It is considered that this regulation can be effective and easily achieved at present.
3. Adopting a full sand mining regulation is not considered a practical or effective solution to the sand mining problems being experienced on Kosrae at present. However, such regulation will be an integral part of tackling sand mining activities on Kosrae in the future but will first require:
    - The development of a good quality, inexpensive alternative sand source
    - The provision of the infrastructure to allow people to access this supply in each of the Municipalities.
    - The development of incentive measures for low volume users or people on subsistence incomes
4. Careful consideration needs to be given as to how the alternative sand source is developed, and in the use of economic incentives for low income and low volume users.
5. An assessment should be made of the potential for exporting sand aggregate to neighbouring island states.

Figure 14 summarizes the proposed timeline for the educational, regulatory and alternative sand source development activities.

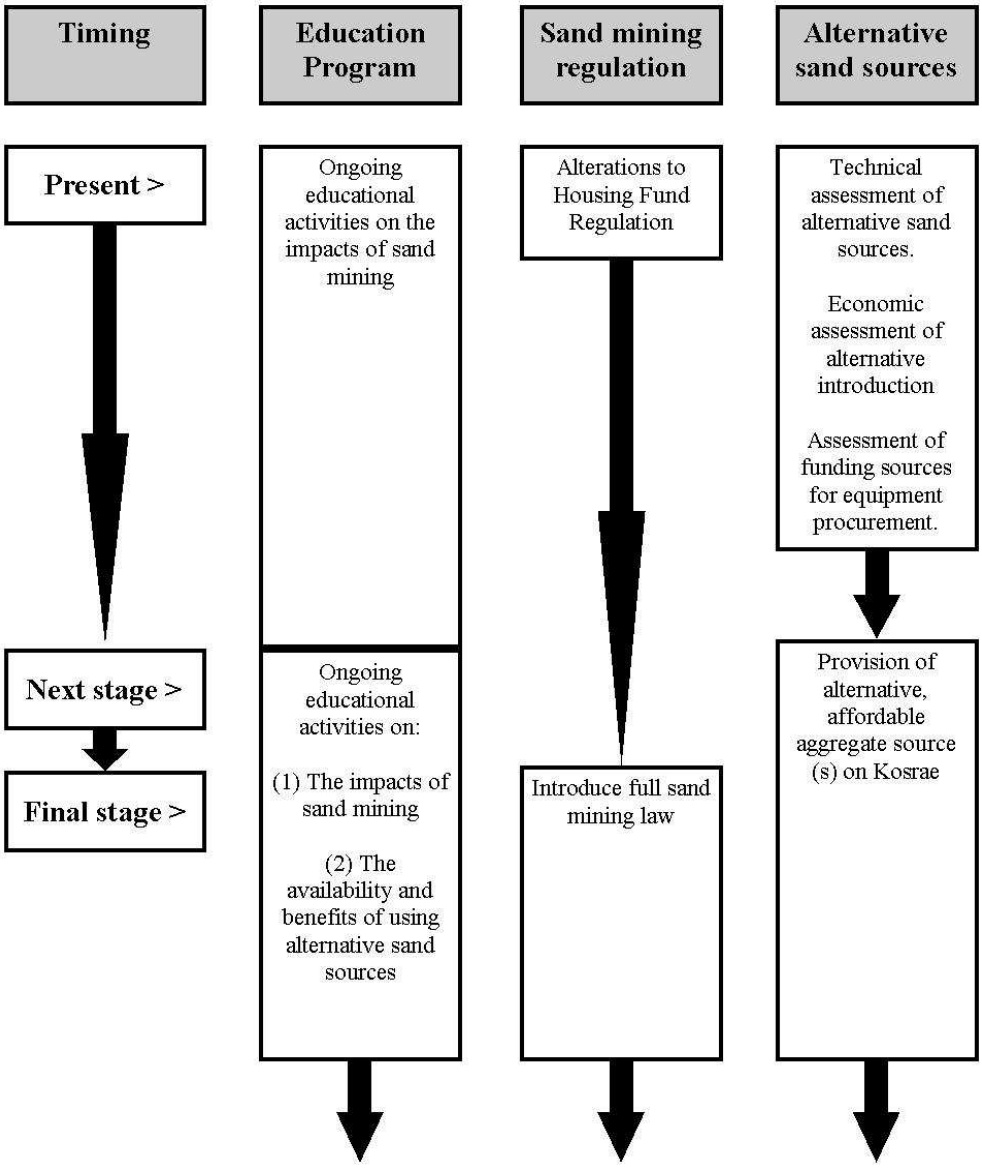


Figure 14: Proposed timeline of the staging of activities for successfully reducing sand mining activities on Kosrae.

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7. Appendix 1: Case Studies of the effectiveness of sand mining legislation from the Caribbean

Island	Overview of Law	Effectiveness and comments
Puerto Rico	No Sand Mining law as yet enacted	• Long term approach being adopted by developing alternative sand sources • Proposed legislation and enforcement once alternatives available
Grenada	Beach Protection Act 1979 • Makes removal of sand, stone, shingle or gravel illegal • Exemption can be granted by Government Minister	• Illegal sand mining increasing despite increasing public and government dissatisfaction and condemnation of the practice. • Reasons for failure of the legislation are: (1) no policy on the supply of alternative sand sources; (2) ineffective enforcement of legislation; (3) underestimation of the extent of the problem
Tobago	• Permitted sand mining sites which include certain beaches	• Sand being removed from beach sites 'closed' to sand mining and extensive erosion occurring on permitted beach mining sites. • No effective controls over permitted or non-permitted sites • No assessment of suitability of beach for sand mining in permitting process • Other sand sources suitable but unpopular as they cost money (are not free)
Montserrat	Beach Protection Ordinance No 9 (1970) • Prohibits and person from using a motor vehicle to remove sand, stones, shingle or gravel from any part of the beach unless written permission from permanent Secretary. Beach Protection Act (1994): • Introduced to tighten sand mining legislation and enforcement.	• Sand mining continued (1970 – 1990). All beaches then closed to sand mining with the exception of three. • Assessment of alternative sources, (1990) - Development of imported sand and local quarry (1992) • Sand mining continued – quarry sand was priced too highly and was of poorer quality than beach sand. • Education campaign to persuade people to use quarry sand. • One beach reopened to sand mining (1993) and was effective in reducing illegal sand mining from other beach areas • Beach Protection Act has not be enacted – illegal sand mining increasing due to the permitted beach being closed due to volcanic activity.
British Virgin Islands	Permitted sand mining sites (mainly beaches and coastal hinterland) Beach Protection Ordinance (1985) • Legal protection to all beaches from removal of beach material or natural barrier except under permit granted by Government Ministry The Mining Act (1980) • Prohibits the removal of construction material from any un-permitted site	• Illegal sand mining occurring but on a reasonably small scale but causing coastal erosion problems • Legislation considered to be ineffective as (1) it is limited in scope – all areas that need to be considered for sand mining are not addressed; (2) sand mining is not directly included • Potential alternatives available (sand deposits in valleys) but no attempt yet made to use this resource.
St Vincent & The Grenadines	Regulation under the town and Country Planning Act (1994) • Control the mining of sand and coral from beaches	• 30% of island sand consumption from beaches • Study of alternatives and impact of sand mining (1993). Development of imported sand source. • Government announces use of imported sand in all construction projects and for any projects where Government concessions have been received from 1 January 1995 • Persons on the south of the island required to use imported sand – some sand mining from beaches still permitted on north side of the island (distant from imported sand landing site) • Panic stockpiling of beach sand after government announcement (exacerbated by opposition political party). 2.5 times annual average sand consumption removed from one beach alone between 18 December 1994 to 31 January 1995. • Lack of communication by Government on the introduction of alternative sources, market cost of imported sand, and lack of enforcement appear to be the main reasons for the public panic.