Improvement of Pukensukar Channel Outlet, Malem

Assessment and recommendations for mitigation works

Introduction

This brief report is in response to a request by the Department of Administration, dated 28 January 1999, to review proposed engineering works to mitigate accretion of coral shingle and sand at the mouth of the Pukensukar Channel in Malem.

A site visit was conducted by Mr Douglas Ramsay and Mr Andy George of the DRC at low tide on the morning of 3 February 1999. This was followed up by a subsequent visit at high tide by Mr Ramsay during the afternoon of the same day. During both visits a discussion was held with the local landowner, Mr Bardon Musrasrik concerning the problem. A subsequent discussion was also conducted with Mr Gladstine Cornelius.

Outline of the problem

Mr. Bardon Musrasrik described the major problem being flooding of large areas of low-lying agricultural land on the landward side of the main road during periods of high rainfall. The flooding was most severe when heavy rainfall coincided with high tidal conditions. Blockage of the channel outlet by sand and coral shingle due to wave action results in flood-water being unable to drain from the agricultural land causing damage to crops. When the channel outlet is open flooding still occurs, but as the tidal level falls, flood waters drain more rapidly from the agricultural land.

Assessment of channel blockage processes

Stabilization of mangrove channels is one of the most difficult tasks to achieve using engineering structures without having a serious detrimental impact upon the surrounding coastline (which can lead to other problems such as increased coastal erosion). In a natural system, with no human impact, a mangrove will normally maintain an open channel naturally. Mangrove channel outlet problems normally occur where there has been some human impact upon the surrounding environment (and this may be due to some change a considerable from the outlet site) for example:

- changes to the drainage characteristics (diversion of streams, restrictions on flood water flows) or
- changes to the movement of beach material along the coastline due to construction or changes someway along the shoreline.

Historic changes to the outlet of the Pukensukar channel and Yeseng River were documented by Xue (1996) which show the progression of shoreline erosion occurring along this coastline. Previously the outlet of the Yeseng River and Pukensukar channel ran parallel to the shoreline to the north-east. The location of the seaward mangroves indicates the seaward boundary of the channel and the previous position of the natural shoreline. It is unclear when erosion began, but may be linked to changes in tidal processes and the supply of sediment caused by sand mining. Wave action is primarily responsible for the landward retreat of the coral shingle and sand beach. It does this by overwashing the beach during stormy conditions at high tidal levels. Overwashing is where waves move beach material from the front face, over the crest and deposit it onto the back face resulting is a steady landward movement of the beach. There is also a wave-induced transport of coral sand and shingle along the beach in a northeast to southwest direction.

At the Pukensukar outlet there are probably two main human impacts linked to the flooding and channel blockage problem. This first is linked to the construction of the main road and changes to the drainage patterns. During flood conditions the culvert under the road is unlikely to be large enough to allow the full flood flow through. This results in a backwater effect resulting in increased water levels within the area of

the agriculture land (which is exacerbated during periods of high tide). The landowner, Mr Bardon Musrasrik confirmed that during heavy rainfalls flood levels were regularly above the top of the invert of the culvert. There are also a couple of pipes across the channel that will trap debris further restricting flow. Further discussion with Mr Gladstine Cornelius confirmed that this culvert did impede flood flows during heavy rainfall. It was also mentioned that a farm road to Mr Bardon Musrasrik's land affected the drainage characteristics resulting in much stagnant water around Mr Cornelius' property which causes a mosquito problem. The farm road was also thought to exacerbate flooding in the area with only a 24" diameter pipe permitting flow between the mangrove areas across the road.

During times of high rainfall, the larger volume of flood-water would also act to "flush out" sediments that have collected at the opening of the channel helping to keep the channel opening clear (the natural movement of beach material from north to south along the coastline will act to transport material across the mouth of the channel). However, if the culvert under the road is preventing the full flood flow to pass through then this flushing effect may not be occurring.

The second influence causing the blockage of the channel entrance is directly due to the amount of sand mining that has occurred along the northern bank of the channel outlet. This has lowered the land levels immediately behind the coral shingle beach to the north of the outlet with this area being submerged during very high tides.

The main influence this is having is on the stability of the coral shingle beach along this part of the coast. The beach now acts as a barrier beach. Storm wave action will cause this barrier to move landward at a greater rate than if land levels behind the beach had been maintained. This wave action (during high tides) will tend to cause overwashing of the coral shingle ridge, flattening the ridge and moving beach material over the land immediately behind. In response to this, the back of the beach along this frontage has been pushed back up by mechanical means. The effect of overwashing is particularly evident around the outlet of the Pukensukar channel where beach material is washed into the channel outlet. It is expected that complete infilling of the channel will occur due to overwashing during more severe wave conditions.

In addition the sand mining has allowed a larger "estuary" area to occur. Such areas tend to act as traps for beach material until a balance occurs between the flushing action of the river flows and the amount of sand and coral shingle within the estuary. With a larger estuary, this balance has been affected, with increased siltation within the estuary occurring to re-establish this natural balance. Furthermore, with the removal of vegetation over the area that has been sand-mined, the land level is now at approximately high spring tide elevation. It is difficult for land vegetation to re-establish over this area due to the high concentration of salt-water close to the land surface. This leaves an area of bare sand that can easily be washed or blown into the river channel.

Removal of material from the channel is having some effect on the immediate coastline to the south. As this removed material is stockpiled on the sand mined area to the north it is resulting in a loss of beach material from the natural beach system. This can be seen with the beach south of the outlet now having retreated behind the line of mangrove trees. By removing the material from the channel there is a disruption to the natural northeast to southwest transport of beach material resulting in exacerbated erosion to the south.

In summary it is apparent that the blockage of the channel is certainly not the cause of the flooding within the agricultural land but it will contribute to some extent in preventing flood waters from draining when the tide falls. However, it is probably not as significant as the constriction caused by the culvert under the main road.

Assessment of the proposed engineering design.
In addition to appraising the processes causing blockage at the outlet of the Pukensukar channel, the site visit was used to assess the suitability of the mitigation works proposed by the Department of Transport and Utilities. The proposed scheme consists of approximately 100ft of grouted rip-rap river training walls with a 150ft long offshore breakwater positioned 45ft offshore of the channel outlet.

A rock breakwater parallel to the shoreline directly in front of the channel will tend to increase the blockage problem at the mouth of the river. Such structures are commonly used to provide coastal protection by both directly stopping wave action but also by modifying the wave pattern and hence the movement of sediment in the lee of the structure. Where there is a supply of beach material being moved along the coastline (such as at this location), sand and coral shingle will tend to be deposited behind the structure to form a bulge in the coast, known as a salient.

Offshore breakwater structures such as this tend to be very effective in trapping sand and coral shingle material being transport along the coastline. Unless carefully positioned, this can result in what is known as downdrift erosion. This is where the coastline (in this case to the south west) is "starved" of beach material as it is being trapped by the structure (to the north east) resulting in an increase rate of erosion and shoreline retreat along the shoreline to the south west of the channel opening.

It is expected that wave damage to the offshore breakwater structure will result in frequent maintenance requirements. The specified rock size with a 2ft diameter constructed with 1:1 side slopes would be relatively unstable under the more severe wave conditions likely to be experienced at the site. It is considered that toe damage to the front face, rock armor displacement to the back face and significant damage at the ends of the structure will all occur due to the steep side slopes of the structure and size of material used. The steep front face will also result in wave reflection from the structure which may well cause the removal of sediments in the surrounding area leading to an increase in water depths (and hence wave heights). This can lead to the occurrence of larger wave heights and may potentially affect the remaining mangroves, which are situated off the coast, and which do provided some protection from wave action.

Turning now to the channel training work, it is also considered that this will not be effective in maintaining an open channel. The width of the bottom of the channel is proposed to be 15ft with 1:1 side slopes with a top width of 23ft. This is much wider than the present naturally occurring channel. By widening the channel this will tend to decrease the flows that occur within it reducing the scope for self flushing or scouring of sediments due to the action of the channel flows. This will result in a requirement for periodic dredging of the channel.

Assessment of alternative solutions
Maintaining an open channel at the outlet will not solve the flooding problem experienced within the agricultural land. Only by increasing the size of the culvert across the road and ensuring that the drainage channels are in as natural and unrestricted condition as possible will flood flows due to heavy rainfall be permitted to drain as effectively as is possible. By allowing these flood flows to drain in such a natural manner, the blockage problems at the channel outlet will be mitigated somewhat due to the increased flushing action of the flood flows.

It is highly unlikely that any engineering works in a area of coastline that is changing such as this will maintain an open channel without further remedial work (i.e. clearing out the channel or altering the engineering works at periodic intervals). As stated before, stabilization of mangrove channels is one of the most difficult tasks to achieve using engineering structures due to the dynamic nature of the coastline in these areas. It is also highly likely that any stabilization scheme will have a detrimental impact on the coastline, particularly to the south which is already suffering from coastal erosion with the beach retreating behind the line of mangrove trees.

Until flood flows are allowed to drain more naturally, work will be required to maintain an open channel. It is considered that periodic dredging is the most cost-effective option and least environmentally damaging method of maintaining the channel open:

- It is suggested that the channel be excavated about 10-15 yards further south than the present cut (closer to the mangroves where there is a small natural channel at present (but far enough away to ensure that their roots are not affected by the dredging operation). The depth and width of the channel should be similar to that of the natural channel.

- It is also suggested that the material dredged from the channel be deposited south of the channel to ensure that the supply of beach material to the eroding coastline south of the channel is disrupted as little as possible.

- It would be advisable to attempt to stabilize the area where sand mining has occurred. This may be an excellent site to attempt some mangrove rehabilitation as there is a good mix of salt and fresh water and supply of sediment which are all required by mangrove trees. Introducing mangrove vegetation may well eventually stabilize the channel banks, trap sediments which could otherwise accrete within the channel and help raise land levels in this area.

- Future sand mining or removal of beach material from this area is not recommended.

The landowner, Mr Brandon Musrasrik, considers that the channel would need to be re-opened four times per year and that it takes and excavator approximately four hours to do so. Using the cost estimate for the proposed engineering works as a guide, and allowing for the normal contingencies and overheads this would cost approximately $234 per excavation or $936 per year (see attached copy of cost estimate). Compared to the cost of completing the proposed works ($16,110) and allowing for an assumed inflationary cost increase on average of 6% per year, the channel could be excavated four times per year for the next 13 years for the same expenditure as the proposed works.

Conclusions and recommendations

From the site visits conducted, and an assessment of the proposed engineering works, the following conclusions and recommendations are made:

- The flooding of the agricultural land is primarily due to the restrictions to the flow caused by the culvert through the main road and possibly due to the farm road to Mr Bardon Musrasrik's land and not due to the blockage of the channel at the outlet.

- The blocking of the channel outlet is linked to the restrictions to the flow caused by the culvert through the main road in preventing flood flows maintaining the channel opening by flushing out sediment within the channel. The sand mining within the area to the north of the outlet has also increased the potential for the channel to become blocked.

- By improving the drainage of the agricultural land and allowing sufficient capacity within culverts and drainage channels for flood conditions to flow unrestricted, the impacts of flooding upon the agricultural land will decrease. This should also improve the flushing of sediments from the outlet of the channel ensuring that the channel opening is maintained for longer periods.

- It is considered that the proposed engineering works may well increase silation at the outlet of the channel and will potentially have a detrimental impact on the surrounding mangrove community and

the coastline to the south. It is expected that the proposed design of the offshore breakwater will experience frequent damage from the wave conditions experienced at the site.

It is considered that the most efficient, cost effective and least environmentally damaging approach is to:

- Investigate ways of improving flood flow drainage from the agricultural land
- Continue excavation, up to 4 times per year to maintain and open channel. It is suggested that the channel entrance be excavated approximately 10-15 yards to the south of the existing outlet to a similar width and depth of the natural channel.
- Deposit the material excavated from the channel along the coastline to the south of the channel to help reduce the impact on the coastline in this area due to the removal of the sediment supply
- Use the area where sand mining has occurred as a trial for mangrove rehabilitation which, in the long term, may improve the stability of this area, the mangrove outlet and channel and the coastline to the north of the channel outlet.
- Conduct no further sand mining or removal of beach material from this area.

Douglas Ramsay
Coastal Engineer
Development Review Commission