Development of Integrated Shoreline Management Planning: A Case Study of Keta, Ghana

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Key words: Shoreline Management, Planning Policy, Coastal Problems and Sea Level Rise

ABSTRACT

This paper focuses on the approach for the development of an integrated shoreline management plan for the coast of Keta. Shoreline management provides a large-scale assessment of erosion and flood risks associated with present land use at the backshore of a coast. It then presents a policy framework to reduce risks to people and development in a sustainable manner. The paper reveals that coastal erosion and flood risk is generally greater along the coast of Keta due to the soft geology and extremely low-lying nature of the shoreline and extensive hinterland relating to the Volta delta. It identifies that even one metre sea level rise could submerge large areas at the backshore affecting communities, land use and environmental quality. The paper recommends the development of storm warning systems, emergency evacuation planning and building of elevated storm surge shelters among others as key measures that should be implemented to manage the flood risk of Keta. Such measures are especially important for the coastal settlers around the Volta delta where the hinterland is so extensive and low-lying that extremely large areas could be flooded in future leaving few safe heavens to which the population could retreat.

The paper concludes that coastal management problems identified in Keta are experienced in other sections of Ghana’s coastline and similarly, along the coast of many developing countries, so the paper provides a direct practical example on dealing with the issue of shoreline management problems for countries with similar problems. Thus, the shoreline management approach developed for Keta could serve as a guide for wider coverage of entire Ghana’s coastline as well as similar coastlines elsewhere.

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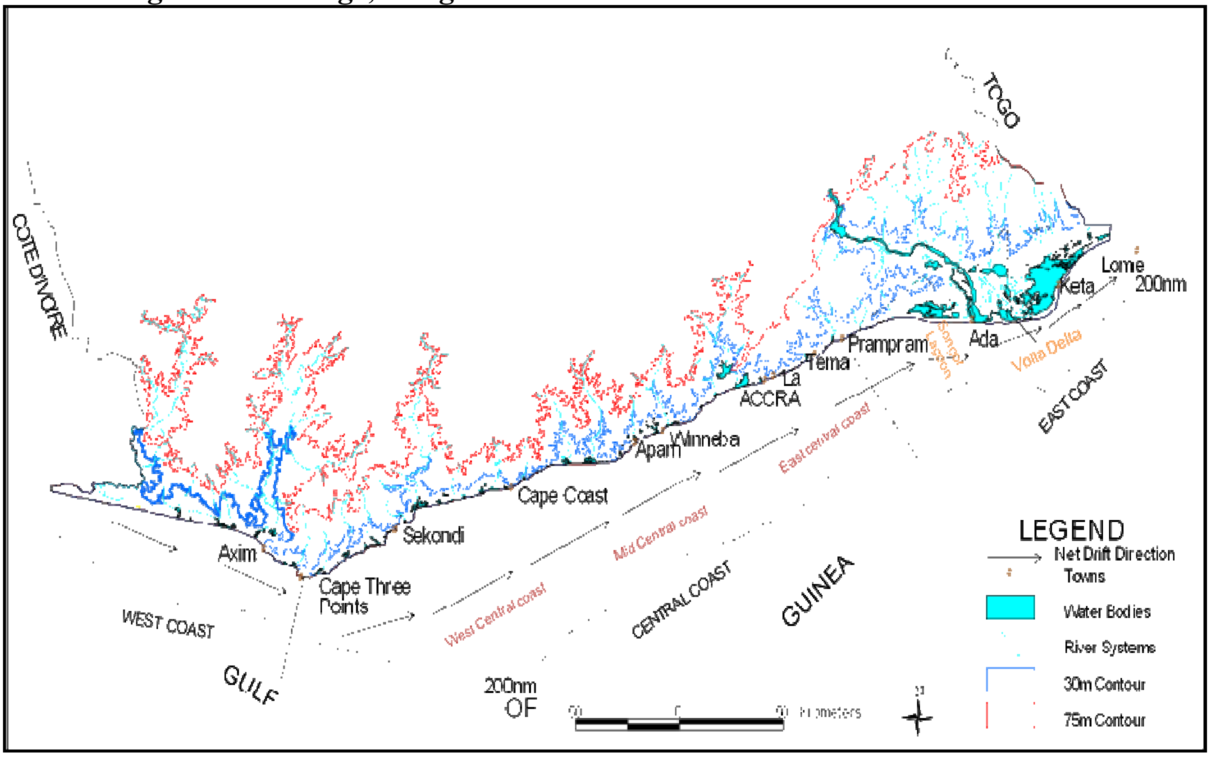
1 INTRODUCTION

The total land area of Ghana is 238,533 km^2 with a coastline of 540km. The ocean coast is mainly high-energy type and has some lowlands, which are prone to flooding. The coastal zone in Ghana is defined as the area below the 30m contour representing about 7% of the land area and it is home to 25% of the nation's total population of about 20 million and a place where about 70% of industries and businesses are located (Armah and Amlalo, 1998).

Figure 1 Ghana and its Location in West Africa

The coast of Ghana has been divided into three, based on geomorphologic characteristics. They are Eastern, Central and Western coast (Figure 2). The **Eastern coast**, which is about 149km, stretches from Aflao (Togo Border) in the East to the Laloi lagoon west of Prampram. It is a high-energy beach with wave heights often exceeding 1 metre in the surf zone (Ly, 1980). It consists of a sandy shoreline and is characterised by erosional processes. Wellens-Mensah et al (2002) explained that the Volta River has a dominant influence on the geomorphology of the Eastern coast. The surface geology of the area is made up of fluvial sediments deposited from the river as well as marine and fluvial-marine sediments. It comprises recent or Quaternary rocks and unconsolidated sediments that are easily identified to consist of clay, loose sand and gravel deposits by rivers at their mouth. The most extensive of these deposits is found at the extreme Eastern end of the coast at the mouth of River Volta and around Keta lagoon. The barrier beaches of this coast comprising medium to coarse sand rise steeply in elevation to about 2m above mean sea level. Behind the beaches is a system of lagoons, the largest being the Keta lagoon.

Figure 2 Drainage, Longshore Drift and Divisions of Ghana's Coastline



After Benneh and Dickson (1988) & Armah and Amlalo, (1998)

1.1 Coastal Problems in Ghana

Coastal erosion, flooding and shoreline retreat are serious problems along the coast of Ghana. Past human impacts, inappropriate management interventions, climate change and sea-level rise have been identified as major contributory factors (Armah, 1991). Several consequences could be expected from sea level rise in Ghana. In particular, low-lying sandy coastal areas at the eastern coast such as the Volta Delta and Keta lagoon could be profoundly affected. The expected impacts of sea-level rise are: direct inundation (or submergence) of low-lying wetland and dry land areas; erosion of soft shores by increasing offshore loss of sediment; increasing salinity of estuaries and aquifers; raised water tables; and exacerbated coastal flooding and storm damage (IPCC, 2007). These impacts will in turn influence coastal habitat, bio-diversity and socio-economic activities.

These problems are a threat to life, properties and developments along the coast including Ghana's rich heritage of historical coastal sites. There are about 40 castles and forts, which were developed along the coast between 15th and 18th centuries by various European countries. These castles and forts were used as trading centres for various goods including slaves. These castles and forts are structures of historic importance to Ghana and Africans, especially, those in Diaspora. UNESCO has designated three of these, namely Cape Coast Castle, St. George's Castle and St. Jago Fort at Elmina as World Heritage Sites.

In spite of the present and expected threat to life and property outlined above, there is no formal management plan for Ghana's shoreline. In fact, data and understanding available on near-shore physical processes that might help critical analysis and management of coastal erosion is fragmented and incomplete. There is also inadequate information on sediment budget, wave characteristics and dynamics of the local current and sediment transport patterns. Apart from these shortcomings, there are also inadequate skilled personnel to carry out research and management of the coastal zone (World Bank and EPA-Ghana 1997).

There is therefore, the need for a more holistic study of the shoreline to develop an integrated shoreline management plan for the coast and recommend appropriate interventions, strategies and mitigations to address the likely socio-economic impacts of climate change and associated sea-level rise on the coast (IPCC, 2007). This paper presents a detailed assessment of the risks associated with coastal processes and presents a long-term policy framework to reduce these risks to people, development, cultural heritage and natural environments of Keta sea front and the adjoining coastline in a sustainable manner.

2 SHORELINE MANAGEMENT PROBLEMS IN KETA

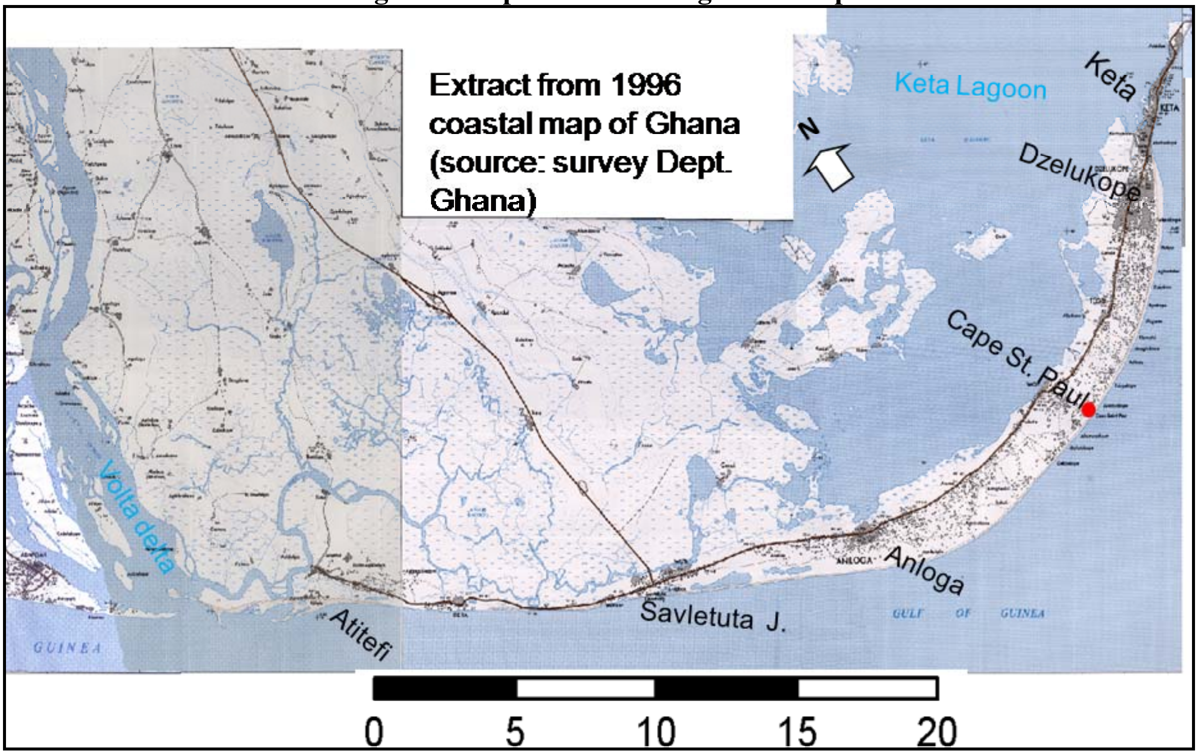
Keta is a littoral town which is located at the west of Keta Lagoon inlet. The town is sited at the eastern end of a narrow littoral strip (Keta strip) that stretches from the east of the Volta estuary to the mouth of Keta lagoon (Figure 3). Keta lagoon (the largest lagoon in Ghana) has large wetlands which extend to the Volta delta. The wetland is a designated Ramsar site under Ghana Wetlands Management Project. The littoral strip separating the lagoon fresh water from Gulf of Guinea sea water is believed to have been form by fluvial sediment deposit from the Volta (Figure 3).

Historical, very large accretion occurred along the entire frontage of the slightly curved littoral strip which ranges between 0.5 km and 2.5km in width (Ly, 1980). However, there was moderate erosion at the frontage of Keta due to the loss of littoral sediment into the lagoon inlet. Unfortunately, shortage of littoral sediment was created by the Akosombo dam which was built on the Volta River in 1964. The dam led to the reduction of fluvial sediment supply from the Volta River from about 71 million m^3/a to a little as 7 million m^3/a (Boateng, 2009). The shortage of littoral sediment created by the Akosombo dam has reduced the accretion of the littoral strip since the late 1960s.

Prior to the construction of the dam on the Volta, there was a natural accretion at Cape St. Paul (Figure 3). However, the situation is different today; Cape St. Paul has been retreating since the construction of the Volta Dam (Armah, 1991 and Allersma and Tilmans, 1993).

Presently, the accretion is occurring at Atetifi and Savletuta Junction located further west of Cape St. Paul and close to the Volta estuary. This has become possible as a result of reduced ebb tidal energy from the Volta which is caused by the reduction of the flow of the river due to the dam.

Figure 3 Map of the Showing Keta Strip



Comparisons of historical shoreline positions 1895 and 1964 indicates accretion rate of 1.8m/year along the curved littoral strip (Boateng, 2009) and retreat of 4m/year between 1923 and 1949 at the frontage of Keta (Ly, 1980). However, Ly, (1980) assessment of post-Akosombo dam recession rate at Keta identified that the Keta section of the coast was retreating at the rate of 8m/year between 1964 and 1975.

The increase erosion in Keta suggests that the reduction of littoral sediment supply caused by Akosombo dam led to the fast erosion of the coastline down-drift the Volta estuary. This situation resulted in a quick recession and devastations on the shoreline and settlement between Keta and Hlove from 1965 to 2002. In fact, since 1965, a series of coastal defences had been developed to halt the recession in this area. The recent and perhaps the largest defence project developed in this area is the Keta Sea Defence which was constructed between 2001 and 2002 with the aimed to intercept the reduced yet significant present littoral sediment drift between Keta and Hlove and possibly halt the recession.

The defence project (Plate 1) had the following key components; construction of an 8.3-km road/causeway between Keta and Hlorve, re-establishing the barrier link lost to erosion. The sea defence has limit further erosion by stabilising the shoreline with one offshore breakwater and seven headland groynes and a feeder beach and beach nourishment was placed between the groyne bays from Keta to Hlorve. Also a flood control structure to provide inhabitants around the lagoon with relief from extreme flooding conditions has been constructed. In addition, land has been reclaimed from the lagoon in the area of Keta, Vodza and Kedzi, to provide areas where housing and businesses lost to the sea can be rebuilt (Ellicott Dredges, 2000). The rock amour groynes constructed as part of the Keta Sea defence were not long enough to stop the transfer of sediment down-drift. In fact, field evidence gathered in 2006 suggests that the groynes have started losing the beach nourishment materials (Plate 2).

However, complete interception of the littoral transfer by constructing long groynes might further reduce or stop the transfer of sediment down-drift but it is likely to cause severe erosion to the coastline of Togo and Benin that seems to benefit from the down-drift transfer of sediment (Blivi et al, 2002). It is reasonable to suggest that integrated approach and perhaps an international effort is required to develop a sustainable management solution to this issue, since any measure aim at intercepting large amount of the littoral transfer at the eastern boundary of this cell would have significant effect on the coast of Togo and Benin.

Plate 1 Aerial View of Keta Sea Defence (*Source: Google Earth*)

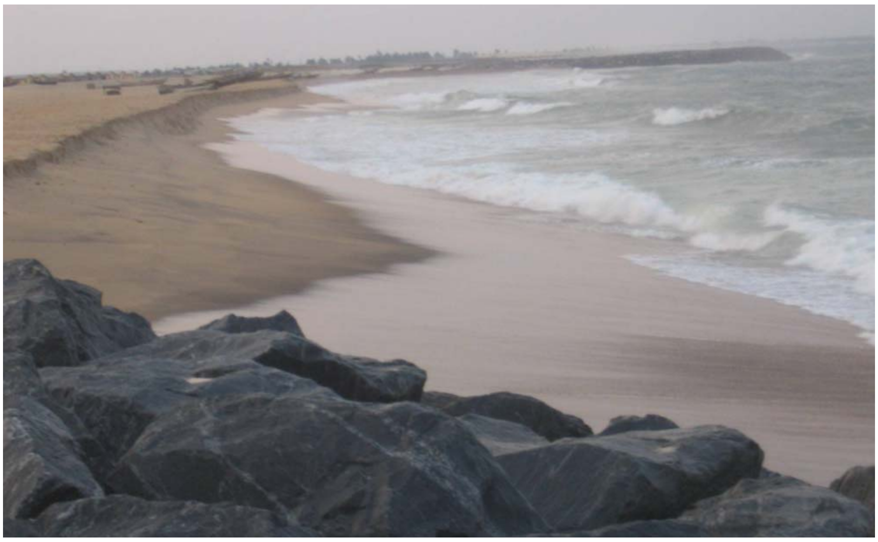


Plate 2 Erosion between Defence Groynes at Keta

3 CONCEPTUAL UNDERSTANDING INTEGRATED SHORELINE MANAGEMENT PLANNING

Coastal management seems to have focus previously on 'site specific' hard structures approach which tend to stabilise a specific section of a coastline and cause a "knock on effect" down-drift (e.g. Keta Sea Defence). Many developed nations with a long history of hard engineering management interventions at the coast are beginning to find that the cumulative impacts of their widespread defence and engineering interest are no longer sustainable when considered alongside potential future risks of climate change and increased public and legislative appreciation of landscape and environmental values. This has led to development of more holistic and potentially sustainable shoreline management methods in some nations (Hooke, 1999; DEFRA, 2006; Boatman et al, 2008; IUCN, 2007 and Mascarenhas, 2008). For example, UK shoreline management planning since the mid 1990s has achieved success in reducing the occurrence of "knock on effects." It has altered thinking away from the basic provision of site specific defences towards a more integrated management of risks at the coast, setting out clearly the locations where protection is likely to be required and others where there are alternative options.

Integrated Shoreline Management Plan (ISMP) is a plan that identifies one coastal defence strategy for a specific length of coastline (a "management unit") and for a defined period of time, typically up to 50 years. An ISMP provides a large-scale assessment of the risks associated with coastal processes and presents a long-term policy framework to reduce these risks to people and the developed, historic and natural environments in a sustainable manner. In doing so, an ISMP is a high level document that defines the broad requirement for provision of flood and coastal defences and protection. It also takes into account the impacts of defences on the natural environment (DEFRA, 2001; Cooper et al 2002)

Cicin-sain and Knecht (1998) explained that shoreline management includes erosion control programmes, protection structures against storms and waves (sea defence), replenishment of beaches as well as prevention and mitigation of coastal hazards (storms, inundation and sea-level rise,). Shoreline management recognises inter-tidal areas, lagoons and waters as a single interacting and indivisible resource unit that lies between the hinterland and the open sea and whose future must be planned and managed as a unified whole (Clark, 1992).

Shoreline management should not be misconstrued with integrated coastal zone management (ICZM) which refers to the management of the interface between the land and the sea and may extend inland and offshore to a variable extent, in most cases to the 30m contour landwards and to the edge of a state's 200 nautical miles exclusive economic zone (Cicin-sain and Knecht, 1998). Taussik, (1995) indicated that coastal zone comprises three elements: the land, the inter-tidal zone (shoreline) and the sea; and further explained that the interrelationships between these three elements are imperfectly understood but widely recognised. Taussik, (1995) analysis clearly outlines the differences and scope of Shoreline Management and ICZM. This indicates that Shoreline Management is a sub-set of ICZM and covers mostly the management of the inter-tidal zone which is the actual boundary between the land and the sea but ICZM considers the boundary between the land and the sea and their influence on the hinterland and the offshore to a large extent.

Effective shoreline management must be holistic and should be based on a sound understanding of the physical processes of the coast, the interconnected nature of coastal systems and the impacts of anthropogenic interventions. The key to achieving sustainable management of the shoreline is based on the knowledge of the physical processes and their interactions along the coast. All management decisions ought to be linked to these processes and the implications for defence assessed in relation to time scales. Management strategies and defence options should be appraised against the overall processes on a broader scale than purely the Management 'Units' or sites specific.

The knowledge and understanding of the physical process of a given coastline could be better developed through the littoral cells and coastal sediment budgets. A littoral cell represents a section of coastline that has coherent characteristics in terms of natural coastal processes (such as wind, waves, tidal currents, geological and littoral features), which are sufficiently independent of adjacent stretches of shoreline. It is a process-based division of the shoreline. Coastal sediment budget on the other hand deals with the volumes of sediment supplied to a particular sector (littoral cell) by onshore and longshore drift and yield from the hinterland and the volumes of sediment lost offshore, alongshore, or landward over a specific period, (Bird, 2000, Limber et al, 2008). According to French (2001), a sediment budget represents a measure of inputs to the sediment system, areas of storage, and output. French explained that an understanding of sediment budget is of paramount importance to any successful coastal defence strategy. In order to be able to decide how to manage a length of coast, it is important to know how much sediment is available, where it is coming from, where it is stored, and how it leaves a particular area.

Since shoreline management is based on a large-scale assessment of the risks associated with coastal processes and the development of strategies to minimise risk to protect, people, development and heritage (cultural and natural). Vulnerability of the land use and development at the backshore to climate change and associated sea level rise and the sensitivity of both natural and built environment to other coastal forces (storm, flooding, waves etc) are very crucial for sustainable shoreline management.

4. DEVELOPMENT OF INTEGRATED SHORELINE MANAGEMENT PLANNING (ISMP) IN KETA

In order to develop ISMP, there is the need to gain geomorphological understanding of the coast based on the conceptual explanation above. Detailed literature review identified that available secondary data on Keta cell were fragmented and very incomplete and do not provide the understanding on physical processes of Keta's coast that might help critical analysis for shoreline management. Information on components of sediment budget, wave and sediment characteristics, the dynamics of the local tidal patterns among other were inadequate. Hence it was necessary requiring this study to undertake a major research effort in that direction to conduct a field survey and collect primary data to fill the gaps in knowledge. This facilitated the development of the geomorphologic understanding of Keta.

It was identified from the results of the field survey that sediment discharge from the Volta and the continuous erosion of the sandy Quaternary formation west of the Volta dominate the sediment supply to the beaches and littoral strip along the coast. Sediment input from various sources (transfer, coastal erosion and fluvial) *into* the coast are distributed along the shoreline by a predominantly wave-induced west to east drift. Rapid tidal currents are generated at inlets and in contribution with the strong wave energy result in significant sediment exchanges. Significant quantities (about 40%) of sediment inputs from erosion and fluvial sources are comprised of mud, fine silt and clay that are possibly lost offshore in suspension to a submarine canyon offshore.

4.1 Flood Risk and Sea Level Rise Sensitivity Assessment

Since ISMP is based on a risk assessment, sea level rise sensitivity assessment was carried out and used as a generic rule base with which to assess the outcomes of alternative adaptation policy options: (Tol, 2008; IPCC, 2007 and DEFRA 2006) and how best each policy option could be used to address risks identified in the case study area. Sea-level rise scenarios map was created and used for comparative assessment of the sensitivity of Keta cell and management units to different sea-level. This facilitated the assessment of alternate adaptation policies and the selection of the best policy option base upon the local circumstances and environmental sustainability.

A geo-reference Shuttle Radar Topographic Mission (SRTM) data (Satellite image with ground elevation) of the eastern coast of Ghana was used to assess the flood risk based on predicted future sea levels and potential storm levels. The data was opened in ERDAS Virtual GIS and three flood layers were created on the image. They are:

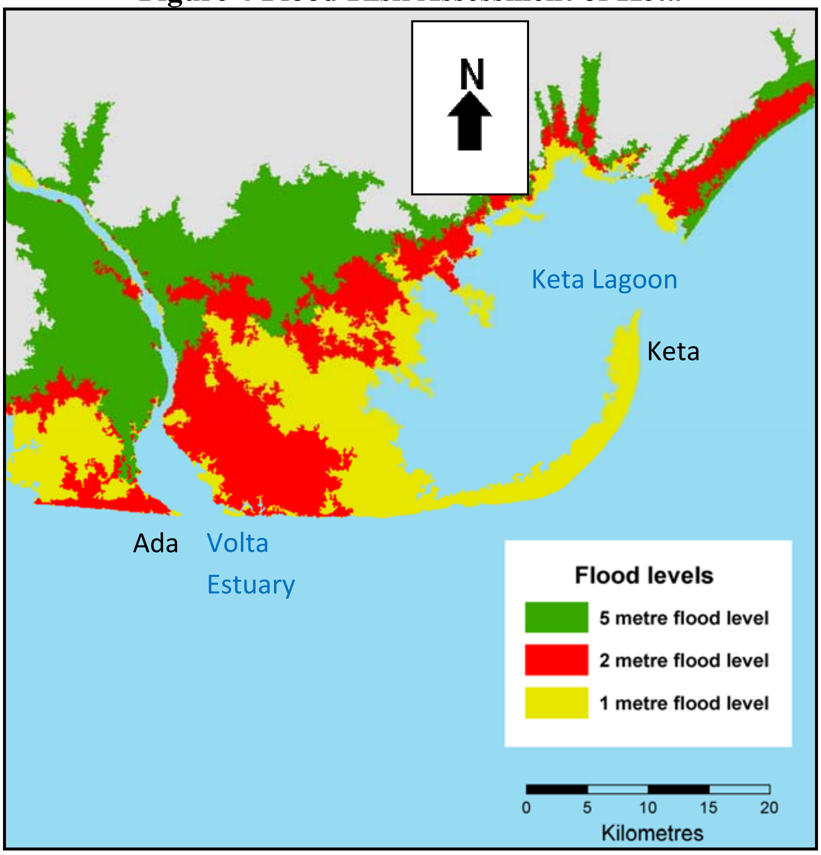
1. **One metre,** (predicted sea-level rise by 2100; Ghana's EPA, 2000),
2. **Two meters** (the latest upper limit prediction for sea-level rise by 2100; Pfeffer, et al, 2008), and

3. **Five metres** (worst case scenario involving catastrophic melting of west Antarctic ice sheet; Vaughan, 2008). The results of this assessment (Flood risk map of Keta coast is presented in Figure 4 below.

The assessment as shown in Figure 4 identified that the Keta is highly venerable to flooding and increase erosion that might be associated with sea level rise. Hence present settlements and developments that are located in areas with the risk of flooding, coastal erosion and potential instability might consider accommodation policies or perhaps retreat, depending on the level of risk (Walsh et al, 2004). Based the above risk it is quite clear that adaptive response potential to manage the risks of land loss, the settlements and infrastructure of the barrier strip between east of the Volta and Keta from submergence by sea level rise is therefore required.

The key management issue of Keta centres on flood defence for settlements and development at the backshore and along the banks of the lagoon in the hinterland. The flood hazard depends critically upon the condition of the natural protective barriers (the littoral strip) and some artificial defence structures. The high flood risk is due to the fact that entire frontage and much of the hinterland of Keta Strip is extremely low-lying (Figure 4) such that all the frontage could be submerged by 1m rise in sea level, and 2m rise in sea level may result in inundation of the whole frontage with some flood waters extending up to 15 km inland.

Figure 4 Flood Risk Assessment of Keta



4.2 Baseline Responses Assessment

After the flood risk assessment a second assessment was carried out based on two scenarios. First, “no active intervention” (Defra 2006 SMP guidance), which delivers consistent baseline case for the whole shoreline of the case study area. Second, “present management” which provides additional baseline case against which to appraise policy options. This analysis provided the understanding of coastal evolution for the two main period; 0 –20 years (short-term) and 20 – 50 years (medium-term). The output for each scenario and period produced statements identifying;

- What the shoreline will look like (morphology and sedimentology),
- Where the shoreline will be (approximate position),
- What has caused this change to occur, and
- What the impacts along the coast will be.

The outcome of this assessment (Table 1) was related to the Sea-level rise sensitivity analysis to enable a critical adaptation response assessment of the case study area.

Table 1 Baseline Responses Scenarios

Location	Year 0-20 (2028)	Year 20-50 (2058)
Keta Strip	The shoreline position may be 20m landward but none of the settlements on this littoral strip may be eroded due to the large coastal buffer land (at least 50m) between the settlements and the sea. However, parts may be flooded due to the low relief of the coast.	The shoreline position could be 52m inland and some of the developments at the backshore may begin to face the challenges of erosion. Sea level may rise to about 0.5m by 2058. This may submerge some sections of the unit frontage.
Keta lagoon inlet	Assuming that no active intervention is taken, beach erosion and landward outflanking of the groynes is the greatest risk. The present nourished beach is expected to narrow, steepen and move landward towards the previous surf zone. The barrier across the lagoon inlet (Plate 1) is likely to be breached frequently and thus allowing more sea water into the lagoon. This will increase the flood risk of Keta and the towns and villages around the Keta lagoon.	The present defences might be destroyed as a result of increased erosion, sea level rise and wave and storm attacks. The shoreline could retreat back to the old position before the Keta sea defence. The barrier across the lagoon inlet could be under water as a result of a half a metre rise in sea level by 2058. The erosion and flood risk to Keta could be as high as it was before the sea defence.

This was followed by the definition of objectives for management of the case study area. The objectives for management of the Keta cell were:

- Management of risks affecting life and properties in Keta.
- Protection of existing developments that are vulnerable based on baseline response analysis, long-term sustainability and the impacts of the physical environmental.

- Ensure that ISMPs comply with the national and international legislations with minimum compromises in respect to the natural environment, navigation, human rights and cultural heritage.
- To implement management policies that allows for future flexibility in response to changes in physical conditions and in socio-economic circumstances at the frontage of the Volta delta and Keta lagoon.
- To manage the Keta cell with due consideration of the potential impacts on adjoining management units or coastline (involving neighbouring countries; Togo and Benin),
- To encourage continuous monitoring of waves conditions, beach levels and beach sediment and coastal defences.
- To conduct further studies on the sediment loss to the canyon and potential onshore sediment input, to ensure that future management can be based on full understanding of coastal processes, flood and erosion risks.

4.3 Strategic Policy Appraisal

After the definition of the objectives, appraisal of four generic shoreline management policy options, identification of one of the four generic policies for each of the following period: short-term (0-20 years), medium-term (20-50 years) long-term (50-100 years) and provision of summary recommendation and justification for the plans was carried out. The four generic shoreline management policy options are outlined below. Each alternative of the policy option was assessed before a preferred option based on technical understanding of the policy drivers, the extent to which it addressed objectives and expert judgement were used to identified the preferred policy for each of the time scales. Below are the ISMP generic policy options outlined by DEFRA, (2006):

- **Hold the existing defence line;** by maintaining or changing the standard of protection. This policy should cover those situations where work or operations are carried out in front of the existing defences (such as beach recharge, rebuilding the toe of a structure, building offshore breakwaters and to improve or maintain the standard of protection provided by the existing defence line.
- **Advance the existing defence line;** by building new defences on the seaward side of the original defences. This policy should be limited to those management units where significant land reclamation is considered.
- **Managed realignment;** by allowing the shoreline to move backwards or forwards, with management to control or limit movement (such as reducing erosion or building new defences on the landward side of the original defences).
- **No active intervention**, where there is no investment in coastal defences or operations.

The results of the policy appraisals, preferred policy option and the justification of the preferred option and summary of the recommended policy option are presented in Table 2 below.

Table 2 Strategic Shoreline Management Policy Appraisal

Location	Hold the exiting defence line	Advance the existing defence line	Management realignment	No active intervention	Selected option and justification
Keta Strip	This will protect the settlements on the littoral strip from erosion but not flooding, since Keta lagoon could flood the settlement from behind. It may lead to the erosion of the presently accreting beach and cause starvation of sediment down-drift in the long-term. Sea level rise may render the present defences ineffective in the long-term.	This may increase the loss of littoral sediment into the canyon offshore. It may offer short-term protection for life and properties on the littoral strip but it will impact negatively on the sediment budget down-drift. This may be detrimental to the conservation interest at the backshore (Keta lagoon Ramsar site).	This will offer a minor protection for life and properties and allow some time for relocation of the settlements. The elevation of the backshore is very low. This makes the backshore of the unit more vulnerable to long-term flood risk. This policy will ensure the continuous supply of sediment to the budget.	This will allow the natural processes to operate and offers some protection to the conservation site at the backshore. It will ensure the landward migration of the wetland in the long-term but at a cost to the settlements on the littoral strip. If this option is considered the settlements must be relocated some distance inland since the areas behind the strip are below sea level.	**Managed re-alinement** in the short to medium-term but long-term decision should be based on **further research**. The first option will ensure the safety of the settlements and Keta Ramsar site. The second option will allow development of realistic and sustainable management plan to deal with future risks.
Keta lagoon inlet	This will protect Keta from erosion and flood in the short to medium term. The expected long-term sea level and the potential impacts of climate change may render the existing defences ineffective.	This will have a negative impact on the sediment budget. It may cause accretion up-drift and erosion down-drift. The low elevation of the unit front, the wetland at the backshore and the predicted future sea levels make it uneconomical to advance the existing line.	This will increase the present erosion and flood risk at Keta. It will also reduce the communication between Keta and the towns and villages east of Keta lagoon. This option will allow the release of the littoral sediment that has been intercepted by the groynes of Keta sea defence down-drift (eastwards). It will require storm warning system and building of elevated storm shelters to which people can retreat.	This option will lead to the destruction of the Keta defence in the long-term. It will lead to flooding and erosion of Keta and its heritage. It may also open up the lagoon inlet and allow the intrusion of more sea water into the fresh lagoon water. The policy will also allow the landward migration of the barrier and the wetland. It will require storm warning system and construction of elevated storm shelters to which people can retreat when floods are predicted.	**Hold the existing line of defence** in the short to medium-term and in the long-term. This will ensure the maintenance of Keta sea defence to reduce flood and erosion risks to life and property in Keta.

N/B Short-term (0-20 years) Medium-term (20-50 years) Long-term (50-100 years)

Summary of plan recommendations and justification

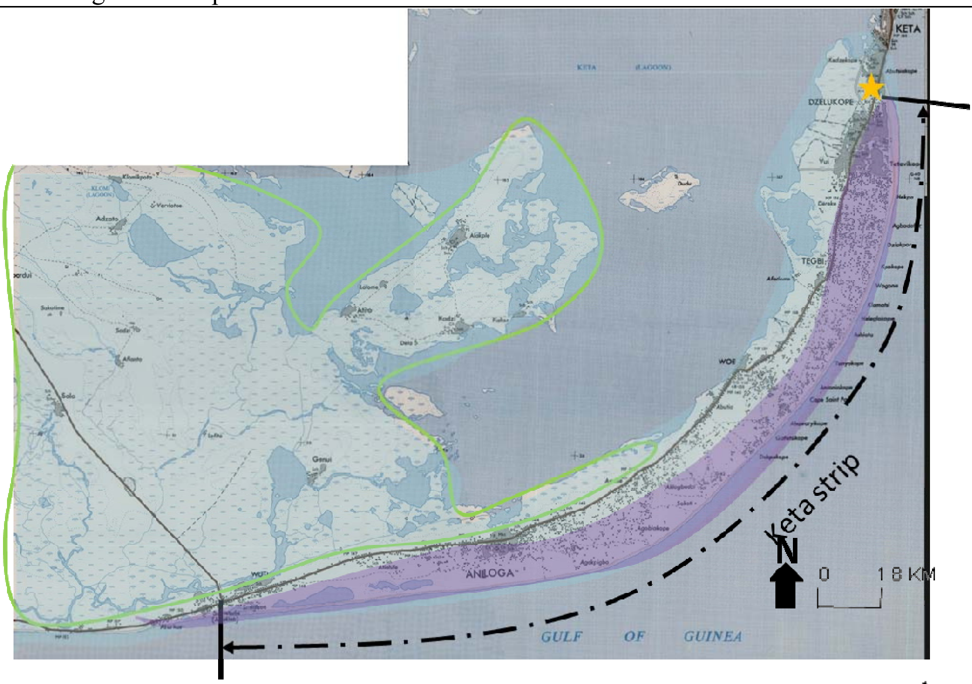
Location reference: Keta Strip

Plan:
The elevation of this whole littoral strip is below the long-term predicted sea level rise of 1 m by 2100. This implies that the entire strip could be submerged by 2100. The size and value of the land, the socio-economic assets on it, the cultural heritage and the conservation interest at the backshore provide the economic justification for protection. However, the level of potential future risk associated with sea level rise offers no such technical justification for protection. Due to the uncertainties with the expected sea level and its potential effects on the unit, short to medium-term measures should be the use on non-structural measures, building regulation, land use planning, education and storm warning system (Boatman et al, 2008; Nicholls; 2007; Taussik, 2005 and IPCC, 2007) to reduce potential flood impacts on life and properties on the littoral strip. Long-term decision should be made based on further research on the realities of future vulnerability and cost benefit analysis of protection and retreat policies.

Policies to implement Plan:
From present day: The policy is to protect life, vulnerable properties and public infrastructures on the littoral strip through **Managed realignment**. A mixture of measures outlined in the plan above would be implemented to change the used the most flood risk zone and also accommodate existing uses to the flood hazards. For this approach to be successful warning system and storm shelters and education of the populace of storm emergency procedures is very critical.

Medium-term: No change from the above policy of **managed realignment** but robust monitoring, warning system, storm shelters and evacuation plans should be in place to prevent fatalities of potential storm surges.

Long-term: The policy should be considered based on **risk, further research** and cost benefit analysis of protection and managed retreat policies.



Erosion risk zone   Flood risk zone   Environmental heritage site   Cultural heritage   Unit boundary

From Present Day	Medium-term	Long-term
Accommodate the risk through Managed realignment	Accommodate the risk through Managed realignment	Decide on long-term policy based upon further reseach

Summary of plan recommendations and justification

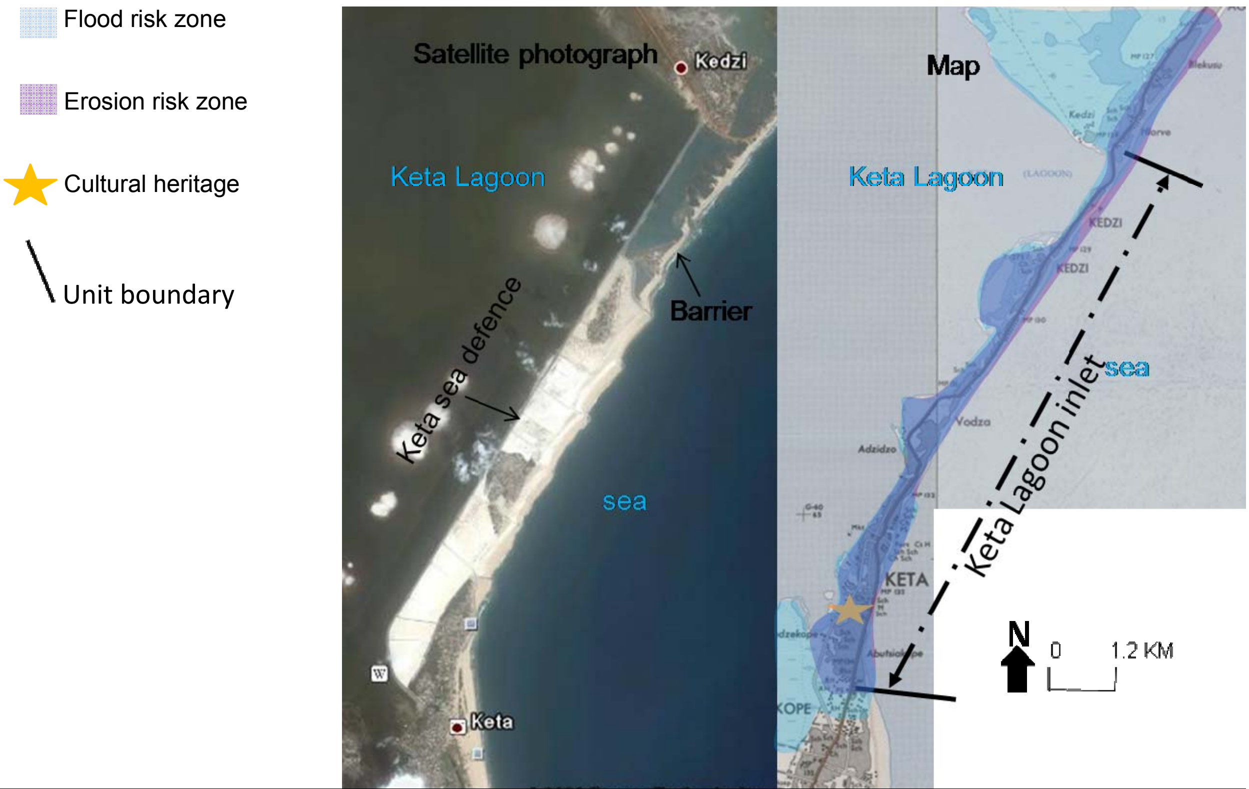
Location reference: Keta lagoon inlet

Plan:
The barrier across the lagoon allows significant amount of sediment transfer down-drift. Sediment transfer across this unit down-drift is very crucial to the coast of the neighbouring countries (Togo and Benin). The plan is to protect life and properties in Keta and also avoid the implementation of measures that may be detrimental to the coast of the neighbouring countries. Already, Keta sea defences seem to serve this purpose and thus provide the technical justification to maintain the present defence scheme.

Policies to implement Plan:
From present day: In the short-term the policy is to protect Keta frontage and maintain the communication link between Keta and the east coast through **hold the existing defence** line policy. The policy will support the barrier, prevent the flooding of Keta from behind and also ensure continuous transfer of littoral sediment down-drift.

Medium-term: No change from the above policy of **hold the existing defence line**. However, there should be continuous monitoring, early warning systems and evacuation plans in place to provide safety in the event of storm surge.

Long-term: No change from the above policy of **hold the existing defence line** but the barrier may be breached as a result of the impacts of sea-level rise causing increased tidal exchange into Keta lagoon and potentially flood Keta from behind and the settlements at its margins. Warning system and storm shelters are required.



From Present Day	Medium-term	Long-term
Prevent retreat through holding the existing defence line	Prevent retreat through holding the existing defence line	Prevent retreat through holding the existing defence line

5. CONCLUSIONS

The entire coast of Keta is under serious threat of coastal recession and flooding due to the soft geology and low-lying topography and the reduction of sediment supply from the Volta. The presence of large lagoon fronted by settled barrier beach means that coastal settlements are at risk of flooding from landward (lagoon) as well as seaward. This makes defending the cell frontage against the rising sea level not only economically expensive, but technically difficult. A possible option is to retreat landwards but as shown in Figure 4, the high ground (areas 5m above sea level) on which settlements east of the Volta estuary to the Keta lagoon inlet could be relocated are about 22km inland.

Assuming the settlements are relocated, what happens to the conservation interest (Volta delta and Keta Lagoon Ramsar site) at the backshore? Should we abandon the conservation site and leave it under the control of the natural environmental forces? In fact, the issues at the coast east of the Volta estuary are very complex and require further research and consultation with stakeholders to make the appropriate decision. The recommended policy options in the ISMPs above were based on the available information and predicted sea level in the future. However, there are uncertainties in the sea level rise prediction and knowledge gaps on the physical processes in the sediment budget. Overall, it is expected future research could change some of the policies recommended in the above plans.

Perhaps attempt made in India, Bangladesh, New Zealand and USA (after Hurricane Katrina) to adapt to the flood risk of their low-lying coastal cities (Mascarenhas, 2004; Nicholls, 2007; Healy and Soomere, 2008 and Boatman, 2008) should be learned and used to accommodate vulnerable settlements in the Volta delta to future flood risks. Example include, coastal buffer zones, building houses on stilt, storm warning and elevated storm shelters among others which enables areas to be occupied for longer before eventual retreat. However, strict land use planning and education should be used to discourage growing trends of human development along the coasts which could exacerbate the vulnerability due to increased risk to life and property. IPCC, (2007) identified that one way of increasing adaptive capacity is by introducing the consideration of climate change development planning, by including adaptation measures in land-use planning and infrastructure design and measures to reduce vulnerability in existing disaster zones.

The study identified that the coastal management problems experience along the coast of Keta are not only experienced in other parts of Ghana's coastline, but many similar developing countries so this research provides a direct practical example on dealing with the issue of shoreline management problems in developing countries. Although the shoreline management methodology developed in this study relates to Ghana's coast particularly Keta (the case study area), it could serve as a guide for wider coverage of entire Ghana's coastline as well as similar coastlines elsewhere. ISMPs could facilitate better understanding and reduction of the risks of coastal erosion and flooding, which may ultimately result in the occupation and economic development of the coastal zone in a more environmentally acceptable and sustainable way. ISMPs could help developing countries to protect life, properties and economic activities along their coast in the short to medium term. In addition, it would raise awareness and encourage critical thinking about the most appropriate and sustainable measures needed for the long-term conservation of wetlands, historical heritage and other special sites of scientific interest in the coastal zones.

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BIOGRAPHICAL NOTES

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