ETESP Soil and Land Reclamation Scenarios










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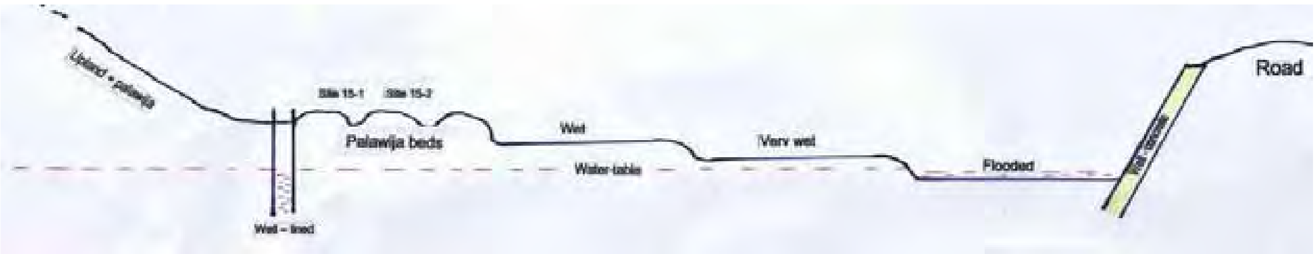
Scenario 1 Sloping Land with No Irrigation or Drainage

Description: The soil is considered slightly to be moderately damaged with salinity levels of 2-4dS/m (Salinity Class SC1) with reclamation normally being attempted by the farmer without guidance. But, farmers are only having limited success and that is normally only on the highest parts of their farms. The main problem with such sites is a high water table and restricted drainage. Water tables at highest part of farms are at 50-75cm with salinity of 0.25-0.50dS/m (Class C2) and the water table is usually at the surface on the lower parts of the farm.

The water on and in the land just cannot escape from the site as there is no active drainage system and the natural stream lines have been blocked, often by man-made structures such as roads and concrete irrigation channels.

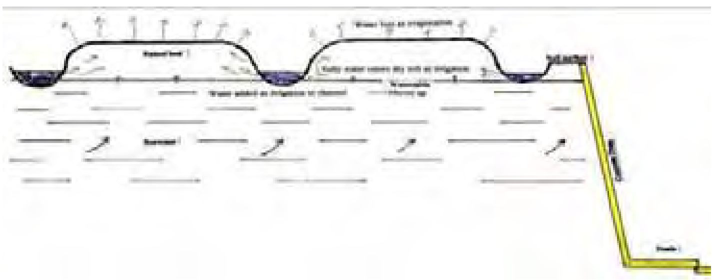
Fig 1.1 Cross Section of typical location



Problems

- High water tables which get closer to the surface as the level of the land falls towards the natural stream lines
- The land in the lower-slope positions is flooded since the water table is actually at the surface
- Man-made structures, such as roads, urban and agricultural drainage ditches and irrigation channels, acting as dams and blocking the drainage
- Inappropriate, surface flow irrigation methods being utilised and these are perpetuating the salinity
- No in-field or on-farm drainage and natural stream lines are no longer active

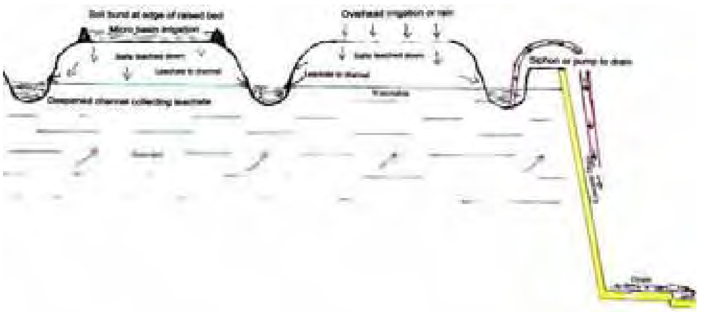
Fig 1.2 Surface Irrigation Perpetuating Salinity



Immediate actions

- Install in-field & on-farm drainage, these can be farmer-installed with guidance and instruction
- Clear, unblock and restore natural drainage lines and ensure they connect to the local river or drain
- Deepen in-field furrows so they can act as drains to remove any saline leachate produced – the farmer can implement this
- Apply irrigation as overhead and not surface-flow, this will better enable soil leaching – use watering cans or appropriate, low-cost technology with piped or pumped supply
- Use salt tolerant varieties and, for the immediate future, only grow palawija on raised beds with overhead irrigation

Fig 1.3 Overhead Irrigation Giving Desalinisation



A palawija cycle must be built into the cropping calendar to allow annual leaching and desalinisation

Possible reclamation problems and effects

- Engineering difficulties bypassing man-made structures requiring minor to medium civil engineering inputs
- Increased salinity and flooding downstream as the saline leachate is removed from the sites and drained to local rivers
- Development of soil acidity under palawija cropping, this is a known problem with some of the soils of the region and soil pH must be monitored. Soils with this possible problem should have large amounts of organic matter (FYM, compost) added to assist immobilise the aluminium in the soil and hence reduce the acidity. Liming materials may also be required. These soils will revert to neutral when flooded for padi in future. *ETESP Soil Acidity & Aluminium*
- Farmers might show some resistance to growing palawija rather than padi but, with selection of high value, marketable crops income generation could be considerably enhanced

Conclusions and Recommendations

These soils can be easily and rapidly reclaimed and brought back into production with relatively low costs and most of the intervention done by the farmer. Inputs such as seed and fertilizer should not be supplied, or applied to the farm, until the salinity level is lowered via the above actions. Even then, salt tolerant varieties of crop should be utilised and, if palawija is grown, soil pH must be monitored.

Scenario 2 Level, low lying close to the coast with drainage and still flooded

Description: The soil is considered to be moderately to heavily damaged and still flooded. Surface water salinity of 1.5-2.0 dS/m (Class 3) and surface soil salinity of 4.63 dS/m (SC2). However, previous irrigation systems are now acting as drainage systems and could be utilised to drain and reclaim this land if some refurbishment was done with channels cleaned and deepened to improve the outflow of the main drains or channels into the sea plus preventing or reducing tidal effects with flood control gates.

Fig 2.1 Typical site previously used for padi

Problems

- High water table and flooding by very saline water which is influenced by tidal action via the existing channel
- Deep sediments deposited by the tsunami which, to date, have not yet been mixed in with the original soil due to flooding restricting access to the land
- High salinity surface water and moderately salinised surface soil giving unsuitable environment for cropping
- No current cultivation and cannot be any cultivation until the land is drained and salt tolerant seed is made available

Sites like this are on almost flat alluvial plains with no obvious high points, still totally or partially flooded, no cropping at all and covered in grasses which are being browsed by buffalo etc and are close to the coast. But, at least one location, there was an operational drainage channel. Refer the photos below. However, local information was that this was, in fact, a previous irrigation system. The in-field water-flow in this channel was fairly fast and there was an outlet into a major channel which was obviously linked to the sea. This drain or channel was flowing - but very slowly. This drainage system was governed by tidal movement and the local estimate was that there is presently between 50-100cm of sludge, sediment and rubbish in the channel or drain.

Fig 2.2 Existing badly silted-up channel

Fig 2.3 Drainage entering main channel

Immediate Actions

- Deepen and clear all existing channels on, around and above the site, ensure all debris and garbage is removed. Much of this can be done by the farmers under supervision and within the “cash-for-work” scheme.
- Cut tidal effects in the main channel by clearing the river / channel mouth and install flood gates to protect the channel. These activities will NOT be low cost and will involve major civil engineering.
- Restore irrigation water supply with an upgraded distribution system. This task will not be low cost and will involve civil engineering expertise – but could be incorporated into the ETESP irrigation programme.
- Use highly saline tolerant rice varieties as such sites will probably be at risk of re-salinisation from sea-water ingression.

Possible reclamation problems

- Sea level continues to rise and inundation could well be an on-going problem, even if tidal gates are installed.
- If highly salt tolerant varieties cannot be located locally for immediate use then they must be located and imported before any planting is done (Thailand has knowledge).

Conclusions and Recommendations

These sites can be reclaimed but at considerable cost due to relatively major civil engineering interventions.

If reclamation proves too expensive then a change of land-use is indicated and the immediately obvious use is to construct fish ponds

No seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed. If reclamation is not to be attempted then a change in land use has to be made or the land abandoned with no more agricultural cropping considered.

Scenario 3 Rain fed area with no active drainage though drainage installed

Description: Level areas previously used for rain-fed rice but out-of-command of local irrigation systems and having the remnants of a soil drainage system. Soil salinity level about 4-6dS/m (SC2) and water table at 30-50cm with salinity level of 0.3-0.6ds/m (C2). Farmers have tried cropping but crops failed and sites now abandoned. Such sites can be quite badly damaged with the surface water virtually stagnant with algae etc growing and water is not passing into the existing drainage canal.

Fig 3.1 Raised bund above the soil drain

Problems

- High soil salinity that, if anything, is getting worse due to evaporation of the saline water from the surface concentrating the salts
- High water table that should not be there since there is a soil drain at the edge of the field but it is NOT collecting and removing water from the field
- Surface water all over the site gives an unacceptable, anaerobic root zone for palawija and the site is far too saline for padi. The site is so wet and stagnant that algae and other water plants are growing
- Water is not entering the existing drain and it is suspected that there might be a plough pan formed over years of puddling with oxen

Immediate Actions

- Clear the drain that passes through the site and also ensure it is cleared down-stream so that any effluent collected can be removed. At the same time deepen the drain to below the rooting depth for palawija (50-60cm). Most of the on-farm work can be done by the farmers under guidance and through the “cash-for-work” scheme.
- Refurbish the full length of the drain where it leaves the farmland and until any effluent that it carries can be safely and environmentally acceptably be removed from the area and into a local, natural stream line or functioning, large drain.
- Establish, by digging, examining, describing and sampling soil profile pits in several locations within the site to establish if there is a restriction to drainage due to a plough pan. If there is a restriction deep-plough or rip to at least 50cm depth to break or rupture any pan or restriction.
- Construct palawija beds and follow Scenario 1 using palawija cropping with overhead irrigation, when required, as the cropping system until salinity is reduced.
- Much of the damage to such drains is not due to tsunami effects but is due to long-term neglect and lack of maintenance

Fig 3.2 Badly damaged and blocked drain

Refurbishment will be mainly a civil engineering task and relatively expensive to implement but very necessary if not essential – not only for agriculture but also for social reasons.

Possible reclamation problems

- Civil engineering inputs will have to be used to ensure that the drainage is safely disposed of and does not flood other areas and create problems downstream if the drain does begin to flow carrying saline leachate
- It may not be economically possible to refurbish the full length of the drain due to expense or lack of relevant civil engineering skills and availability. Similarly, if safe disposal of the saline leachate cannot be guaranteed then the work should not proceed
- Inability to install / supply irrigation water could be a problem, but the ground-water can be used and the quality of the ground-water should improve with time as the salinity of the area is reduced. Also, the rainfall is relatively good (about 1700mm/annum) and, in the past, was good enough for rain-fed rice to be grown

Conclusions and Recommendations

- There are no insurmountable reasons as to why such sites cannot be reclaimed and brought back into production. However, the reasons for the present lack of flow from the fields to the existing drains must be established and remedial measures taken
- No seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed or at least underway. After reclamation it is strongly recommended that saline tolerant varieties of crops should be ustilised to ensure there is no future crop yield reduction or failure due to any salinity build up – this is possible if the deep subsoil is also salinised to some extent and capillary rise can resalinise the topsoil

Scenario 4 Lower slopes of irrigation schemes, close to fish ponds

Description: This scenario is found mainly in the Pidie and Bireuen areas and is associated with the lower slope positions of irrigation schemes, near the coast and where fish ponds already exist.

Fig 4.1 Cross section from village on high ground to fish ponds and the sea

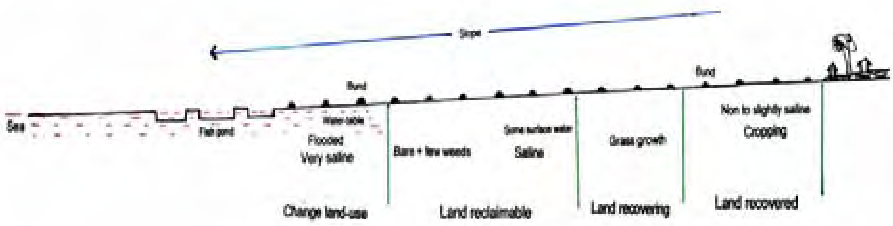


Fig 4.2 Collector Drain

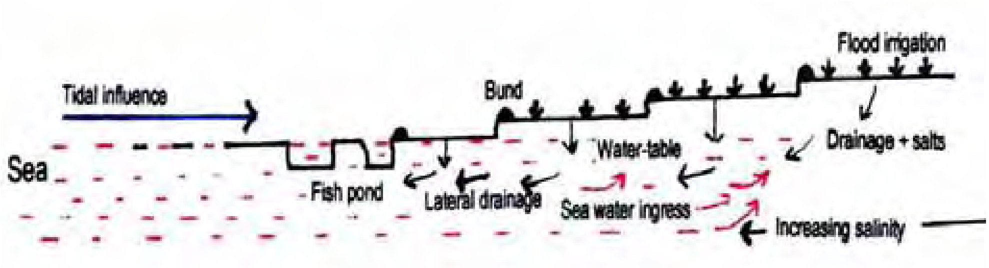
The irrigation schemes have an operational water supply system and some basic drainage channels – though what the farmers call drainage is really overflow systems that remove excess irrigation water from one irrigated field to the next field down-slope.
However, there is often a larger drainage channel running directly down-slope at the opposite side of the field from the inlet for the irrigation water, hence there is some drainage of the land.

Problems

There is a progression of salinity increase down-slope with the soils at the top of the slope already back in production (Scenario 5) and the soils at the lowest points being badly flooded and very saline. There are at least two possible reasons for the salinity of these lower slope sites:

- Tidal influence and sea water ingress via the water-table, and
- Accumulation of salts in the lower slopes due to the sub-surface, lateral or sideways drainage of the soils further upslope. This is a natural phenomenon and is to be expected in any irrigation scheme, in particular where there has been inadequate provision of soil drainage

Fig 4.3 Salinisation of low lying site from the sea and irrigation



Salinisation is happening from the sea plus from the land and, for the worst affected areas, there is probably no way to reclaim the land and land-use should probably be changed to construction of fish ponds.

Immediate actions

- A decision has to be made as to whether the land-use should be changed to construction of fish-ponds and where reclamation should be carried out. One indicator or guideline should be the severity of the flooding on the surface and, also, if there is tidal influence – that is, does the flood increase and decrease with the tide? If there is obvious tidal influence then the land-use should be changed
- Where there is no tidal influence, but the land may still be flooded, then the drainage should be increased immediately – this can be done by installing drainage ditches across the slope (on the contour) and ensuring any drainage collected is discharged into the collector drain down the edge (down-slope) of the irrigated area leading to the fish ponds and the sea
- In the areas further upslope, where the land is recovering and grasses are starting to grow, the drainage should be increased as suggested above and this will speed up the recovery process. Diagrams are presented in Scenario 5 of such drains

Possible reclamation problems and effects

- With the installation of drains there will be an immediate increase in the amount of water, mainly saline, draining off the land trying to find its way to the sea. All channels downstream and the outlet to the sea must be unrestricted or increased flooding at the shoreline will happen.

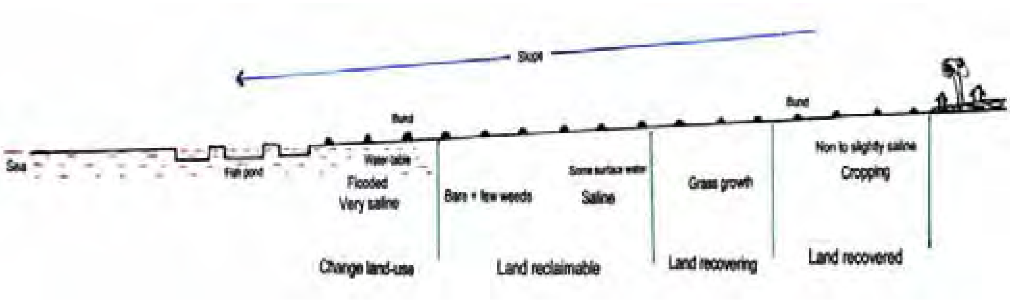
Conclusions and Recommendations

- The services of an experienced soil / land drainage engineer should be used to design and oversee the installation of the suggested drains and, in the worst effected areas, no seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed or at least underway.

Scenario 5 Flat to very gently sloping wetland-rice areas within irrigation

Description: This scenario is found mainly in Bireuen plus other places where there are large, well established irrigation systems. Cropping has re-commenced in these areas and the combination of irrigation and even minimal drainage has lead to leaching of the salts and reclamation of the land. Farmers are monitoring the recovery themselves and start to cultivate when there is strong, green growth of natural grasses on their fields.

Fig 5.1 Cross section from village on high ground down-slope through padi area



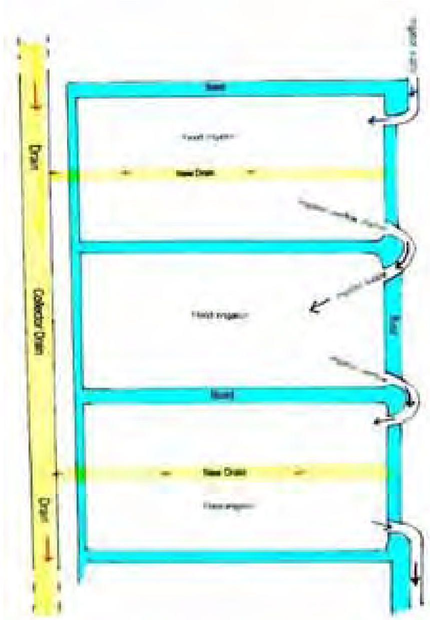
The situation of this scenario is depicted on the right hand side of the diagram where the lower captions read "land recovered" and "Land recovering".

Very little intervention is now needed on this scenario but, if there had been a more comprehensive drainage system, this land could have been back in production much sooner.

Problems:

Land is this category no longer has a problem of any great significance, but there is an increase in salinity as one progresses down-slope away from the village on the high ground – this is because the first land to be leached would be the highest land and the saline leachate would have drained laterally down slope and added to the salinity of the lower slope sites. As long as there is sufficient rainfall plus continued application of irrigation water the land will continue to recover as the salts are leached out further and further down the slope.

Fig 5.2 Field and Collector Drains



Immediate actions

Consideration should be given to improving the existing drainage system to ensure there is no future build-up of salinity through normal irrigation of the land. In addition, a study of the water management and irrigation applications should be carried out to ensure that sufficient water is applied to ensure that there is an adequate "leaching fraction" being applied to ensure leaching. If there were ever to be another disastrous tsunami and vast amounts of salt water were again dumped on the field the improved drainage system would speed-up the recovery process.

Additional drains should be installed on the contour; across the width of the padi fields and disgorge into the existing collector drain. The field drains should be deep enough to ensure that the bottom of the drain is below the maximum rooting depth of the crop (rice) being grown and, generally should be somewhere between 60 – 75cm deep, whilst the existing collector drains are already about 100cm deep.

Fig 5.3 Field Drain

Reclamation problems and effects

With the installation of drains there will be an immediate increase in the amount of water, some of it possibly quite saline, draining off these upper slope sites and trying to find its way down-slope to the sea.

All channels downstream and the outlet to the sea must be unrestricted or increased flooding at the shoreline will happen.

Fig 5.4 Drainage Ditch / Collector Drain

Conclusions and Recommendations

Although land falling into this category is largely recovered, or recovering, improving the drainage network system can only be of benefit for the immediate and long-term future and will help ensure there is little or no build-up of salinity with continuing irrigated agriculture – however, good water management will also be important.

Land in this category should receive all available inputs, especially improved seed, as soon as possible to help boost agricultural output.

Scenario 6 Rain-fed Land with Trapped Saline Water

Description: This scenario refers to land that was inundated but, normally, by a gentle flood that did little physical damage and the flood usually cleared quickly. Such areas have been encountered inland on the north and east coast virtually at the limit of the tsunami flood. However, similar areas have been encountered on the west coast where the floods were generally much more ferocious.

Problems: As explained in some of the other scenarios, once water gets into an irrigation scheme it is virtually trapped there – this is by design with field bunds constructed to ensure the water remains on the fields. Once water, be it irrigation, rainfall or flood-water enters the fields it has to either infiltrate into the soil or evaporate. When sea-water infiltrated the soils became salinised and, if most of the water evaporated, the remaining water left on the surface was even more saline. If saline water infiltrates then the hope is that there is active drainage operating and any salts will be leached down the profile and removed via that drainage. However, fresh water has to be applied to the soil surface for this process to work.

However, in areas without irrigation the only source of fresh water will be from rainfall and, unless there is extremely high rainfall, leaching the salts out will take a very long time and may never be 100% successful. Volumes of water that must pass through the soil to remove salts are discussed and presented in the Soil Specialist's Mobilisation Report, ETESP October 2005.

Immediate Actions: Whether the damaged area is rain-fed or irrigated the first action that must be taken is to ensure there are field-drains installed and operating. If expert advice can be obtained from a Drainage Engineer then that advice should be followed. If no expert advice is available then field-drains excavated to 75 – 100cm depth should be installed on-the-contour - that is at right angles to any slope - and the field drains should discharge into a collector drain of greater depth which runs parallel to the slope and removes any leachate from the site.

A simple, schematic design is presented as Figure 6.1 – this diagram shows the presence of an irrigation supply but the same design would be used in rain-fed fields. As an initial step drains could be spaced at 50 to 75 metres apart. Final spacing would depend on expert advice or could be established by trial and error to see how quickly recovery is achieved – if it is achieved.

Fig 6.1 Field Drains + Collector

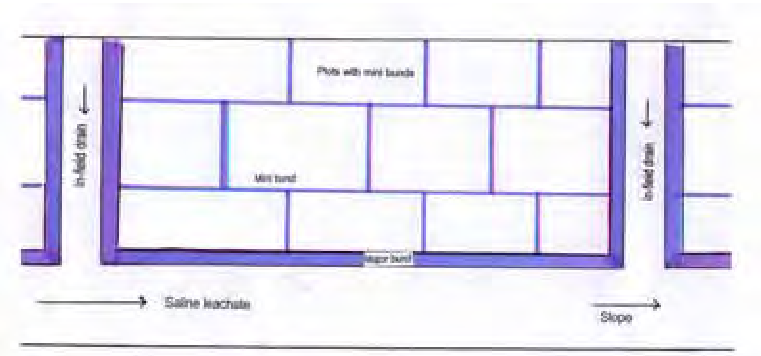
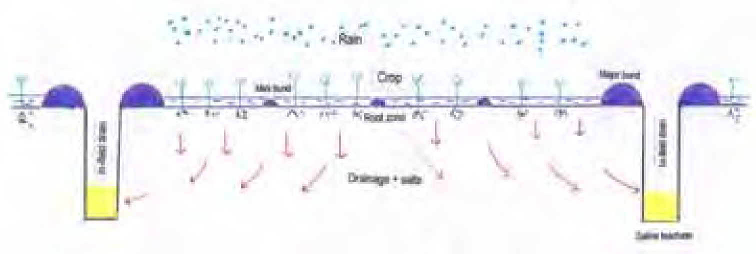


Fig 6.2 Field Drains Cross Section



For reclamation of such sites it is essential that:

- There is sufficient rainfall to wet the soil to depth and hence leach the salts downwards

- The drainage system is operating and drains are cleared or excavated to about 100cm depth, this will allow leachate to drain from the subsoil, and hence continue to remove any salinity that accumulates at depth, on the assumption that there is sufficient rainfall to build up a water-table

When there are long spells with no precipitation, salts that have leached down the profile during wet spells will "migrate" back to the surface when the rainfall stops. This is due to evaporation from the surface and capillary rise from the water-table or subsoil and is a natural phenomenon

Conclusions & Recommendations: In such rain-fed scenarios the recommended ETESP reclamation process is the same as for irrigated areas, apart from the inability to apply extra water via irrigation:

- install or clear the drains – if labour supply and funds allow deepen them to 100cm

- mix-in the sediments – unless the sediment is deep sand (>20cm), if sand then move most of the sand. In fact a thin layer of sand helps rainfall infiltrate the soil and reduces runoff and evaporation losses

- apply organic manure or compost and apply fertilisers then, after a few heavy rain falls

- plant a first crop – a salt tolerant species such as water-melon possibly being used

In the rain-fed situation the recovery will take a much longer time since, even during a massive rainstorm, only about 10mm of water will be added to the soil – this is one tenth of what is recommended when irrigation water is available. The progress of how deeply the leaching process is reaching can be calculated using one of the ETESP tools "Irrigation Leaching Progress". Rainfall, if it is in sufficient quantity and the reliability is good, will slowly leach the salts down the profile to some extent but it will be a very slow process and patience will be required by the farmer before his land is recovered.

In some situation the possibility of using some form of emergency irrigation should be considered. Such possibilities could include:

- Applying overhead irrigation via water-cans – if there is a source of water to use
- Utilising water from drainage ditches if the salinity is low enough - <0.5dS/m

Some possible interventions are presented in the Site Visit report to Oxfam Sites, ETESP, March 2006

Scenario 7 Areas Behind Sand Bars on the West Coast

Description: Some farmers are cultivating the high spots close to the coast behind sand bars in several places on the west coast. One such location was noted approximately 10 minutes south of WP 71 in the figure below. It should be stressed that this scenario has been noted only whilst passing through the area and no details of soil conditions on the ground have been established at this time, but cultivation has started.

Fig 7.1 Location of Scenario 7

Fig 7.2 Scenario 7 and ISRA Mapping

***NB** The above Figures are not produced to be the same scale but are not vastly different in scale. The grid on the left hand map is at the 1:50,000 scale*

Study of the ISRI mapping in that area, enhanced with the road (GPS track) alignment, indicates that the scenario in question lies more or less on the boundary between the purple and dark green areas on the ISRI map. The purple area represents moderately to heavily salinised land, with and without significant sediment additions, and generally with coarse textures whilst the dark green represent medium textured soils which are classified as moderately damaged due to medium levels of salinity and sediment coverage.

The scenario would be described as better drained areas behind the sand bars that are starting to be cultivated presumably because they have leached enough to have low enough salinity to allow cropping. There are low spots between the cultivated areas and these are still flooded. In general the cultivated patches are very irregular in shape due to the flooded channels that exist.

Suggested Intervention: One suggested intervention that could be beneficial would be to deepen the channels in the wet and flooded areas. This enable better drainage and the excavated material could be used to build up the high spots. In this way there would or could be advantages with:

- More regularly shaped plots for cultivation
- Deeper soil for cultivation
- Improved drainage between the plots, especially if the channels can be drained outwards towards the sea into the coarse textured zone mapped by ISRI

Study of the contours on the topographic map show that the coastal strip in this area is quite narrow and any land that can be reclaimed could possible be of value if there are sufficient local people still in the area trying to re-commence farming. A graphic representation of the existing cross-section with an indication of the intervention is shown below.

Fig 7.3 Cross Section of Scenario with Proposed Intervention

Recommendation: Immediate implementation of this intervention could be done by the farmer with some technical guidance and he could excavate material from the low spot(s) adjacent to his cultivated area and start to build up a deeper soil bed on the high spot. Some time would have to be allowed for the salinity in the excavated material to leach out through the effects of rainfall. However, to carry out more extensive excavation and link the low spots converting them to drains would require assistance in the form of civil engineering advice and use of heavy equipment.

Scenario 8 Peat and Other Swampy, Flooded Areas

Description: As with Scenario 7 the description of this scenario is still in the early stages and is presented simply to offer one or two very simple points which might assist in decisions whether to attempt reclamation, with a view to cultivation, or not. Many such areas already have drainage ditches or channels excavated and these channels or ditches are normally virtually full to the top. Some of these channels are flowing and some are not.

Most areas like this are natural swamps (rawa) or are close to swamps and the water within them can often be totally non-saline, though may well be acidic; the reaction of the water depends on the source of that water. Acidity can be found when the water has been derived from acidic soil areas – such as peat-lands or upland areas with acidity and aluminium problems. Salinity can be found when the swamp or area has been inundated by the tsunami flood.

The scenario was first seen at Desa Suak Geudebang in Aceh Barat and is represented by WP 76 in the figure 8.1:

- As can be determined from the map this site is only 500metres from the coast, virtually at sea level and is 1.5km from a large swamp area which lies to the north east
- The channels were full to the top with water but the quality of that water was not tested – neither salinity nor reaction (pH)
- Soil depth above the water level was about 20cm, again the type and status if that soil was not tested since the channel could not be crossed

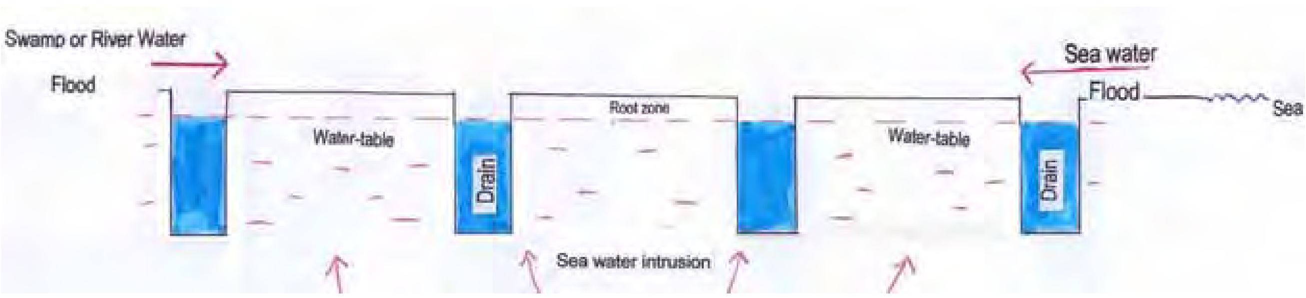
Some of the features of land in this scenario are summarised in the table below with criteria which should be checked and considered before reclamation commences.

Fig 8.1 Extract of Topographic Map around Suak Geudebang

Features of Swampy Flooded Areas

Feature	Problem / Benefit	Reclamation
Water is stagnant in the channels	There is no active drainage	Can an out–flow drain or channel be constructed that will facilitate removal of the stagnant water
Water is flowing in the channels	There is some active drainage	If the area was saline there is every chance the salinity has cleared via rain-fall leaching the surface layers
The site has some elevation	Having some elevation above the sea drainage is, in theory, at least possible	Drainage will work as long as out-flow is greater than inflow – continued flooding or the natural supply entering the swamp
The site is virtually at sea level	There will be very little hydraulic gradient and water from the sea may enter the site as often as water drains to the sea	Major drainage problem plus sea water ingression risk
The water is acidic in reaction (pH<5.5)	If the water is acidic the land may be acidic	Determine the source of the acidity before doing anything else
The water is neutral (pH+/- 7)	No immediately obvious chemical problems	Perhaps only drainage is required
The water is saline	What is the source of the salinity?	If from the soil then reclamation leaching is required. If from sea-water ingress or sea-water flooding the risk could be too high to consider reclamation
The water is non-saline	No immediately obvious chemical problems	Perhaps only drainage is required

Figure 8.2 Cross Section of Swampy Flooded Land



Risks and Problems: If the above site at Suak Geudebang was to be considered for reclamation there are major risks or problems to be faced; the site is 500m from the sea and almost at sea level so is at risk from sea-water flooding and salt water intrusion. Lying down-slope from a major swamp area the site is also at risk from flooding from the swamp at times of heavy rain.

Scenario 9 Damaged and Blocked River Channels

The Situation: A problem affecting much of the tsunami-affected area, with the most damage on the west coast, is the state of the river channels. In many places the river channels are blocked or flow is badly restricted due to the amount of debris in the rivers. The debris comprises:

- trees and other plant material, part of the destruction and deposition legacy of the tsunami
- non-vegetative material such as parts of bridges, houses and other structures
- silt, sand and other soil materials being trapped by the above debris

In addition, the actual estuary of many rivers is blocked by sandbars that have been built up, moved or created by the tsunami wave. This scenario has direct effect on Scenario 10.

Figure 6.1 Clogged river

Figure 6.2 River Flooding

The Problems: The effect of this debris and sand-bars is that the river flow is vastly reduced or stopped all together; often the river is considerably wider than it was and very often flooding the land through which it flows. The knock-on effects are that the river is no longer able to transport water from upstream – and this water will contain the saline leachate from the sites that are being reclaimed – and remove the dissolved salts from the land by transporting them back to the sea. The large lagoons or ponds being formed by this river flooding will slowly be increasing in salinity.

If the rivers were flowing as they used to they would be greatly assisting the recovery of the land by removing any saline leachate that is discharged into them from upstream drains, as it is the flooded areas will be slowly becoming more saline.

In addition, the flooding could, in time, lead to extensive damage to roads and bridges since the foundations will become unstable as they get saturated with water – also if that water is saline, as most of it will be, then the salinity could have adverse effects on the concrete structures it is flooding. Similarly, large expanses of virtually stagnant water could create health hazards as they could be breeding grounds for various insects and disease vectors.

Amelioration Requirements: Although dealing with river channels is not part of the remit of the Soil Desalinisation and Improvement Specialist it is considered that factors such as this will need to be addressed at some time - and the sooner the better. If the rivers cannot remove saline leachate that is being produced as part of the restoration of agriculture then the success of the whole operation could be at jeopardy.

What has to be done would include:

- clearing any sand-bars at the mouth of the rivers where they discharge into the sea – this has been previously mentioned in ETESP reports. This would be a major task and would involve the use of sea-going dredgers which would have to gain access to the rivers via the sea
- once the river mouths were cleared the same action would be required back-up the course of the river – that is the main river channel deepened by dredging
- at the same time all debris would need to be removed from the river-course to enable normal river flow to resume

All of these tasks would involve major civil works and use of specialized, heavy equipment and prove a very expensive operation.

Recommendations: Some competent body, such as a rivers authority or hydraulics institute, should consider compiling a proposal or concept note as to exactly what is required; each river will be different so a separate document would be required for each location.

The proposal or concept note would then have to be brought to the attention of some funding agency in the hope that funds could be found or made available to, at least, carry out a feasibility study to detail the environmental risks and suggest possible remedial interventions.

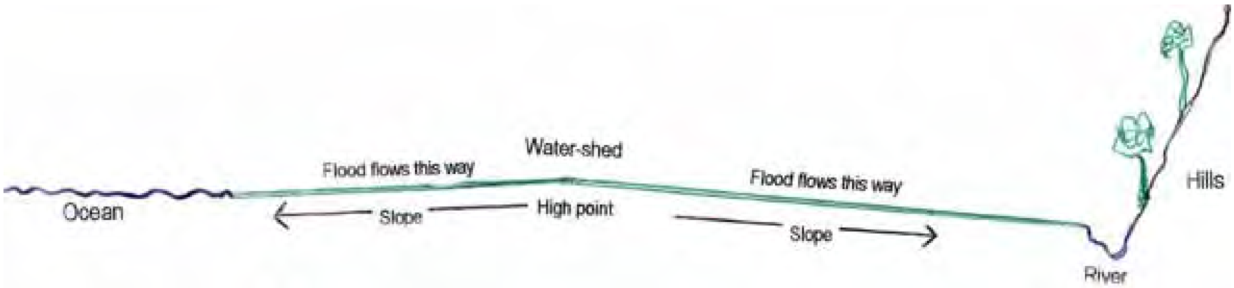
Scenario 10 Areas where the Land Slopes Inland away from the Coast

Description: In several west coast locations it has been noted that the land slopes away from the sea and towards the interior. The normal scenario is depicted in Figure 10.1 and often comprises:

- a sand bar parallel to the shore line, though sand bars do not always occur
- a slight increase in altitude for some distance inland till a highpoint or watershed is reached
- a steady loss of altitude for several hundred meters, usually with
- a river or stream line running more or less parallel to the coastline and below a hill front

One such location is found at Lambadeuk (Lambade in Fig 10.4) in Peukan Bada, Aceh Besar just to the west of Banda Aceh. It should be noted that there is not always a sand bar and the land just slopes gently upwards from the shoreline.

Figure 10.1 Scenario Cross Section



The situation can be seen in Figures 10.2 and 10.3. In Figure 10.2 there is slope upwards to the road, which runs below the coconut palm, whilst Figure 10.3 is the view from the bridge over the canal at the road down-slope towards the ocean. In this case the 'high-point" or water-shed appears to be the road line. The road can be seen in Figure 10.4.

Fig 10.2 Up-slope to the road & sea

Fig 10.4 Spot Heights *(yellow boxes)*

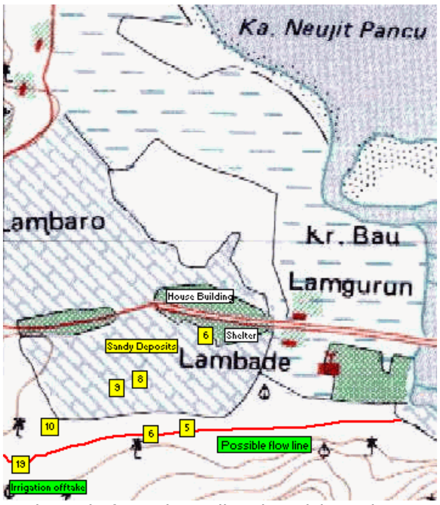


Fig 10.3 Down-slope from road to sea

The drain shown in Figures 10.2 And 3 runs northwards from the yellow box (5) on the possible flow line, through the "a" of Lambade and the yellow box (6) directly northwards towards the sea. The small ridge, represented by the contour line, seen entering the area just below the road in the lower left corner, continues eastwards towards Lamguran and lies at about 15masl. The stream line is not marked on the map but the red line has been drawn in the approximate valley bottom position.

Advantages: When the tsunami struck the flood would have swamped the area in question and continued inland as everywhere else until it met the hills. However, at most locations in this scenario the flood would have cleared relatively quickly due to the land sloping and the presence of a river below the hill-front. In the Lambadeuk location the situation was further improved by the presence of drains constructed for a small local irrigation scheme.

Problems: In some locations the area inland loses the slope and the land becomes flat and, in this situation, the flood water became trapped in any low lying points in the flat area. Also, the river channels often became blocked very rapidly with the debris carried by the flood and the escape route for the flood was removed. Where water was trapped in such locations the situation has been made worse by drains being dug towards the ocean since, if the drains were dug deep enough, they allowed the sea water to cross the watershed and flow inland.

Necessary actions: if this situation possibly exists then it is essential that before any drains are dug that link to the ocean:

- New, detailed topographic mapping or even just spot height mapping should be done from the shore line to the flood, this way the slope of the land can be determined
- Check the river channels or river courses that do exist to see just where they go and that they eventually do lead to the sea. The channels must also be checked to ensure they are not blocked (Refer Scenario 9)

Removal of drainage effluent could be via a very long circuitous route and not directly towards the ocean

Scenario 11 Sandy Deposits on Wetland Irrigated Areas

Description: tsunami damage comprised the physical destruction of infrastructure and uprooting of trees etc by the wave, littering the land by dumping debris carried by the wave and dumping sand and soil materials carried from the ocean or redistributed on land by the wave. This subject is covered more in ETESP Soil Conditions for Wetland Rice. This scenario attempts to present the effects of and actions required when sand was deposited. The normal areas where sandy sediments are located are close to the shore line since sands carried by the tsunami were deposited relatively soon after the wave hit the land – from then on the wave was redistributing topsoils that its action eroded.

Fig 11.1 Sandy Sediment on Soil Surface

Fig 11.2 Grayish Coloured Sands Over Brownish Original Soil

Effects: As stated in the ETESP Report "Sandy Sediments" deposit of sediments on the soil surface has various effects:

- Depth of deposit, as such, was not particularly important in itself (Executive Summary, ETESP, 2005)
- In many areas where recovery is underway farmers were simply ploughing in and mixing deposits with the original soil, with the addition of fertilisers and organic manures. In some locations the addition of sediments was considered beneficial
- Non-sandy deposits were and should be thoroughly mixed in with the original soil by ploughing
- The detrimental effect of an increase in surface level in irrigation areas covered with sandy, or other deposits, must be considered since the increase in surface level could mean that the land is no longer under irrigation command and cannot be irrigated
- When the deposits are coarse textured, generally sand or fine sand, effects are more severe and specific actions need to be taken

Problems: Sands deeper than 15 or 20cm depth are a problem since:

- sands offer very low moisture reserves for plant growth and survival (low AWHC)
- sands offer very low reserves of nutrients for plant growth (low inherent fertility and low fertility potential – low CEC)
- sands have very high infiltration rates and any irrigation water would pass to depth very rapidly, this is no good for wetland rice
- in some areas the additional depth of sediment on top of the original soil could mean that the irrigation supply is no longer able to supply irrigation water to the land – the land could be too high and "out-of-command"

Necessary Actions: Before other interventions are installed it is necessary to have a rapid survey carried out to map the distribution and depths of sandy deposits. This is not a formal soil survey and could be accomplished by an auger survey or chisel-pits making note of depths of natural horizons or layers defined by soil colour and / or soil texture. The number of points to be described depends on the planned use, mapping scale, size of the area and can be calculated with the ETESP tool "Survey Density". In most cases deep sandy sediments would only be a big problem in planned irrigation areas. The necessary steps required are:

1. In areas where there are proven sand deposits a survey should be planned to map at the scales of 1:2,000 to 1:2,500, or at scales that the engineers decide would suit irrigation planning. In many areas new, detailed topographic mapping may be required as a first step
2. During the soil investigations 5 – 10% of the sites should have bulk soil samples taken from 0-25, 25-50, 50-75 and 75-100cm depths and sent to the laboratory for basic soil analyses covering pH, salinity, macro nutrients and exchangeable cations plus CEC. The analyses will confirm the need for reclamation leaching, pinpoint obvious deficiencies and indicate fertiliser applications
3. Once the sand depth / distribution map is compiled decisions have to be made if sand deeper than 15 – 20cm is to be moved, removed or a decision made to abandon using the land for irrigated agriculture
4. If sand is moved or removed it must be disposed of in an environmentally acceptable manner. In some cases the sand may be pushed to the side to form protection banks or bunds that could be of value for planting such crops as coconut. In other areas the sand might be removed and spread over the surface of areas that are sandy and already cultivated with suitable crops – such as coconut, the extra depth might be useful as extra root zone. In some cases there may be no place locally for sand disposal – consideration then needs to be made of the economics of trucking the sand to another location or abandoning the land as far as irrigation is concerned
5. In areas with shallow sandy sediments, the sediment must now be incorporated into the underlying soil by ploughing – the initial ploughing should be done with the land dry and be to as great a depth as can be achieved. Large tractors with specialized ploughs, such as moldboard, may be required and agricultural engineering expertise should be employed. The addition of organic manures and fertilisers is recommended at this time
6. After dry-ploughing, land to be used for irrigated rice should then be puddled following the techniques normally used by farmers but again puddling should be to as great a depth as possible and thoroughly done. Where the sediments are sandy the sand fractions will move to the bottom of the puddled zones since sand settles out more quickly than silts and clays – there is every chance that after a few seasons the land will display surface characteristics not too dissimilar to the state pre-tsunami.
7. Monitoring, as suggested in the ETESP report "Soil Conditions for Wetland Rice" should be carried out.