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# PEATLAND FLOOD PROTECTION ENGINEERING – APRIL EXPERIENCE IN COASTAL RIAU

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**SUMMARY**

APRIL manages extensive peat soil concessions that include natural forest and plantation. Area for fiber plantations is limited and includes the margins of seasonal floodplains in a climate having 500 mm of rain in wettest months. It is highly desirable, now that no more concession land is forthcoming, to fully utilize all marginal land including floodplains. APRIL could find little previous experience of tropical peat engineering to draw on and so developed its own. A peaty-silt soil dike dating to 2007 has kept most floods out of 800 ha of floodplain plantation; it is now being rebuilt to larger dimensions. A first all-peat dike was completed in 2014. It has withstood floods to date enabling fiber production on 1,000 ha of floodplain, previously problematic, to be on track to full production. *Acacia crassicarpa*, the tree crop, tolerates wet soils but not prolonged flooding. These protection works aim to limit flood duration and hasten post flood drainage. Where possible the flood waters are diverted to flow along riparian corridors of natural peat swamp forest and away from plantation. Planning requires hydro data to determine the flood return period, duration and levels, the dike gradient as well as catchment spatial data. Reclamation economy of scale is always a challenge. Dikes are constructed from peat soil taken from a canal dug immediately on each side. Long arm hydraulic bucket excavators are the standard tool for construction. Depending on the in-situ bulk density of peat, each cubic measure of raised compacted dike requires two units of dug material. Design aims to hold a head of 1.5 m flood water, plus a minimum of 1 m freeboard. If needed flood water will be released into the plantation canal before the safe head is exceeded. A dike cross section of around 40 square meters has proven adequate for sites having minimal flow energy of flood water. Geo-felt folded between layers of compacted peat, and sand filled bags, have been used to reinforce critical points. Work is normally done in the drier season when river flows are lowest. Weathering loss of the dike material must be replaced every few years, and material must eventually be brought in. The dike crest can be surfaced with mineral material to serve as a light vehicle road, and grass or bamboo established to assist stability.

***Keywords***: *floodplain, catchment plan, hydro data, flood return period, peat dike, flood diversion corridor, acacia plantation, flood duration tolerance, geo-fabric*

## INTRODUCTION TO FLOOD PROTECTION

Now that APRIL development of concession lands is completed with more land unlikely in the current policy setting, attention has turned to intensifying fiber output from the most challenging bits of concessions. For example, seasonal flood plains of shallow peat and silt soil, long since cleared of natural cover that had conservation value, have been brought into production. This sort of land tends to be interspersed with marginal small holdings; a patchwork of fragmented ownership (Bathgate *et al.,* 2011) that rule out the landscape scale flood diversion scheme as an option. In the case of one APRIL plantation on seasonal floodplain (Figure 1), much of the upstream catchment has been cleared for agriculture without regard to watershed function. Floods now occur on average 100 days a year (Figure 2); for lower parts of this plantation the options are to build high dikes or restore to flood-tolerant natural forest.

In another location a dike barrier has been built to deflect waters away from plantation and into riparian corridor of recovering peat swamp forest, with aim to keep it hydrated, less prone to fire (Prat *et al.*, 2013) and reduce the seasonal non-flooded period when agricultural squatters could move in. Flood diversion is complemented with drainage systems within the plantations to reduce the duration of flooding. A broad approach is to carry out marginal improvement work each rotation, aimed at reducing the incidence and duration of flooding in the critical period when a newly replanted crop of trees is establishing. Crop vulnerability to short periods of flooding diminishes with stand height; 2 m height by 6 months age is standard for *Acacia crassicarpa*.

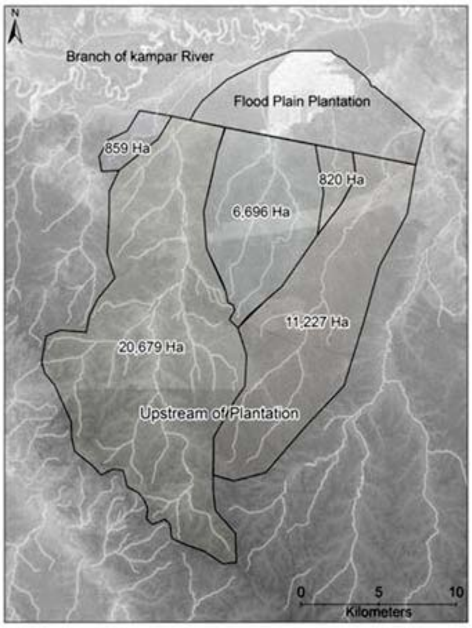


Figure 1: Example of catchment situation of plantation on seasonal floodplain; to the south 40,000 ha of agricultural catchments bring flash runoff, to the north a meandering Kampar R. is fed by a large catchment to the west. Based on Nov 2011 radar image, the light area in plantation is flood water – see Figure 2.

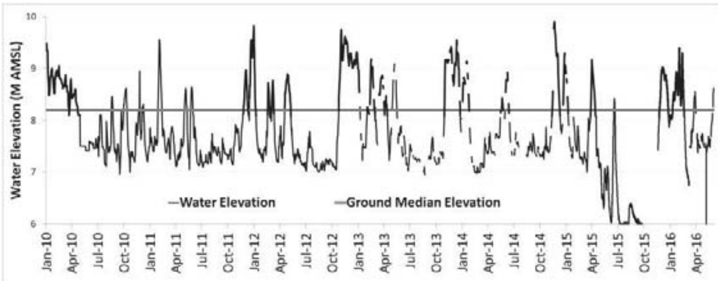


Figure 2: Six-year hydrograph constructed from logged data for central location in plantation depicted in Figure 1

## PLANNING

Incompletely developed land in coastal Riau attracts would be agricultural settlers who practice opportunistic burning repeatedly as dry spells allow (Bathgate *et al.*, 2012). APRIL flood protection work to support fiber development involves a sequence of providing access, occupying the land, combating informal settlement and fire, and providing local people with formal livelihoods. In that context the embankment raised against flood often serves a key role as a light road for patrol and fire suppression. Peatland plantations are typically served by a grid of small roads in tandem with roadside drains, or small canals, for transport. The aim of flood protection is to reduce the incidence and severity of floods, particularly while the fiber crop is being established. Submersion of plantations by a ten year return period flood may be acceptable. Canals provide an option, before dikes get overtopped, of channeling flood water through the plantation landscape and beyond with minimal impact. *Acacia crassicarpa* while intolerant of prolonged flooding (Orwa *et al.*, 2009), when mature can survive several months flooded, as in Figure 4 provided water flows, not stagnates (person observation, lead author).

Flood protection works need thorough planning. Whole catchments need to be considered; this has recently become a legal requirement for operating on peatland (Ministry of Environment and Forestry, 2016). Protection work requires hydrological data on the flood return period. An example of a catchment plan requiring flood diversion work is given in Figure 1. Where up-catchment runoff via a major river affects plantations and infrastructure, ten years of rainfall and flood level data is a minimum required to plan. Shorter period detail of flow gradients and responses within the project area can be correlated with the long record to build up the picture. To provide data, water poles are installed first on major rivers at access points. Figure 2 is an example of such a hydrology record. Flood return estimates have a major bearing on the design, cost and expected benefit from flood protection work. There are no design codes. Initially APRIL found little practical experience at dike construction with tropical peat to draw on and so developed its own techniques and standards.

## DIKE CONSTRUCTION

Over the past decade a number of low dikes have been erected on APRIL concessions to protect fiber estates and road infrastructure from seasonal flooding. Peat dikes can be a practical solution where flood water turbulence and energy are minimal. In the flat coastal landscape this is usually the case. An embankment of local soil is erected as a flood barrier, ideally combined with a flood diversion channel along the outer side. Soil is commonly peat, silt or a mix of these. Large woody debris that is embedded in the peat deposit adds structural reinforcement. A pair of canals dug 20 m plus apart is dug to borrow local material for a dike. The outer canal directs floods away from plantation and inner canal drains excess rainfall from plantation. Guideline for maximum safe hydraulic head is 1.5 m. Earthworks are seldom reinforced, dike strength depends on mass. A 40 $m^2$ section is usually adequate mass, built in stepped profile to 1:2 gradient to provide access for excavator to reach and to compact by rolling (Figure 3). Where there are bends in the dike the spacing between side canals is increased for strength and the profile of the dike widened on one side to provide a counterweight to flow pressure.

The long section gradient of a dike is designed and marked to accommodate the gradient of the flood water and to provide a minimum freeboard for the dike crest of 1 m for mineral soil, 1.5 m for compacted peat. A safe width of dike crest is 6 m where it is used as a light road; a minimum crest width is 4 m. Peat material will settle and requires topping up before the first flood season. Be prepared to release water, e.g. over a tarpaulin spillway, to the inner canal to reduce hydraulic head before a dike is damaged by rising water. The plantation canal system inside a dike provides an option to channel spill water through the plantations and out; the optimum water table depth below ground surface for *Acacia* growth can be compromised for a period. Plan to complete earthworks in the drier season.

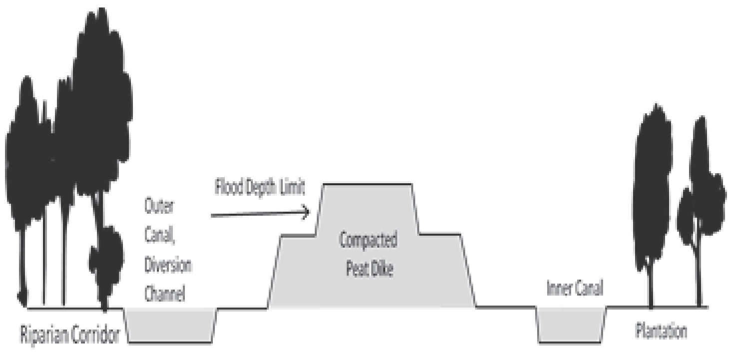


Figure 3:Schematic profile of typical peat dike built to protect plantation

Figure 4: Mature Acacia plantation under flood, Dec 2014; the flood water is between 1 and 2 m deep (refer to Figure 2)

## DIKE MATERIALS

In the interest of cost the bulk of structural earthwork is built with on-site materials including peat. This is shifted a minimum distance to raise the dike. Peat is compacted approximately double; 2 $m^3$ of dug peat to build 1 $m^3$ of dike compacted in situ. The approach is to use on-site material in sufficient quantity for strength; reinforce only at critical points. Ideal options, like digging out the peat deposit down to mineral substrate, are too costly. Preexisting canals in the dike path that need to be closed with peat may need strengthening to resist liquid soil being forced up in the inner canal by hydraulic pressure. Driven piling from local wood has too short service life before rotting at the waterline. Geo-fabric mat folded in deep loops to enclose compacted peat can be built into the outer faces of a dike, if dry season canal levels permit equipment operation. Another option is large fabric bags filled with soil and laid on felt matting for load bearing in critical points. A potential weakness of synthetic fabric is it can burn, e.g. fishermen's small fires and even cigarette burns, and may be best covered with soil.

The long arm excavator, or semi long arm, is the standard earthwork tool. Construction scheduling and costing is based on an average number of swings of the excavator arm to cut soil and move it to final position in the dike, e.g. 10 swings (peat is compressed at 2:1) at a fixed rate per swing. Logistic considerations include fuel and support barges, security for equipment and fuel; with logistic support for excavators the earthworks can proceed in parallel at multiple locations.

## MAINTENANCE

A light vehicle patrol road along a dike crest serves to patrol for illegal activity and fire, and also compact peat earth works. In time dike crests are surfaced with mineral soil as running surface. A road gives significant benefit for forest maintenance activities during the rotation, including fire and pest surveillance, security, forest measurement and inspection. The peat dike can be constructed to heavy traffic standard but at much higher cost; the haul road needs a much wider base well-spaced from the flanking canals, and also needs layers of heavy grid material to separate the road from underlying peat embankment. Without this, under heavy traffic the peat soil tends to squish into the flanking canals, raising requirement for canal cleaning and embankment maintenance. Peat material is eroded by rain and wind, and needs periodic replacement. Eventually peat soil may need to be long hauled in on the dike crest; taking material from the flanking canals tends to undercut the dike base and hasten its erosion.

## CONCLUDING DISCUSSION

The aim of the peat based flood protection works is to minimize flood duration and impacts. Unlike civil work a dike is seldom designed to debit flood waters within a few days or to never fail. A sufficient performance objective for fiber plantation flood protection may be to halve the duration and extent of annual flooding, and safety considerations may be less rigorous than for civil works. Woody peat and silt soils have proven adequate to construct the durable multi-purpose dikes, roads and other flood protection works that serve forest management operations in the flood prone landscape. To date some 30 km of low (1.5 m head) dikes are successfully protecting plantations. As a next step forward, design of peat-based dikes that involve flood gates and pumping are being considered.

## ACKNOWLEDGEMENTS

The success of flood protection engineering within APRIL forestry has very much depended on the effort and skill of field supervisors who have developed practical solutions to new challenges in construction – to get it done on time and within budget, and learn by doing. Particular thanks are due to the Project team of Ardi Putra and Tigor Nainggolan, and Lowland team Rosef Putra, Ucin Muksin and others.

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