RSPO | Roundtable on Sustainable Palm Oil

DRAINABILITY ASSESSMENT PROCEDURE

November 2019

Drainability Assessment Procedure for Replanting of Existing Oil Palm on Peatlands

RSPO | Roundtable on Sustainable Palm Oil

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RSPO Drainability Assessment Procedure

This Procedure was developed by RSPO with technical assistance from Wetlands International (Dipa Rais and Arina Schrier) under the guidance of the RSPO Peatland Working Group 2,

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- Rahmadi Dadi, Independent Land and Water Development Specialist
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Revision Table

No	Amendment	Version	Date
1	Correction of document date	V 1.0	11 June 2019
2	Addition of section: Prior drainability assessments [Section III, Annex 5] (pg. 52)	V 1.0	11 June 2019
3	Addition of table A5-1 of section: Prior drainability assessments [Section III, Annex 5] (pg. 52)	V 1.1	30 November 2019
4	Addition of revision table (pg. III)	V 1.1	30 November 2019
5	Update of table A5-1 [Section II, Annex 5] (pg. 51)	V 1.1	30 November 2019
6	Revision of text [Section II, Annex 5] (pg. 51)	V 1.1	30 November 2019

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Glossary

Tropical Peat:	A soil with cumulative organic layer(s) comprising more than half of the upper 80 cm or 100 cm of the soil surface containing 35% or more of organic matter (35% or more Loss on Ignition) or 18% or more organic carbon. Note for management of existing plantations in Malaysia and Indonesia, a narrower definition has been used, based on national regulations: namely soil with an organic layer of more than 50% in the top 100 cm containing more than 65% organic matter. For country/region specific definitions refer to the 'RSPO Organic & Peat Soil Classification'.
Basal contact:	Interface between two stratigraphic layers, like peat layer and clay, peat layer and sand layer, etc.
Peatland delineation:	Differentiation of peatland from surrounding non-peatland on map
Natural Drainability:	Ability of a peatland to be drained by gravity, without mechanical devices such as pumps.
Drainage base/ Natural Drainage Limit:	The level below which it is no longer possible to drain the land by gravity alone.
Drainage Limit Elevation:	The increase in water level in drainage channel in proportion to distance to receiving water body that is required to enable water to flow.
Receiving Water Body:	River, Lake or Sea toward which drainage water is discharged from the plantation.
Rotation Cycle:	The life cycle of the oil palm, on peatland which is taken to be 20 years.
Subsidence Stratum:	Defined area of homogeneous soil subsidence rate.
Replanting Peatland:	Area of peat soil to be replanted.
Drainage Limit Time:	The time that it takes for the peat soil to subside to the natural drainage limit.

Preface

The RSPO Drainability Assessment Procedure has been developed to support oil palm growers to assess future subsidence and flood risks of peatlands and adjust their management processes to reduce subsidence rates and prolong the workable lifetime of their plantations. It will enable the growers to phase out oil palm and introduce more water-tolerant crop types or restore natural vegetation prior to the plantations subsiding to river or sea levels. They will also enable compliance with the requirement to undertake drainability assessments prior to any replanting on peat as specified in the RSPO P&C 2013 (Indicator 4.3.5) and P&C 2018 (Indicator 7.7.5).

The Procedure has been developed with technical assistance of Dipa Rais and Arina Schrier of Wetlands International under the guidance of the RSPO Peatland Working Group 2 over the period July 2017-January 2019. During this period two stakeholder workshops were held to seek input on the principles and practicability of the Procedure. Testing of the Procedure has been undertaken by four companies and the Procedure has been reviewed by three independent reviewers.

This Procedure was first issued in April 2019 and will be utilized for an initial implementation period of 12 months, after which it will be reviewed and adjusted where necessary based on the experience gained.

All RSPO member companies as well as non-members are encouraged to use this Procedure in the initial implementation period so as to be able to provide feedback. Feedback can be sent by email to the RSPO secretariat at ghg@rspo.org .

Faizal Parish, Global Environment Centre

Joshua Matthews, PT Bumitama Gunajaya Agro

Co-chairs RSPO PLWG-2

March 2019

1. Introduction

1.1 The different perspectives of drainability

There are different ways of looking at drainability. From an agronomic point of view, it is important to maintain high yields and to create a good drainage system, specifically in peat. The drainage system must be robust and effective during both dry and wet periods. In other words: the drainability i.e. the ability to drain by gravity alone, must be such that it enables high yields to be obtained, prevents flooding and enables the maintenance of optimum water levels for the crop. From an environmental and economic perspective an extra dimension comes into the picture: is this drainage viable in the long-term and is this drainage sustainable?

Peatlands emit carbon dioxide (CO_2) when drained contributing to the greenhouse effect and global climate change. Peatlands also subside when they are drained, and in some cases the peatland surface may subside to near or at the natural drainage limit/drainage base[1] (i.e. the level below which it is not possible to drain by gravity alone). The duration and severity of flooding will increase over time when the peat surface gets closer to the natural drainage limit. In the long term, sufficient drainage of a peatland to enable crop production may become a challenge, particularly during wet periods, because drainage by gravity is no longer possible, leading to serious environmental and operational issues such as continuous flooding, saline intrusion, accessibility issues and yield losses.

If assisted drainage in the form of water pumps is applied, increased operational costs will be incurred, possibly to the extent of negative return of investment. In addition, Pumped drainage will lead eventually to total loss of the peat layer and permanent flooding when pumping becomes non-viable or the concession period ends. It is therefore critical to stop drainage before reaching a point of no return.

1.2 Why a Drainability Assessment

A drainability assessment is conducted to predict the potential lifespan of a plantation planted on peat by estimating the drainage base and the expected time that the limit will be reached by taking into consideration the subsidence rate of the assessed area. This differs from determinations of current drainability through field observations and measurements **(**see **Appendix 3)**. Current drainability can only be used to help to guide current water and plantation management practices in the plantation, but not predict future risks as required under the RSPO P&C.

[1] In the rest of the text the term ‘drainage base’ will be used in place of ‘natural drainage limit’ .

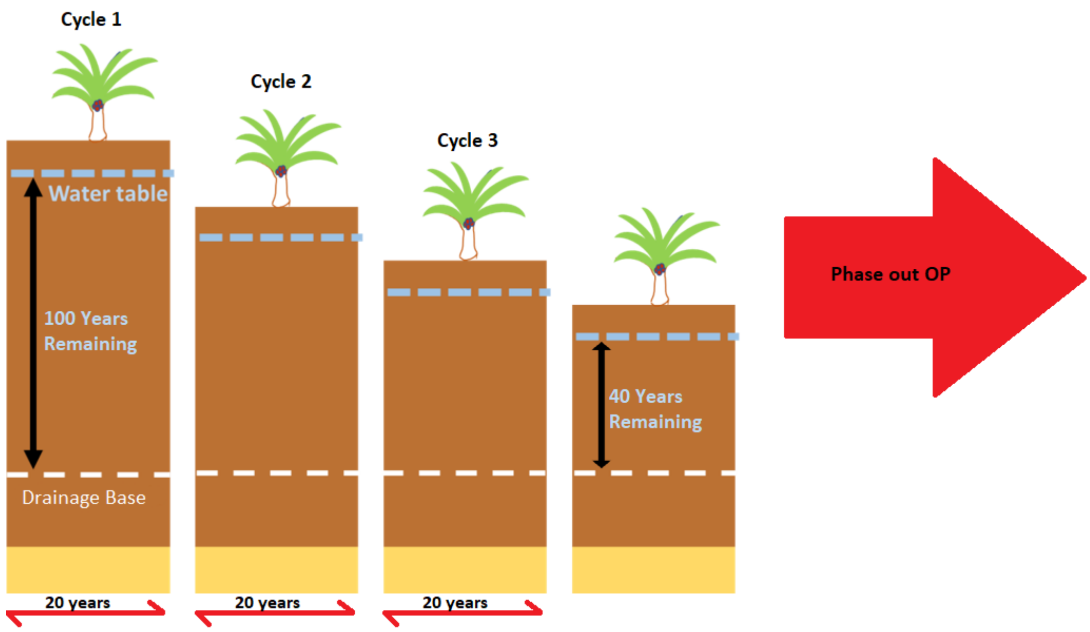

Figure 1: Estimation of the Drainage base and estimated lifespan left through RSPO Drainability assessments leads to phasing out of oil palm cultivation 40-years prior to reaching the drainage base.

Long before an irreversible stage of land loss is reached, plantation managers should ask themselves these urgent questions: What is the long-term viability of my drainage? Should I replant oil palm considering the long-term drainability perspective? To be able to answer these questions, RSPO requires a Drainability Assessment to be undertaken starting fifteen years after planting (approximately 5 years before replanting) the oil palm on peat (refer to **Annex 5**). The assessment result (see **Figure 1**) is used to set the timeframe for future replanting, as well as for phasing out of oil palm cultivation at least 40 years, or two crop cycles, whichever is greater, before reaching drainage base for peat. When oil palm is phased out, it should be replaced with crops suitable for a higher water table (paludiculture) or rehabilitated with natural vegetation as specified in the RSPO P&C 2018:

> *"For plantations planted on peat, drainability assessments are conducted following the RSPO Drainability Assessment Procedure, or other RSPO recognized methods, at least five years prior to replanting. The assessment result is used to set the timeframe for future replanting, as well as for phasing out of oil palm cultivation at least 40 years, or two cycles, whichever is greater, before reaching the natural gravity drainability limit for peat. When oil palm is phased out, it is replaced with crops suitable for a higher water table (paludiculture) or rehabilitated with natural vegetation."*
>
> *-Indicator 7.7.5 (C), P&C 2018-*

1.3 A safeguard threshold

It is important to stop drainage before the drainage base is reached. The threshold or safeguard of 40 years, or 1-2 meter above the drainage base is built in, because of the seriousness of the medium to long term risks of soil subsidence in peatland areas. Soil subsidence will not stop completely after rewetting, and in the case that the surrounding area is drained there will often be a certain degree of drainage impact. Taking into consideration the future rise of sea levels[2], land that is currently just above the mean sea level is at high risk of becoming unproductive and flooded in the future, even if drainage stops. From a sustainability perspective it is also important to leave a sufficient layer of peat for rehabilitation of vegetation.

1.4 Drainability Assessment Procedure

This procedure provides guidance on how to assess future drainability. Field observations, mapping and calculations will determine the future drainability. For the future drainability the question that must be answered is: how long will it take for the peat surface to subside to a level two crop cycles above the drainage base (approximately 1-2 meter, depending on the rate of soil subsidence).

[2] Sea levels are predicted to rise by between 0.3-2.5m by the end of the current century (NOAA, 2017)

2. Drainability explained

2.1. Drainability

Drainability refers to the ability to drain an area by gravity, i.e. drainage without mechanical devices such as pumps. In drained peatlands, the drainability may change over time because the peat soil is continually subsiding. At a certain point in time, the peat surface will subside to close to the drainage base. The drainage base (see **Figure 1**) is defined as the level below which it is no longer possible to drain the land by gravity alone.

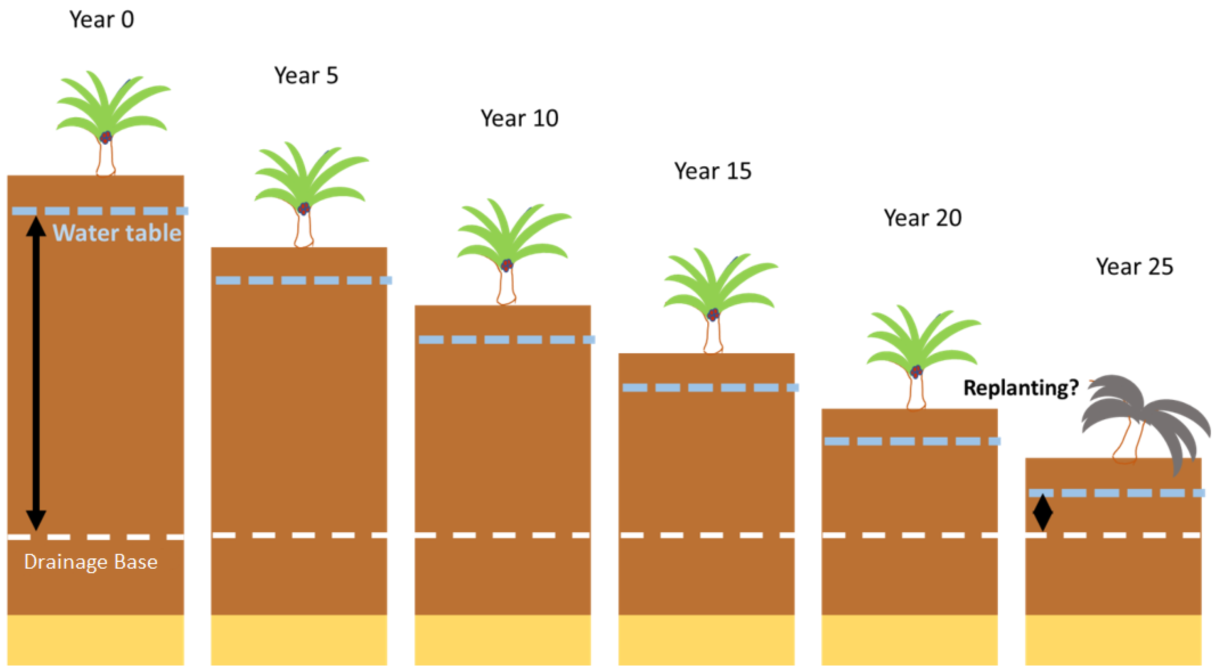

Figure 2: How peat soil subsidence impacts the depth to the drainage base (natural drainage limit). Over time, the peat layer above the drainage base may become too shallow to permit replanting.

Figure 2 explains the drainability process over time. In year zero, drainability is good, and the palms grow well. The drainage however causes the peat soil to subside, and over a period of 15 years, the peat surface has subsided (e.g. at a rate of 5 cm per year) closer to the drainage base. The drainability may still be good and therefore the grower does not experience any problems in year 15. Between years 15 and 20 the grower starts to consider replanting. The question now is: is the area still suitable for replanting of oil palms? What is the thickness of the peat layer above the drainage base? And how many years will it take before problems, such as increasing occurrence and duration of flooding, are experienced?

This guideline provides guidance on how to assess the drainage class (based on field observations) and how to determine the time that it takes for the peat surface to subside to a level where the peat surface is 'two crop cycles away' from the drainage base. The 'two crop cycles away' (approximately 40 years) threshold is built in to ensure a certain degree of conservativeness which is needed to avoid flood problems timely and to capture tidal influences. Note that plantations will rarely be flooded by sea water, and often not by river water except for relatively narrow riparian zones of a few km. Instead, plantations on peat are usually flooded by rain water that cannot be drained out anymore once subsidence has reduced the peat surface elevation and gradient below critical levels.

2.2. The drainage base

The drainage base inside the plantation is in most cases based on the water level in the closest receiving water body and on the distance to this water body. If the receiving water body is very near, the relation between the water level in the water body and the drainage base inside the plantation is strong. If the closest receiving water body is at a further distance, the drainage base inside the plantation will be at higher elevation than the water level in the water body. This is because there must be a difference in the water level before the water can flow. A general rule of thumb is that for each kilometer of distance into the plantation, the drainage limit elevation increases by 20 cm relative to mean sea level (DID Sarawak, 2001) (Figure 3) i.e. the water profile in the peat soil must have a minimum gradient (slope) of 1 in 5,000 for the water to flow to the water body. In this guidance, we consider the drainage base and we exclude (mechanical) pumping which may create an unnatural drainage base in some areas.

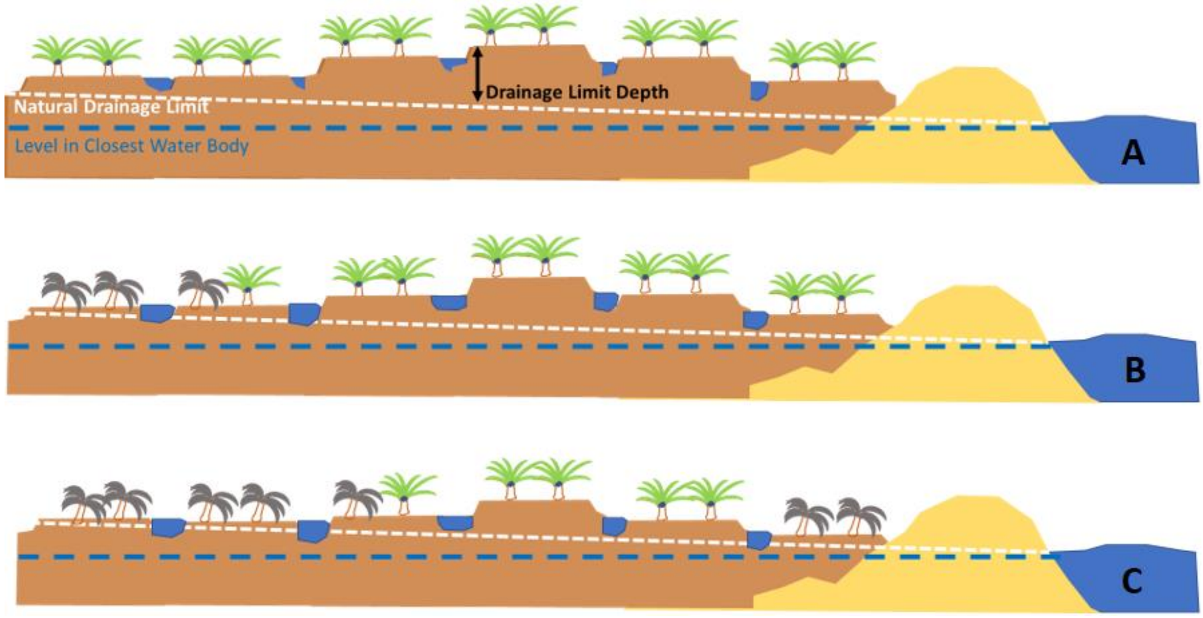

Figure 3: A cross-cut of a peat area which is close to a natural receiving water body. The cross-cut illustrates the impact of soil subsidence on the drainability of a peatland explained at three points in time (figures 3A: above, 3B: middle and 3C: bottom). If the peat surface subsides to near to the drainage base, plantation drainability will decrease, there will be extensive flooding during the wet season and palms that have their roots in the water for too long will die. As the duration of flooding increases the land will become unsuitable for cultivation.

Figure 3 explains how drainability problems may develop over time. It shows the drainage base relative to the average water level in the receiving water body. Plantations located further away from the receiving water body will have a larger distance between 'the water level in the water body' and 'the drainage base'. Although in the early stage (Figure 3A) all palms may grow well and there will be no drainage problems, in the later stages (Figures 3B and 3C) problems may develop because of peat subsidence. The closer the peat surface subsides to the drainage base, the more difficult it will be to maintain gravity drainage from the plantation into the receiving water body and, conversely, to prevent water from entering the plantation at times of high-water level in the receiving water body. Figure 3C shows that in this example more than 50% of the plantation surface area has subsided to near the drainage base and as a result the palms in these areas will suffer from a water saturated root environment.

2.3 Tidal influence

For coastal plantations, the ability for water to drain out from an estate is influenced by the tides. During high tide the raised water level may reduce drainage, while during low tide level, drainage may be enhanced. For the purpose of calculating the drainage base in coastal plantations the mean tide level is taken (a detailed explanation is given in **Appendix 4**). Along the coastline of South east Asia, the mean spring tidal range varies between 0.4m along the west coast of Aceh through 3.8m in the Straits of Malacca to 5.4m in the Papua province. This means that the high tide level may be between 0.2 and 2.7m above the Mean Tidal Level. In the Drainability Assessment Procedure, the assumption is made that tidal influences are addressed by leaving a buffer of 40 years or two crop cycles before the plantation subsides to the drainage base.

3. Drainability Assessment

It is important to know the drainability status of a plantation on peat not only before replanting, but also in general. This is to determine whether there will be long-term viability of the drainage in the peatland.

3.1 Assessment Procedures

The assessments that is required by the P&C 2018 is described in this Procedure. The basic principles to be followed in the Procedure is described in the following steps.

(1) Determine the Drainage Base - see Section 2.2 above.
(2) Calculate the predicted future subsidence of ground level based on default or in situ subsidence measurements.
(3) Determine the number of years before the land will subside to the drainage base (assuming constant subsidence rate).
(4) If the time before the site subsides to the drainage base is ≥ 40 years, the area may be replanted whereas if it is <40 years replanting is not allowed.

3.2. Predicting Future Drainability in a plantation

RSPO requires that an assessment of future drainability is undertaken before any peatland area is replanted. In order to enable this to take place RSPO has developed this Drainability Assessment Procedure. Such assessments can be undertaken at two levels of detail (TIER 1 – simple with limited data and use of conservative default parameters and TIER 2 – more complex requiring collection of significant data)

For both TIER approaches, drainage base, elevation and peat thickness are required to calculate depth to drainage base. The peat subsidence rate is used as a factor to calculate the 'time-to-drainage base' (Fig. 4).

This Procedure provides guidance for a two-tier approach i.e. TIER 1 and TIER 2. It is up to companies to decide which TIER is most appropriate for them to use. The tiered approaches provide a systematic way of determining the drainage limit depth in peatlands. The outcome of the assessment at TIER 2 level has higher precision and confidence, but also requires more resources than that of TIER 1. The outcome of a TIER 1 assessment is a quick and less costly way to determine the allowance for replanting, following RSPO regulations, but this approach is conservative, and therefore a larger caution-range is built in. The details for the TIER1 and TIER2 approaches are outlined in the **Annexes 1 and 2** respectively. In line with the principle of continuous improvement, a company may undertake an initial assessment at TIER 1 level, but subsequently may gather the data to undertaken final assessments at TIER 2 level.

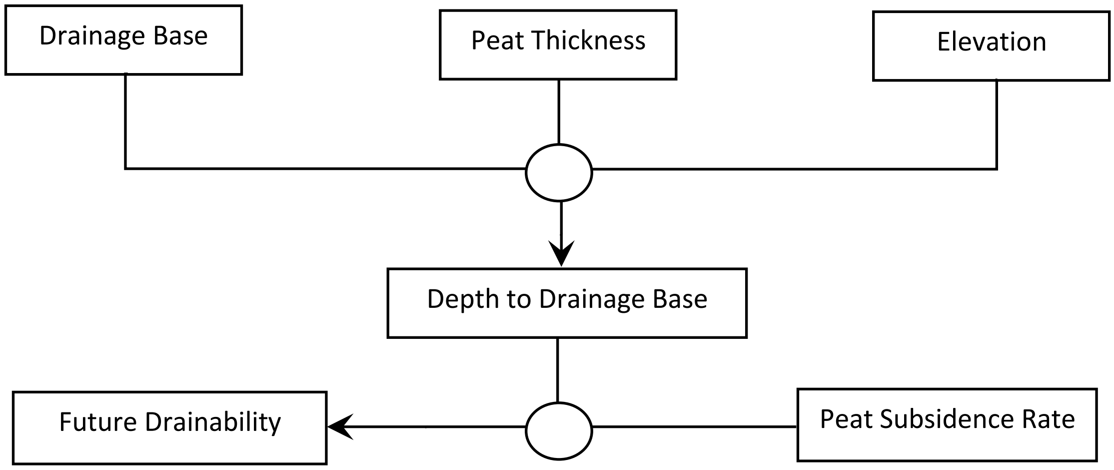

Figure 4: Key elements for Future Drainability Assessment

The difference between the two TIER approaches is the data requirement and level of confidence of the outcome. For the TIER 1 approach, for each separate peatland area delineated for replanting, an average value is required for drainage base, peat thickness, and elevation. For the TIER 2 approach, for each sub unit (stratum) within each peatland area delineated for replanting (e.g. a block or group of blocks), an average value is required for drainage base, peat thickness, and elevation. For both TIER approaches a company's own data must be used for peat surface subsidence rate, except in cases where not enough data is available (at least 3 years of measurements taken at minimum quarterly basis at enough representative locations), or where data is not sufficiently reliable. In these cases, a default value for peat surface subsidence of 5 cm/year may be used (based on Carlson *et al,* 2015).

Broadly, the degree of detail required for the data at each approach can be described as:

TIER 1 (See **Annex 1**): Assessment at **replanting-area level**. One centroid data point per delineated discrete (single) peat replanting area is needed as input data for elevation and drainage limit, and besides, a map for distance from the middle of the concession area to the discharge point from the plantation to the nearest outside water body is needed. The outcome can be presented in a simple excel table. For each peatland replanting area, the distance to drainage base will be calculated, as well as the time that it will take to subside to the drainage base. For each peatland replanting area, the drainability assessment will indicate whether the replanting can take place or not.

TIER 2 (See **Annex 2**): Assessment of subsidence **stratum**-level. A stratum is in this case a discrete unit of land (refer 3.2.1) that has a relatively homogeneous peat surface subsidence rate. This can be a zone (for example along a river), a management block or a group of management blocks. If the project area is not homogeneous in terms of peat surface subsidence, stratification based on soil subsidence measurements could be carried out to improve the accuracy and precision of the assessment. One centroid data point per separated stratum for each delineated replanting peatland is needed as input data for elevation and drainage limit, besides a map for distance from the middle of each stratum to the most relevant closest discharge water body. The outcome can be presented in an excel table. For each stratum within each delineated replanting peatland, the drainability assessment provides a 'go' or 'no-go' for replanting.

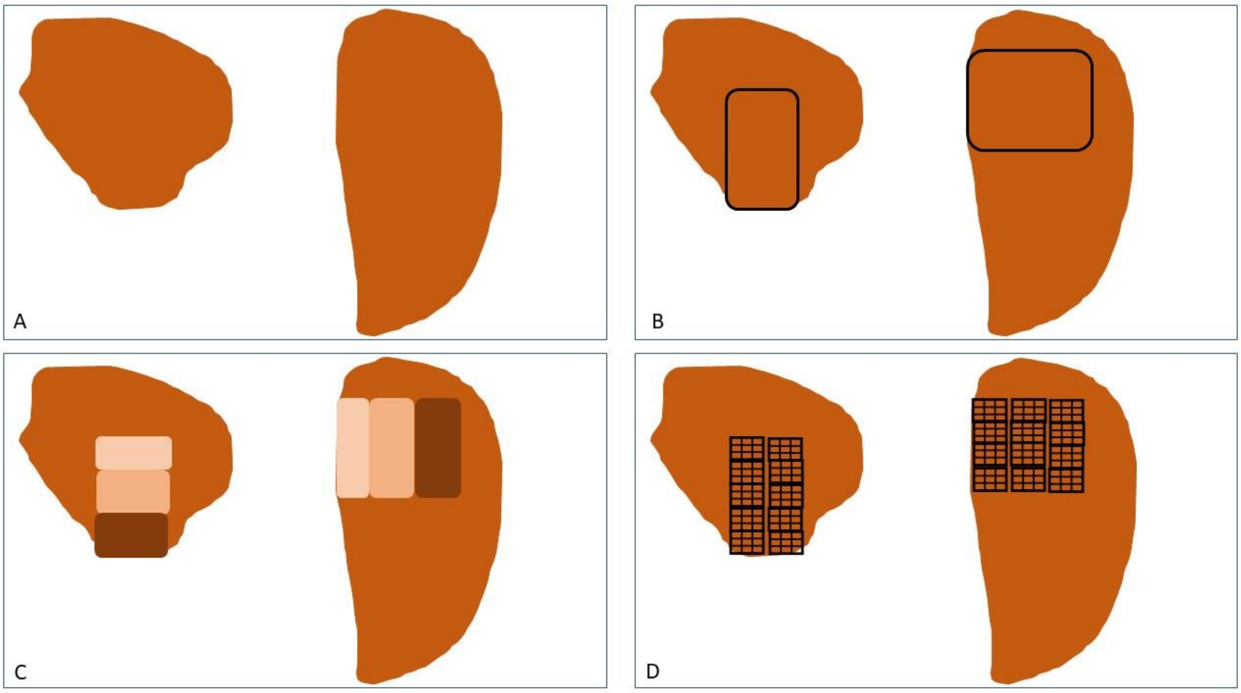

Figure 5: This figure illustrates the delineation of two separate peatlands (A) and the difference in TIER 1 (B), and TIER 2 (C) or (D).

Figure 5A shows the peatland areas within the concession. Figure 5B delineates individual replanting areas. If TIER 1 is used, one average value for peat depth, referenced elevation (e.g. above mean sea level), distance to discharge point at water body and peat surface subsidence rate is required per individual replanting area for calculating the height that the peat surface lies above the drainage limit (figure 5B). If TIER 2 is used, average values are required to calculate the height of the peat surface above the drainage base for each separated homogeneous stratum, e.g. based on peat surface subsidence rate and/or peat type (Figure 5C) and/or planting blocks (Figure 5D).

3.2.1. Discrete unit of land for drainability assessment

In order to facilitate the maximum economic return of development on peatland area in a sustainable manner, growers are encouraged to adopt TIER 2 assessment, subdividing the proposed replanting area into smaller land units. For practicality in implementation, the smallest land unit could be defined as the smallest field / block management units (for example, the Manuring or Harvesting Block, whichever of a smaller land size, approximately 20 to 40 Hectare).

Due to natural terrain variation, depth to drainage base is not uniform and varies across the peatland area. TIER 2 assessment allows more detailed mapping and generates separate outcomes for each land unit. Figure 6 illustrates the benefit of TIER 2 assessments in a replanting area. In the example, the concession area is subdivided into 12 smaller management blocks with one centroid data point per individual block. Several blocks with lower drainage base and DLT $\geq$ 40 years can proceed for replanting, while others cannot. In this example 50% of the concession could be replanted for the next cycle. Due to the inherent limitation of TIER 1 assessment, where only 1 mapping point for the entire large concession on peatland, the grower risks phasing out the entire concession from replanting.

Figure 6 Illustrates the results assessment of the drainage limit time (DLT) of peatland areas within the concession.

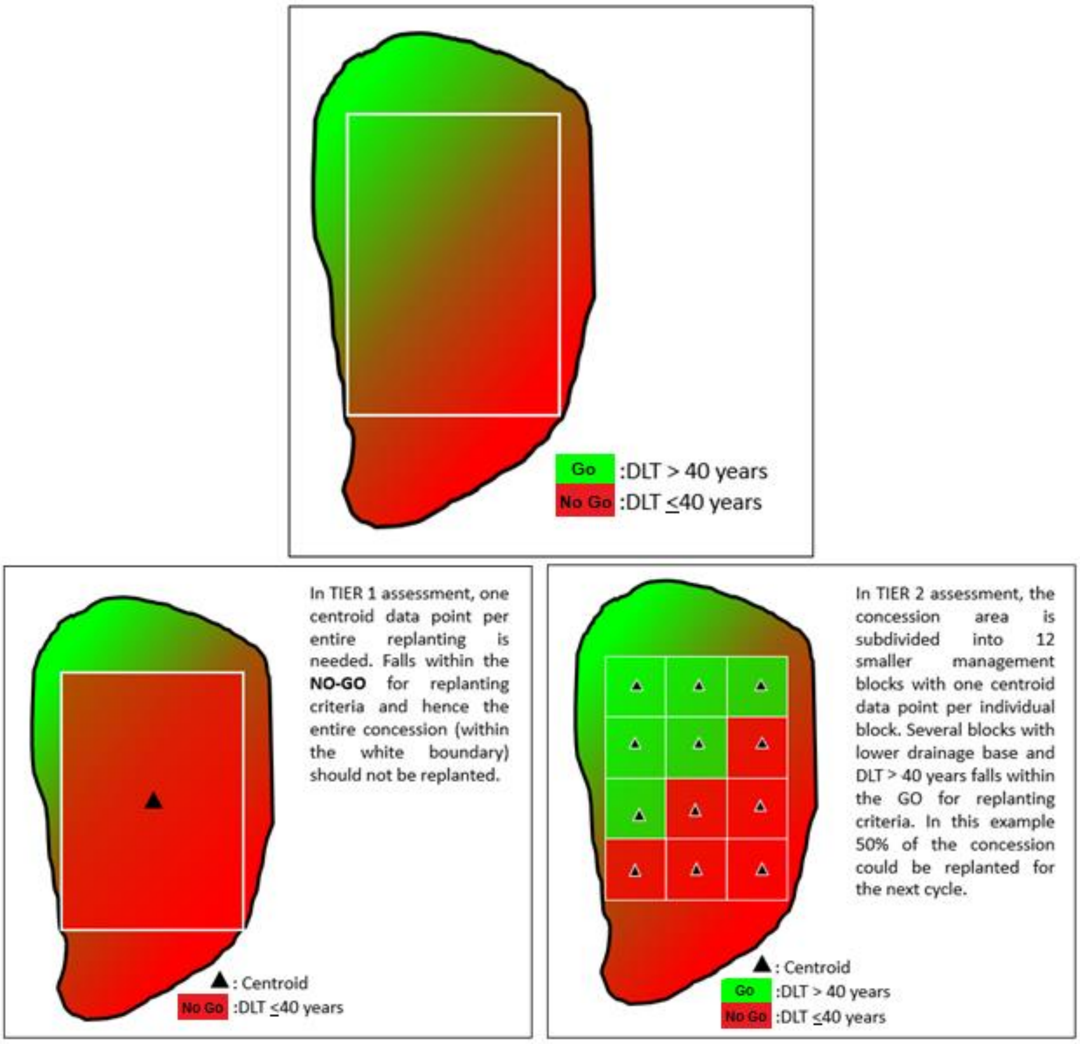

Figure 6: Shows the difference of 'discrete land unit' and the resulting assessment implications between using TIER 1 & TIER 2 assessments.

4. Required information

Before replanting on peat, grower companies are required to perform a drainability assessment in the area(s) proposed for replanting. This assessment must be conducted five years prior to replanting i.e. fifteen years after initial planting on peat, noting that there is some flexibility on this in the initial period after adoption of the 2018 P&C as specified in **Annex 5**.

For all TIER 1 and 2 assessments of 'future' drainability the following information is required:

1. Depth of peat layer to drainage base (in centimeters (cm))
2. Information on the elevation of the surface/base of the peat layer/peat basal contact (the peat bottom)
3. Drainage Limit Time (DLT, in years), based on depth of peat layer to drainage base and peat surface subsidence rate
4. Whether the DLT is below or above the required 40 year limit (two-crop cycle threshold) (Go if DLT>40 years, or No-go if DL ≤40 years)

In the paragraphs below, it is explained how to calculate the depth to drainage base, the basal contact elevation and the drainage limit time. It is also explained how to deal with the two-crop-cycle threshold.

4.1. Depth to drainage base

The depth to the drainage base is the vertical distance between the present land surface to the elevation of the drainage base, as illustrated in Figure 7. Depth to drainage base is the outcome of applying the TIER 1 or TIER 2 approaches. TIER 1 uses one-point averages per delineated replanting area, TIER 2 uses one-point averages per separated stratum in each replanting area. For both approaches:

$$D_{DB} = Z_S - Z_{DB}$$

Where

D_{DB} : Depth to drainage base (cm)

Z_S : Land elevation, i.e. from site DEM (m-msl)

Z_{DB} : Drainage base elevation, i.e. from drainage base map

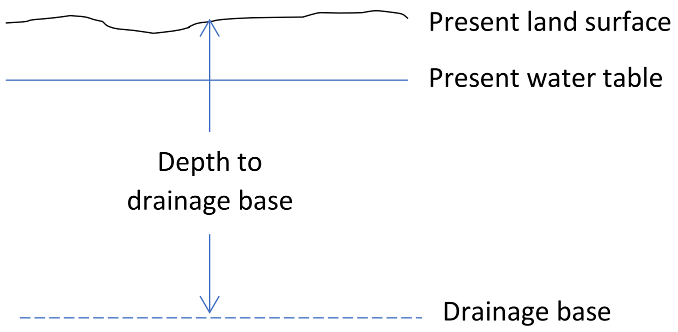

Figure 7: Illustration of positions of land surface, drainage base, and depth to drainage base

4.2. Basal contact elevation

Where the base of the peat layer is above the drainage limit, the peat layer may disappear completely before the two-crop cycle threshold is reached. This can be checked by comparing the peat depth to the distance/depth to the drainage base.

Basal contact of peat or peat base (i.e. the elevation of the base of the peat layer) can, for example, be calculated and mapped by overlaying a site Digital Elevation Model (DEM) against a peat map, by using simple arithmetic:

$$Z_{BC} = Z_S - D_P$$

Where

Z_{BC} : Basal contact elevation (m-msl)

Z_S : Land elevation, i.e. from site DEM (m-msl)

D_P : Peat thickness, i.e. from site peat map (m)

In locations with a basal contact above the drainage base, drainage and subsidence may continue without the land ever reaching its drainage base (ie becoming not possible to drain by gravity) . In such situation, where the drainage base is further below the surface than basal contact of the peat (DDB > Dp) the phase-out of the planting on peat based on drainability assessment does not apply (refer **Figure 8**).

Some countries apply regulations related to peat basal contact drainage or exposure of the underlying mineral soil in certain conditions. For example, in Indonesia, wherever the mineral subsoil beneath the peat layer contains quartz sand or acidic clay (categorized as Potential Acid Sulphate Soil, PASS) basal contact exposure or drainage is prohibited. From the same perspective, other regulations render drainage of acidic clay as damaging to the environment.

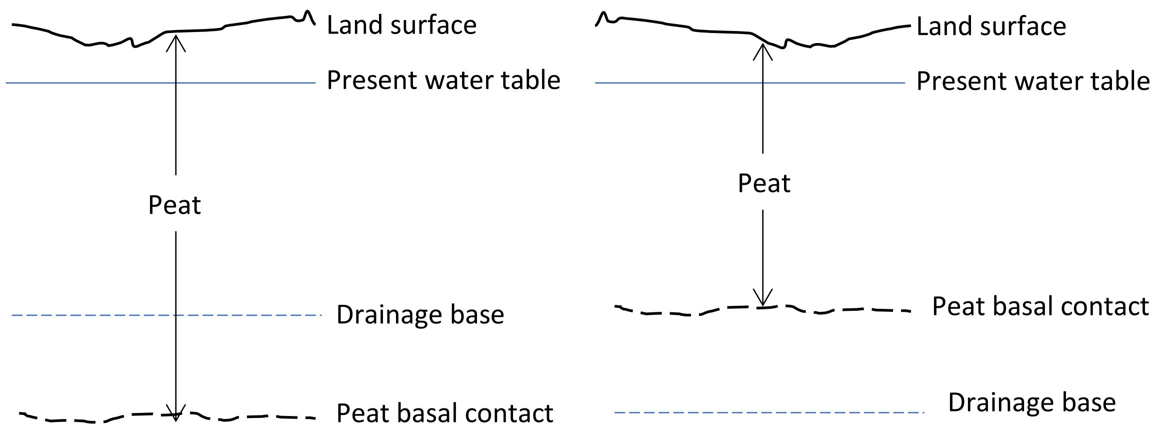

Figure 8: Illustration of vertical profile of peat soils showing relative positions of peat basal contacts against drainage bases: basal contact below drainage base (Drainability assessment fully applies) (left) and basal contact above the drainage base (Phase-out of plantation following drainability assessment does not apply) (right).

However, it should be noted, that some countries apply regulations related to peat basal contact drainage or exposure of the underlying mineral soil in certain conditions. For example, in Indonesia, wherever the mineral subsoil beneath the peat layer contains quartz sand or acidic clay (categorized as Potential Acid Sulphate Soil, PASS) basal contact exposure (ie allowing the loss of the entire peat layer) or drainage is prohibited. From the same perspective, other regulations specify drainage of acidic clay as damaging to the environment. In addition, if the drainage base is just below (eg less than 50cm) the peat basal contact, then the future drainage of the land will also be very difficult. In such case it is also recommended to phase out production or introduce alternate crops prior to the peat basal contact being reached.

4.3. Drainage Limit Time

The Drainage Limit Time (DLT) is the time required, with continuing subsidence, for the peat surface to subside to the position of the drainage base. DLT can be calculated, and can be mapped with raster arithmetic, by the following formula:

$$DLT = \frac{D_{DB}}{S}$$

Where

DLT : Drainage Limit Time (year)

D_{DB} : Depth to drainage base (cm)

S : Subsidence rate (cm/year)

4.4 Result of Drainability Assessment Procedure

4.4.1 Report

The results of the Drainability Assessment procedure should be in the form of a report including details on the site, methodology and data sources used. Results of the assessment (in table and map form) and management measures to be introduced based on the results.

The Result of the drainability assessment should be described in a report as detailed in section III of **Annexes 1 or 2**.

4.4.2 Submission of the report

The report of the Drainability Assessment in the format prescribed in Annex 1 and 2 should be submitted to the RSPO Secretariat (ghg@rspo.org) within one month of completion and prior to the time of any RSPO audit. Reports submitted prior to the end of March 2020 (the initial implementation period) should include a section with comments on the ease and challenge to undertake the drainability assessment.

The reports will enable the RSPO Secretariat in association with the RSPO PLWG2 to review the experience in undertaking the assessment and make required adjustments (if any) to the Drainability Assessment Procedure. All reports submitted to the RSPO secretariat will be for internal use only and not be made publicly available.

4.5 Next steps

4.5.1: Action to be taken based on results

In line with Indicator 7.7.5 P&C 2018, " *the assessment result is used to set the timeframe for future replanting, as well as for phasing out of oil palm cultivation at least 40 years, or two cycles, whichever is greater, before reaching the natural gravity drainability limit for peat*."

The result of the Drainability Assessment may fall into different categories as in Table 2:

Table 2: Categories of assessed areas and implications on replanting

Category	Description	Implication
1	The proposed replanting area is in the category of more than 40 years to the drainage limit	Replanting can take place for one or more 20 year cycle.
2	Part of the proposed replanting area is in the category of 40 years or less to the drainage limit	The portion of the proposed replanting area with less than 40 years to the drainage limit should not be replanted. Depending on the size and configuration of this land – the company should decide to go ahead or not with the replanting on the remainder of the land
3	The proposed replanting area is in the category of 40 years or less to the drainage limit	No replanting to take place. Decision should be taken on appropriate management strategy – ie planting with more water tolerant crops (paludiculture) or rehabilitation to natural peatland ecosystem)

4.5.2 Options for management of land not suitable for replanting

In line with Indicator 7.7.5 P&C 2018, *when oil palm is to be phased out,* it should be *"replaced with crops suitable for a higher water table (paludiculture) or rehabilitated with natural vegetation".* These options are elaborated below:

a) Alternative Crops

Productive land use on rewetted peatland with crops that are adapted to the high water levels in peatlands is called 'paludiculture'. Species cultivated are normally indigenous peat swamp forest species adapted to growing in peat with naturally high water levels. More than 400 Peat swamp forest (PSF) species have been identified to have productive use (Giesen, 2015). For centuries, the local populations have used paludiculture techniques to cultivate crops that are native to peatlands, such as sago (starch for noodles and cookies), rattan (for furniture), gelam (for pole-wood and medicinal oil), jelutong (for latex), tengkawang (illipe nut, for vegetable oil) and purun grass (for thatching and basketry). Some of these species have been planted at scale – eg Sago and jelutung and there are established markets for these. For other species further work is needed to develop and scale up production and develop markets. This is, however, a necessary investment to sustain productivity of the peatlands. Further information on Paludiculture is provided in various references including the RSPO Manual on Best Management Practices for Management And Rehabilitation Of Natural Vegetation Associated With Oil Palm Cultivation On Peat (Parish *et al*, 2019), Giesen (2013 and 2015) and Giesen and Nirmala (2018).

b) Rehabilitation to natural ecosystem

Peatland which has been taken out of oil palm production can be rehabilitated to forest or other natural ecosystems. Such areas can be rewetted through blocking of the drainage canals to bring the water near or at the surface. Indigenous peat swamp forest tree species can be planted in the shade of the remaining palms or directly in areas which have been cleared of palms. It is recommended that in open areas fast growing secondary forest species such as Mahang (*Macaranga pruinosa*), Gelam (*Melaleuca cajiputi*), Parapat *(Combretocarpus rotundatus)* or Tenggek Burung (*Melicope lunu-ankenda*). Further details of appropriate species and techniques are given in the RSPO Manual on Best Management Practices for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Peat (Parish *et al*, 2019)

4.5.3 Socio-economic and operational considerations

The location and allocation on the land which may be removed from production may influence the strategy for future use of the land.

a) Scheme smallholder land (Plasma)
If the land which cannot be replanted is that which is allocated for scheme smallholders (plasma) – there may be some significant social implications if this area is removed from production. There are several options which may be considered – allocating other land for smallholder (plasma) production; developing a viable paludiculture or alternative crop option for plasma farmers; or providing other forms of compensation.

b) Land adjacent to existing conservation areas versus small fragments
If the peatland which cannot be replanted is adjacent to existing conservation areas, then there would be a good argument for rehabilitating them to enable an expansion of the conservation areas. However, if they are small isolated fragments (less than 10-20 ha) – it may not be viable to rehabilitate them to conservation areas and other productive use (eg paludiculture) should be considered.

4.5.4 Development of management plan or strategy for the areas not to be replanted

It is important that there is a clear management plan or strategy for all areas which are taken out of production. This could be done by having a separate plan or a section in a revised integrated management and monitoring plan for existing conservation areas. Such plans should specify the rehabilitation or wet production measures that will be undertaken at the site including the removal of oil palms, blocking of drains, fire prevention and rehabilitation measures as appropriate.

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ANNEX 1. DRAINABILITY LIMIT ASSESSMENT METHOD – TIER 1 APPROACH

I. Procedure Summary

This Annex is an integral part of the Drainability Assessment document, and is intended as a step-by-step guidance for Future Drainability Limit Assessment and reporting of oil palm plantations on peatland. The main principles of the assessment have been given in the main document and will not be repeated in this guidance.

Future Drainability Assessment under the TIER 1 approach follows the main principles of AARD & LAWOO (1992) drainability classification as presented by Ritzema (2002), with a few simplifications. The AARD & LAWOO classification is based on distance to nearest water body, tidal range and water level fluctuation, and also the position of basal contact (peat base) relative to drainage base. In this Annex the future drainability does not take into consideration the tidal range and water level fluctuation of the receiving water body but instead takes only one average water level as the reference.

The TIER 1 approach can be summarized into 6 major steps (see Figure A1 below), that are further described in the following sections:

1. Calculation of average drainage base of peatland replanting area
2. Calculation of average peat thickness of peatland replanting area
3. Calculation of average ground elevation of peatland replanting area
4. Calculation of depth to drainage base of peatland replanting area
5. Assignment of average (Default) subsidence rate of peatland replanting area
6. Projection of future drainability of peatland replanting area

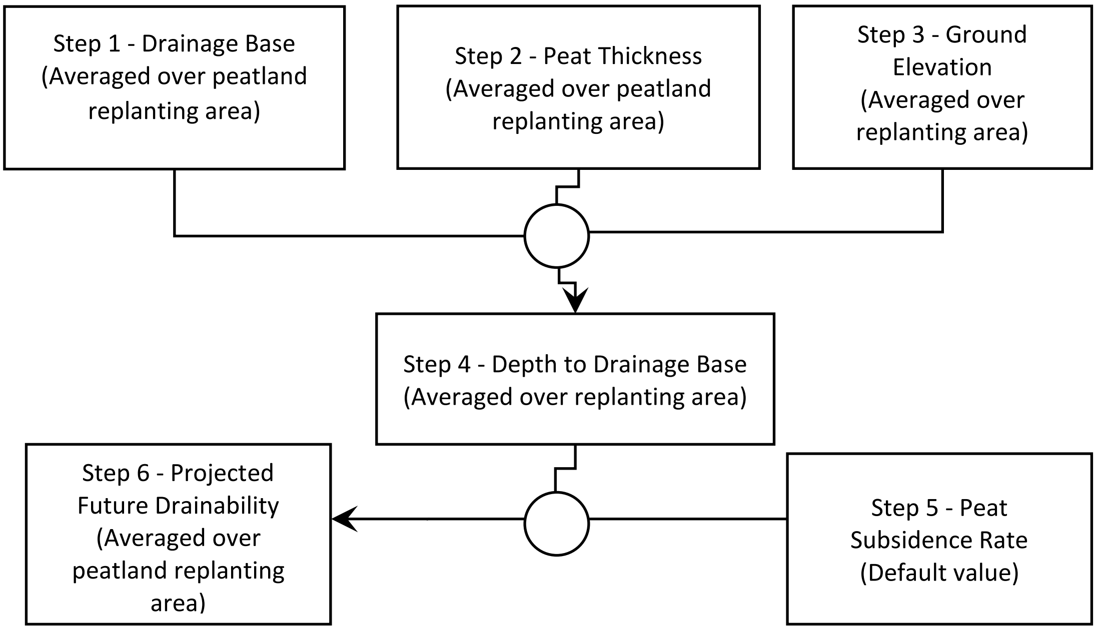


Figure A1-1. Future Drainability Assessment Flow Chart for TIER 1 Approach

As summarized in Figure A1, the drainage base, ground elevation of the peatland and the thickness of the peat layer are required to calculate depth to drainage base. Subsequently, the default peat subsidence rate is used as a factor in calculating future drainability by:

1. First determining the Drainage Limit Time (DLT), i.e. the time required, with continuing subsidence, for land surface to drop to the elevation of the Drainage Base, and
2. Checking whether the DLT exceeds the Two-Crop Cycle Threshold (TCCT), i.e. 40 years threshold.

II. Assessment Procedure

2.1 Determine Drainage Zone(s)

The main function of a drainage system in a plantation is to manage the ground water table and hence to create the right environment to maximise crop production. The drainage system must be robust and effective during dry periods to maintain optimum water levels for the plant to produce high yields, and during wet periods to prevent water logging and flooding. Typically in a plantation, the design of the drainage system needs to take into consideration the ground terrain and topography as well as the natural streams and water courses that crisscross the area. Consider a plantation with 4 parcels of peatland, A, B, C and D (See Figure A1-2).

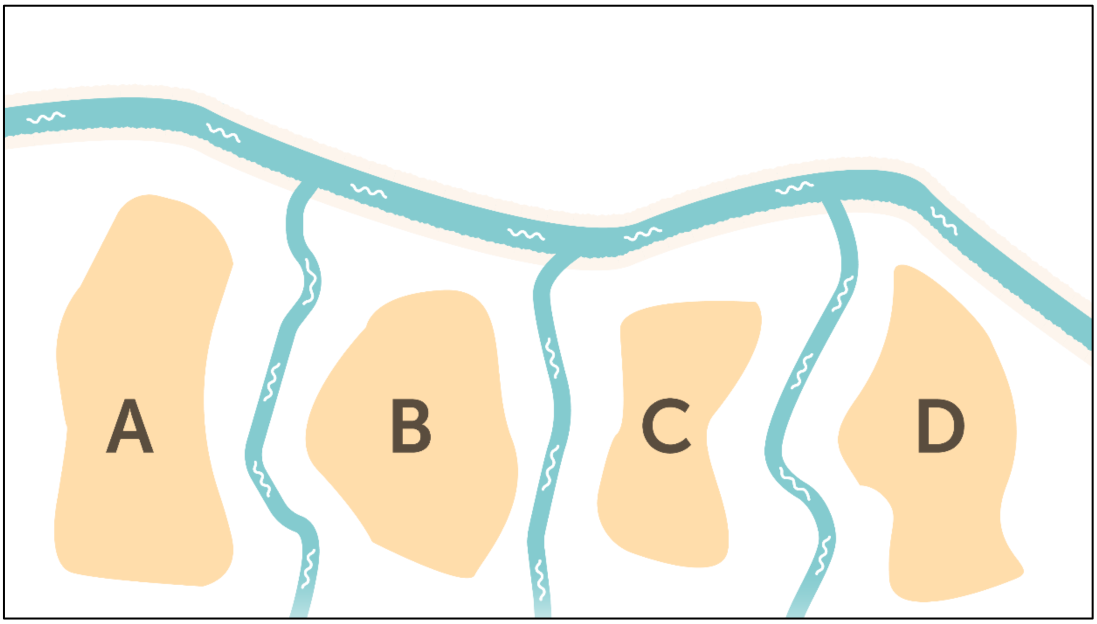


Figure A1-2. Illustration of an Oil Palm concession consisting of 4 separate peatland areas : A, B, C, D.

Drainage of parcels A and B is best effected by having a series of collector drains connecting both parcels to the nearest stream (i.e. the left stream). The drainage water would then flow into the receiving water body at Drainage Outlet D1. The whole sub-basin (of parcels A and B) would collectively be termed as Drainage Zone 1. Similarly for parcels C and D, the drainage water would flow into the receiving water body at Drainage Outlet D2, and the whole sub-basin would be termed as Drainage Zone 2. (See Figure A1-3 & A1-4)

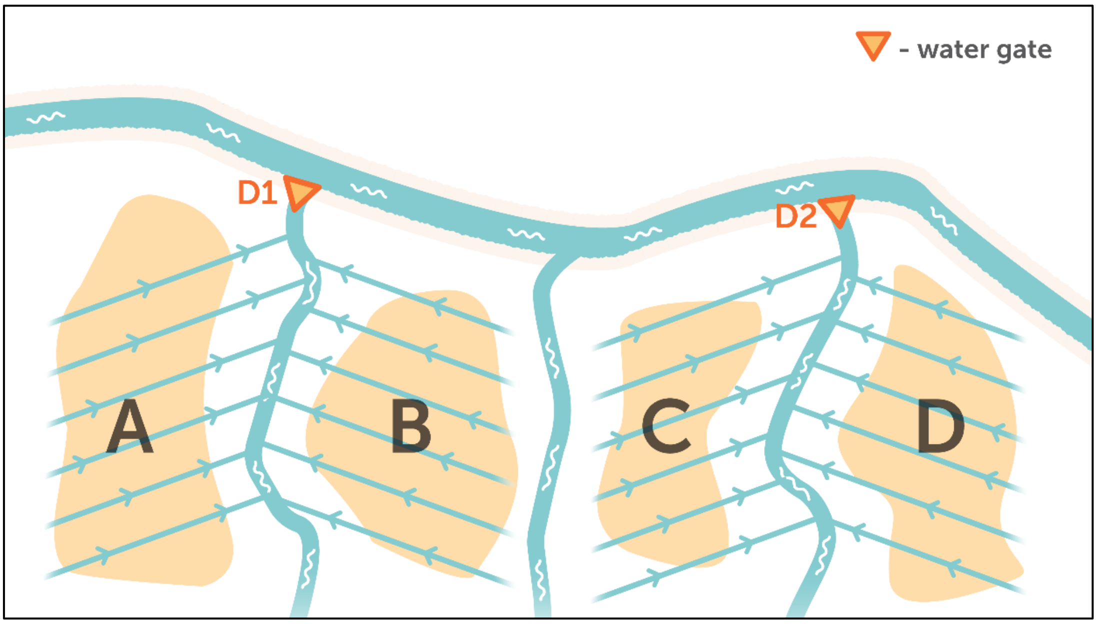


Figure A1-3. Internal drainage systems flowing into separate drainage outlets Drainage outlet 1 (D1) and Drainage outlet 2 (D2)

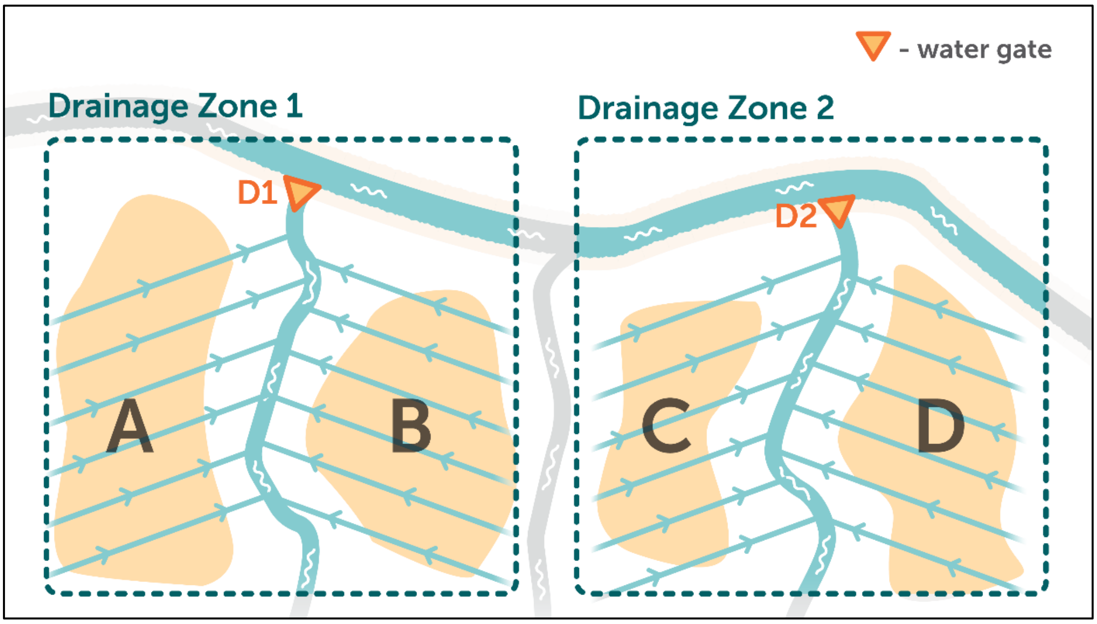


Figure A1-4. Illustration of an Oil Palm concession showing the internal drainage systems and the demarcation of the entire area into two Drainage Zones

When carrying out the Drainability Limit Assessment for the plantation, we should treat each Drainage Zone separately.

2.2. Calculation of Drainage Base

Step 1. Calculate centroid(s) of peatland replanting area
The boundary of peatland replanting area must be clearly defined (delineated). If the peatland replanting area comprises several parts/individual peatlands, each part must be delineated as a single entity. The delineation MUST ONLY COVER REPLANTING AREA ON PEATLAND (see also illustration on Figure A1-5). The Centroid coordinate(s) of the peatland replanting area(s) is calculated as average Longitude (X) and Latitude (Y) of boundary(s) vertices.

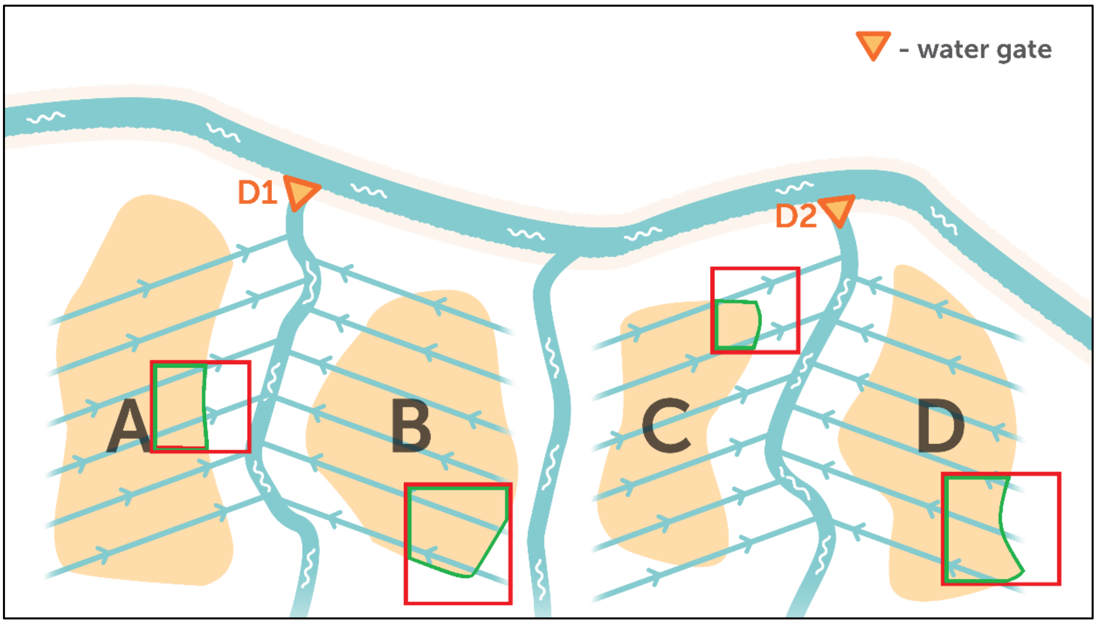


Figure A1-5. Illustration of an Oil Palm concession consisting of 4 separate peatland areas. Replanting is planned to take place in red boundaries, but peatland replanting area consists only areas in green boundaries.

When using ArcGIS, centroid coordinate can be calculated by using Calculate Geometry in Attribute Table Contextual Operation (Right Click).

Step 2. Identify and calculate distance to the nearest natural water body

Step 2.1.
Identify the current discharge point of drainage water from the plantation to the nearest external water body and mark its location (eg. drainage outlet D1 or D2 in Figure A1-5)

Step 2.3.

By using centroid(s) found in step 1 find the shortest straight line (distance) between the centroid(s) to the discharge point to the receiving water body). In ArcGIS this can be done by using Near Tool.

Step 3. Calculate water level elevation at the discharge point to the relevant natural water body

Using point ID or coordinate(s) of the water body point(s) found in step 2.1, estimate annual mean water level elevation at the point. The elevation may be measured relative to the elevation of the plantation or referred to standard datum, i.e. mean sea level. The source of data for water elevation must be credible, such as official record, remote sensing analysis, land survey, etc.

Step 4. Calculate Drainage Base
Calculate Drainage Base by using the following formula

$$Z_{DB} = Z_{NWB} + 0.0002 \times \Delta X_{NWB}$$

Where
Z_{DB} : Drainage Base (m-msl)
Z_{NWB} : Annual mean water level elevation at nearest natural water body (step 3) (m-msl)
ΔX_{NWB} : Distance to the nearest natural water body (step 2) (meters)

2.3. Calculation of average peat thickness

Step 1. Provide peat thickness map
Provide a peat thickness map of the peatland replanting area. If the replanting area comprises several parts/individual peatlands, each part must be delineated as a single entity. The map must be as accurate as possible, with 10 cm vertical resolution or finer. If a peat thickness map is available in raster format, its horizontal resolution must be 100 meters or finer.

The peat thickness must be up to date at the time of assessment and created from peat thickness samples that meet the following requirements: at least 30 percent of the samples are obtained not more than 1 year prior to time of assessment and the oldest samples are not more than 3 years (calculated from the year the drainability assessment is done). If the above requirements cannot be met, the peat thickness values of the map must be updated by accounting for subsidence taking place between the map date (year) and the assessment date (year).

Step 2. Calculate average peat thickness
If peat thickness map is in raster format average value can be calculated based on individual pixel values. If peat thickness map is in vector format, average peat thickness can be calculated based on class(area)-weighted values.

2.4. Calculation of average elevation of peatland replanting area

Step 1. Provide Land Elevation Map or Digital Elevation Model
Provide Land Elevation Map (LEM, vector) or Digital Elevation Model (DEM, raster) of peatland replanting area. If the replanting area comprises several parts/individual peatlands, each part must be presented as a single entity. Land Elevation Map or DEM should be referenced to standard datum (mean sea level) and can be obtained and/or processed from various sources such as: LIDAR, photogrammetry, IfSAR, drones or (previous) direct land survey(s). If land survey(s) are conducted, the main drainage outlet to the nearest water body can be used as initial (starting point) for the elevation measurement. In turn, the drainage outlet point must be referenced to standard datum (mean sea level) by using official benchmark(s) or known pixel elevation(s) on remote sensing image(s) (LIDAR, IfSAR, etc).

The DEM or LEM must be up to date at the time of assessment. If the map date is more than a year old, the elevation values of the map must be updated by accounting for subsidence of the peatland over the same period.

Step 2. Calculate average elevation of peatland replanting area
If using DEM (raster format), average value can be calculated based on individual pixel values. If using LEM (vector) average land elevation of peatland replanting area can be calculated based on class(area)-weighted values of the LEM.

2.5. Calculation of Depth to Drainage Base

Step 1. Provide drainage base(s) of the peatland replanting area(s) (results from Section 2.1 above)

Step 2. Provide average ground elevation(s) of the peatland replanting area(s) (results from Section 2.3 above)

Step 3. Calculate depth to drainage base of the peatland replanting area(s) by using the following formula

$$D_{DB} = Z_s - Z_{DB}$$

Where
D_{DB} : Depth to Drainage Base (m)
Z_s : Average land elevation, found in Section 2.4 (m-msl)
Z_{DB} : Drainage Base, found in Section 2.2 (m-msl)

2.6. Default subsidence rate for peatland replanting area

For TIER 1 approach, the Default subsidence rate of 5 cm/y must be used as average subsidence rate of the peatland replanting area.

2.7. Projection of future drainability of the Peatland Replanting Area

2.7.1. Drainage limit time (DLT)

Step 1. Provide average Peat Thickness as obtained in Section 2.3.

Step 2. Provide Depth to Drainage Base (D_{DB}) as obtained in Section 2.5.

Step 3. Use Default subsidence rate value (S) as defined in Section 2.6.

Step 4. Compare average peat thickness found in Step 1 against representative depth to drainage base found in Step 2. If the depth to Drainage base is more than the depth of the peat – then the drainage base is in the mineral soil below the peat – then the DLT does not need to be calculated

Step 5. Calculate drainage limit time (*DLT*) by using the following formula

$$If\ D_P \geq D_{DB}\ : \quad DLT = \frac{D_{DB}}{S}$$

Where
DLT : Drainage Limit Time (year)
D_{DB} : Depth to Drainage Base, found in Section 2.2 (cm)
D_p : Peat Thickness, found in Section 2.3 (cm)
S : Subsidence Rate (Default value = 5 cm/y)

Example:
In Figure A1-5 and Table A1, *DLT*s of four peatland areas were calculated.

Table A1-1. Table of illustrative data for Figure A1-5 containing basic information on average peat thickness, representative depth to drainage base, average subsidence and calculated drainage limit time of a concessions consisting of 4 separate peatland areas.

Peatland Area	Average peat thickness (D_P) (meters)	Depth to Drainage Base (D_{DB}) (meters)	Average Subsidence Rate (S) (cm/year)	Drainage Limit Time (DLT) (years)	NRI (DLT vs NRT) (years)
A	4.5	2.7	5	54	14
B	5.2	3.34	5	66.8	26.8
C	4.2	3.43	5	68.6	28.6
D	3.8	1.3	5	26	-14

2.7.2. No replanting (no-go) indicator (NRI)

For TIER 1 approach, a No Replanting (No-go) planting Indicator map is not required, since a single value (for single unit of peatland) or a table (for multi-unit peatland) is sufficient. The NRI value can be evaluated by simply subtracting DLT value(s) by 2 crop cycle period (40 years).

$$NRI = DLT - 40$$

If NRI > 0, threshold has not yet been reached. If NRT is zero or a negative number, that means the two-crop cycle threshold has been reached and **NO** replanting is allowed on the corresponding peatland

From Table A1-1, it is apparent that NRI has been reached in peatland areas D, because the calculated DLT is less than the (40 years).

III. Reporting

Reporting must follow the below reporting format, and must include the following information:

1. Site Descriptions: Geographic and administrative locations (with maps), descriptions of peatland/ landscape and watershed/main river/coastal area
2. Summary Table of concession area, peatland area in concession, date of peatland planting (current cycle) and peatland replanting area.
3. Full descriptions of assessment process: method, map of peatland replanting area, source of data, assumptions, limitations.
4. Summary Table of assessment result. For TIER 1 reporting, a Summary Table for the following information ***for each peatland replanting area*** must be submitted:
   i. Average peat thickness (meters)
   ii. Average elevation (meters above mean sea level)
   iii. Distance from centroid to the discharge point to nearest water body (meters)
   iv. Average water level elevation at the discharge point (meters above mean sea level)
   v. Drainage base elevation (m)
   vi. Depth from peat surface to drainage base or peat base (basal contact), whichever shallower (meter)
   vii. Subsidence rate (default value of 5cm/year)
   viii. Drainage Limit Time (years)
   ix. No replanting (no-go) indicator (NRI) (Go if DLT>40, or N if DL ≤40)

5. Supporting data, maps, and other relevant information used in the calculation as in the following table

Table A2. Summary Table for TIER 1 Drainability Limit Assessment Report

Peatland Replanting area	Size of replanting area (ha)	Average peat thickness	Average elevation	Distance from centroid to nearest water body node	Avg. water level elevation at the nearest water body node	Drainage base elevation	Depth to drainage base or peat basal contact	Subsidence rate	Drainage Limit Time	No replanting (no-go) indicator (NRI)
A										
B										
C										
…										

6. Conclusion of Assessment including area of Plantation on peat proposed for replanting or non-planting as a result of the assessment. Proposed management measures for areas proposed not to be replanted (eg rehabilitation to natural vegetation or planting with paludiculture crops).

ANNEX 2. DRAINABILITY LIMIT ASSESSMENT METHOD – TIER 2 APPROACH

I. Procedure Summary

This Annex is an integral part of main Drainability Assessment document and is intended as a step by step guidance in Future Drainability Limit Assessment and reporting of oil palm plantations on peatland. Main principles of the assessment have been given in the main document and will not be reintroduced in this guidance.

Future Drainability Assessment under the TIER 2 approach follows the main principles of AARD & LAWOO (1992) drainability classification as presented by Ritzema (2002), with a few simplifications. The AARD & LAWOO classification is based on distance to nearest water body, tidal range and water level fluctuation, and also the position of basal contact (peat base) relative to drainage base. In the TIER 2 assessment the future drainability does not take into consideration the tidal range and water level fluctuation of the receiving water body but instead takes only one average water level as the reference.

Future Drainability Assessment under TIER 2 approach can be summarized into 6 major steps (see Figure A2-1 below), that are further described in the following sections:

1. Calculation of average drainage base of replanting peatland area averaged per stratum
2. Calculation of average peat thickness of replanting peatland area, averaged per stratum
3. Calculation of average ground elevation of replanting peatland area, averaged per stratum
4. Calculation of depth to drainage base of replanting peatland area, averaged per stratum
5. Calculation of average subsidence of replanting peatland area based on measurements, averaged per stratum
6. Projection of future drainability of replanting peatland area, averaged per stratum

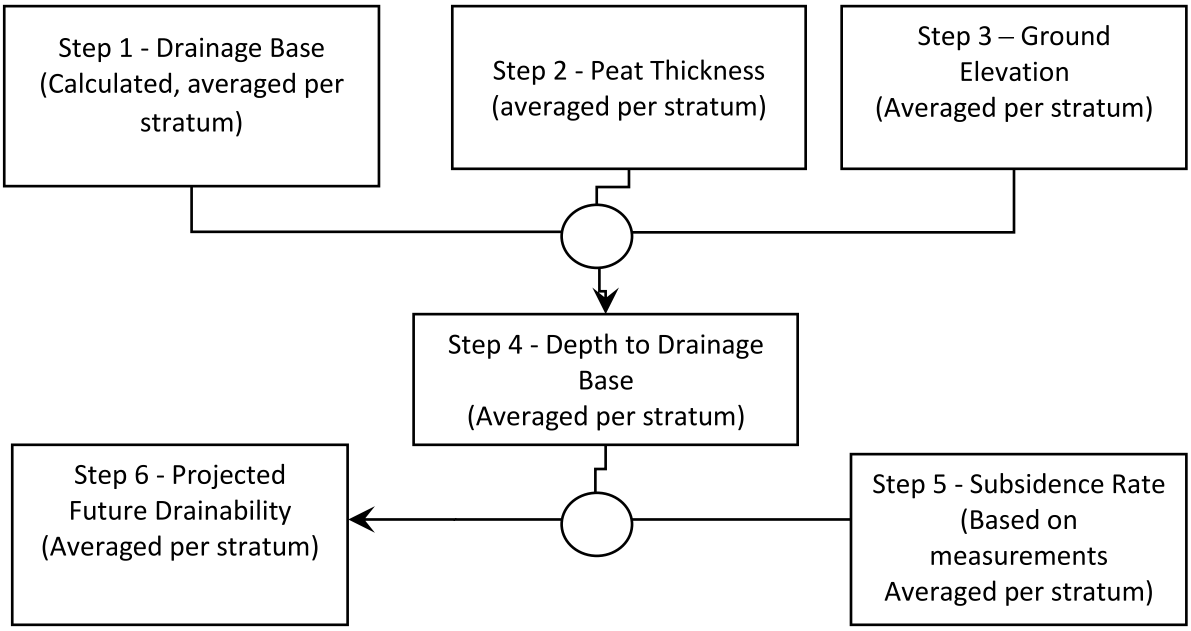


Figure A2-1. Future Drainability Assessment Flow Chart for TIER 2 Approach

As summarized in Figure A2-1, the drainage base, elevation of the peatland and the thickness of the peat layer are required to calculate depth to drainage base. Subsequently, subsidence rate is used as a factor in calculating future drainability by:

1. First determining the Drainage Limit Time (DLT), i.e. the time required, with continuing subsidence, for land surface to drop to the position/elevation of the Drainage Base, and
2. Checking whether the DLT exceeds the Two-Crop Cycle Threshold (TCCT), i.e. two-crop cycle (40 years) threshold.

II. Assessment Procedure

2.1. Determine Drainage Zone(s)

The main function of a drainage system in a plantation is to manage the ground water table and hence to create the right environment to maximise crop production. The drainage system must be robust and effective during dry periods to maintain optimum water levels for the plant to produce high yields, and during wet periods to prevent water logging and flooding. Typically in a plantation, the design of the drainage system needs to take into consideration the ground terrain and topography as well as the natural streams and water courses that crisscross the area. Consider a plantation with 4 parcels of peatland, A, B, C and D (See Figure A2-2).

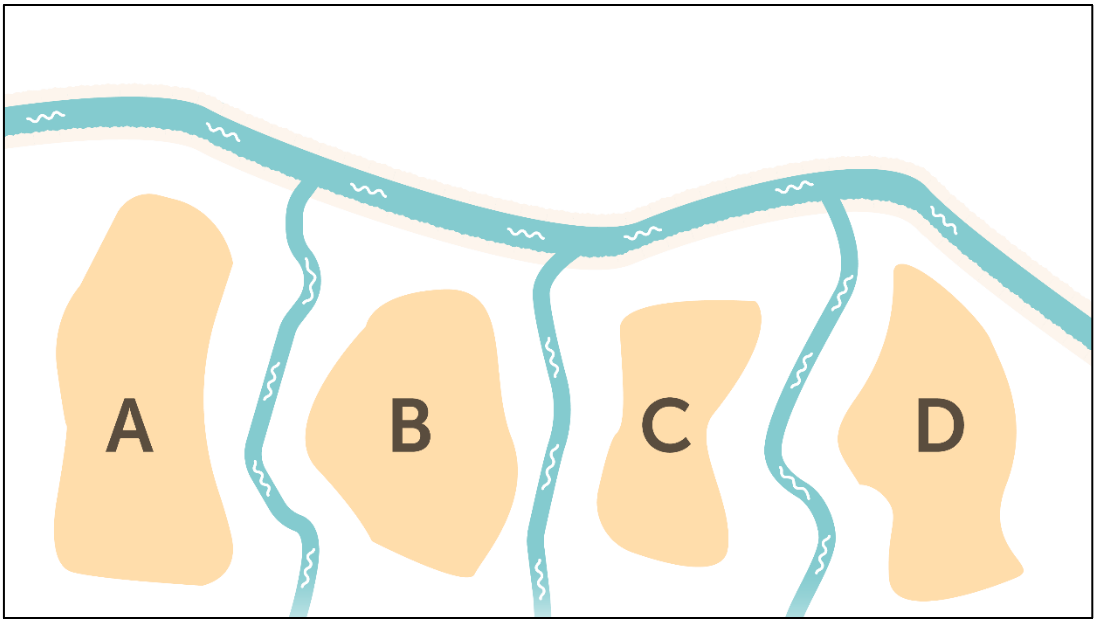


Figure A2-2. Illustration of an Oil Palm concession consisting of 4 separate peatland areas: A, B, C, D.

Drainage of parcels A and B is best effected by having a series of collector drains connecting both parcels to the nearest stream (i.e. the left stream). The drainage water would then flow into the receiving water body at Drainage Outlet D1. The whole sub-basin (of parcels A and B) would collectively be termed as Drainage Zone 1. Similarly for parcels C and D, the drainage water would flow into the receiving water body at Drainage Outlet D2, and the whole sub-basin would be termed as Drainage Zone 2. (See Figure A2-3 & A2-4)

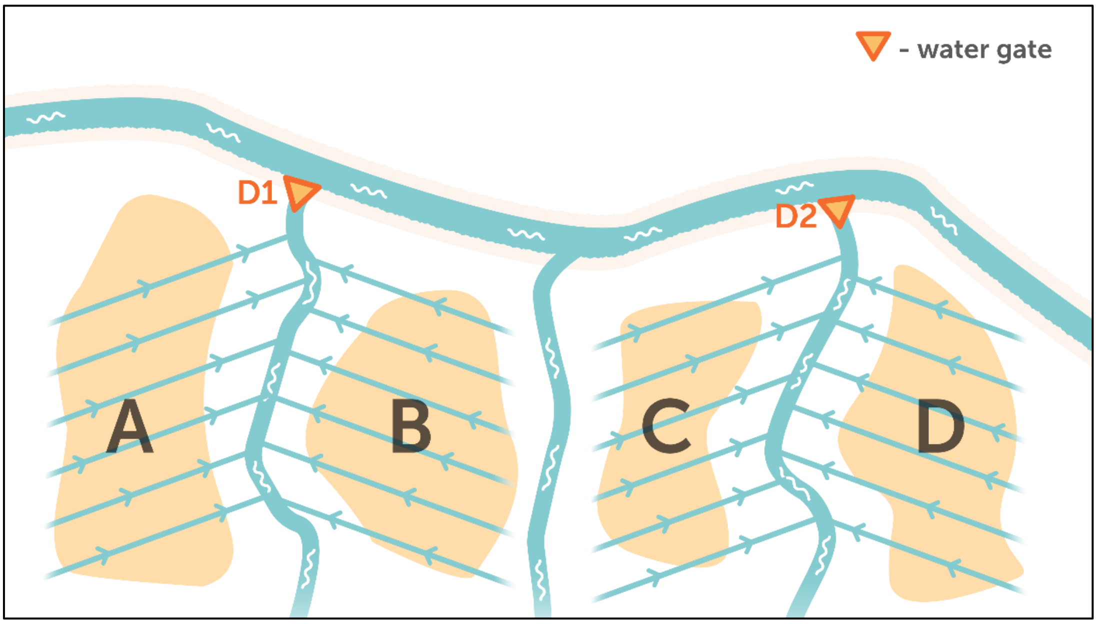


Figure A2-3. Internal drainage systems flowing into separate drainage outlets Drainage outlet 1 (D1) and Drainage outlet 2 (D2)

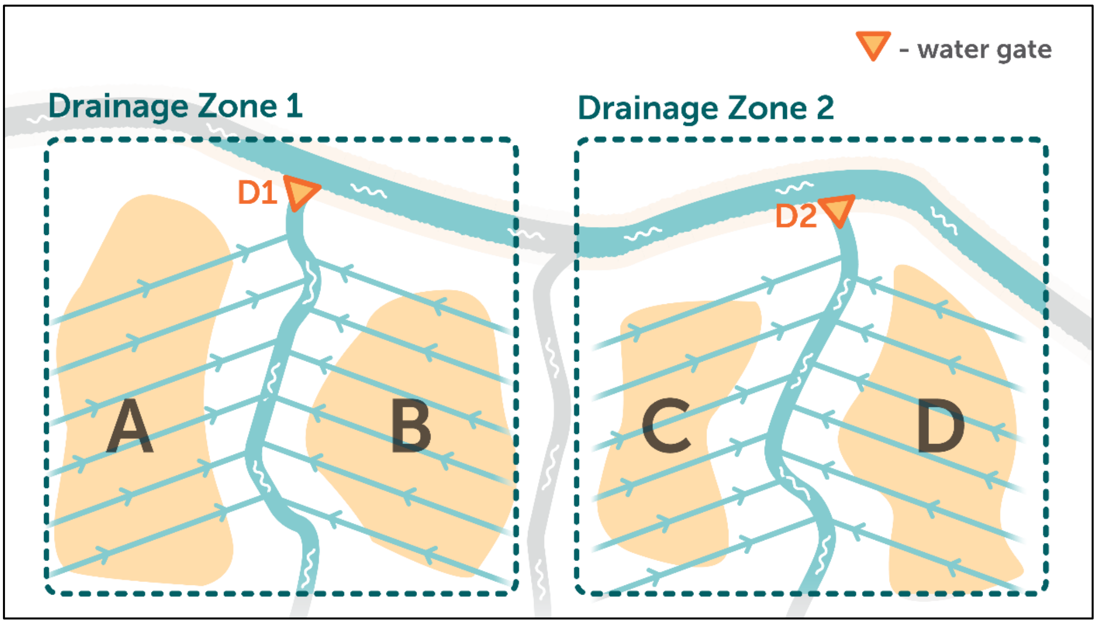


Figure A2-4. Illustration of an Oil Palm concession showing the internal drainage systems and the demarcation of the entire area into two Drainage Zones

When carrying out the Drainability Limit Assessment for the plantation, we should treat each Drainage Zone separately.

2.2. Calculation of Drainage Base

Step 1. Calculate centroid(s) of replanting peatland area

Boundary of replanting peatland area must be clearly defined (delineated). The delineation MUST ONLY CONTAIN REPLANTING AREA ON PEATLAND. All mineral soil area must be excluded. If the replanting peatland area comprises several parts/individual units, each part must be delineated as a single entity.

Step 1.1. Stratify replanting peatland area

Every part of replanting peatland area that shows variability, which can result in variations to the subsidence rate, must be stratified. This stratification can be based on, among others:

1. Planting blocks
2. Peat thickness
3. Any combination of the above

Grower(s) must justify and describe any stratification factor(s) chosen in the assessment.

Step 1.2. Calculate centroid of each spatial unit in the strata of the replanting peatland area

Centroid coordinate(s) of each spatial unit in the strata of the replanting peatland area(s) is calculated as average longitude (X) and Latitude (Y) of boundary(s) vertices. When using ArcGIS, centroid coordinate can be calculated by using Calculate Geometry in Attribute Table Contextual Operation (Right Click).

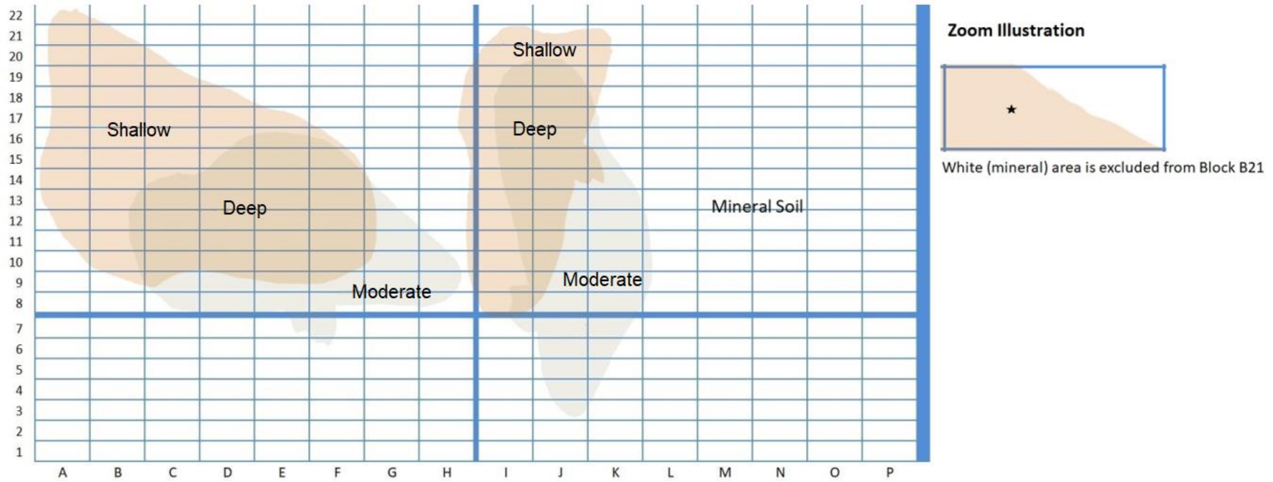


Figure A2-5. Illustration of an Oil Palm concession consisting of 2 separate peatland areas. Replanting is planned to cover the entire concession, but the peatland replanting area consists only peatland areas. Only replanting blocks on peat soils are taken into account in the assessment. The peatland replanting area is further stratified by using parameters planting block. Every planting block that consists of different peat maturity/subsidence rate must be divided accordingly into separate spatial units with their own centroids. See also zoom illustration of Figure A2-5.

Step 2. Identify and calculate distance to the receiving water body

Step 2.1. Water Management efforts in the landscape outside a concession area

Choose applicable water management options from the following:

1. Grower(s) has no power, and/or right, and/or ability, and/or capacity to do or get involved in drainage related water management efforts in the landscape outside its own concession area;
2. Grower(s) has power, and/or right, and/or ability, and/or capacity to do or get involved in drainage related water management efforts in the landscape outside its own concession area; When choosing option 2, grower(s) must provide sufficient evidence that can prove the correctness of the assumption. This evidence can be official note(s) or declaration(s) from relevant authority, valid national or sub-national law(s) or regulation(s), official action plan or development plan for the area.

Step 2.2.

Choose relevant natural water bodies for the assessment based on Option chosen in Step 2.1.

For Option 1: Select the existing discharge point of the current drainage from the Plantation to the nearest water body

For Option 2: Identify relevant natural water bodies by following the steps presented in **Annex 3** Procedure A, Step 1 and 2.

Step 2.3.
By using centroid(s) found in Step 1, find the shortest straight line (distance) between the centroid(s) to the discharge point. In ArcGIS this can be done by using Near Tool.

Step 3. Calculate water level elevation at relevant natural water body

Using point ID or coordinate(s) of the water body point(s) found in Step 2.2, estimate the annual mean water level elevation at the nearest water body point(s). The elevation must be referred to standard datum, i.e. mean sea level. The source of data for water elevation must be credible, such as official record, remote sensing imagery, etc. User can also estimate water elevation by using scientific method, for example based on river-slope, etc. Grower(s) can alternatively follow procedure B in **Annex 3**.

Step 4. Calculate the Drainage Base
Calculate Drainage Base by using the following formula

$$Z_{DB} = Z_{NWB} + 0.0002 \times \Delta X_{NWB}$$

Where
Z_{DB} : Drainage Base (m-msl)
Z_{NWB} : Annual mean water level elevation at nearest natural water body (step 3) (m-msl)
ΔX_{NWB} : Distance to the nearest natural water body (step 2) (meters)

2.3. Calculation of average peat thickness

Step 1. Provide peat thickness map
Provide peat thickness map of peatland replanting area. If the replanting area comprises several parts/individual peatlands, each part must be presented as a single entity. The map must be as accurate as possible, with 10 cm vertical resolution or finer. If peat thickness map is available in raster format, its horizontal resolution must be 100 meters or finer.

The peat thickness must be up to date at the time of assessment and created from peat thickness samples that meet the following requirements: at least 30 percent of the samples are not more than 1 year from the time of assessment, and the oldest samples are not more than 3 years (calculated from the year the drainability assessment is done). If the above requirements cannot be met, the peat thickness values of the map must be updated by accounting for the peat subsidence over the period between the map date (year) and the assessment date (year).

Step 2. Calculate average peat thickness
If peat thickness map is in raster format average value can be calculated based on individual pixel values. If peat thickness map is in vector format, average peat thickness can be calculated based on class (area)-weighted values.

2.4. Calculation of average ground elevation of peatland replanting area

Step 1. Provide Land Elevation Map or Digital Elevation Model
Provide Land Elevation Map (LEM, vector) or Digital Elevation Model (DEM, raster) of replanting peatland area. If the replanting area comprises several parts/individual peatlands, each part must be presented as a

single entity. Land Elevation Map or DEM must be referenced to standard datum (mean sea level) and can be obtained and/or processed from various sources such as: LIDAR, photogrammetry, IfSAR, drones or (previous) direct land survey(s). If land survey(s) are conducted, the drainage outlet can be used as initial (starting point) for the elevation measurement.

The DEM or LEM must be up to date at the time of assessment. If the map date is more than a year old, the elevation values of the map must be updated by accounting for subsidence of the peat over the same period.

Step 2. Calculate average elevation of replanting peatland area
If using DEM (raster format), average value can be calculated based on individual pixel values. If using LEM (vector) average land elevation of replanting peatland area can be calculated based on class(area)-weighted values of the LEM.

2.5. Calculation of Depth to Drainage Base

Step 1. Provide drainage base(s) of the replanting peatland area(s) (results from Section 2.1 above)

Step 2. Provide average ground elevation(s) of the replanting peatland area(s) (results from Section 2.3 above)

Step 3. Calculate depth to drainage base of the replanting peatland area(s) by using the following formula

$$D_{DB} = Z_s - Z_{DB}$$

Where
D_{DB} : Depth to Drainage Base (m)
Z_s : Average land elevation, found in Section 2.4 (m-msl)
Z_{DB} : Drainage Base, found in Section 2.2 (m-msl)

2.6. Calculation of average subsidence rate representative of the site

Step 1. Provide table of stratified time-series averaged subsidence as exampled in Table A2.1. Note that in case the site consists of multiple peatland areas, there must be separate Table for each area (or part of area).

Step 2. For each stratum, calculate Weighted subsidence, i.e. the product of each averaged subsidence (S_i) and its representative peatland area of the block where subsidence pole is installed (A_i) where *i* denote index number.

Step 3. For each stratum, calculate total peatland area of the blocks where subsidence poles were installed, and the sum of weighted subsidence.

Table A2.1. Table of illustrative data containing information of Subsidence Pole code, Block area of the subsidence pole, time-series averaged subsidence and weighted subsidence (subsidence x area) for Stratum A (Deep)

Subsidence Pole number	Block Area (ha)	Averaged Subsidence (cm/y)	Weighted Subsidence cm-ha/yr
1	4	4.6	18.4
2	4	4.1	16.4
3	4	3.8	15.2
4	4.2	3.8	15.96
5	3	4.1	12.3
Total	19.2		78.26

Table A2.2. Table of illustrative data containing information of Subsidence Pole code, Block area of the subsidence pole, time-serial averaged subsidence and weighted subsidence (subsidence x area) for Stratum B (Moderate)

Subsidence Pole number	Block Area (ha)	Averaged Subsidence (cm/y)	Weighted Subsidence cm-ha/yr
21	4	3.4	13.6
22	4	3.4	13.6
23	3.3	3.3	10.89
24	4.1	3.6	14.76
Total	15.4		52.85

Step 4. Calculate average subsidence representative of the stratum by using the following formula

$$S = \frac{\sum_{i=1}^{n}(A_i \times S_i)}{\sum_{i=1}^{n} A_i}$$

Where
A : Area of the stratum/Spatial Unit
S : Subsidence rate of the stratum/Spatial Unit
i : Stratum index
n : Total stratum number

For example, based on Table A2.1 and A2.2, average subsidence for stratum A:

$$S = \frac{78.26}{19.2} = 4.1\ cm/y$$

And for stratum B:

$$S = \frac{52.85}{15.4} = 3.4\ cm/y$$

2.7. Projection of future drainability of Peatland Replanting Area

2.7.1. Drainage limit time (DLT)

Step 1. Provide average Peat Thickness as obtained in Section 2.3.

Step 2. Provide Depth to Drainage Base (D_{DB}) as obtained in Section 2.5.

Step 3. Use average subsidence rate value (*S*) as obtained in Section 2.6.

Step 4. Compare average peat thickness found in Step 1 against representative depth to drainage base found in Step 2. If the Depth to drainage base is greater than the depth of the peatland ($DD_B > D_P$) – then the Drainage Limit Timer based on drainability is not applicable

Step 5. Calculate drainage limit time (*DLT*) by using the following formula

$$If\ D_P \geq D_{DB}\ :\quad DLT = \frac{D_{DB}}{S}$$

Where
DLT : Drainage Limit Time (year)
D_{DB} : Depth to Drainage Base, found in Section 2.5 (cm)
D_p : Peat Thickness, found in Section 2.3 (cm)
S : Average Subsidence Rate, found in Section 2.6 (*x* cm/y)

Example:
In Figure A2.-5 and Table A2.3 *DLT*s of several spatial units of stratified replanting peatland areas were calculated.

Table A2.3. Table of illustrative data for Figure A2-5 containing information on average peat thickness, representative depth to drainage base, average subsidence and calculated drainage limit time of a concessions consisting of 2 separate peatland areas stratified further by using parameters planting block and peat depth.

Stratum/ Spatial Unit	Average peat thickness (D_P) (meters)	Depth to Drainage Base (D_{DB}) (meters)	Average Subsidence Rate (*S*) (cm/year)	Drainage Limit Time (DLT) (years)
A22 Shallow	1.5	1.6	3	not applicable ($DD_B > D_P$)
…	…	…	…	…
B21 Shallow	1.6	1.2	4	30
…	…	…	…	…
C14 Shallow	2.4	2.1	3	70
C14 Deep	5.2	1.8	5	36
…	…	…	…	…
J12 Deep	6.2	2.5	5	50
J12 Moderate	3.8	2.5	4	62.5
…	…	…	…	…
So forth..	So forth..	So forth..	So forth..	So forth..

2.7.2. No Replanting (no-go) Indicator (NRI)

The No Replanting (no-go) Indicator (NRI) value can be evaluated by simply subtracting DLT value(s) by 2 crop cycle period (40 years)

$$NRI = DLT - 40$$

If NRI > 0, threshold has not yet been reached. If NRI returns zero or negative number, that means two-crop cycle threshold has been reached and **NO** replanting is allowed on corresponding peatland

For Tier 2, the results should be illustrated in a table and a map

From Figure A2-5 and Table A1, it is apparent that NRI has been reached in units B21 and C14, because the calculated DLTs are less than two-crop cycle (40 years).

III. Reporting

Reporting must follow the below reporting format, and must include the following information:

1. Site Descriptions: Geographic and administrative Locations (with maps), Descriptions of peatland/landscape and watershed/main river/coastal area.
2. Summary Table of concession area, peatland area in concession, and peatland replanting area
3. Full descriptions of assessment process: method, map of peatland replanting area, source of data, assumptions, limitations
4. Summary Table of assessment result. For TIER 2 reporting, a Summary Table for the following information ***for each stratum in peatland replanting area*** must be submitted:
   i. Average peat thickness (meters)
   ii. Average elevation (meters above mean sea level)
   iii. Distance from centroid to the discharge point to the nearest water body (meters)
   iv. Average water level elevation at the discharge point to the nearest water body (meters above mean sea level)
   v. Drainage base elevation (m)
   vi. Depth from peat surface to drainage base
   vii. Subsidence rate (default value or actual data) (meters/year)
   viii. Drainage Limit Time (years)
   ix. No replanting (no-go) indicator (NRI) (Go if DLT>40, or N if DL $\leq$40)

   A map to show the replanting and no replanting areas, based on the assessment and associated management decision needs to be included

5. Supporting data, maps, and other relevant information used in the calculation

Table A2. Summary Table for TIER 2 Drainability Limit Assessment Report Summary

Stratum Or spatial unit	Size of unit (ha)	Average peat thickness	Average elevation	Distance from centroid to discharge point at nearest water body	Avg. water level elevation at discharge point to the nearest water body	Drainage base elevation	Depth to drainage base	Subsidence rate	Drainage Limit Time	No replanting (no-go) indicator (NRI)
A										
B										
C										
…										

Data and description of detailed calculation must be submitted in separate document or as an Annex

6. Conclusion of Assessment including area of Plantation on peat proposed for replanting or non-planting as a result of the assessment. Proposed management measures for areas proposed not to be replanted (eg rehabilitation to natural vegetation or planting with paludiculture crops).

ANNEX 3. IDENTIFICATION AND CALCULATION OF WATER LEVEL ELEVATION OF RELEVANT NATURAL WATER BODIES

Procedure A. Identification of Relevant Natural Water Bodies for TIER 2 Assessment (Option2)

The methodology in **Annex 3** is only applicable for use under TIER 2 Assessment where the company has selected option 2 – ie Grower(s) has the power, and/or right, and/or ability, and/or capacity to undertaken or get involved in drainage related water management efforts in the landscape outside its own concession area; When choosing option 2, grower(s) must provide sufficient evidence that can prove the correctness of the assumption. This evidence can be official note(s) or declaration(s) from relevant authority, valid national or sub-national law(s) or regulation(s), official action plan or development plan for the area.

I. Identify landscape/peat dome where peatland replanting area belong

↓

II. Select the final water bodies (rivers) that drain the peat dome in I

↓

III. Select all rivers that drains to the final rivers in II

↓

IV. Relevant water bodies = II + III

Step 1. Select and delineate all possible relevant natural water body in the landscape

Step 1.1. Prepare water body dataset of the landscape in polyline format. Peatland landscapes are usually marked by the presence of peat dome(s). Grower(s) must know which peat dome or peatland the concession is situated. By knowing the peat dome/peatland it is possibly to identify the lowest water bodies/rivers that act as the final outlets for all smaller water bodies on the peat dome/peatland. So, all relevant water bodies in the landscape are (1) all water bodies that act as the final outlet of the smaller water bodies, and (2) all smaller water bodies that finally discharge to final water bodies. Each individual water body/river branch must be given unique ID/name/code. Water body data must come from credible source(s) or digitized directly from remote sensing image(s). If the landscape also bordered by sea, coastline must be included by default as relevant water body network.

Step 1.2.a. Select only relevant water body lines, i.e. depositional rivers and connected lakes (if there are, they are usually oxbow lakes) with mineral river beds. Generally depositional rivers are marked by numerous meanders. Systematically, selection process can be done by removing all (part of) water body lines that fall under any of the following category

(1) Erosive rivers

(2) Streams with peat river bed (see also Figure A3-1)

(3) Man-made water body, such as canals, ponds, except engineered rivers that were initially depositional rivers

If the selection can be completed in Step 1.2.a, proceed to Step 2.
If not, for example for water body line(s) without sufficient information available to distinguishing the above 3 criteria, proceed to Step 1.2.b.

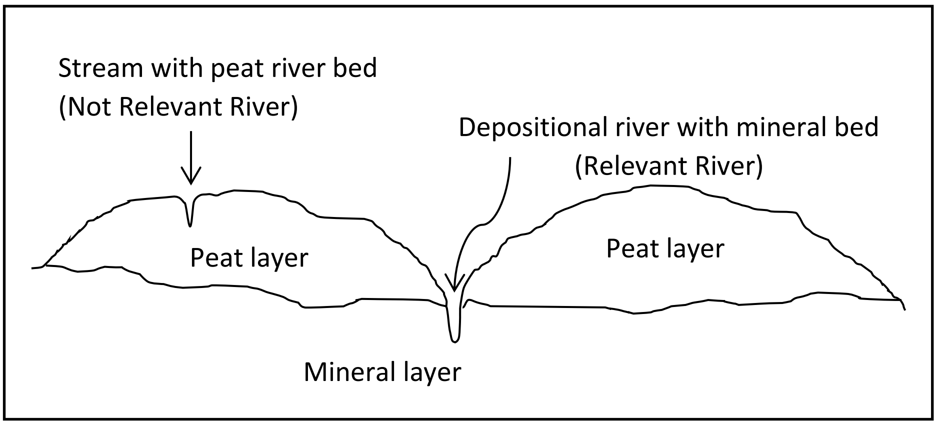


Figure A3-1. Illustration of relevancy of blackwater streams in regard to river bed type

Step 1.2.b. Select only relevant water body lines by performing the following steps

Selection based on erosivity category

(1) For each water body lines whose relevancy cannot yet be ascertained calculate and find maximum water body belt-width (b_w). See also Figure A3-2

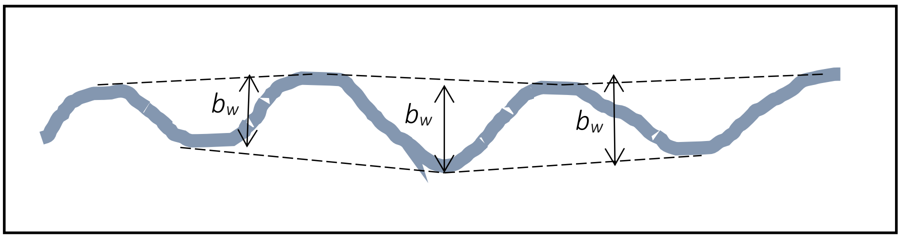


Figure A3-2. Illustration of belt-width calculation, showing river stream line (blue) and river belt line (dotted line)

(2) From (1), partition each line into reaches with lengths of 10 to 20 times the maximum belt-width

(3) From (2), calculate sinuosity (K) of each reach, as :

$$K = \frac{L_S}{L_R}$$

Where
K : Sinuosity
L_s : Stream length of the reach
L_R : Segmental valley length of the reach

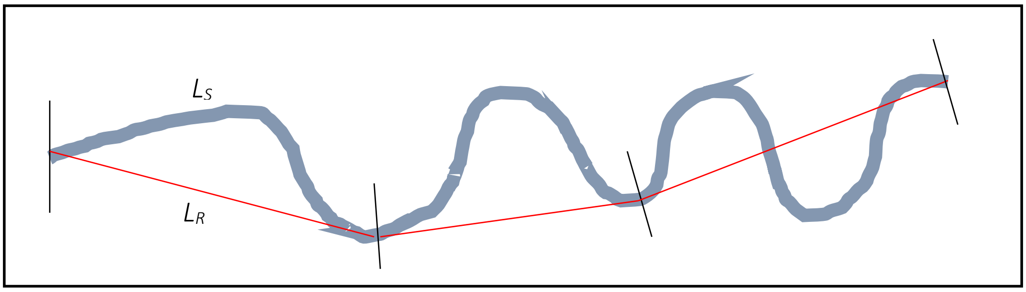


Figure A3-3. Illustration of a river stream line partitioned into 3 reaches, showing stream length (blue) and segmental valley length of the reaches (red)

(4) From (3), classify reaches based on erosivity category (Leopold and Wolman, 1960) i.e. depositional ($K \geq 1.5$), erosive ($K \leq 1.1$), or transition ($1.1 < K < 1.5$),

(5) From (4), across the entire reaches, by using moving-window (e.q. window of 5 reaches, 8 reaches, etc.) from downstream to upstream along the stream line, identify reaches within window whose majority members are erosive (i.e. >50% $K \leq 1.1$) and mark as E group.

(6) To filter only depositional rivers, remove all reaches with E group majority, starting from upstream.

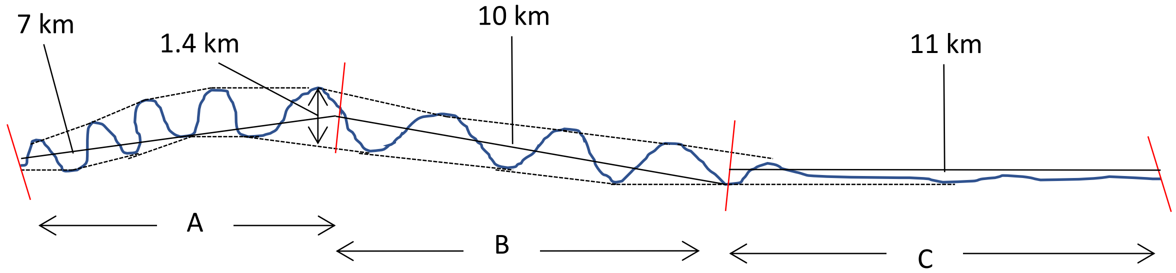
Selection based on river bed category

(7) Identify all blackwater streams in rivers obtained in (6) by overlaying them with peatland map of the landscape. In case of doubt, or the presence of large uncertainties over the peatland map, perform a supervised classification (e.q. by using software such as ECognition, ERDAS, ENVI, etc.) based on spectral signatures of remote sensing image(s) using known blackwater stream river pixels as trainers.

(8) Create 1 km spatial buffer on non-blackwater stream rivers as resulted from (6) and (7)

(9) From (6), (7), and (8), remove all blackwater streams that fall outside 1 km spatial buffer resulted in (8).

Example



A river has been found to have maximum belt width of 1.4 km. It was decided to partition the reach into three reaches of 20, 16, and 15 km lengths (actual stream lengths, not straight line lengths). Those are within 10 times to 20-times maximum belt width. Further analysis shows the valley lengths of reaches A, B and C were 7 km, 10 km, and 11 km respectively. The results are summarized below

Reach	**A**	**B**	**C**
Stream length (L_S) (km)	20	16	15
Valley length (L_R) (km)	7	10	11
Sinuosity ($K = L_S/L_R$) (km/km)	2.86	1.60	1.36
Category	Depositional	Depositional	Transitional

It was clear that river reaches A and B are depositional river, and are relevant and can be used as reference water body. But river reach C must be discarded, not to be used a reference.

Step 2. Partition relevant water body lines (e.q. those obtained in step 1) into smaller segments (e.g. 25 meter segments, or 100 meter segments), then convert them into vertex points or nodes. Example can be found in **Appendix 1**

Step 2.1. Partitioning into segments can be done in ArcGIS by using Densify Tool and assigning desired value as the segment interval in dialog box. Conversion from vertices to points can be done by using Feature Vertices to Points Tool (for ArcGIS 9.X or older). In ArcGIS 10.X or later versions this can also be done by using Generate Points along Lines Tool, choosing Distance as Point Placement Parameter, choosing Meter as Unit Parameter and assigning the desired value in Value Field. It is advised to use as smaller segment as possible, preferably no larger than 100 meters.

Step 2.2. Calculate coordinates of the points by using Add XY Coordinates Tool.

Procedure B. Calculation of Water Level Elevation of Relevant Natural Water Bodies

This procedure requires DEM, contour map, or other sources of elevation data of the landscape as an initial reference for the calculation and can be done through 2 options.

Option a. Successive Over Relaxation (SOM) method

Step 1a. Generate SOM nodes

(1) Overlay points obtained in Section A Step 2 on DEM (or other elevation maps), then extract elevation values to the points. In ArcGIS this can be done by using Extract Values to Points Tool. By default, ArcGIS names the extracted values (Attribute Table) as "RASTERVALU". This attribute name can be changed as desired.

(2) Identify all points whose locations are at the outer-most position of each region or cell of elevation class along the stream line direction (see also Figure A3-4). If the elevation source is a contour map, find points that are the closest to contour line by using Near Tool and assign associated contour line elevation values to the points.

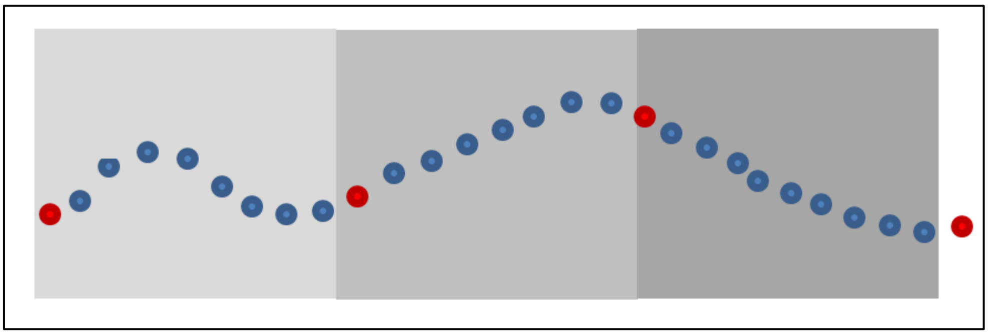


Figure A3-4. Illustration of vertex points of a relevant water body line, whose stream line crosses 3 regions (cells) of elevation class (shown in graduated color). Red dots represent points at the outer-most position of each region, and serve as the Fix-Nodes over which blue dots can be relaxed.

Step 2a. Calculate SOM

(1) Export the points obtained in Step 1a to Excel file, where at least the following attributes can be found: ID, XY Coordinates, River branch ID/Code/Name, extracted elevation value (RASTERVALU, or whatever name was assigned), and Node Status (Fix Node or Non-Fix Node).

(2) In the Excel file, for each water body branch assign a new column, e.g. column G, for storing recursive results

(3) Assign a new column dedicated for SOM formula, e.g. column H

(4) Copy extracted elevation values found in column RASTERVALU, or whatever name used in Step 1a (1), to column G.

(5) In column H write formulas based on the following rule:

- For Fix-node rows: cell values must be exactly the same as RASTERVALU, or whatever name used in Step 1a (1)
- For non Fix-node rows:

$$H_i = \frac{G_{i-1} + G_{i+1}}{2}$$

Where *G, H* denote column and *i* denotes row.
For example:
Formula for cell H32 = (G31+G33)/2
Formula for cell H67 = (G66+G68)/2
Formula for cell H154 = (G153+G155)/2
And so on…

(6) Assign a new column (e.q. column I) dedicated for calculating Absolute Difference between column G and H. So, formulas for column H must follow the following rule:

$$I_i = |G_i - H_i|$$

Where *G, H, I* denote columns and *i* denotes row.
For example:
Formula for cell I32 = ABS(G32-H32)
Formula for cell I111 = ABS(G111-H111)
Formula for cell I234 = ABS(G234-H234)
And so on…

(7) Assign a new cell (e.q. cell J1) dedicated for calculating Maximum Absolute Difference (MAD) between column G and H. So, formula for cell J1 must follow the following rule:

$$MAD = MAX(|G_i - H_i|)$$

Where *G, H* denote columns and *i* denotes row.
Since MAD can be calculated from column I, cell J1 can be calculated accordingly.
For example, if the data starts at row 2 and ends at row 932, then:
Formula for cell J1 = MAX(I2:I932)

(8) Determine MAD threshold. The lower MAD value the better SOM result can be achieved at the cost of longer computing time. Therefore, a trade-off must be found with common sense. In general, a threshold value 1/1000 of the unit within expected accuracy scale of the system is sufficient. For example, if the expected accuracy of the system is within meter scale and the SOM uses meter as the unit, setting MAD threshold at 0.001 meter is sufficient. Similarly, if the expected accuracy of the system is within meter scale and the SOM uses millimeter as the unit, setting MAD threshold at 1 millimeter is sufficient, but setting MAD at 0.001 mm is wasteful.

(9) Create a macro (VBA) with the purpose of recursively copying column H to column G as long as cell J1 value stays above MAD threshold. An example of a macro code is given in box below (please consult Microsoft website for more detail in macro writing); assuming data starts at row 2 (row 1 is usually used as column name), data ends at row 932, the system is in meter, MAD threshold is set 0.001 meter, and calculation formua is written in Sheet1:

```
Dim c As Double
Sub Calculate_SOM()
c = Sheets("Sheet1").Range("J1").Value
While c > 0.001
c = Sheets("Sheet1").Range("J1").Value
Range("H2:H932").Copy
Range("G2:G932").PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks:=False,
Transpose:=False
Wend
Application.CutCopyMode = False
End Sub
```

Note: In the above code we directly utilized Copy-Paste operation in Worksheet instead of in macro itself. This speeds up the calculation since in-worksheet operations are multithreaded (take advantage of multi-core processors) while VBA itself is single-threaded.

(10) After executing the macro in (9), column G will be relaxed and more naturally resemble water surface elevations compared with previously cascade elevations. Therefore, by using already available XY coordinates, this new water body elevations in column G can be exported to new points in ArcGIS.

Option b. Chained-Slope method

Step 1b. Generate Chained-Slope (CS) calculation nodes

Identify outlet for each relevant water body line, then perform the same steps as Step 1a.

Step 2b. Calculate chained water level elevation of relevant drainage network lines starting from downstream

(1) Export the points obtained in Step 1b to Excel file, where at least the following attributes can be found: ID, XY Coordinates, River branch ID/Code/Name, extracted elevations, Outlet ID, and Node Status. In this case Node Status is the status for CS calculation, instead of SOM.

(2) In the Excel file, for each water body branch assign a new column (e.q. column H) for calculating distance between adjacent nodes (ΔL) by applying the following formula

$$\Delta L_i = \sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2}$$

Where X and Y are Longitude and Latitude values respectively, and i denotes row (node position). For example, if XY coordinates are respectively stored in columns B and C, then

Formula for cell H32 = SQRT((B32-B31)^2+(C32-C31)^2)

Formula for cell H66 = SQRT((B66-B65)^2+(C66-C65)^2)

Formula for cell H100 = SQRT((B100-B99)^2+(C100-C99)^2)

And so on…

(3) Assign a new column (e.q. column I) for calculating distances between consecutive Fix-nodes (ΔL_{CS}) by using the following rule

- For Fix-nodes $\Delta L_{CS,i}$ = 0
- For other nodes calculate cumulative distances

$$\Delta L_{CS,i} = \Delta L_i + \Delta L_{i-1}$$

- Each distance between two consecutive Fix-nodes is retrieved from cumulative distance of immediate antecedent node

For example, if rows 56 and 103 are Fix-nodes, then

Formula for cell I56 = 0

Formula for cell I57 = I56+H57

Formula for cell I58 = I57+H58

Formula for cell I59 = I58+H59

So on…

Formula for cell I102 = I101+H102

Formula for cell I103 = 0

And distance between Fix-node 56 and Fix-node 103 = I102

(4) Assign a new column (e.q. column J) for calculating slope between consecutive Fix-nodes (α) by using the following rule:

- For coast lines nodes

$$\alpha_i = 0$$

- For Fix-nodes

$$\alpha_i = \alpha_{i-1}$$

- For other nodes calculate slopes by

$$\alpha_i = \frac{\Delta H_{CS,i}}{\Delta L_{CS,i}}$$

Where

$\Delta H_{CS,i}$: Elevation difference between two consecutive Fix-nodes

$\Delta L_{CS,i}$: Distance between two consecutive Fix-nodes

For example, if rows 56 and 103 are two consecutive Fix-nodes, while extracted elevations (RASTERVALU) are stored in column E, then

Formula for cell J56 = J55
Formula for cell J57 = (E103-E56)/I102
Formula for cell J58 = (E103-E56)/I102
Formula for cell J59 = (E103-E56)/I102
So on…
Formula for cell J102 = (E103-E56)/I102
And…
Formula for cell J103 = J102

(5) Assign a new column (e.q. column K) for calculating node elevations, starting from the most downstream node of each branch, by using the following rules:

- Elevation of coast line nodes is zero
- Elevation of the most downstream (junction) nodes that discharge to coast line nodes is zero
- For non coast line nodes, elevation of the most downstream (junction) node equals the elevation of the nearest node of the outlet branch
- For non coast line, non-junction nodes, there applies:

$$H_i = H_{i-1} + \alpha_i \times \Delta L_i$$

Where *H* represents node elevation

For example, if row 52 is a coastline node that acts as the outlet for row 91, then

Formula for cell K52 = 0
Formula for cell K91 = K52
Formula for cell K92 = K91+J92*H92
Formula for cell K93 = K92+J93*H93
And so on…

(6) Having calculated all node elevations, by using XY coordinates, export the nodes to ArcGIS point shapefile.

References

Leopold, L.B., Wolman, M.G. 1960. River meanders. Bull. Geol. Soc. Am. 71:769–794.

ANNEX 4. DEM AND PEAT THICKNESS GENERATION

Procedure A. Elevation and Peat Thickness Surveys

Approach

As the sizes of the plantation areas to be evaluated are usually far smaller than the peatland landscape within which they are situated, direct measurements (land survey, drone or LIDAR flight) are feasible sources of data for site DEM and peat map generation. For LIDAR-based DEM generation, standard practices have been developed elsewhere (for example http://desktop.arcgis.com/en/arcmap/10.3/manage-data/las-dataset/using-lidar-in-arcgis.htm) and the subject is not covered in this guideline.

A peat thickness map is needed to create the site drainability map. Peat thickness measurements can be done by using a manual auger. It is recommended to place peat thickness measurements at the same location as the levelling sample points, to increase work efficiency.

Step by Step Procedure

Step 1. Define minimum sample size

It is recommended to base the minimum number of sample points on Slovin's formula (Guilford and Fruchter, 1973; Yamane, 1967):

$$n = \frac{N}{1 + Ne^2}$$

Where

n : Minimum number of required sample points

N : Number of population, i.e. total number of cells of the output DEM or peat map raster covering the actual area

e : Planned margin of error = 100% – Confidence level

Example:
Plantation area = 5,000 hectares
Planned mapping unit (DEM or peat map resolution) = 1 hectare (100 m cell-size)
Planned confidence level = 90%

Solution:

$$N = \frac{5{,}000\ ha}{1\ ha} = 5{,}000$$

$$e = 100\% - 90\% = 10\% = 0.1$$

$$n = \frac{5{,}000}{1 + 5{,}000 \times 0.1^2} = 98$$

Step 2. Plan measurement transects

Having determined the minimum number of sample (points), the next step is to arrange the sample points over the survey (concession) area. For this purpose the area is partitioned into *n* sub-areas (grids), each for a sample point. Make sure the entire peatland area(s) of the site is covered. For the above example, the concession is partitioned into 98 sampling points. Centre points of the grids are assigned a sample point location.

For concession areas that have been set up with planting blocks, the block can be used as partition grids if preferred so, as long as the number of blocks is sufficient to meet the minimum required sample points. If not, more than one sample point per block needs to be assigned while maintaining 'as evenly spatial distribution' as possible.

Plotting the points on a map, a visual inspection can be made to determine the most efficient way (based on proximity to roads, other access, distance between points, etc) of converting (connecting) the points into transects (trajectories). Additional sampling points may be added along transects, when required, especially in cases where the micro-topography of the land has been altered into mini-domes.

Step 3. Conduct measurement survey

Step 3a. Measure height difference along transects for DEM generation

Plan the survey properly to make sure that all transects connect to each other (to form at least one continuous line), and that at least one transects can be connected (referenced) to known elevation benchmark(s) or to location(s) with known elevation(s), in order to calculate elevations of each sampling points.

Measure height difference along survey transects by using a levelling device such as a theodolite, optical water pass or simple transparent U-hose method. The use of optical devices such as theodolite or optical water pass might be a challenge. In most cases, the land surface of peatlands is so soft that it makes stabilizing the theodolite or water pass tripod (and the nuveau plane) difficult and time consuming. Failure in stabilizing the tripod introduces systematic errors to the outputs.

As an alternative to the theodolite and optical water pass, traditional U-hose water levelling can be used instead. The basic principle of the U-hose method is to make use of nuveau plane (the flatness property of the water surface) across any U-pipe (or U-hose in this case), as depicted in Figure A4-1. The land elevation difference between point A and point B ($\Delta H_{A\text{-}B}$) is obtained as

$$\Delta H_{A-B} = a - b$$

As the survey advances along a transect, the measurements proceed from point B to point C, from C to D, and so forth, until sufficient transect length has been covered and the ups and downs of the points across the line are fully presented. It is not necessary to record coordinates at every step, because it may be laborious; therefore, only points intended (planned) as sample points require coordinate-recording. An illustration is given in Figure A4-2 and the levelling calculation template (MS Excel) which can be downloaded from the RSPO website (resources → supplementary materials)

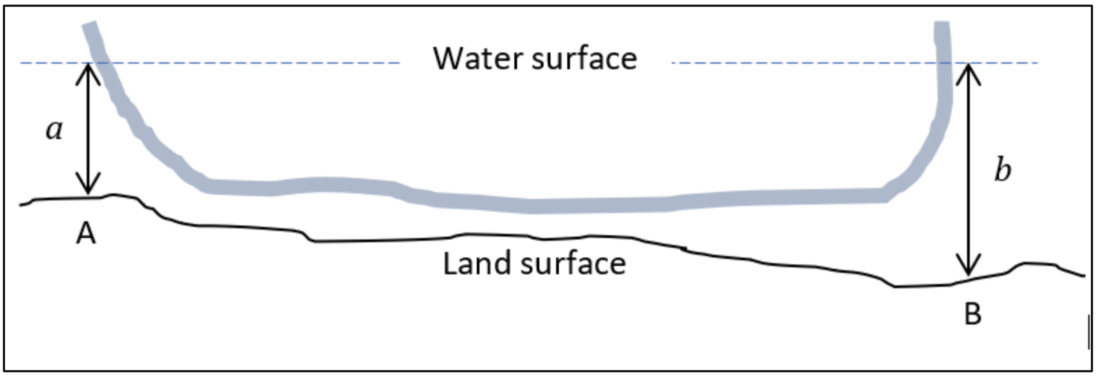


Figure A4-1. Illustration of U-hose water levelling survey.

At least one of measurement point must be referenced to standard datum (m-msl) In order to do so perform any of the following options. Note that option (1) is preferred to option (2).

(1) Connect (measure elevation difference between) any known measurement point of any transect to the nearest elevation benchmark (known official elevation point). Retrieve the benchmark elevation to be used later in referencing to standard Datum.

(2) Connect the survey transect to water elevation of nearby rivers large enough (≥30 m wide) to be fully visible in secondary DTM sources such as SRTM or ALOS PALSAR. Make several connections (multiple connection points) to reduce uncertainties. Retrieve elevations of the river connection points from secondary DTM(s) for later use.

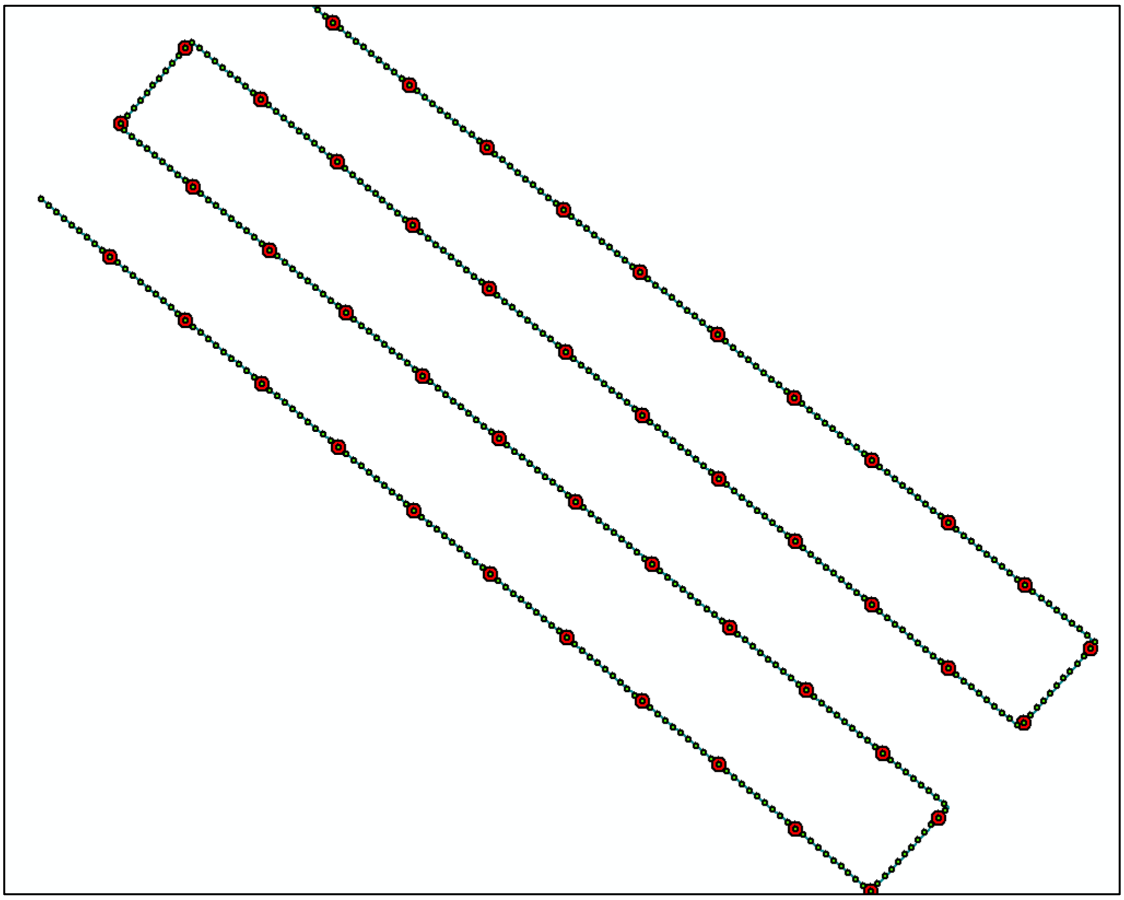


Figure A4-2. Illustration of 4 transects connected to each other through continuous U-hose levelling survey with 40 meters measurement interval (green dots). Coordinates are only recorded at planned 400 meters interval measurement points (red dots).

Step 3b. Measure peat thickness along transects for peat map generation

Peat thickness measurement can be done by using a manual device such as manual Corer, Auger or similar device. More advanced method such as Ground Penetrating Radar (GPR), Geoelectric, Low-Energy Seismic Imaging or other method can also be used as long as it is validated by sufficient number of correlation boreholes. Details of this advanced method can be found in various standard references on Geophysics.

The most commonly used corer for peat soils in SE Asia usually features a half-cylinder core chamber and a flip-cover. Other types of corer may feature different core chambers. For fibrous, woody, peat soils the smaller the corer/auger diameter, the more efficient it is to operate. Measuring peat thickness by using a manual corer or auger is done in a series of attempts. At each attempt the corer/auger is inserted/pushed into the peat soil at vertical direction. A peat sample is taken in the chamber or groove at a certain depth before the corer/auger is pulled out and the sample in the chamber/groove is inspected for the presence of underlying mineral substratum (usually sand or clay). As long as mineral substratum is absent the attempt is repeated by gradually increasing its insertion depth. Once the substratum is found, the insertion depth to the substratum uppermost position is measured. An illustration is given in Figure A4-3.

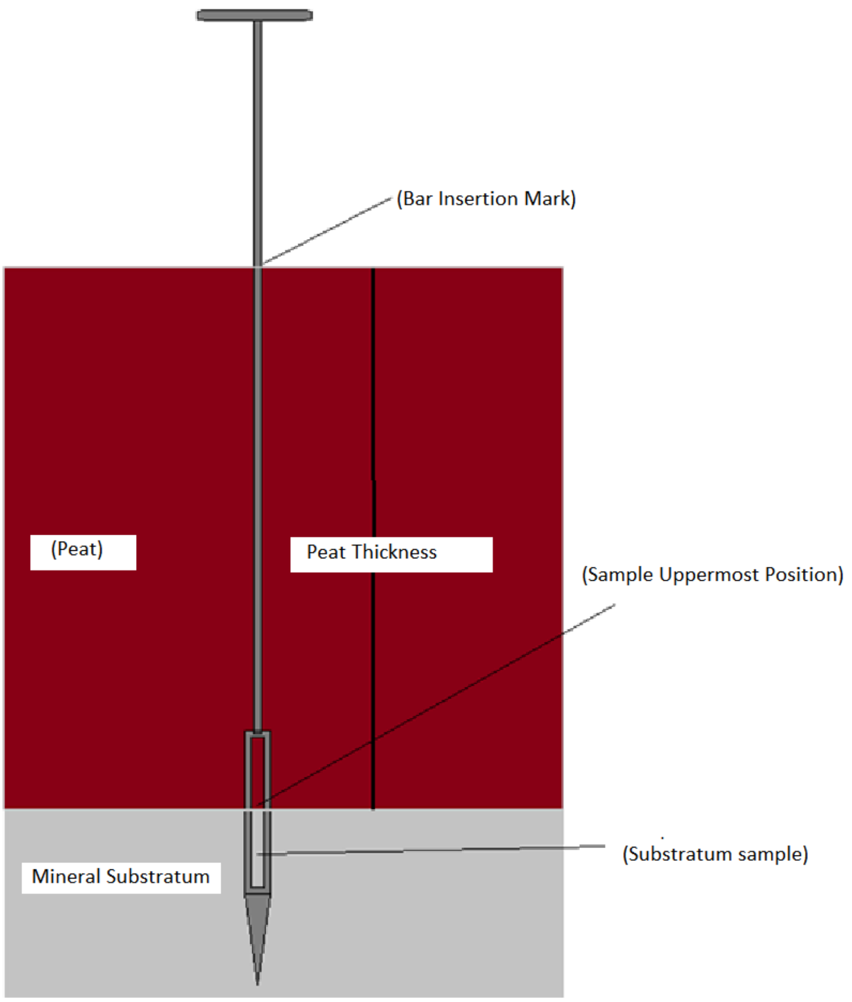


Figure A4-3. Illustration of the use of a peat corer or auger.

Step 4. Data digitization and processing

Step 4a. Height difference data

In principle, the calculation is based on chained/sequential elevation differences along transect lines. Elevation at point B equals elevation at point A plus height difference value between point A and B. Formally, in sequential formula it reads:

$$h_{i+1} = h_i + \Delta h$$

Where

h : Relative elevation (cm), i.e. measured elevation when not yet referenced to standard datum.

Δh : Elevation difference between sequential position (cm), calculated as subtraction of back-sight readings and fore-sight readings measured in levelling survey. See also Calculation Template file.

i : Sequence indices 1, 2, 3,… so forth

To get a clearer picture please examine Calculation Template file accompanying this document.

Reference elevation data to standard datum can be done by offsetting relative elevation by using the following formula

$$H_i = h_i + \alpha$$

Where

H : Elevation, referenced to standard datum (cm-msl)

α : Elevation offset (cm)

while

$$\alpha = Z_b - Z_m$$

Where

Z_b : Actual elevation at benchmark or reference position (cm-msl)

Z_m : Measured relative elevation at benchmark or reference position (cm)

As shown in Figure A4-4, relative elevation at a benchmark or a reference position can be measured by measuring its height difference from one (or more) sampling point (along red line).

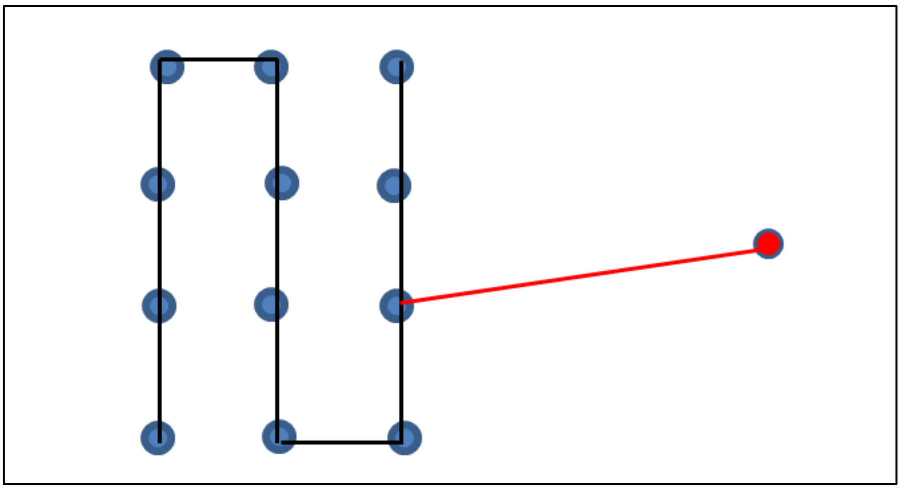


Figure A4-4. Illustration of 12 elevation sampling points (blue dots) arranged along 3 transects (black lines), a benchmark (red dots).

Step 4b. Peat thickness data

Processing peat thickness data is simple. Data is presented as XYZ, where X, Y columns denote coordinates while Z represents peat thickness.

Procedure B. DEM and Peat Thickness Map Generation

Approach

Elevations and peat thickness data (on the sample points) gathered in the survey as explained in section 3.1 are used to generate the site Digital Elevation Model and peat thickness map in raster format by using a standard geostatistical method (Kriging). More information about geostatistical analysis can be found in ESRI documentation web page 2.

The quality of the resultant site DEM and peat map can be assessed by using a standard cross correlation method in geostatistical procedure (see also ESRI documentation web page 1)

Step by Step Procedure

Step 1. Prepare interpolation points

The source of interpolation points is elevation data or measured peat thickness data resulted from Procedure A step 4. The data must be in XYZ format shapefile, where XY is the coordinate values, while Z is the peat thickness (m or cm) or elevation value (m or cm-msl).

Step 2. Set interpolation parameters

Standard/best practice of geostatistical procedure must be followed, for example ESRI documentations on Geostatistical Analysis. For the purpose of this Guidance, the following parameters are to be set as follows:

Parameters	Value	Description
Optimize Model	Do It	This makes sure that correct semi variogram model is chosen
Nugget	Zero	This makes sure that predicted values are as close as possible to the actual values at sampled locations
De-clustering	Yes	This helps remove spatial bias from unrepresentative sampling whenever clustered data are present

Step 3. Perform geostatistical analysis (Kriging)

A best practice Kriging procedure is available at ESRI website
http://desktop.arcgis.com/en/arcmap/10.3/tools/3d-analyst-toolbox/how-kriging-works.htm

Basically, once a geostatistics tool is made available, a user is required to supply interpolation input data and set several interpolation parameters. The interpolation result is named as a GA Layer by default. The user needs to export this GA Layer into Raster by specifying raster resolution.

Step 4. Data Quality Control

In the quality control process the raster interpolation is checked against artefacts such as bull's eyes, unrealistic values, extreme outliers. Bull's eyes and unrealistic values are the result of individual or clustered outliers and should have been prevented by the declustering process. But they may appear anyway, and if so, they can be removed by masking and removing the outlier points and re-doing the geo-statistical process using the corrected point source.

ANNEX 5. TRANSITION ARRANGEMENTS FOR DRAINABILITY ASSESSMENT PROCEDURE

I. Intent of 5-year Buffer Period

In the currently approved Indicator 7.7.5 related to Drainability assessment there is a requirement that drainability assessments are conducted using the RSPO Drainability Assessment Procedure - at least five (5) years prior to replanting.

The intention of this provision was to ensure that Companies did not wait till the last moment prior to replanting to undertake the Drainability Assessment. The period of 5 years was used for alignment with another requirement in P&C 2018 (Indicator 3.1.2) that required *"an annual replanting programme projected for a minimum of five years (but longer where necessary to reflect the management of fragile soils) with yearly review be available"*.

The intent of 7.7.5 was that at the early stage of identification of any peat area for replanting (through 3.1.2), that the process to prepare a drainability assessment would also be initiated. Undertaking a drainability assessment at an early stage will give the grower an understanding on what information is needed for the drainability assessment (especially for data on subsidence rate for the plantation concerned as well as accurate information on the elevation of the replanting area versus the drainage outlet) as well as obtaining a provisional result based on existing or default data.

Undertaking the initial assessment five years prior to the planned replanting could highlight the need to:

a) Gather additional subsidence data from the site concerned (failing which a conservative default of 5cm/year would be used;
b) Introduce enhanced management measures e.g. water management to slow the rate of subsidence; and
c) Gather more accurate elevation data for the plantation and the outlet.

If such additional information was gathered the assessment could be repeated at a later date prior to the replanting when a more accurate assessment of future drainability could be made. It was felt that this would make the drainability assessment more accurate and give better predictions.

However, if this is strictly to be followed, the earliest that replanting could be undertaken after the adoption of this requirement in 2018 would be in 2024 (assuming the initial Assessment was undertaken in 2019). Therefore, no planting could be undertaken during the period of effectiveness of the RSPO P&C 2018. This was not the intention of this provision.

Concerns with this provision were highlighted by growers prior to the adoption of the P&C 2018 and as a result it was agreed that, the matter would be reviewed by the Peatland Working Group and a solution found by developing a transition arrangement where the five-year requirement could be phased in starting 2019.

A related problem is that companies highlighted the difficulty to know exactly when a particular area would be replanted – given some variability in the age of replanting in peatland areas (between 15-25 years)- with an average of 20 years. This may cause challenges during implementation and auditing where there could be differences of opinion on the appropriate replanting date and hence required timing of the drainability assessment. It has therefore been agreed that it would be best to restate the requirement in the following way: "Drainability assessments would need to be initiated 15 years after first planting on peat". The actual replanting date may be determined based on the status and productivity of the plantation as well as the results of the drainability assessment. Then, at least 12 months prior to the planned replanting – the assessment could be repeated to verify the option for replanting or phasing out of the plantation.

II. Transition arrangement

In order to have a smooth initiation of the Drainability assessment and avoid any misunderstanding during auditing the following transition arrangements have been agreed for the period 2019-2024. Starting 2019, all relevant RSPO member companies shall conduct an initial Drainability Assessment for all areas of oil palm on peat that are older than 15 years (and may therefore be expected to be due for re-planting between 2019-2024. Companies may decide on whether to replant based on this initial assessment (refer to figure A5-1).

For areas scheduled for replanting in 2019 - 2021, companies have the option to defer the final decision on replanting by up to **two years** to enable more information, especially subsidence data from the sites concerned, to be collected. With regard to areas scheduled for replanting in 2022 -2024, companies have the option to repeat the assessments prior to the scheduled time for replanting, based on additional data gathered between 2019 till the scheduled time for replanting.

The results of the initial assessments in 2019 should be documented in prescribed reporting format and provided to RSPO Secretariat within one month of completion as input to the review of initial implementation – so that experience can be a basis for refinement of the DAP as appropriate.

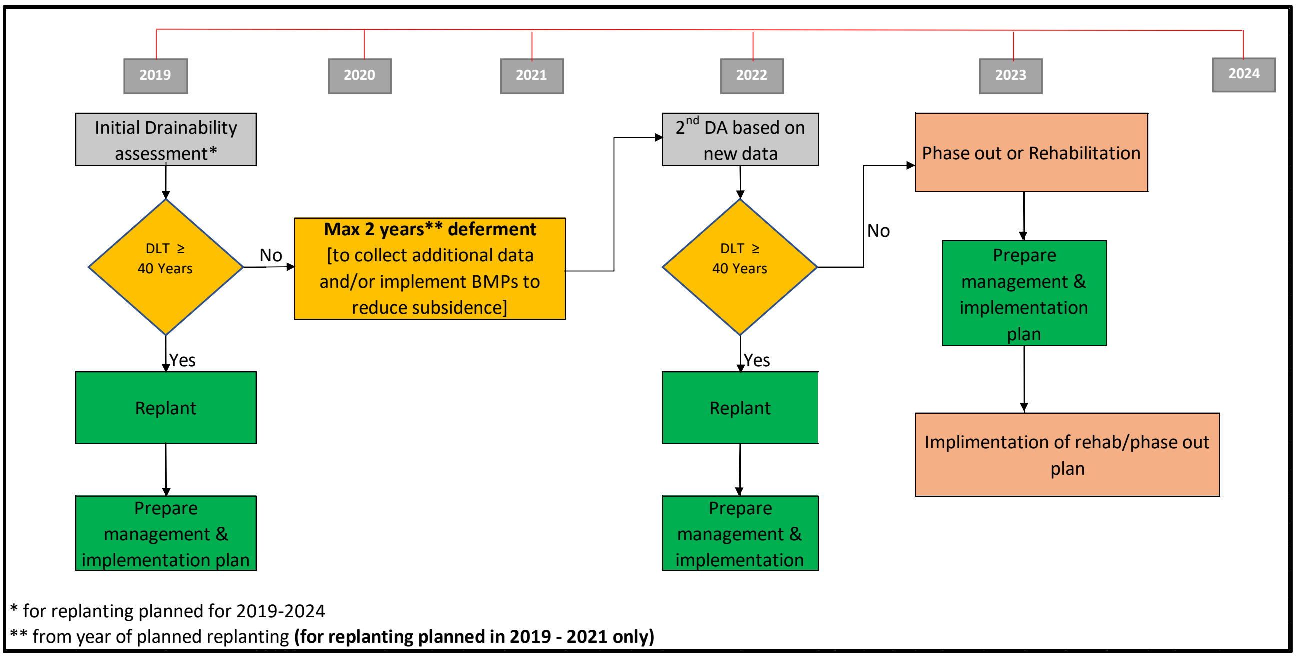


Figure A5- 1: Drainability assessment transition period for planted peat areas older than 15 years i.e. may be considered for replanting 2019-2024.

In 2020 companies should prepare initial drainability assessments for areas planted in 2005, i.e. anticipated to be replanted in 2025. Companies could either decide based on the initial assessment or gather additional information and repeat the assessment at latest by 2024 to make a final decision.

III. Other issues

Prior Drainability Assessments

For companies that have completed drainability assessments using alternative methodologies for the period of 11 June 2019 – 15 November 2019, they are required to submit their assessments to RSPO for review prior to any replanting being undertaken. Starting 15 November 2019 onwards, all alternative methodologies require confirmation by RSPO prior to use.

Drainability assessments which have been completed and have commenced replanting activities before 11 June 2019 may continue replanting as planned based on the results of the completed assessment(s).

Table A5-1: Requirements for submission of prior DA assessments and replanting of peat areas

Scenario	Requirement
DA conducted before 11 June 2019	**Areas replanting started before 11 June 2019** Replanting may proceed as planned
DA conducted before 11 June 2019 covering multiple years (e.g. DA conducted in 2018 for replanting through 2019-2025)	**Areas replanting started before 11 June 2019** Replanting may proceed as planned **Remaining areas** To send DA report (other method) to PLWG2 for review. Planting to start after passing the review **OR** Conduct DA based on RSPO methodology & submit to RSPO (for DA procedure revision purposes only)
DA conducted between 11 June - 15 Nov 2019	To send DA report (other method) to PLWG2 for review. Planting to start after passing the review; **OR** Conduct DA based on RSPO methodology & submit to RSPO (for DA procedure revision purposes only)
DA conducted 15 November onwards	To send DA methodology to PLWG2 for review. Once approved, DA can be conducted using the approved methodology; **OR** Conduct DA based on RSPO methodology & submit to RSPO (for DA procedure revision purposes only)

Submissions and proposals may be sent through email at ghg@rspo.org.

Acquisitions

Companies which have been acquired by RSPO members which contain planted areas on peat which have been replanted after November 2013 or Nov 2018 without having undertaken a prior drainability assessment are required to conduct a drainability assessment for all said areas planted for more than 15 years by the acquiring company.

Results of the drainability assessment shall determine whether the replanted areas shall be maintained or rehabilitated as per Indicator 7.7.5 of the P&C 2018.

Planting cycle on peat

Based on information from RSPO member companies, the normal time period for replanting in peat is 20 years (shorter than the normal 25 years for plantations on mineral soil) as a result of generally reduced yields due to serious leaning, disease etc.

In order to avoid a possible loophole being created by companies artificially extending the "life" of the plantations on peat in order to avoid undertaking a drainability assessment or complying with its requirements, companies should be required to start conducting the drainability assessments starting 15 years after prior planting on peat (figure A5-2).

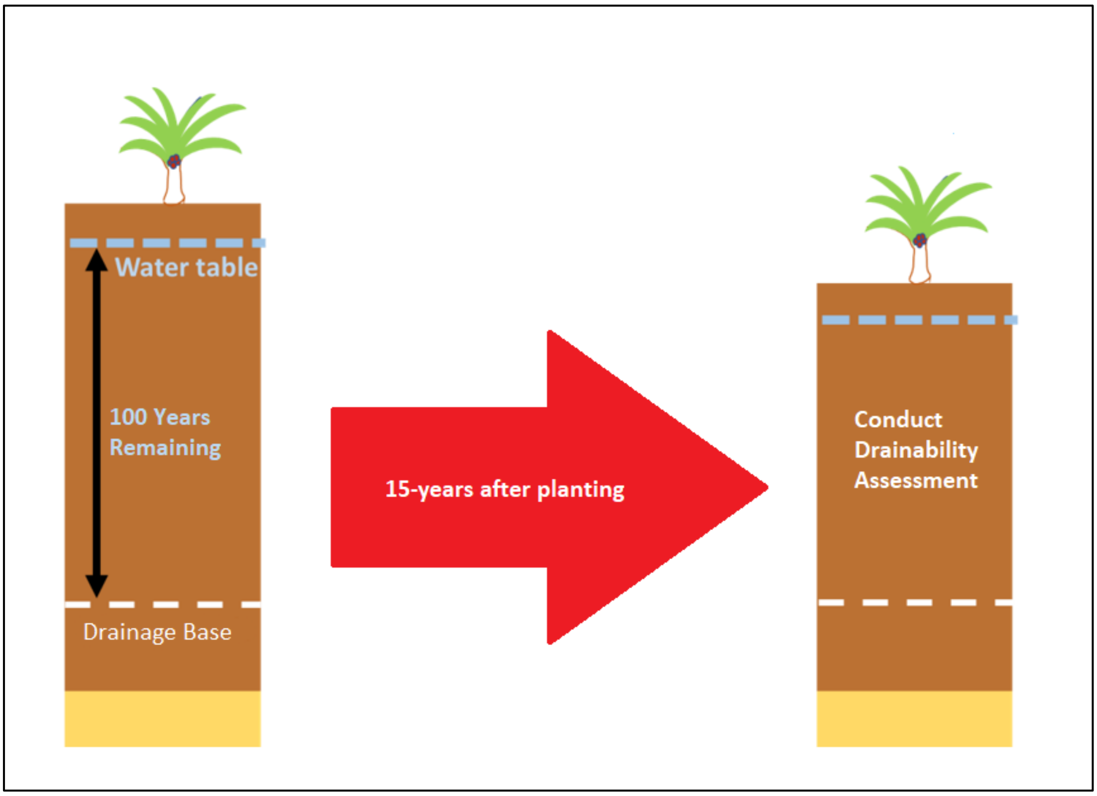


Figure A5-2: Initial drainability assessments conducted 15-years after planting (equals 5-years prior to replanting assuming 20-year crop cycle) for plantations with crop cycles >20 years

A company which has undertaken best management practices on peat and has, as a result, minimised leaning of palms and was still achieving high yields at the age of 20 years may make a justification to extend the current cycle (i.e. delay the replanting), provided that a drainability assessment had been completed and the assessment shows that the plantation is not within 40-years of subsiding to the drainage limit.

APPENDIX 1. CALCULATION EXAMPLE (TIER 2)

Calculating reference water body

Area

Area for this example has been anonymized, with a total area of 3332 hectares. About 95 percent of the area is peatland.

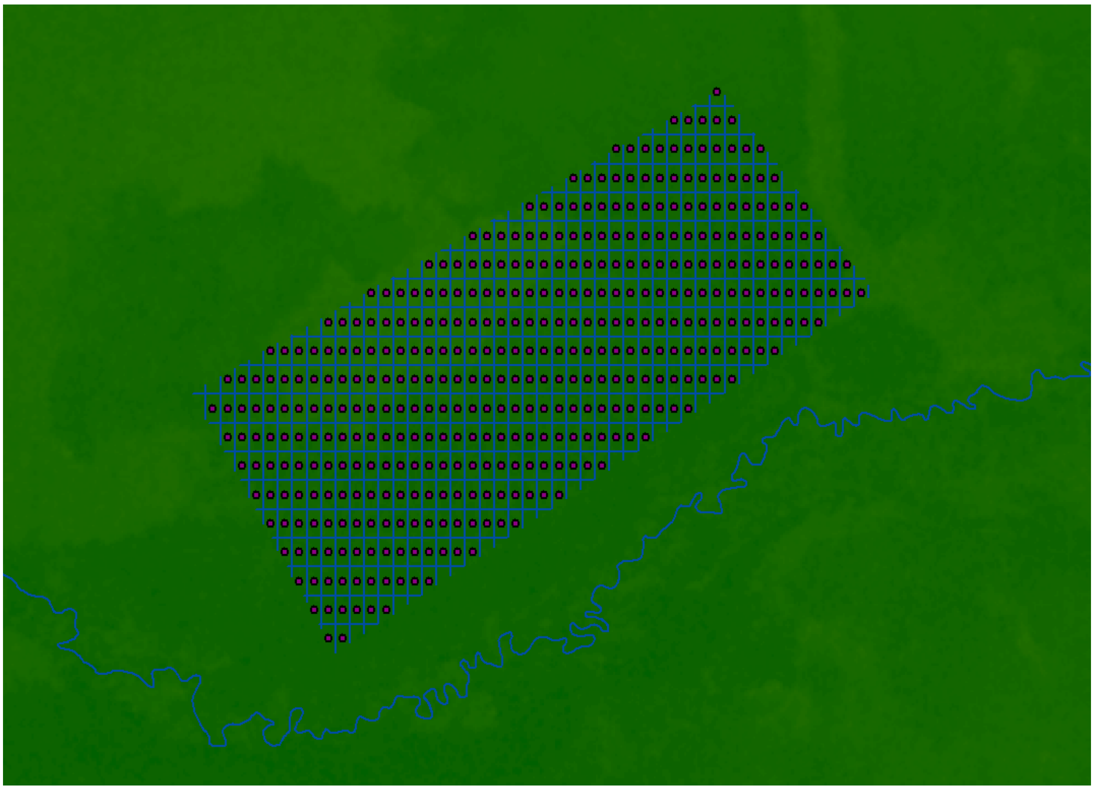


Figure AP-1

Assumption

Assumption chosen in water body selection process is Option 2:

Grower has power, and/or right, and/or ability, and and/or capacity to do and get involved in drainage related water management efforts in the landscape. Choosing this assumption enabled us to choose the lowest water body in in the landscape as reference, instead of the closest ones to the location.

Investigating river type of the reference water body

The reference water body type was assessed by following procedure given in **Annex 3**, as follows

1. River belt lines were delineated as shown in the Figure AP1-2. From the belt lines we were able to calculate its maximum belt width, i.e. 1311 meters.

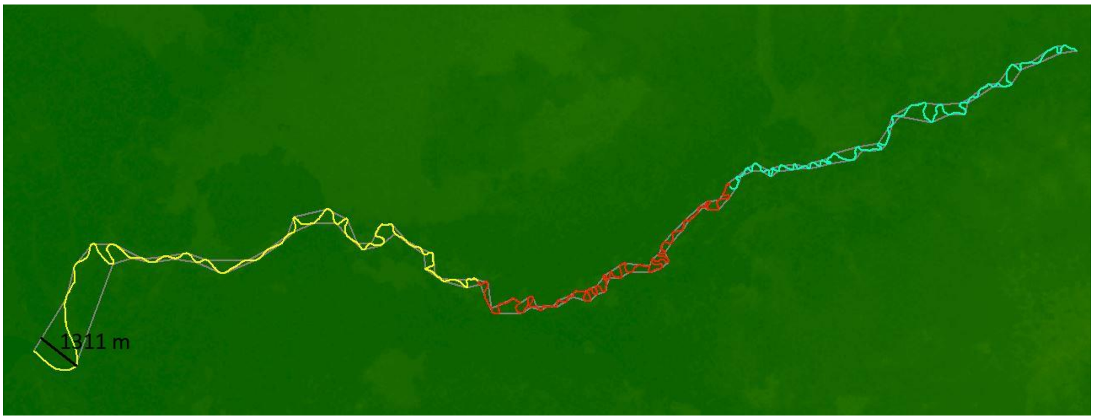


Figure AP1-2

2. By using the maximum belt width we decided to split the river into sections with length of about 10 to 20 times maximum belt width, shown in different colours in Figure AP1-2 (A: cyan, B: red, C: yellow). The resulted section lengths are 19000, 19000, and 24848 meters for A, B, C respectively

3. We calculated valley length of each segment (reach) as shown as straight lines with different colours in the Figure AP1-3. The resulted valley lengths are 14099, 8464, and 11679 meters for A, B, C respectively

Figure AP1-3

6. River types were then assessed by dividing section lengths by the valley lengths as shown in the following table. It was concluded that all sections are depositional, and hence are valid reference, and no segment need to be discarded.

Section	Section length (m)	Valley length (m)	Sinuosity	Type
A	19000	11679	1.63	Depositional
B	19000	8464	2.24	Depositional
C	24848	14099	1.76	Depositional

Mapping water level at reference water body

Reference water body in the area discharges directly to the sea. Therefore, we know that average water level at the most downstream location of the water body is at zero-meter elevation from sea level. Meanwhile at the most upstream section (section A, Figure AP1-4) of the river the annual average water level is about 1.5 m-msl. By using these two water level elevation figures, i.e 0 m-msl and 1.5 m-msl we were able to interpolate water level elevation values in between the two extremes along the river.

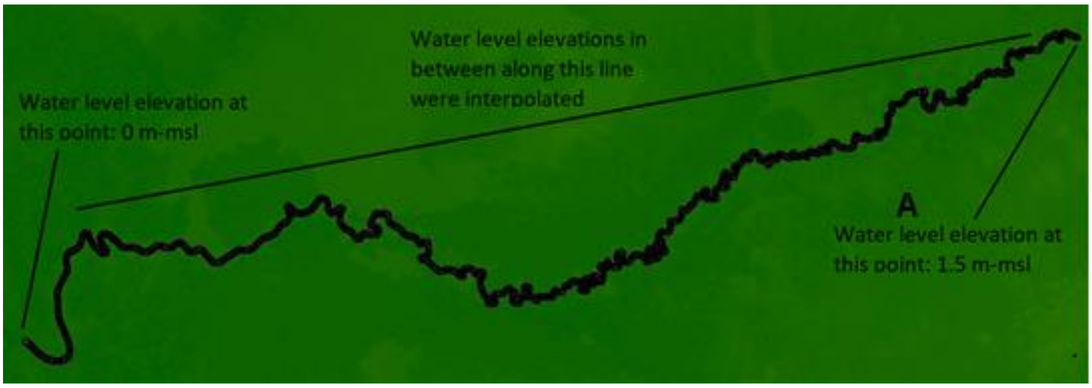


Figure AP1-3

In order to do so the river line was converted into nodes of 25 meter interval, as shown in zoomed view in Figure AP1-5.

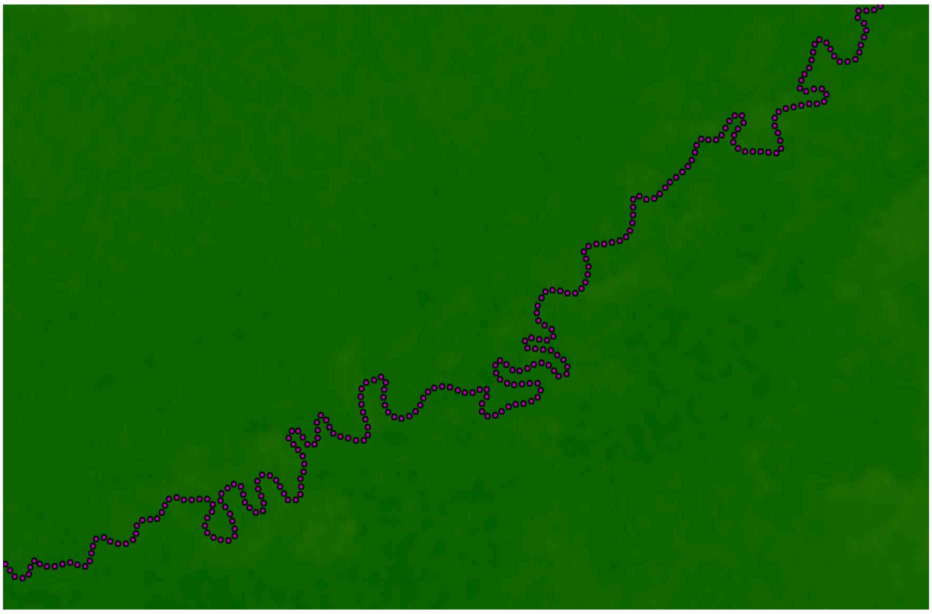


Figure AP1-5

We used chained slope method in **Annex 3.** The slope was calculated by using water elevation values at the most upstream (1.5 m-msl) and the most downstream nodes (0 m-msl), and the stream length between those two extremes (62906 meters).

$$Slope = \frac{1.5 - 0}{62906} = 0.0000238$$

Since nodes interval between nodes was set constant at 25 meter length, the chain slope calculations used only one slope value and were performed from the most downstream node, as follows:

Node 0 = 0
Node 1 = 0 + 0.0000238*25 = 0.000596
Node 2 = 0.000596 + 0.0000238*25 = 0.001192
Node 2 = 0.001192 + 0.0000238*25 = 0.001788
And so forth…

A snapshot of the resulted water level elevations at nodes is given in the following figure

Table

Reference_WB_49S

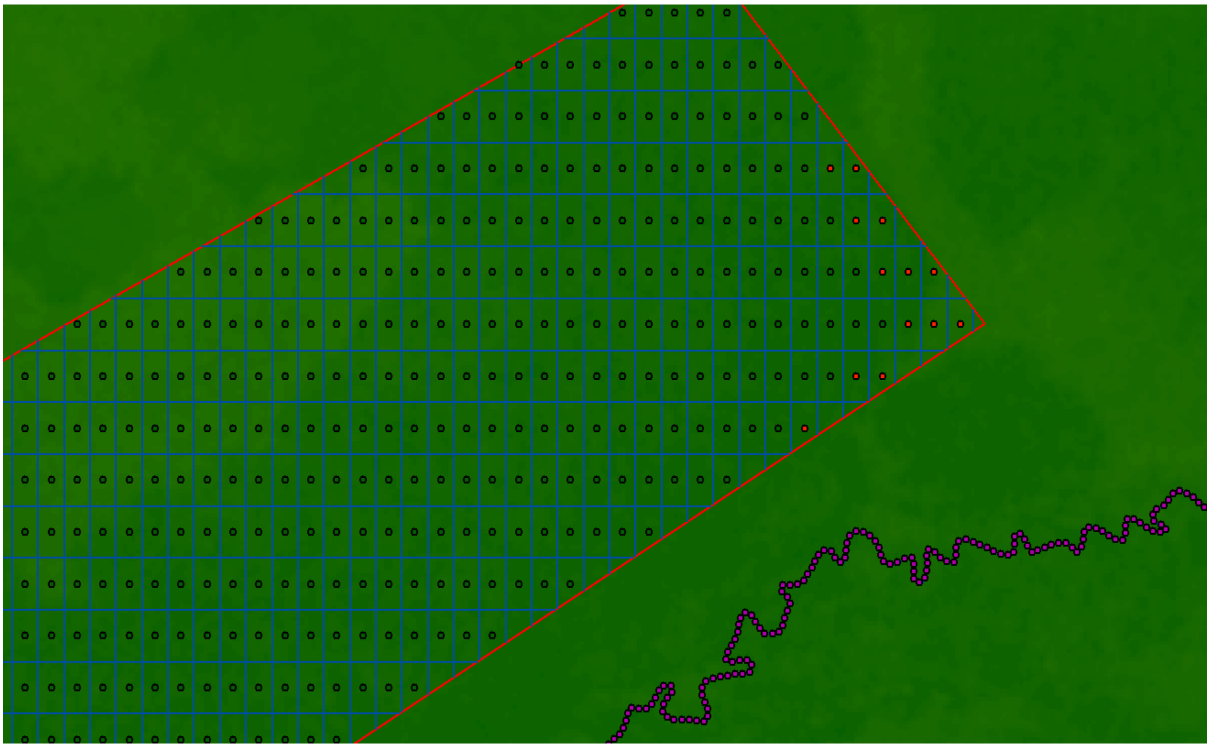
OBJECTID *	Shape *	ID	Z_m
280	Point	810	1.115775
279	Point	811	1.117152
278	Point	812	1.11853
277	Point	813	1.119907
276	Point	814	1.121285
275	Point	815	1.122663
274	Point	816	1.12404
273	Point	817	1.125417
272	Point	818	1.126795
271	Point	819	1.128173
270	Point	820	1.12955
269	Point	821	1.130927
268	Point	822	1.132305
267	Point	823	1.133682
266	Point	824	1.13506
265	Point	825	1.136438
264	Point	826	1.137815
263	Point	827	1.139192
262	Point	828	1.14057
261	Point	829	1.141948

0 (0 out of 1089 Selected)

Reference_WB_49S

Calculating drainage base

Centroids of the planting blocks were created in ArcGIS and the resulted points were used to represent average land elevation and peat thickness of the blocks where they belong. In the following figure, replanting blocks on peat soil are presented in green dots, while blocks on mineral soils in red dots.



The following attribute table of the centroids shows list of data that include Block Number (ID), land surface elevation (Z_m), peat thickness (Peat_m), Identity of the nearest water body nodes (Ref_ID) and distances to the nearest water body nodes (RefDist_m). It also marks whether the blocks are on peat soil or mineral soil (pYN).

Table

Centroid_49S

OBJECTID *	Shape *	ID	Z_m	Peat_m	Ref_ID	RefDist_m	pYN
19	Point	378	5.3	0	303	2800.878	0
20	Point	379	5.3	0	303	2794.05	0
236	Point	234	3.2	0	303	888.6431	0
270	Point	268	3.5	0	303	1195.513	0
271	Point	269	5.3	0	302	1209.686	0
304	Point	302	3.5	0	302	1637.535	0
305	Point	303	7.1	0	276	1675.372	0
306	Point	304	7.7	0	276	1658.025	0
334	Point	332	3.2	0	303	2005.192	0
335	Point	333	2.9	0	302	2029.855	0
336	Point	334	4.4	0	276	2071.546	0
360	Point	358	4.4	0	303	2394.414	0
361	Point	359	3.8	0	303	2403.095	0
303	Point	301	3.5	1.155841	302	1607.083	1
235	Point	233	3.5	1.327237	303	993.7776	1
269	Point	267	3.2	1.327237	303	1211.385	1
359	Point	357	3.8	1.327237	303	2402.378	1
18	Point	377	5.3	1.524048	303	2821.875	1
35	Point	394	4.4	1.524048	303	3218.059	1
333	Point	331	2.3	1.524048	303	1994.779	1

0 (0 out of 411 Selected)

Centroid_49S

Drainage base for each block was calculated by using formula given in the **Annex 2** document:

$$Z_{DB} = Z_{NWB} + 0.0002 \times \Delta X_{NWB}$$

The results are filled in column VII of the table below. Depths to drainage base were calculated based on formula given in the main document. Drainage limit times in this example were calculated by using example value of 3.5 cm/year

lock Num	Surface elevation (m-msl)	Peat thickness (m)	Nearest water body node ID	Distance to nearest water body node	Water level elevation at the nearest water body node (m-msl)	Calculated Drainage Base (m-msl)	Depth to Drainage Base (m)	Drainage limit time (year)
I	II	III	IV	V	VI	VII = VI+0.0002 *V	VIII = II-VII or VIII=III Whichever is smaller	IX =VIII/Subsidence
1	2.60	3.05	591	1045.82	0.69	0.90	1.70	48.6
2	3.50	3.12	551	1103.36	0.74	0.96	2.54	72.5
3	2.90	3.41	591	1380.88	0.69	0.96	1.94	55.3
4	2.30	3.43	591	1423.45	0.69	0.97	1.33	37.9
5	2.60	3.48	551	1421.67	0.74	1.03	1.57	44.9
6	2.90	3.43	551	1326.59	0.74	1.01	1.89	54.1
7	2.90	3.34	551	1256.34	0.74	0.99	1.91	54.5
8	3.20	3.27	550	1209.69	0.74	0.99	2.21	63.3
9	3.20	3.74	591	1766.12	0.69	1.04	2.16	61.7
10	3.20	3.74	591	1777.28	0.69	1.04	2.16	61.6
11	3.20	3.76	591	1810.55	0.69	1.05	2.15	61.4
12	3.50	3.79	551	1773.21	0.74	1.10	2.40	68.7
13	2.00	3.73	551	1697.93	0.74	1.08	0.92	26.2
14	3.20	3.64	550	1642.88	0.74	1.07	2.13	60.8
15	3.20	3.52	502	1528.23	0.81	1.12	2.08	59.6
16	2.60	3.41	502	1397.97	0.81	1.09	1.51	43.2
17	3.20	3.30	502	1285.69	0.81	1.07	2.13	60.9
18	2.90	3.22	494	1194.59	0.82	1.06	1.84	52.6
19	4.40	3.94	652	2091.64	0.60	1.02	3.38	96.5
20	3.20	4.02	591	2165.75	0.69	1.12	2.08	59.4
21	2.90	4.04	591	2174.86	0.69	1.12	1.78	50.8
22	2.90	4.05	591	2202.14	0.69	1.13	1.77	50.6
23	3.20	4.06	551	2141.69	0.74	1.17	2.03	58.0
24	5.30	3.96	551	2079.79	0.74	1.16	3.96	113.2
25	2.60	3.87	502	1959.82	0.81	1.20	1.40	39.9

APPENDIX 2. ASSUMPTIONS USED IN THE ASSESSMENT

Tidal influence

Drainability problems mostly exist when excess rainwater cannot be drained from plantations to discharge into rivers/sea during wet periods. Tidal influences may play a role in drainage problems, and may extend up to 30 km up river from the coast. For this Drainability Assessment the assumption is made that tidal influences are captured in the 'two-crop cycle-threshold', or in other words: it is assumed that the 1-2 meters-distance-to-drainage-base (2 crop cycles) threshold is enough to cover tidal influences (see also paragraph 2.3 for more explanation) and therefore tidal influences are not included in the calculations separately.

For the Drainability Assessment the assumption is made that Mean Water Level (MWL) shall be used as reference water level. There are several landmark water levels in the tidal system: Highest Astronomical Tide (HAT), Mean High Water Springs (MHWS), Mean High Water Neaps (MHWN), Mean Sea Level (MSL), Mean Low Water Neaps (MLWN), Mean Low Water Springs (MLWS), and Lowest Astronomical Tide (LAT). Any of these landmark water levels can be used in defining the reference water level for calculation of Drainability Limit, and the choice will depend on perspective and purpose, which adds complications to the calculation. Even after simplifying landmark water levels into just three: High Water Level (HWL), Mean Water Level (MWL) and Low Water Level (LWL), there is still a need to define and justify which level should be used.

From an agronomic point of view the LWL can be chosen, since by installing flap-gate(s), or similar structures, the tidal influence can (partly) be prevented. However, where flap-gates are installed there is no longer any free-flowing water in the system and whenever flap-gates fail the land may be flooded. From an environmental point of view the HWL can best be used as reference water level, since this provides a far better safeguard against peatland subsidence. For this Drainability Assessment the MWL is used as the reference water level, as a compromise between HWL and LWL. (See **Appendix 4** for a more in-depth discussion on Future Drainability Assessment of Tidal Peatlands).

Subsidence

The current RSPO P&C requires that subsidence of peat soils shall be minimized and monitored. Therefore, it is assumed that growers will measure soil subsidence at reliable spatial and temporal intervals. In the case that less than 3 years of data is available (the minimum required), or the approach to data collection to determine the peat soil subsidence rate does not reflect the requirements, a scientifically robust default value can be assumed for peat soil subsidence in SE Asia.

For this default value, a peat surface subsidence rate is assumed based on science. **Carlson *et al* (2015)** performed an independent study commissioned by the RSPO Emission Reduction Working Group. They studied 66- peer reviewed papers that were available in 2015 and selected 24 site studies based on accuracy criteria that were suitable for the meta-analysis. The average peat surface subsidence rate in these 24 sites (Riau, Johor and Sabah) was **4.7 cm per year with an average confidence interval of 1.8 cm** which provides a **range of 2.9 cm/yr to 6.5 cm/yr**.

Based on this study, a **default value for the rate of peat surface subsidence of 5 cm/yr** is assumed and shall be used in the calculations if a company's own data is not available or is not sufficient. It is always better and encouraged to use own data.

Delineation of replanting area

Replanting of oil palms is often a gradual process, documented in a long-term replanting plan. Before any replanting on peat is carried out, a drainability assessment is required by RSPO. A drainability assessment has a validity of a **maximum of 5 years**. If the assessment is older than 5 years, it needs to be updated with new data (peat surface subsidence rate, DEM and peat thickness based on peat subsidence rate etc). If the entire concession is planned to be replanted, each peatland unit (illustrated as A, B, C, and D in Figure AP-1) must be delineated separately. This means the borders of each of the brown areas (Figure AP-2) must be drawn. Then for the TIER 1 method, the centroid of each peatland can be calculated.

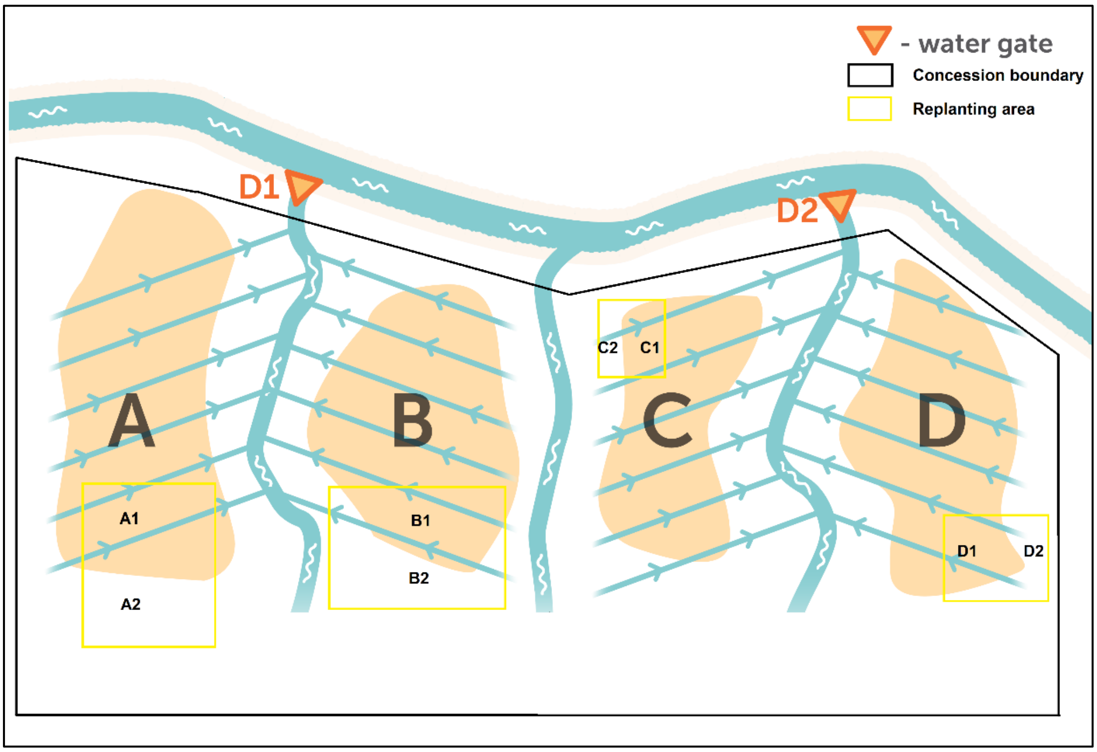


Figure AP2-1. Illustration of an Oil Palm concession consisting of several peatland areas (A, B, C, and D) and several planned replanting areas

But, if only part of the peatland is planned to be replanted (i.e. partial replanting) and the other part is not going to be replanted within 5 years, then only part of the peatland needs to be delineated. In the above example replanting is planned to take place in the areas delineated by yellow, thus only brown areas in yellow boxes need to be delineated. In this case the centroid points, as used in the TIER 1 method, will be different from the previous example, as illustrated in the following Figure AP-2.

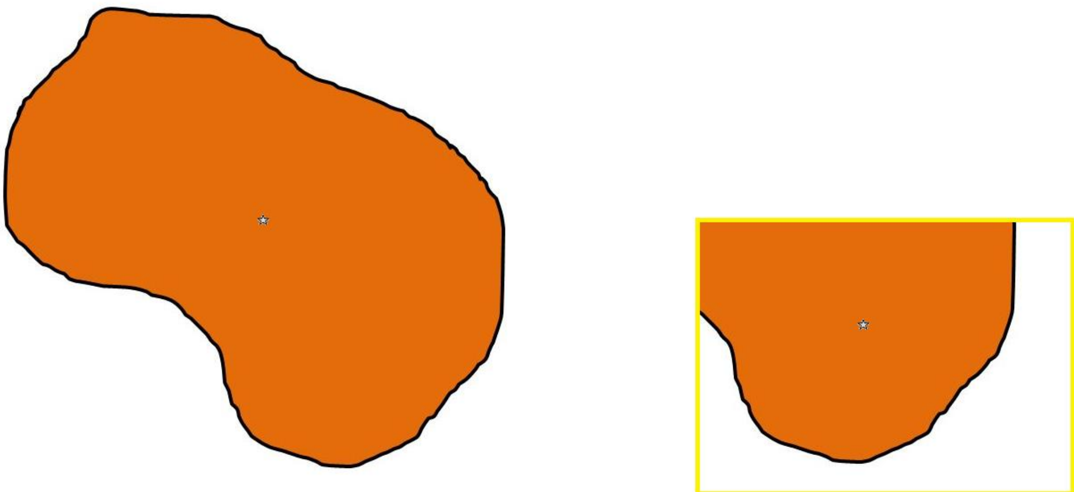


Figure AP-2. Illustration of delineation of peatland area (brown) and centroid (star). Left: For whole peatland area, Right: For partial replanting

The above rule applies for gradual replanting as well. In gradual replanting, every boundary of the peatland in the replanting areas at each phase must be drawn, and the centroid must be calculated individually.

National regulations

It is assumed that National Regulations have precedence in every case.

Conservativeness

The TIER 1 method is a simplified method. This means automatically that the TIER 1 method should also be the most conservative. The simplification includes that it is a **Lumped method**: The replanting area is not partitioned spatially, instead it is treated as a single lumped area, or group of areas. Secondly, it is a **Static method**: Peat surface subsidence rate, for example, is assumed to not vary from year to year, but is instead assumed to be constant by using site-specific, historical subsidence rates or a conservative default value of 5 cm/yr. **A certain conservativeness** is built in, because simplification always comes with a loss of accuracy. Conservativeness includes certain assumptions that will be explained in more detail under 'Landscape Management'. The choice of the assumptions sets the degree of conservativeness and has consequences for the choice of the relevant reference natural water body for the calculation in the assessment. Growers must explain their assumptions in their report.

Landscape management

Before choosing the most relevant reference natural water body, growers need to determine their status with respect to the landscape outside their concession area:

Option 1

Grower(s) has no power, and/or right, and/or ability, and/or capacity to do or get involved in drainage related water management effort in the landscape outside its own concession area. As a consequence of choosing this assumption the choice of relevant water body must be the closest one(s) to the concession area,

Option 2

Grower(s) has power, and/or right, and/or ability, and/or capacity to do or get involved in drainage related water management effort in the landscape outside its own concession area; Growers are assumed to have some degree of control or indirect control on drainage management of the landscape surrounding their plantation. When regular flood problems begin to emerge, stakeholders located close to the main water body are assumed to perform dredging. This provides benefit to stakeholders further upstream.

As a consequence of choosing this assumption, the choice(s) of relevant water body must be the correct one(s); these are most likely to be high order streams. With a low water level at the reference water body the resultant drainage base will be deeper below the peat surface. Growers must demonstrate that the relevant authority is going to mitigate flood problems in the future, by referring to official written regulations, roles and duty, historical examples, etc. Growers can also demonstrate that landscape stakeholder will react to flood problems, that downstream stakeholders are undertaking dredging and that this will pave the way for upstream stakeholders.

APPENDIX 3. QUALITATIVE ASSESSMENT FOR CURRENT DRAINAGE STATUS IN A PLANTATION

Current Drainability in a plantation

To get an insight into the current drainability status, it is important to know the dynamics of the water level inside the plantation relative to the water level in the nearest natural water body, which can be a river, lake or sea. If the plantation is relatively close to the sea, water levels during high tide and low tide should be measured inside the estate perimeter drain relative to the level of a natural water body outside the estate. As discussed earlier, at further distance to the water body, the drainage base level will be higher than the water level in the water body.

Highest tide in river | *Lowest tide in river* | *Water Level Gauge*

Figure AP3-1. Example of a river water level at different tidal state

Based on observations in the field and water level measurements, the following drainability classes are used by growers to determine the 'current drainability':

Class 1 - Good Drainability - where the excess water in the field can be drained by gravity even during the highest tide and/or during the most wet periods.

Class 2 - Moderately Good - where excess water in the field can be drained by gravity > 50 % of the tidal cycle, sometimes with the help of bunds and flap-gates and/or where water in the plantation can be drained during the wet period before the palms start to suffer.

Class 3 - Poor Drainability - where excess water in the field can be drained by gravity < 50 % of the tidal cycle and/or where water in the plantation cannot be drained during the wet period; palms start to suffer.

Class 4 - Very Poor Drainability - where excess water in the field cannot be drained by gravity even at lowest tide and/or where water in the plantation cannot sufficiently be drained during the wet period; palms start to suffer.

If the peat area of scope is found to be in Drainability Class 3 or 4 it is recommended that a Quantitative Drainability Assessment (at TIER 1 or TIER 2 level) is performed as soon as possible, since it is very likely that the drainage base is near or has already been reached, while over time, peat surface subsidence will increase the drainability problem. The Quantitative Drainability Assessment will determine the urgency of the situation.

In the situation that the peatland area being viewed is found to be in Drainability Class 1 or 2, it is likely that the drainage limit is not yet reached, but it is uncertain when the drainability limit will be reached. A Quantitative Assessment is required to give an insight into the depth of the drainage limit.

Tidal influences in coastal areas can be partly prevented by bunds and flap-gates (Fig. 2). Bunds are protective structures to prevent inflow of excess or saline water into the fields at high tide. Details on the construction and maintenance of bunds and flap-gates can be found in the RSPO BMP for existing plantations on peat. In the RSPO Drainability Assessment it is assumed that tidal influences are captured in the 'two-crop cycle-threshold', or in other words: it is assumed that the 1-2 meters-distance (2 crop cycles) threshold from the drainage limit is enough to cover tidal influences. Companies that experience large tides in their plantations are encouraged to check this assumption against their local conditions.

Figure AP3-2. System with Bund and Flap Gates. The Flap Gates closes automatically during high tide, preventing influx of tidal water (Left). The Flap Gates open automatically during low tide, allowing drainage (Right).

APPENDIX 4. REFERENCE WATER LEVELS FOR FUTURE DRAINABILITY ASSESSMENT OF TIDAL PEATLANDS

Selection of Reference Water Levels

Drainability determines how easy a land can be drained or to drain naturally. The degree and classification of drainability depends on perspective. With gravity drainage in tidal area the degree of drainability is only determined by topography and tidal range. Meanwhile, in natural condition, natural drainability of coastal peatland is mostly determined by topography and high-water level. This means, in tidal area, peatlands can only survive when their elevations are above high tidal water levels. This is because peat soils cannot sustain under constant or periodic backflow of salt or brackish-water. Therefore, choosing the correct reference water level for calculating drainage base elevation becomes crucial.

There are several landmark water levels in tidal system: Highest Astronomical Tide (HAT), Mean High Water Springs (MHWS), Mean High Water Neaps (MHWN), Mean Sea Level (MSL), Mean Low Water Neaps (MLWN), Mean Low Water Springs (MLWS), and Lowest Astronomical Tide (LAT). Basically, any of these landmark water levels can be used in defining reference water level for Drainability Limit calculation, and the choice actually depends on perspective and purpose, which adds complication to the calculation. For practical reason, we can simplify landmark water levels into just three: High Water Level (HWL), Mean Water Level (MWL) and Low Water Level (LWL).

Future drainability under agricultural scheme can be assessed by considering the implementation of tidal drainage where flap-gate(s), or similar structures, are operated. In this scenario LWL can be chosen as a reference water level. Long term implication of this choice is that the calculated drainage base will end up below MWL, and the headroom level of 40 years away from drainage base may end up below HWL or MWL. In this situation, if future land elevation is below HWL or MWL, it is impossible to do a "Return To Nature" after abandonment, because the land is likely to be flooded by salt or brackish-water permanently or periodically.

If mean water level is chosen as a reference in calculating future drainability, the calculated drainage base is going to be higher than MWL. However, depending on the subsidence rate, the headroom level of 40 years away from drainage base may be above or below HWL. In this scenario, if the future land elevation is below HWL, "Return To Nature" after abandonment in the future, becomes impossible since the land will be flooded by salt or brackish-water periodically (during high tide).

Only by choosing HWL as a reference water level, can the "Return To Nature" scenario be assured with greater certainty. Nevertheless, in certain situations, choosing MWL can also provide some degree of assurance. Therefore, MWL can be regarded as a compromise, and be applicable.

Examples (simulation) of two uses of reference water level choices are given in the following paragraphs. Figure AP4-1 illustrates the two examples.

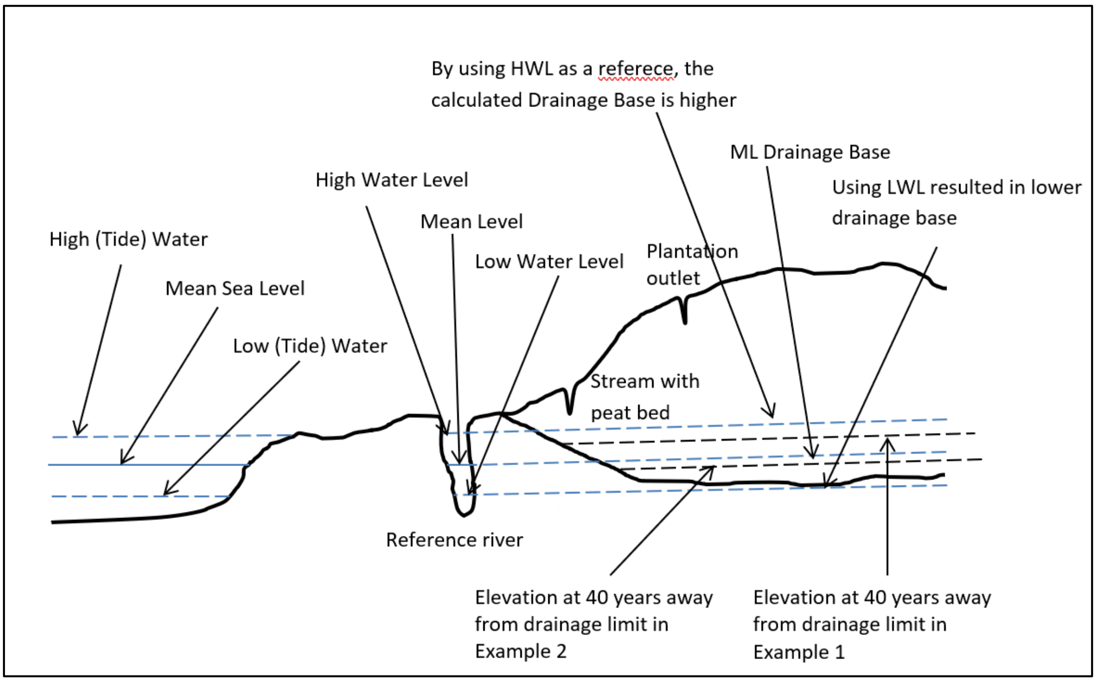


Figure AP4-1. Illustration of drainage base elevations that are referenced to high, mean, and low water levels respectively.

Example 1: Choosing Mean Water Level as a reference level

With 3 meters tidal range, the highest water level elevation would be about 1.5 meters above sea level. If we use mean water level (0 m-msl) as a reference level, the drainability limit elevation would be so close to 0 m-msl. And with 3 cm/year subsidence, land elevation at 40 years away from drainability limit (time of abandonment or return to nature) would be at 1.4 m-msl. The land is still going to be flooded during high tide, and it is likely that the areas close to the sea will become more suitable for mangrove. It can be seen that choosing mean water level as a reference level may not guarantee a possibility of "Return To Nature" after abandonment.

Example 2: Choosing Low Water Level as a reference level

In many places in Indonesia tidal ranges are so big that it may reach 4-5 meters amplitude. In this scenario, a tidal system with 3 meters amplitude is taken as an example. If we would take LWL as a reference, it would be -1.5 m-msl (1.5 m below mean sea level). That means drainage limit elevation would be so close to 1.5 m below mean sea level. With subsidence rate of about 3 cm/year, the elevation above drainage limit (time of abandonment or return to nature) at 40 years would be 10 cm below mean sea level. If the land is not restored and subsidence continues until this level is reached, the land would be flooded during high tide, and even extending for some time during low tide period. The tides usually affect peatlands through open channel system only. But with this, it will also affect the land with salt or brackish-water overland flow. Over time this may eventually change the ecosystem from peatland to salt water. **Therefore, using LWL as the reference is not an option in this assessment. Using HWL as the reference is recommended, while using MWL is acceptable as a compromise.**

Variability of Tidal Range

Around the SE Asian coasts, spring tide ranges (Figure AP4-2) are a meter or less on the south west coast of Sumatra, but they increase to more than 3 meters in the narrows of the Straits of Malacca. They are up to 1 meter on the south-west coast of Kalimantan, and somewhat larger (up to 2.8 meters) on the east coast. North-east of the Arafura Sea tide ranges of more than 5 meters occur in estuarine inlets along the southern coast of Irian Jaya, where tidal bores are generated, moving upstream as steep waves as the tide rises. Tidal oscillations are also complicated by wind action. Northeast winds over the China Sea build up the water level south of Singapore by as much as 0.5 meters between January and March, while south-east winds raise winter sea levels a similar amount along the southern coasts between Timor and Java."

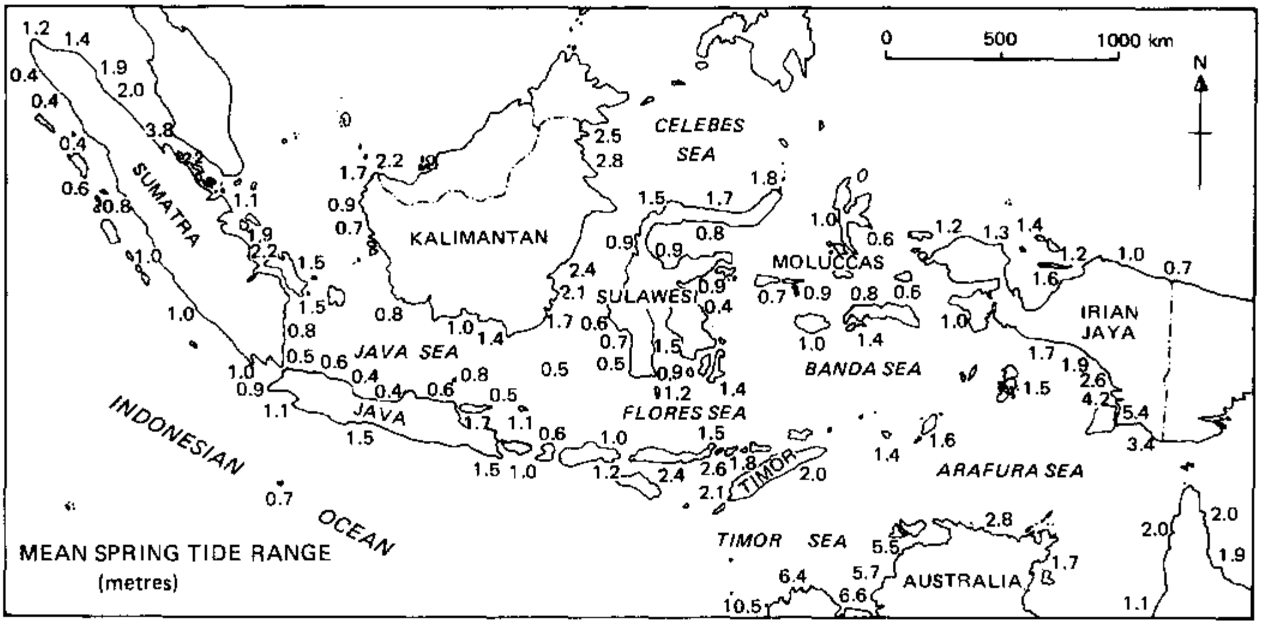


Figure AP4-2: SE Asia's tides. Source: http://archive.unu.edu/unupress/unupbooks/80197e/80197E02.htm).

On the basis of this information and bearing in mind the location of coastal peatlands in SE Asia, it would appear that phasing out plantation operations once the peat surface is within 1 to 2 meters height above the drainage base should be sufficient to prevent flooding at high tide, but, as is recommended in **Appendix 3**, this assumption should be checked against local conditions.