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Advice
Drainage Plan Farm 70
Salamá, Puntarenas, Costa Rica

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ABSTRACT

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This report presents a "second" opinion of the drainage plan for the teak plantation Farm 70, Salamá, Puntarenans in Costa Rice. The report discusses options to reduce the risk of high watertables in this teak plantation (71.56 ha).

Keywords: drainage, teak plantation, Costa Rica, desgin

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Contents

1 Introduction

This report has been prepared at the request of Stichting Terra Vitalis, Heuvel 13, Oosterhout, The Netherlands. The Stichting has requested a second opinion on the drainage plan prepared by the BARCA Company for Farm 70, Salamá, Piedras Blancas, Puntarenas, Costa Rica. This teak farm is located in the southwest region of Costa Rica (8^0 30' 79 - 8^0 30' 64 and 82^0 53' 87 - 82^0 54' 03), a region characterized by high rainfall, especially in the period May to November. The BARCA Company is developing the area as a teak reforestation plantation. Because of the heavy rainfall intensity, flat topography, soils with low hydraulic conductivity and impermeable layers close to the soil surface, an intensive drainage system is required. The drainage plan covers an area of 72.56 ha.

Figure 1 Location of the farm

In the verification team report prepared by Coillte Consult in September 2007, a number of questions are raised regarding the risk of high water tables and river erosion, i.e. (Coillte, 2007):

- Is the drainage plan realistic?
- Are the design assumptions correct?
- Is the proposed drainage system capable to lower the watertable to 0.90 m below ground level within 36 hours after a critical rainstorm?
- Is the maintenance plan adequate?

In the verification report, the judgment of an independent hydrologist/drainage specialist was recommended.

This report presents the findings of this “second” opinion. The report is based on the English translation of the following project documents:

- Drainage Plan Farm 70 (FDE 02), August 2007.
- Special Report RPS 11-2007, Flooding of Salamá River, Farm 70. 8 October 2007, (in Spanish with an English translation).
- Verification team report, VTR-70 1-07, September 2007.
- Notes on hydraulic conductivity for farm 70, Salamá, Puntarenas, Costa Rice (December, 2007.
- Data presented in the report FDS 00 – *Documentos de selección de sita finca 70* (in Spanish).
- Data presented in the report Aguas, “*Proyecto Estudio papra la Estimación de Caudal de Drenaje y Capacidad de Sistema de Bombeo en la Finca Salama 140 hectáres, Zona Sur*.’

2 Drainage plan

2.1 Design criteria

The design of the drainage system is based on the criteria presented in Table 1.

Table 1 Criteria used for the design of the drainage system (FDE 02, p 18)

Drain depth	1.4 m
Bed width	0.6 m
Site slope	1
Watertable	0.9 m
Discharge	33 mm/d
Hydraulic conductivity	depending on soil type
Impermeable layer	“”

The design depth is based on the crop requirements: a minimum depth of the watertable of 0.9 m (FDE 02, p. 6). References on optimum watertable depths for teak (*Tectona grandis*) in literature are scarce. It is well known that teak requires a well-drained soil, preferable porous loam to sandy loam soils (Krishnapillay, 2002). Teak can also tolerate extreme rainfall from a low of 750 mm to a high of 3750 to 5000 mm per year (Evans and Turnbull, 2004). It requires, however, good drainage as it will not tolerate prolonged flooding. Thus the selected design depth of the watertable seems to be appropriate.

The design discharge (33 mm/d) is based on a rainstorm with a frequency of occurrence of once in 20 years (FDE 02, p. 17). The discharge was calculated based on data of Coto 47 Meteorological Station (period 1970 – 1990) using the probability method developed by Gumbel (Notes, p. 4). The calculation is not included in the report thus could not be checked, but the method seems appropriate.

A 40% reduction in the design discharge because of surface runoff is mentioned (FDE 02, p. 15). This reduction factor, however, has not been used in the design (FDE 02, p. 18).

The Verification Team Report (Coillte, 2007) mentioned another criterion: maximum period of flooding: 36 hours. In other words, 36 hours after the design (extreme) rainfall the watertable should be back at the design depth of 0.90 m. This criterion was not used in the design.

2.2 Soil and hydrological input data

To design a drainage system, next to the design depth and design discharge, data on the soil and hydrological conditions are required. This data has been provided.

2.2.1 Rainfall

Rainfall varies considerable both in time and in place, e.g. the long-term average rainfall recorded at the meteorological station Río Claro is significantly higher than the rainfall recorded at Palmar Sur (Table 2).

Table 1 Long-term rainfall records recorded at Río Clro and Palmar Sur

	Precipitation (mm)	
Meteorological station	Río Claro* (1989-2006)	Palmar Sur* (1941-2000)
January	115	51
February	113	51
March	170	82
April	293	231
May	493	412
June	496	396
July	512	366
August	594	428
September	627	503
Soctober	685	681
November	530	357
December	256	97
Year	**4881**	**3656**

* Río Claro is located at 08°40 N; 83°3 O and Palmar Sur at 08°57 N; 83°26 O(Fig.1)

The extreme rainfall events obtained from the Estacio Salama (period 2006-2007, maximum about 190 mm/d) are significantly higher than the rainfall events from the Registro Estacion Piedras Blances (period 1998 – 2004, max. about 90 mm/d), see Figure 7 in Report Aguas, 200. Thus rainfall varies considerable from place to place and from year to year. It is recommended to obtain the rainfall data from the Registro Estacion Piedras Blances for he period 2004 – 2007 and to compare these with the data from Estacio Salama. By comparing the two data sets an estimation can be made of the frequency of occurrence of the September 27, 2007 rainstorm.

2.2.2 Soils

The soil type ranges from sandy loam to clay, on average clay loam (Table 3).

Table 3 Soil classification (Report FDS 02, FDS 05)

Soil pit	**sand** (%)	**silt** (%)	**clay** (%)	**Classification**
70 A - Ap	55.0	25.0	20.0	sandy loam
70 A - A2g	45.0	30.0	25.0	loam
70 A - Bw1	38.9	29.6	31.5	clay loam
70 A - Bw2	20.0	35.0	45.0	clay
70 A - Bg3	20.4	39.6	40.0	clay loam
70 A - Bg4	23.5	35.0	41.5	clay
70 B - Ap	52.7	32.3	15.0	sandy clay loam
70 B - A2	47.0	35.0	18.0	loam
70 B - Bw1	29.4	35.6	35.0	clay loam
70 B - Bw2	27.5	31.2	41.3	clay loam
70 B - Bw3	24.2	30.2	45.6	clay
70 B - Bw4	28.2	29.3	42.5	clay
Average	**34.3**	**32.3**	**33.4**	**clay loam**

2.2.3 Hydraulic conductivity

To obtain a representative value of the hydraulic conductivity 24 measurements were done (Table 4). The variation in hydraulic conductivity is high (range 0. 4 < K < 35 m/d), but this is quite normal. The average hydraulic conductivity is also quite high (13.1 m/d) for the type of soil (mainly clay loam).

Table 4 Hydraulic conductivity (Ref. Notes on hydraulic conductivity)

• Number of measurements	24
• Average	13.1 m/d (corresponding drain spacing 67 m)
• Minimum	0.4 m/d
• Maximum	35 m/d
• St. deviation	11.7 m/d
• Geometric mean	7.3 m/d (corresponding drain spacing 50 m)

2.2.4 Topography

Surprisingly no topographic map has been prepared, although data on the topography is essential to assess the effectiveness of a drainage system. For the longitudinal profile of the drains, the farm has been levelled (Report FDS 02, Annex 2). It is recommended to use this data to prepare a topographic map. It is noted that the levels ("Terreno") of block H (range 7.00 – 9.00) are completely different compared to the other blocks (range 86 – 89). Probably a processing error: this should be checked.

2.3 Drain spacing

2.3.1 Design approach

For the design, the steady state approach was used (FDE 02, Section 2.5, p. 9). Three formulas are presented, i.e. Donnan, Hooghoudt and Ernst. It is not clear which formula was finally selected to calculate the drain spacing. This is not so important because the three formula's are based on the same principles and yield more or less the same results (Ritzema, 2007).

The criterion that the watertable should be back at a depth of 0.9 m after 36 hours has not been used in the design. To use this design criterion a different approach, the so-called unsteady-state approach, should have been used, e.g. the Glover-Dumm formula (Ritzema, 2007).

2.3.2 Calculated drain spacing

The calculated drain spacing varies between 6 and 48 m (FDE 02, Section 3.6, Table 1). The actual calculations are not included in the report, thus they could not be checked. The hydraulic conductivity seems to be the main variable that determines the difference in drain spacing. Based on these calculations, two drain spacing have been selected, respectively 25 and 37.5 m. Why these two spacing have been selected is not clear.

2.3.3 Verification of the drain spacing

The drain spacing were checked by calculating the spacing for the average (mean) and geometric mean of the hydraulic conductivity. Both values are used to calculate drain spacing (Oosterbaan and Nijland, 2007). The geometric mean yields smaller (and thus safer) drain spacing as it puts more emphasis on the low values in the range of measurements. The average hydraulic conductivity (K_a = 13.1 m/d) results in a drain spacing is 67 m. The geometric mean (K_g = 7.33 m/d) yields a drain spacing of 50 m. Thus is can be concluded that the selected drain spacing, i.e. 25 and 37.5 m, include safety margins of respectively 100 and 50%.

The extreme rainfall event (189 mm) on 27 September 2007 (Report RPS 11-2007) has been used to check the drain spacing using an unsteady-state approach. A spreadsheet model based on the Zeeuw-Hellinga approach (Ritzema *et al.*, 1998) was used. The results are presented in Table 5.

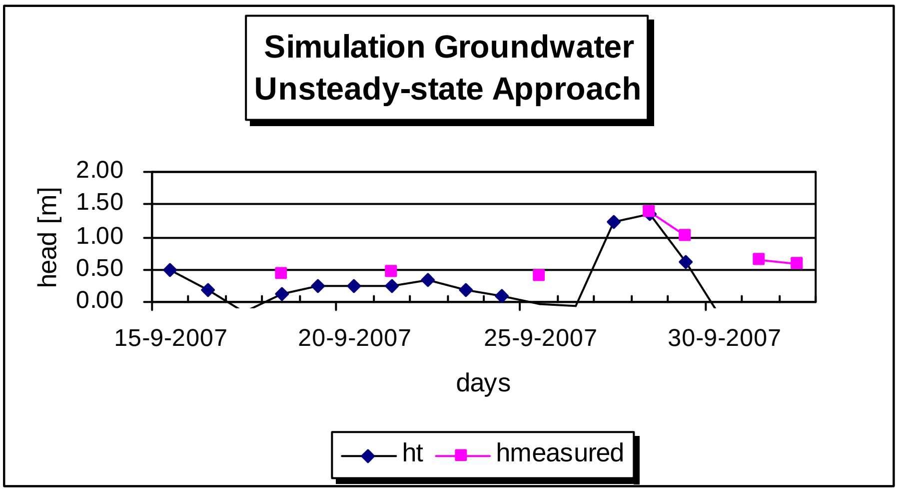
Table 5. Simulation of the drop of the watertable after the extreme rainfall event on September, 27, 2007

Input:

• hydraulic conductivity	(K)	1.80	[m/d]
• thickness of peat layer	(D)	4.00	[m]
• drainable pore space	(mu)	0.15	[-]
• drain spacing	(L)	25	[m]
• time step	(dT)	1	[d]
• design head difference	(h_0)	0.50	[m]

Measured and simulated head (difference water level midway between drains and in the drain) and corresponding discharge

Day	Rain [mm]	h_t [m]	q_t [mm/d]	$h_{measured}$ [m]
15-09-07	8.2	0.50	49.0	
16-09-07	0	0.17	49.0	
17-09-07	2	-0.14	16.3	
18-09-07	55.2	0.12	-12.6	0.42
19-09-07	8.2	0.26	11.2	
20-09-07	9.4	0.25	24.6	
21-09-07	24.8	0.25	23.4	0.45
22-09-07	39.2	0.35	23.6	
23-09-07	0	0.20	34.0	
24-09-07	17.2	0.08	18.5	
25-09-07	0	-0.04	7.8	0.40
26-09-07	4.8	-0.06	-3.6	
27-09-07	189.2	1.23	-5.4	
28-09-07	12.4	1.34	130.3	1.40
29-09-07	20.6	0.61	**144.8**	1.02
30-09-07	7.8	-0.30	60.9	
01-10-07	45.4	-0.40	-26.6	0.65
02-10-07	0.0	-0.23	-35.3	0.60



The simulations indicate that with the selected drain spacing the watertable indeed drops back to 0.90 m after 36 hours. Thus it can be concluded that the selected drain spacing are appropriate.

2.4 Management of the drainage system

To avoid flooding, a three-step approach in managing the drainage system is proposed, i.e. (FDE-02, p. 22):

- Construction of a check (flap gate) at the outlet to the Salamá River
- Construction of a manually operated gate at the farm outlet
- Installation of a pump (25 000 gallons per minute equivalent to about 230 mm/d) to evacuate excess water during period of high water levels in the Salamá River .

The decision to close the gates and start pumping will be based on observation well measurements: 0.8 m being the critical level.

2.4.1 Pumping capacity

The pumping capacity is sufficient: the pump can evacuate about 230 mm/d and the highest rainfall recorded up to now is 190 mm/d (on 15/10/2006, Aguas, 200?). It is, however, risky to have only one pump because of breakdown and maintenance. To increase safety, it is recommended to use, instead of one unit, two 12.500 gallon/min units.

2.4.2 Operation of the pump and gate

To base the decision to close the gates and start pumping on monitoring ground water levels is quite risky (who will do the measurements during these periods of extreme rainfall) and cumbersome? It is more logical to start pumping when the water level in the drainage system upstream the gate exceeds a certain level.

To reduce the risk of failure, it is recommended to investigate the option to install an device to automatically start the pump when the water level in the drain reaches a critical level.

Alternatively, and mainly as a preventive measure, pumping can start have rainfall has exceeded a certain value. As it takes time before the watertable will start dropping after the pump has started, it is recommended to start pumping after the rainfall has exceeded e.g. 30 mm/d (being the design discharge).

2.5 Maintenance of the drainage system

The selected drain depth (1.4 m) is rather deep. To maintain these deep drains in loamy soils can be problematic. This issue has not been addressed in the project documents.

2.6 Flood protection

The flooding that occurred after the heavy rainfall on September 27, 2007, was the result of this extreme rainfall and river water overtopping the river banks. The risk of flooding from the river has not been assessed in this report, as there is no data available on river flows during extreme rainfall conditions. It should be realize that improving the drainage conditions is only useful if the flood protection issue is also addressed.

To assess the risk of flooding the following actions are recommended:

- Prepare a topographic map of the farm (see Section 2.2.3).
- Obtain a topographic map of the regions (scale 1: 50 000)
- Survey the bank/dike along the farm, including a few cross section of the River Salamá (include the levels of the opposite bank).

3 Conclusions and recommendations

1. The design criteria, i.e. a design depth of the watertable of 0.9 m and a design drain discharge of 33 mm/d, appear to be appropriate, although no conclusive evidence could be obtained from literature.

2. The design criterion that the maximum period of flooding should be less than 36 hours was not used to calculate the drain spacing.

3. Surprisingly no topographic map has been prepared, although data on the topography is essential to assess the effectiveness of a drainage system. To design the longitudinal profiles of the drains, the farm has been levelled. It is recommended to use this data to prepare a topographic map.

4. It was not possible to recalculate the two selected drain spacing, i.e. 25 and 37.5 m, directly as the data presented in the project documents is incomplete. The order of magnitude, however, seems to be on the safe site.

5. The extreme rainfall events on September, 27, 2007, was used to verify the selected drain spacing under extreme conditions. Based on the presented data on the watertable drawdown it can be concluded that the selected drain spacing are appropriate.

6. Rainfall varies considerable from place to place and from year to year. The extreme rainfall data from the obtained from the Registro Estacio Salama (period 2006-2007, maximum about 190 mm/d) are significantly higher than the rainfall events from the Registro Estacion Piedras Blances (period 1998 – 2004). Data of the period 2006-2007 should be compared to check the validity.

7. It is recommended to operate the pump and gate based on water levels in the drains and not on the groundwater level measurements. The option to install an automatic operation systems should be investigated.

8. A double pump unit of 12 500 gallon per minute instead of one single 25 000 gallon per minute unit will increase safety.

9. The selected drain depth (1.4 m) is rather deep. To maintain these deep drains in loamy soils can be problematic. This issue has not been addressed in the project documents.

10. The flooding that occurred after the heavy rainfall on September 27, 2007, was the result of this extreme rainfall and river water overtopping the river banks. The risk of flooding from the river has not been assessed in this report, as there is no data available on river flows during extreme rainfall

conditions. It should be realize that improving the drainage conditions is only useful if the flood protection issue is also addressed.

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