Proceedings of Heap Leach Mining Solutions, 2016
October 18- 20, 2016, Lima, Peru
Published by InfoMine, © 2016 InfoMine, ISBN: 978-1-988185-03-3

Solution collection pipes on slopes

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Abstract

The solution collection system commonly used in heap leach facilities consists of a basal drainage layer of crushed rock (overliner) and embedded perforated pipes installed above the geomembrane and below the ore heap. The solution percolates vertically downward through the entire ore column, flows along the overliner, and enters the pipes with zero hydraulic head. The pipes are designed and spaced to convey the operational leach and design storm flows while maintaining low hydraulic heads on the geomembrane.

Some heap leach facilities are constructed in mountainous terrain with steep slopes where it is not practical to place overliner. This is the case for the Creston Mascota gold mine (Phase 3), owned and operated by Agnico Eagle Mexico. The ore is crushed to a nominal size of 9.5 millimeters (mm) with a maximum fines content of 6.5%. A finite element seepage model was developed for Phase 3 of the heap leach facility to determine the hydraulic head created on the geomembrane for different scenarios. Two zones were evaluated: a bottom area with a “flat” (gentle) slope and a steep (2H:1V) side slope. The bottom area was designed with a 1-meter (m) thick overliner and the steep side slope was designed with no overliner, the crushed ore was in direct contact with the geomembrane. It was assumed that a single pipe at the toe of the slope would be sufficient to remove the solution without having an increase in the hydraulic head on the geomembrane on the slope. However, the results show that a series of solution collection pipes are required on the slope to lower the hydraulic head. The seepage model was run several times decreasing the pipe spacing until a hydraulic head less than 2 m was achieved. The results of the seepage model were compared with the results obtained using the conventional drain spacing equation used in the industry to calculate spacing of drain pipes on flat ground. The results of the seepage model indicate that solution collection pipes are required on steep slopes in order to maintain low hydraulic head on the geomembrane.

Introduction

The Creston Mascota gold mine is owned and operated by Agnico Eagle Mexico and located approximately 150 kilometers (km) west of the city of Chihuahua, Mexico. The heap leach facility is located in mountainous terrain and the Phase 3 expansion is located in a valley between two mountains.

Phase 3 was graded with a gentle sloping area (about 4% to the east) between mountains with slopes no greater than 2H:1V (Figure 1).

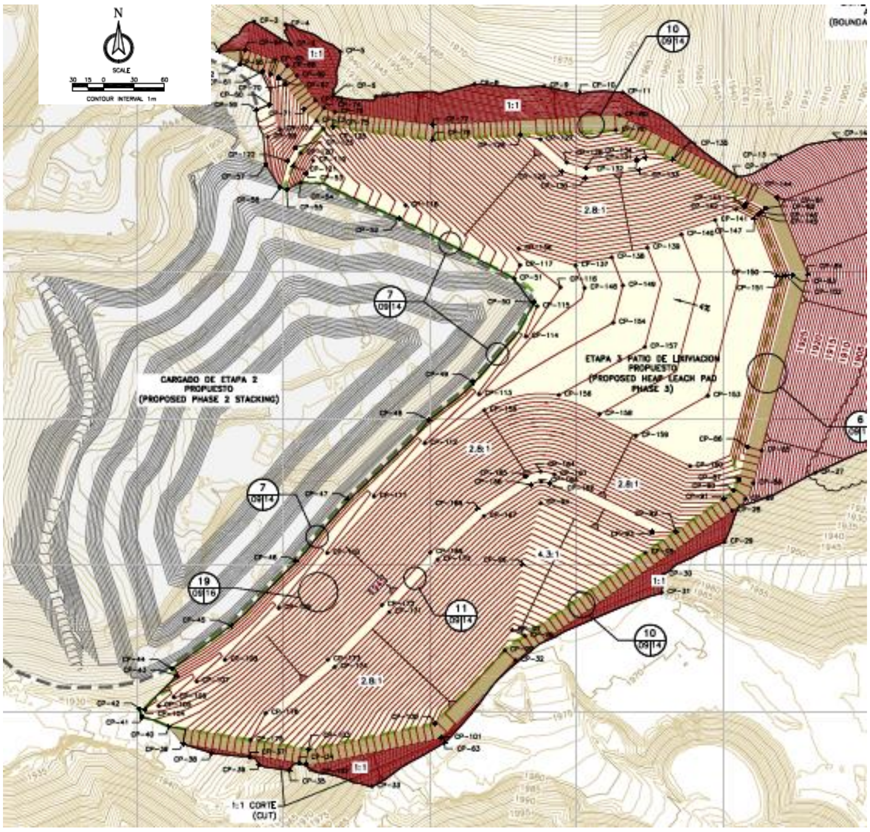

Figure 1: Grading plan for Phase 3

The “flat” area was designed with a 1-m-thick overliner, whereas the slope areas were designed with no overliner, and the crushed ore was in direct contact with the geomembrane. The nominal size of the crushed ore is 9.5 mm with a maximum fines content of 6.5%.

The overliner is generally used as a protective layer to protect the geomembrane’s integrity from damage during ore placement. The second function of the overliner is to promote leachate solution drainage into the piped leachate collection system and, therefore reducing head loading on the liner (reducing the potential risk of leachate solution losses through the liner) and maximizing solution recovery.

In the design of the solution collection system, it was expected that a single pipe at the toe of the slope would be sufficient to remove the solution without having an increase in the hydraulic head on the geomembrane on the slope. At first, it was assumed that the solution irrigated on the ore in the slopes, after reaching the liner, would convey quickly along the sloping ground to the pipes located at the toe. After conducting a preliminary seepage model, it was found that the hydraulic head on the geomembrane was higher than the maximum allowed. Therefore, a series of seepage models were run placing laterals on the slope at different spacing until a hydraulic head less than 2 m was achieved.

Numerical method

The Finite Element Method (FEM) was used to model the seepage on the slopes using the software program SEEP/W. The material properties of the overliner and crushed ore are shown in Table 1.

Table 1: Material properties

Material	Saturated hydraulic conductivity (cm/s)
Overliner	1.0×10^{-2}
Crushed Ore	3.5×10^{-3}

A 1-m thick overliner (drain gravel) was used in the "flat" area and the height of the ore was assumed to be approximately 50 m. The solution is applied at a rate of 12 liters per hour per square meter (L/hr/m^2), but a rate of 18 L/hr/m^2 was used in the model (150%). The model was run assuming saturated conditions under steady-state flow. The pipes were modeled using a zero head pressure boundary condition.

Figure 2 shows the model section in the "flat" area. Two cases, pipe spacing at 20 m and 15 m, were evaluated.

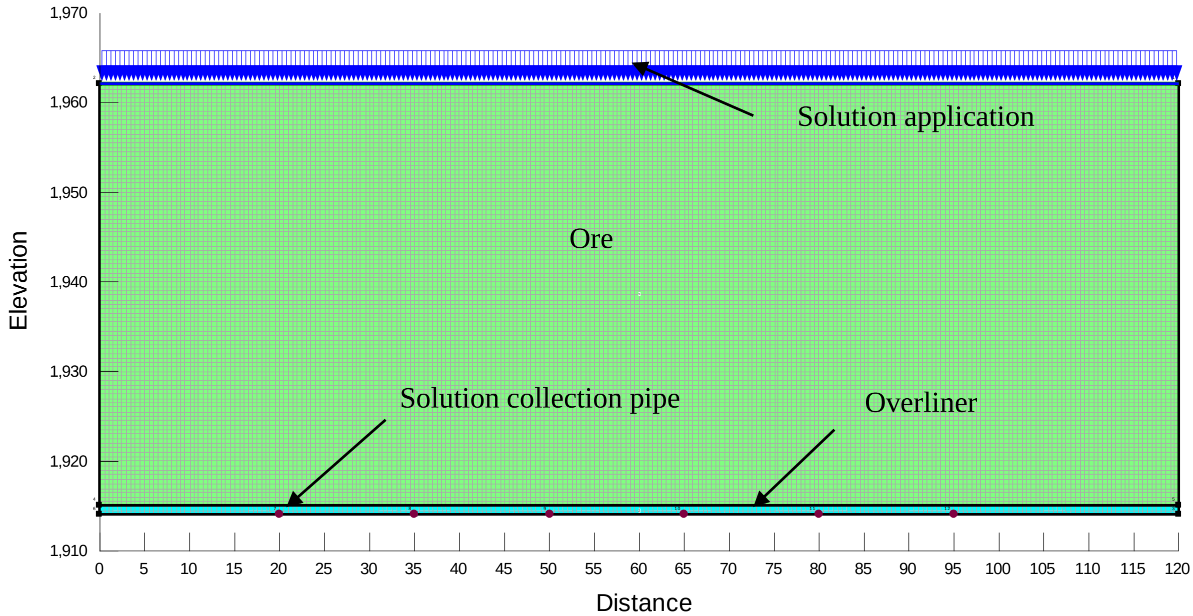

Figure 2: Model section in the "flat" area

Figure 3 presents the model section assumed on the slopes. An intermediate bench approximately 6 m wide was specified in the design. In this case, several models were performed changing the pipe spacing on the slope until a small hydraulic head was obtained.

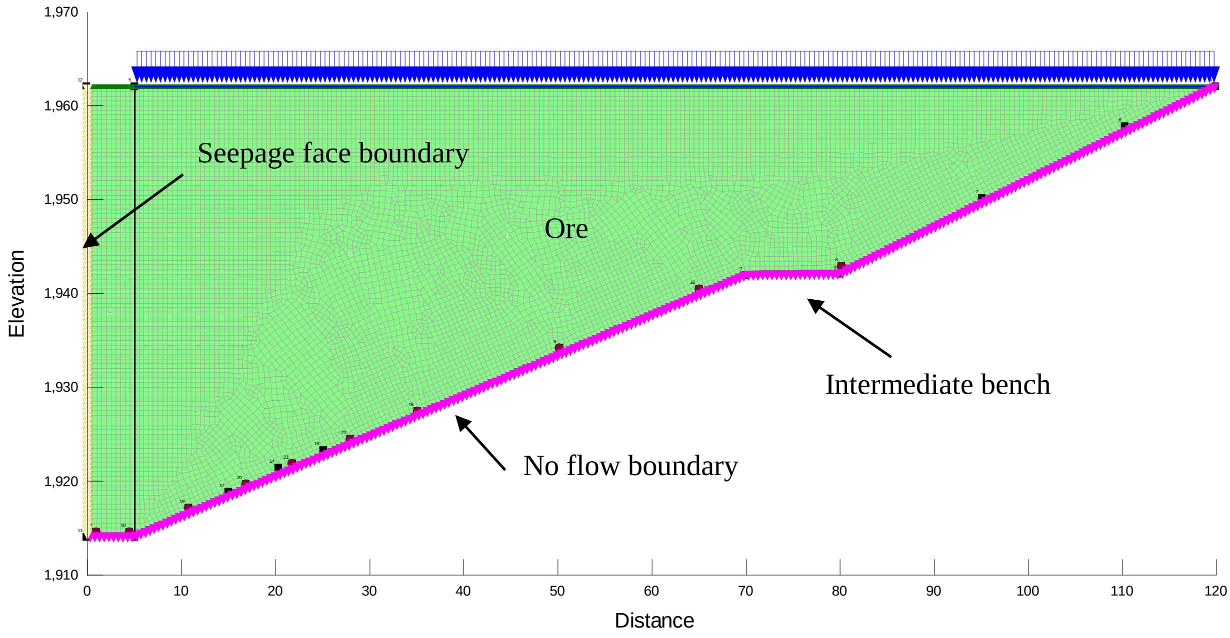

Figure 3: Model section on the slope

Results

Flat area

Figure 4 shows the hydraulic head (zero head pressure) developed by pipes separated 20 m apart. The head calculated is approximately 2.3 m, which is higher than the 2-m head required by the design.

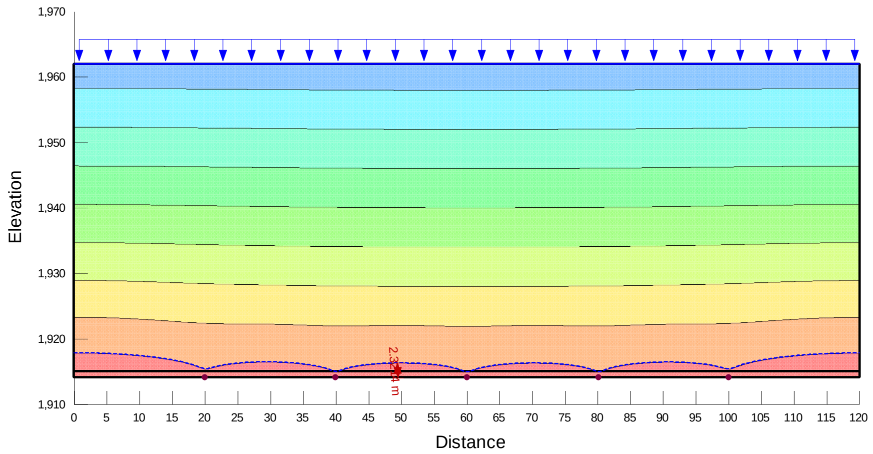

Figure 4: Model section in the flat area with pipes placed 20 m apart

Figure 5 shows the results of the seepage model using pipes separated 15 m apart. The maximum head is approximately 1.6 m.

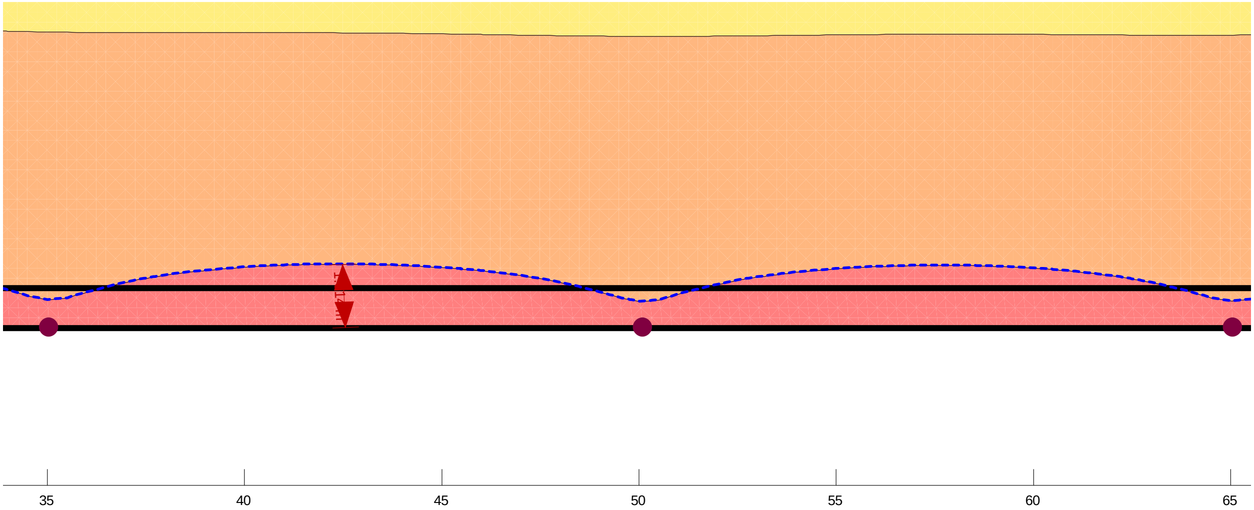

Figure 5: Model section in the flat area with pipes placed 15 m apart

Slopes

Figure 6 shows the results of the seepage model using two pipes at the toe of the slope. No pipes are placed on the slope. The maximum head is about 16 m and at the right upper corner, the model shows ponding indicating that the solution collection system is not sufficient to convey the solution application rate.

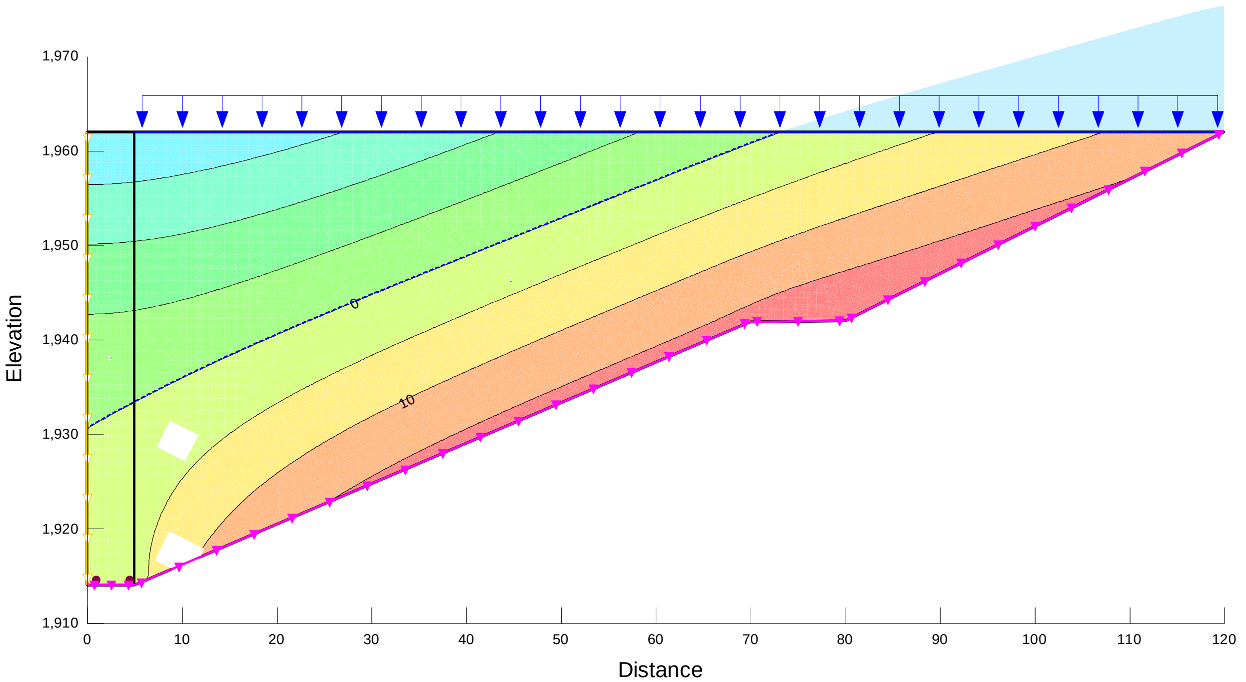

Figure 6: Two pipes placed at the toe of the slope

When pipes are placed on the slopes, the head is substantially reduced. Figure 7 presents the results for a pipe spacing of 15 m. In this case, the head is approximately 6 m near the toe. The results indicate that less pipes are required at the top of the slope and more pipes are required near the toe to reduce the head to acceptable levels.

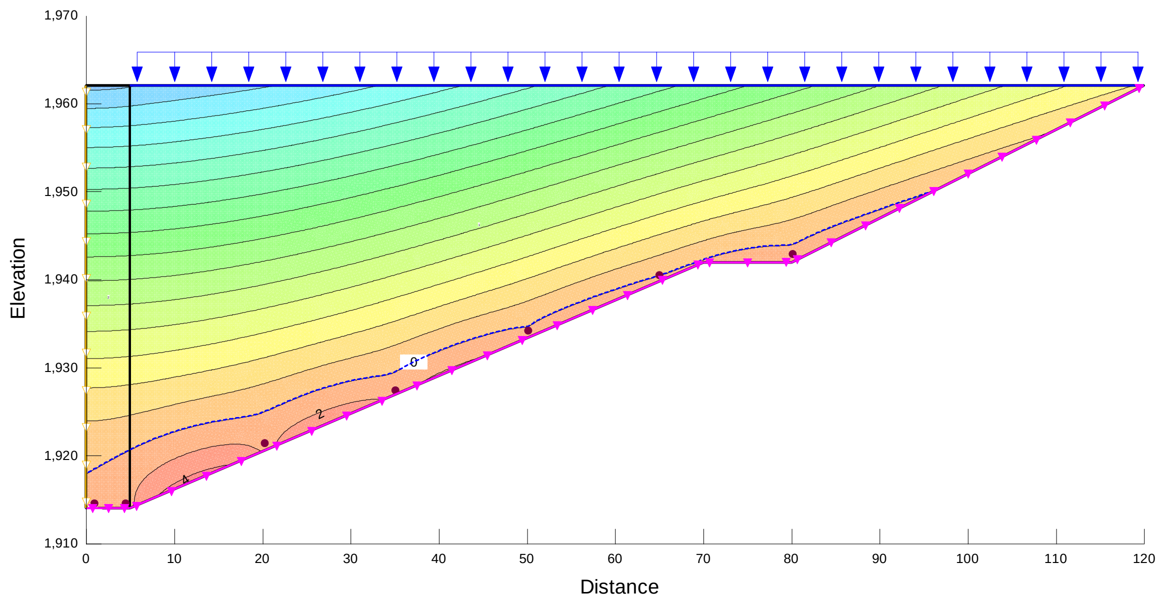

Figure 7: Pipes on the slope separated 15 m apart

Figure 8 shows the results for pipes separated 6 m near the toe of the slope. In this case, the head is reduced to a level below the maximum allowable head of 2 m.

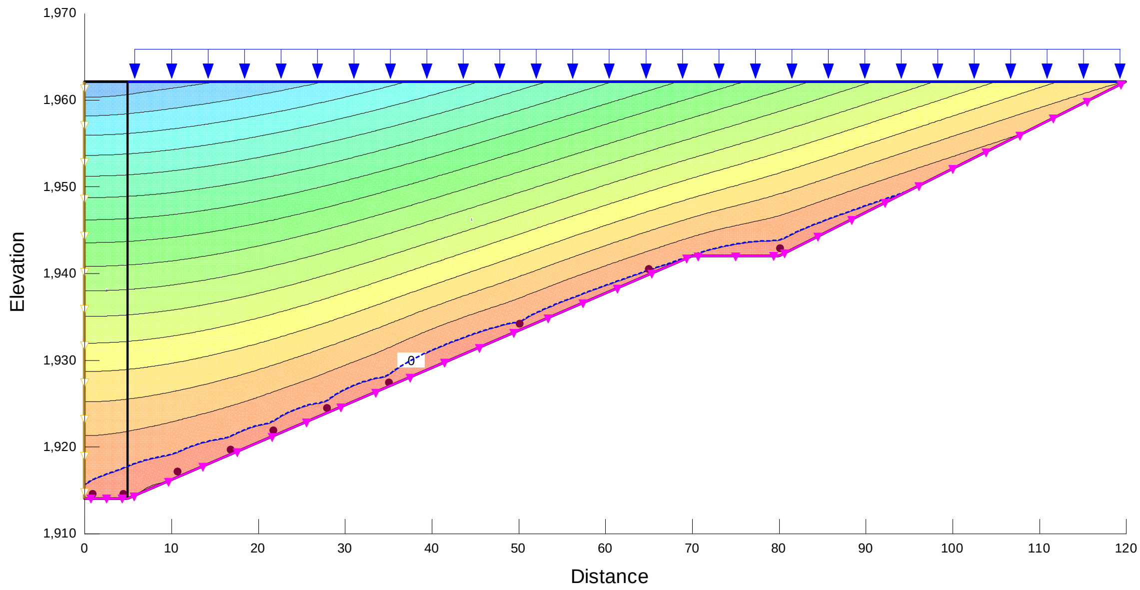

Figure 8: Pipes on the slope separated 6 m near the toe

Empirical pipe spacing calculation

The solution collection pipe spacing was also determined by the empirical equation below for estimating the peak hydraulic head on the pad liner system between pipes (Hooghoudt, 1940).

$$H = \frac{L}{2} \times \left(\frac{W}{K}\right)^{0.5}$$

Where:

H = maximum mid-point hydraulic head on liner (usually 1.5 m for a 0.6-m overall head), 2 m was allowed in the design

L = drain pipe spacing (to be determined)

W = application rate of 18 L/hr/m^2 (150% pregnant leach solution)

K = hydraulic conductivity (permeability) of pad drain material (1 x 10^{-2} cm/s)

Using this equation, the pipe spacing is about 14 m, which is consistent with the results of the seepage model for the “flat” area.

Conclusion

It was expected that a single pipe at the toe of the slope would be sufficient to remove the solution without having an increase in the hydraulic head on the geomembrane on the slope. However, the results show that a series of solution collection pipes are required on the slope to lower the hydraulic head. The model was run several times decreasing the pipe spacing until a hydraulic head less than 2 m was achieved.

The results of the seepage model were compared with the results obtained using the conventional drain spacing equation used in the industry to calculate the spacing of drain pipes on flat ground. Similar pipe spacing was obtained using the empirical equation and the seepage model.

The results of the seepage model indicate that solution collection pipes are required on steep slopes in order to maintain low hydraulic head on the geomembrane. For the Creston Mascota gold mine, a pipe spacing of 15 m was recommended for the “flat” area. For the slopes, a pipe spacing of 6 m was recommended near the toe (lower third) and 15 m apart in the middle third. No pipes were required in the upper third.

References

Hooghoudt, S.B. 1940. General consideration of the problem of field drainage by parallel drain, ditches, watercourses, and channels. Publ. No. 7 in the series Contribution to the knowledge of some physical parameters of the soil (titles translated from Dutch). Bodemkundig Instituut, Groningen, The Netherlands.