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Comparison and development of ditch structures (bed pipe barriers) in reducing suspended solids concentration in waters flowing from peat mining sites

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Ditch structures are used to reduce the transportation of eroded peat from peat mines during high runoff events. In this article, new types of control structures were compared with traditional ones. Two different experiments were performed under laboratory conditions. First, hydraulics were studied by determining the discharge at different water levels. Second, the effectiveness of the constructed barriers in reducing the transport of peat was measured. The results of the study show that attenuating the runoff peak by storing water in the ditch network is the most effective way of reducing the concentration of suspended solids of waters flowing from peat mining sites. The water intake location also has a small effect on the transport. The new type of control barrier retains the runoff peaks. Its outlet is situated close to the water surface where the concentration of suspended peat is less than at greater depths.

Introduction

Environmental problems related to peat mining in Finland

Peat mining for energy production is increasing in Finland. Presently, peat is produced over an area of 53 000 ha. Altogether 120 000 ha, which is 1.2% of the total Finnish wetland area, has been reserved for peat mining. Approximately 22% of the central heating and 8% of the electricity supply in the country are produced by burning peat.

Previous studies show that the most important water quality problem associated with peat mining is the transport of suspended solids (Sallantaus 1984). During intense runoff events, peat erodes from the surface of the soil and from the channel bottoms (Kløve 1997c). The sediment transported from the site settles downstream in rivers and lakes. The settled organic material con-

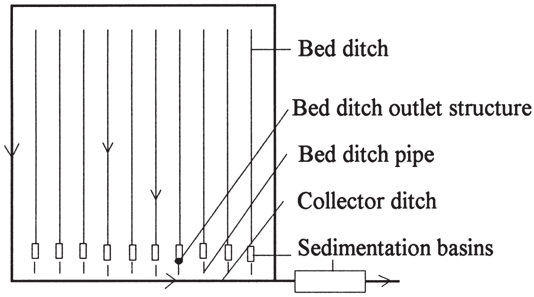

Fig. 1. Traditional basic water treatment method used on all Finnish peat mines

sumes oxygen in lakes (Westling and Bengtsson 1991). Eutrophication of downstream lakes has been noted by Granberg (1986) and by Marja-aho and Koskinen (1989).

The traditional basic control alternative

The traditional, basic water treatment method focuses on reducing peat concentrations in drainage water (Fig. 1). The peat load from the bed (field) ditches is reduced using small sedimentation basins. The water from all the small sedimentation basins is then collected in a collector ditch from which the water runs into a large sedimentation pond. Between each of the small sedimentation basins and the collector ditch there is a structure which is used to reduce the transport of peat particles, especially large floating particles. The structure is a barrier placed in the bed ditch in front of the bed pipe. These are therefore known as "bed pipe barrier" (bp barriers). Details are shown in Fig. 2. The large sedimentation pond is designed for a 1 m h^{-1} surface load during a design runoff of 300 l s^{-1} km^{-2}.

The basic method works best during low runoff. It has been shown by Ihme *et al*. (1991) that a bed ditch structure and a small sedimentation pond can remove 78–97% of the incoming suspended solids load. Measurements on the large pond at the outlet indicate a 30–40% removal of the remainder of the suspended solids (Selin and Koskinen 1985). However, during peak runoff, sedimentation is not effective (Kløve 1997b) and the transport of suspended solids is high (Sallantaus 1983). It has been observed that the hydraulic load can exceed the design values by as much as three times. Observations show that during these high runoff events, sediment is resuspended in the sedimentation basins (Selin and Koskinen 1985).

Development of more advanced pollution control alternatives

Increased water treatment is required for all new mines in Finland. The present proposal by the Finnish National Board of the Environment for the year 2005 requires substantial improvement in peat drainage water treatment. Both suspended solids and nutrients need to be better removed. The annual suspended solids load should be reduced by 2/3 from the 1993 level. To fulfill these new, strict water pollution requirements, several new methods have been introduced during the last decade.

Table 1. Comparison of different drainage water treatment alternatives. The list is based on personal communication with Vapo Oy and from publications Savolainen *et al.* (1996ab).

Method	Cost of Investment (FIM ha^{-1})	Cost of Maintenance (FIM $ha^{-1}yr^{-1}$)	Removal Target for SS (%)	Area with treatment (ha)	Special require-ments
Traditional methods					
Settling ponds	450–1 100	50–200	30–40	50 000	Suitable soil
Bp barriers	300–600	75–100	78–97	53 000	none
Advanced methods					
Chemical treatment	900–4 500	320–1 150	91	1 850	Mine > 100 ha
Artificial wetlands	55–72	5 500			Available
Gravitation	190–940	5–50			wetland
Pumps	1 600–3 000	30–210			
Infiltration or evaporation	500–2 500	100–150	92	300	Suitable area
Peak runoff controll	150–250	5–20	95	80	Ditch volume

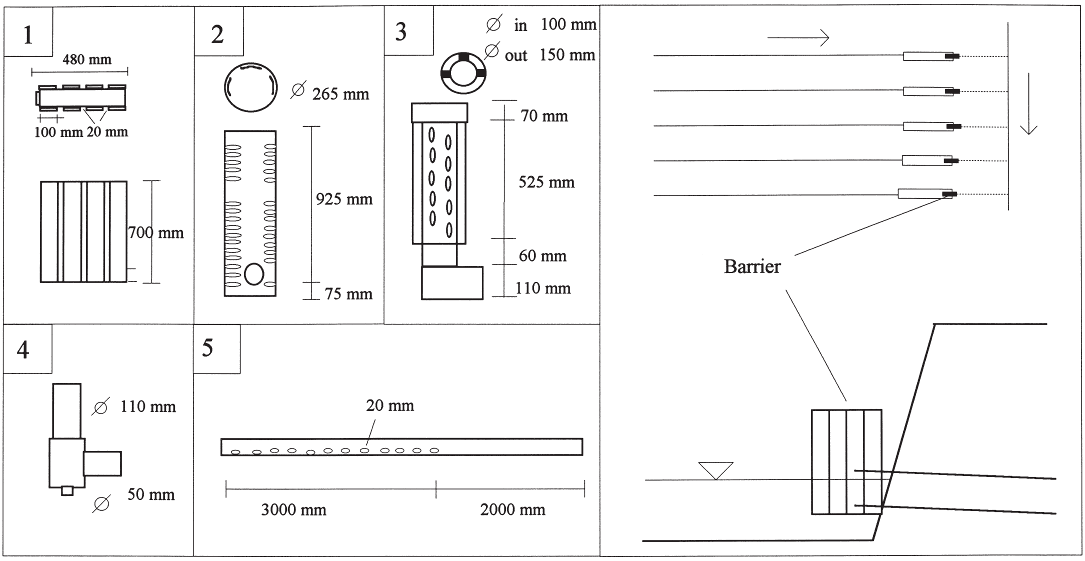

Fig. 2. Dimensions of bp barriers 1–5. Location of barriers on peat mine.

The most frequently used treatment alternatives are listed in Table 1. Because the reduction percentage is based on a limited amount of data, usually collected during summer months, the values are here called target values. The true removal percentage for the whole runoff season is probably much lower. During the cold season, high hydraulic loads reduce the sedimentation of peat particles and low water temperature reduce the biological removal of nutrients. The cost related to each method is quite variable due to extra expenses incurred, for example, by the building of roads, electricity lines, by land purchases and by extra work-force requirements, etc.

The traditional methods are used on all of the 50 000 ha of Finnish peat mines. These methods are fairly easily constructed at most mines, require little maintenance and are relatively cheap. The cost of maintenance includes yearly dredging of the sedimentation ponds and the occasional renewal of bp barriers. However, as mentioned earlier, the pollutant reduction is not always satisfactory. At some mines, the water authorities have required that the basic method be improved through additional water treatment methods. So far, advanced treatment has only been used on a small number of mines. The usefulness of such methods is restricted, in many cases, by very special requirements such as land availability etc. Also, the expense of the method can be too high compared to the benefit gained. For example, chemical treatment is not economically feasible on mining areas smaller than 200 ha. All of the various methods are here in summary reviewed.

The method whereby a wetland is used for cleaning the runoff water from peat mines was introduced by Ihme and colleagues in the late 1980s (Ihme 1994, Ihme *et al.* 1991). When the water flows through a mire, the concentration of constituents is reduced through biological, chemical and physical processes (Heikkinen *et al.* 1994). Removal efficiencies of over 30% for nitrogen and phosphorus and of over 55% for suspended sediments have been observed. A practical problem with this method is that it requires a suitable wetland area which should correspond to at least 3.8% of the drainage area (Ihme 1994, Savolainen *et al.* 1996a). Removal efficiencies are, moreover, reduced during high flows and low water temperatures.

Drainage water purification by infiltration or evaporation has been tested on some research basins. During an experimental period it was found that almost all suspended solids and nutrients were removed (Selin *et al.* 1994). The long term effect and eventual reduced removal capacity of the infiltration site is not known. The method requires an infiltration area corresponding to approximately 10% of the drainage area. Furthermore, the soil should be permeable and the watertable should lie at a sufficient distance from the soil

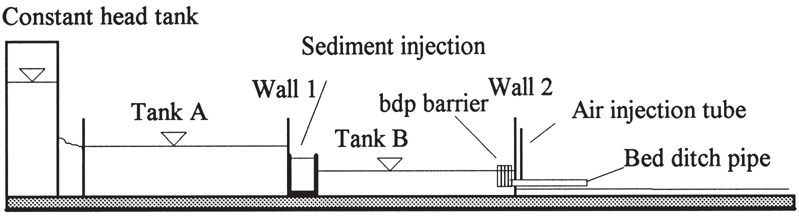

Fig. 3. The experimental setup for the hydraulic experiments.

surface. The use of the method is restricted to the summer months.

The most expensive method for drainage water treatment is chemical treatment, e.g. the use of ferrisulfide in drinking water production (Selin *et al.* 1994). Dissolved matter is precipitated and settled in ponds. Removal of phosphorus, turbidity, color and COD is almost total at low flows. Nitrogen reduction is 25–50%. However, since the method is not used during snow-melt runoff, not all of the annual load is treated with this system. Chemical treatment is economically feasible in areas larger than 200 ha.

It has been shown by the use of a mathematical model that the transport of settlable peat can be almost completely removed through runoff detention (Kløve 1994, 1997a). It is the only method designed to remove suspended solids during peak runoff when the load of suspended solids is exceptionally high. The principle of the runoff detention method involves damming water during high runoff events. The resulting decrease in peak flow increases the residence time in sedimentation basins and drainage networks. Consequently, more suspended material will settle, less material will be eroded and less peat will be transported downstream. The detention time needed for suspended solids removal depends on the settling characteristics of the material being transported. The use of the runoff detention method is presently restricted owing to a lack of sufficient hydrological information on peat mines and on the hydraulics of bed ditch structures. When runoff is high, the bed ditch structures, which are in use today, have only a marginal ponding effect.

Objectives

The traditional basic method is used at all mines. Therefore, an improvement of this method would reduce the total load of suspended solids considerably. Because very little information exists on bp barriers, a study and consequent improvement of this water treatment method could lead to the introduction of systems which would decrease the total peat load considerably.

The main objective of this study was to compare different bp barriers used to control the transport of suspended solids. Further, the mechanisms responsible for preventing peat from being transported through such barriers were studied in order to further the development of these structures. The study was carried out by performing experiments with clean water to determine the hydraulic function of the systems and by performing tests with peat to measure the characteristics governing material transport through the tested structures.

Description of bed pipe barriers

The bed pipe (bp) barrier is used upstream from the pipe that connects the bed ditch with the collector ditch. It is located at the outlet of the bed ditch, downstream from a small sedimentation pond as shown in Fig. 2. Five different hydraulic structures were tested, see Fig. 2. Barriers 1 and 2 are used at most peat mines. These structures have traditionally been used to prevent clogging of the bed pipe caused by large slices of peat. Since the 1980s, the control of solid matter transport has become increasingly important and new structures have therefore been introduced. In Barrier 3, three metal scrapers attached to the outer pipe are used to clean the perforated holes by turning the pipe. Barrier 4, which is a t-shaped structure in front of the bed pipe, has previously only been used at the Pohjansuo mine (Jämsänkoski, Finland). The barrier 4 type structure is the only structure that is certain to control the flow because its contraction (50 mm in this case) is much smaller than the 110 mm cross section of bed pipe. Barriers 3, 4 and 5 prevent the transport of floating peat because they take water from at least 5 cm below the surface. It is assumed that barrier 5 floats on the water surface and takes water from just below the surface. The interest in this type of barrier has been extensive and it has already been applied at several peat mines. The barrier is in principle more sustainable than other types because it lies on the bottom of the bed ditch and does not, therefore, easily get caught in the mining machines and destroyed as is often the case with other types of barrier. Both barriers 3 and 5 were further developed during this study to perform as desired hydraulically.

Methods

The program of experiments involving bp barriers was based on knowledge gained from previous field observation and modeling work. It has been shown that increased detention reduces the transport of peat considerably (Kløve 1997a). Furthermore, it is also known that the transport of floating peat can increase the suspended solids (Kløve 1997c) load thereby clogging structures. The desired barrier characteristics considered to be the most important in this study were:

— detention of runoff during storms (hydraulics effect)
— prevention of transport of floating peat (geometric effect)
— functionality, i.e. resistance to clogging, durability, etc. (not tested in this study).

The hydraulic features of the barriers were considered to be the most important factor controlling the transport of peat from the bed ditch. The assumption was that the more a pipe would pond the water during runoff and suspended solids load peaks, the lower the transport of peat would be. The residence time in ditches and sedimentation ponds increases and, therefore, the eroded material has more time to settle. Reduced flow peak reduces the flow velocity and consequently also the erosion of channel bed deposits.

Geometric effects can be divided into filter and location effects. The filter removes particles larger than 2–4 cm. The location of water inlets in barrier structures also affects sediment transport. During the transport, the concentration of sediment decreases from the water surface towards the channel bed (Leliavsky 1955). The water is cleanest at the water surface. However, in case of peat mining, peat often floats at the water surface and the lowest sediment concentration of sediment is to be found a few centimeters below the surface.

It is important to design a barrier so that clogging is prevented. The flow can easily be regulated by constructing pipes that have small perforations. However, pipes easily get clogged and are therefore unsuitable (Kløve 1994, Savolainen *et al.* 1996b).

The experimental program included three stages. First, the hydraulics of the barriers were studied. Second, the transport of peat through the barriers was studied in two tests. The importance of runoff detention was measured. Third, a new barrier was tested and developed based on the results from the first experimental stage.

Hydraulics

The experimental setup for the hydraulic experiments is shown in Fig. 3. The hydraulic function was tested with clean water. In each experiment, an 8 m long and 1.1 m wide glass tank (B) was filled with water. Thereafter, a plug was removed from the downstream end (wall 2) and the water was allowed to flow through the structure and out of the 110 mm pipe into air pressure. The water level in tank B was continuously monitored with a pressure probe. For each structure, these observed water levels were used to obtain a unique dependency between discharge (Q) and stage (H). Tank A and the small tank placed in tank B are used in a later experiment.

For some structures, it was necessary to calculate two H-Q relationships because the relationship depended on whether or not the water level was rising or falling. The discharge was lower for the same water level during the rising of the water level than during its lowering. This was due to the fact that the free water surface in the pipe is maintained when air is sucked into the pipe and the flow consequently reduced. When hysteresis occurred, the relationship for the rising water level was obtained by allowing air to enter via a tube placed immediately after the barrier (Fig. 3).

Peat transport through bp barriers

The peat used in the experiments was sieved horticultural peat (Puhti 85). The peat had an initial

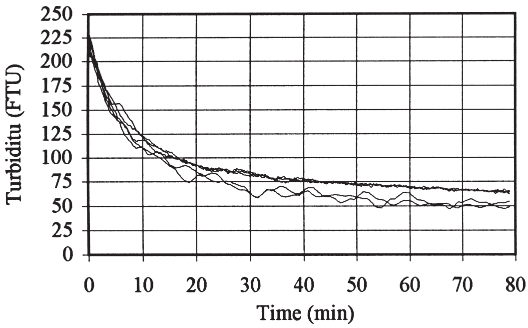

Fig. 4. Settling of peat used in the peat transport experiments.

moisture content of 58%. The settling of the non-floating portion of the peat was determined five times at 20 °C with a Staiger Mohilo 7 100 MF turbidity meter and a settling column of 850 mm in height and 90 mm in diameter. The results are shown in Fig. 4. The settling characteristics of the Puhti 85 peat is similar to those of base soil peat (Kløve 1994). The relationship between turbidity and peat concentration was found to be similar in the material used here and in the solid matter transported from the Pohjansuo peat mine during snowmelt runoff.

Effect of barrier geometry

The transport of peat through different barriers was studied using an experimental setup similar to that shown in Fig. 3. All five barriers were simultaneously placed at wall 2 in tank B in order to insure similar inflows of peat to each barrier (Fig. 5a). The inflow and outflow from tank B was 10 l s^{-1}. Each of the five barriers were placed at such a depth that its discharge was 2 l s^{-1}. An iron weight was placed on pipe 5 to make the water inlet sink just below water surface. The flow was reduced to 2 l s^{-1} by reducing the pipe diameter considerably.

In each experiment, 2 kg of peat was inserted during the constant 10 l s^{-1} discharge into a small tank downstream of wall 1 (Fig. 3). After mixing in the small tank, the water flowed into tank B and towards the outlet and through the barrier. The experiment was continued until the water was clear of peat particles. The average concentration during the experiment was approximately 100 mg l^{-1} and the peak concentration was 1 000 mg l^{-1}. The water which passed through a barrier was filtered of peat using a polyester filter (0.3 kg m^{-2}) (Fig. 5b). Before the quantity of peat was determined, the filters were dried for 2 days at 105 °C.

The experiment was repeated five times. During the experiments, the discharge was measured for each barrier and the sediment transport value adjusted according to deviations from 2 l s^{-1}. The percentage change in discharge was multiplied by the observed transport value and added to the observed transport value. The peat that settled between the repetitions of the experiments was not removed so the amount of peat in the tank increased after each experiment. Before the data was treated statistically, the possible trend in observations was removed by subtracting the average of each repetition from the result obtained for individual barriers. The effect of barrier was tested using analysis of variance. The differences between the barriers were tested using Duncan's multiple range test (Montgomery 1991). The difference between the largest mean value and the smallest mean value was tested using the *t*-test.

The effect of runoff detention on peat transport

The importance of the hydraulic characteristics of the barrier in controlling peat transport was determined by studying two similar barriers with different Q-H curves. Barrier number 4, with a 32 mm and 110 mm contraction was used. The pipes were placed at wall 2 (Fig. 3). First the larger 110 mm diameter pipe was tested, thereafter, the tank was cleaned and the smaller 32 mm structure was tested. Each experiment was repeated three times.

A runoff peak with high peat concentration was simulated. First tank A, upstream from experimental tank B, was filled with water. The water level in experimental tank B was initially 280 mm with no flow. A peat/water mixture of 2 kg peat and 10 l water was placed in the small 0.6 m^3 tank after wall 1 (Fig. 3). The water from the upper tank, A, was then allowed to flow through a 110 mm diameter pipe into the small tank and then into tank B. After the barrier, the peat was collected as explained above. The ratio of maximum storage to maximum outflow in tank B was used as a measure of theoretical detention time. The *t*-test was used to test differences in mean values.

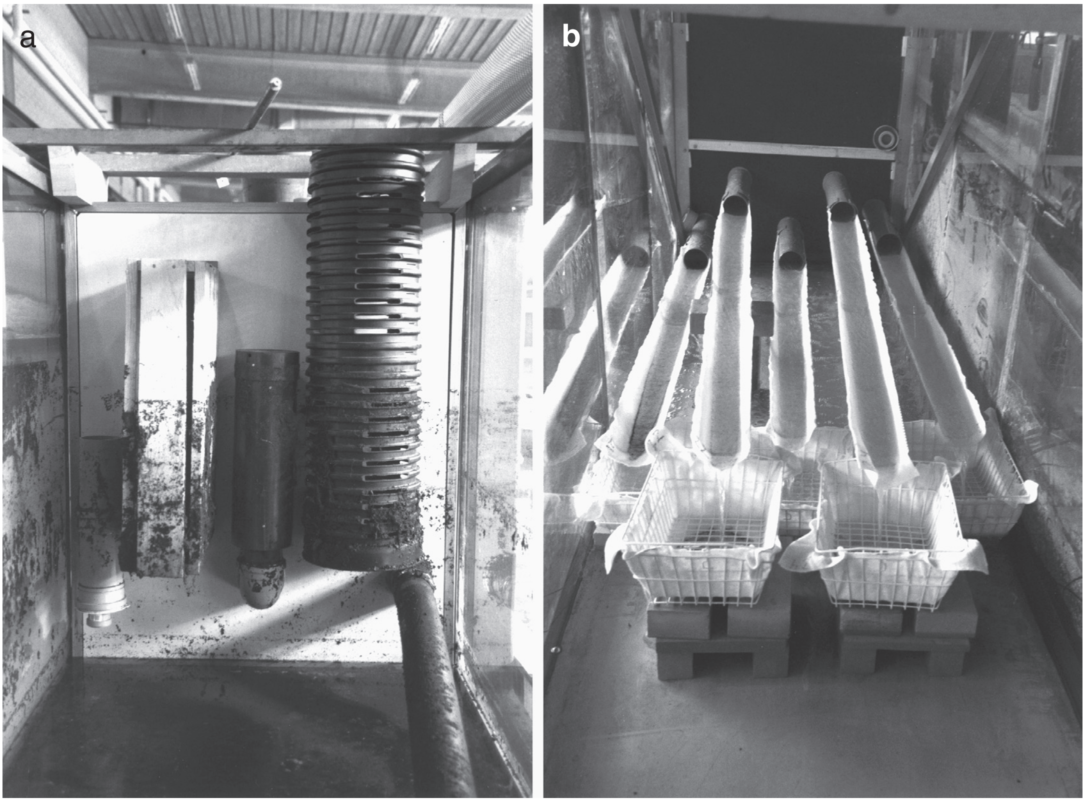

Fig. 5. Photos taken upstream (a) and downstream (b) of wall 2 (Fig. 3) during experimental setup.

Results and discussion

Hydraulics

The results of the hydraulic experiments are given in Fig. 6. It can be seen that the H-Q curves obtained for the 110 mm bed pipe are almost identical to those barriers 1 and 2 which means that these barriers do not affect the flow. However, since they prevent clogging of the pipe, they might, in some cases, also affect the H-Q relationship. Different H-Q relationships were, as already discussed, observed for falling and rising water levels, as shown for the 110 mm pipe and barriers 1 and 2 in Fig. 6. This hysteresis effect occurs when the flow condition in the 110 mm pipe controls the discharge. Both barriers 3 and 4 have different H-Q relationships than the 110 mm pipe and these structures do restrict the flow. The hydraulics of a new barrier developed in this laboratory study are explained in a separate section below.

Barrier 5 did not function as expected. It was *a priori* assumed by the manufacturer that it would float and follow the water level in the ditch. This should have given a constant and rather small flow of water through the barrier and the ponding effect would have been obvious. However, none of these desirable features were observed in the laboratory tests. When the water level rose, the upstream part sank below the surface considerably. The downstream part of the barrier rose into the air due to an air pocket which formed stopping the flow completely. The phenomenon of barriers rising and cutting off the flow has also been observed in the field by the author and by P. Selin, P. Kaunismaa, P. Bagge, A. Vepsäläinen & K. Sikström (unpubl.) with regard to a similar structure. Some barriers have, however, been observed to function in the field. This is due to the fact that, in some cases, when the downstream end of the bed barrier is below the water surface no air pocket is formed because the air cannot enter the water. When the barrier was pushed below the water surface and filled with water, the H-Q curve shown

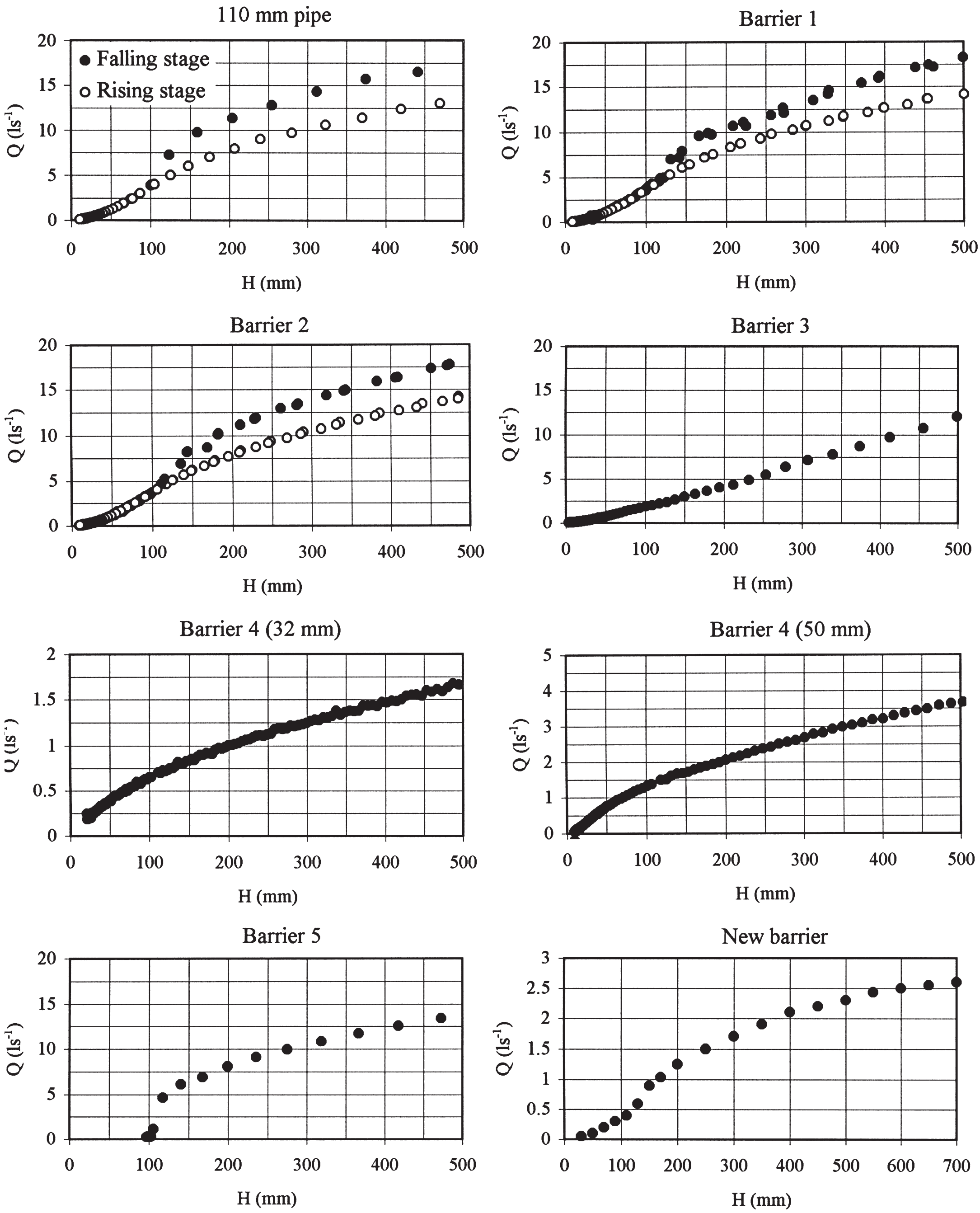

Fig. 6. The relationship between water stage H (mm) and discharge Q (l s^{-1}) for the structures tested.

in Fig. 6 was obtained. Under such a conditions, the flow resistance of the barrier is small. The use of a barrier of type 5 is not recommended due to the possibility of zero flow. Further development and hydraulic tests are necessary before this structure can be used effectively.

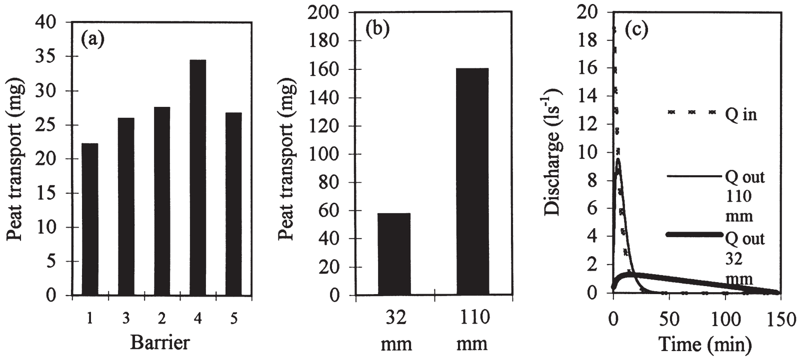

Fig. 7. (a) The effect of barrier geometry on peat transport, (b) the effect of runoff detention on peat transport and (c) inflow and outflow hydrographs during the detention experiment.

Peat transport through bp barriers

Geometry

The measurements show that differences in barrier geometry have no significant effect on the peat transport. The average peat transport through all five barriers during a 2 l s^{-1} discharge is depicted in Fig. 7a. A variance analysis reveals that less than 1% of the variations in sediment transport can be explained by the type of barrier. Transport is lowest through barriers 2, 3, and 5. These all take most of the water from below the surface. The highest sediment transport occurs through barrier 1, which takes water from the surface. It is not possible to separate different means using Duncan's test at a 95% level of confidence. However, the differences in means between the best and the worst barrier is significant with a probability of over 99.9%. The somewhat increased peat transport through barrier 4 as compared with barriers 2 and 3 could be due to the fact that the water inlet is close to the bottom of the tank where the peat concentration is always higher than immediately below the surface.

Detention

Runoff detention is the main characteristic reducing sediment transport (Fig. 7b). When the barrier with the 110 mm contraction is used, the amount of peat transported is on average 160 mg which is 2.8 times higher than when the barrier with the 32 mm contraction is used. The difference in means is significant with a probability of more than 99.9%. The 32 mm barrier ponds the water in the tank and releases it gently. The outflow hydrographs look quite different, as shown in Fig. 7c, and the amount of transported sediment is also very different. In the case of the larger barrier, the detention time (V_{max}/Q_{outmax}) is only 8 minutes whereas in the case of the smaller barrier, the detention time is 100 minutes. Consequently, the sediment transport is reduced because the peat has much more time to settle when the outflow is low.

Development of a new barrier

The investigation discussed here shows that the structures used currently do not considerably detain runoff and do not therefore decrease the pollution load efficiently. In principle, the outflow peak could be reduced using a type 4 barrier by selecting a small enough diameter for the inlet pipe that controls the flow through it. However, these pipes easily become clogged and would probably have to be cleaned too often. The need for the development of new structures is therefore obvious.

A new barrier structure was developed using the results obtained from the previous experiments in order to achieve a better control of peat transport. The objective was to obtain an H-Q curve for the structure similar to that of barrier 4 with a 32 mm diameter inlet pipe (Fig. 5). This was obtained thus coupling low discharge with high water level using the principle outlined in Fig. 8. By using a floating construction that follows the water level (as barrier 5 was supposed to do but did

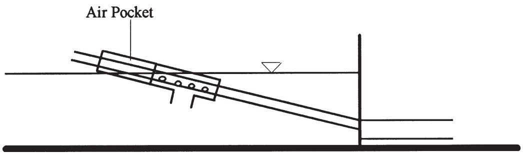

Fig. 8. Schematic of a new barrier developed to control peat transport.

not), the siphon effect in the pipe is prevented because the end of the pipe is in the air. Consequently, high discharges will not occur in the pipe despite the large inlet diameter. It can be seen from Fig. 6 that the maximum runoff from the new structure is below 3 l s^{-1} which means that runoff values would always be below 300 l $s^{-1}km^{-2}$, the design value for sedimentation basins.

Optimal placement of the new structure could further reduce peat transport and decrease the need for maintenance. Field observations suggest, that the barrier should be placed some distance from the end of the bed ditch where mining machines have to turn around. The machines usually drop peat into the ends of the ditches where the barrier is located. Consequently the barrier sometimes becomes covered with peat. A further advantage gained by placing the barrier far below the mine surface is that damages caused by mining machinery can be avoided. The use of plastic materials in the barrier structure rather than of wood to avoid accidents and the destruction of tyres on mining machinery is favourable.

A detention test revealed that the average amount of peat transported through the new barrier is lower than is the case with the 32 mm contraction, although the difference is not significant. Before the barrier can be used on a large scale, the effect of ice formation and snowmelt events on barrier function should be tested. Preliminary results show that the pipe might freeze preventing runoff. In this case, the structure must be removed before the start of winter. The structure could also be used in combination with various outlet structures (Kløve 1997a) to increase detention capacity during the summer period.

The effect of barriers on peak flows during different rainfall intensities

The results obtained in this study show that the detention of runoff peaks is the best method for reducing the transport of suspended peat from peat mines. A calculation was carried out to show the effect of different barriers on reducing high flows caused by a 5 mm effective rainfall. Runoff from a 500 m long bed ditch draining an area of 1 ha was calculated. A ditch section typical of peat mine drainage was used to obtain the relationship between channel water stage and channel volume. The trapezoidal section had a width of 30 cm and lateral side walls sloping with a 5 (vert.) in 1 (horiz.) gradient. Five different rainfall intensities were obtained by dividing the volume obtained from the 5 mm rainfall over an area of 1 ha by five durations ranging from 1.5 to 48 hours. The rainfall intensities thus obtained ranged from 0.28 to 9.3 l $s^{-1}ha^{-1}$ (0.1–3.3 mm h^{-1}). Such effective rainfalls are in agreement with observations from 10 peat mines (Sallantaus 1983) which showed a maximum summertime instantaneous runoff of 7 l $s^{-1}ha^{-1}$ and a maximum springtime runoff of 10 l $s^{-1}ha^{-1}$. The average annual runoff from peat mines equals the annual runoff from Finland which is approximately 0.1 l $s^{-1}ha^{-1}$ (Sallantaus 1983). Because the inflow (rainfalls in Fig. 9a) and ditch volumes were known, the outflow was obtained using reservoir routing, see for example Raudkivi (1979).

The results of the simulations indicate that those barriers which are in use today have a far smaller damming effect than the newly developed structure (Fig. 9). For barriers 1 and 2, outflow almost corresponds to inflow with only a little attenuation of the peaks for all rainfall intensities. In the field, there might be some attenuation due to clogging of the structures. For more damming structures, the runoff peak is reduced for high inflow intensities. During low intensity rainfall, none of the barriers affect the peak flow significantly. A balance between effective rainfall inflow and runoff from the ditch is reached when the water level in the ditch only rises by a small amount. Runoff is easily conveyed through the barrier and water is not dammed in the ditch.

Runoff detention may have some negative effects on peat production. The damming of runoff water could raise groundwater levels in such a way that the time for drying of the top soil layer could be prolonged. In most cases, there is no danger of flooding the mine surface because the available storage capacity in ditches usually ex-

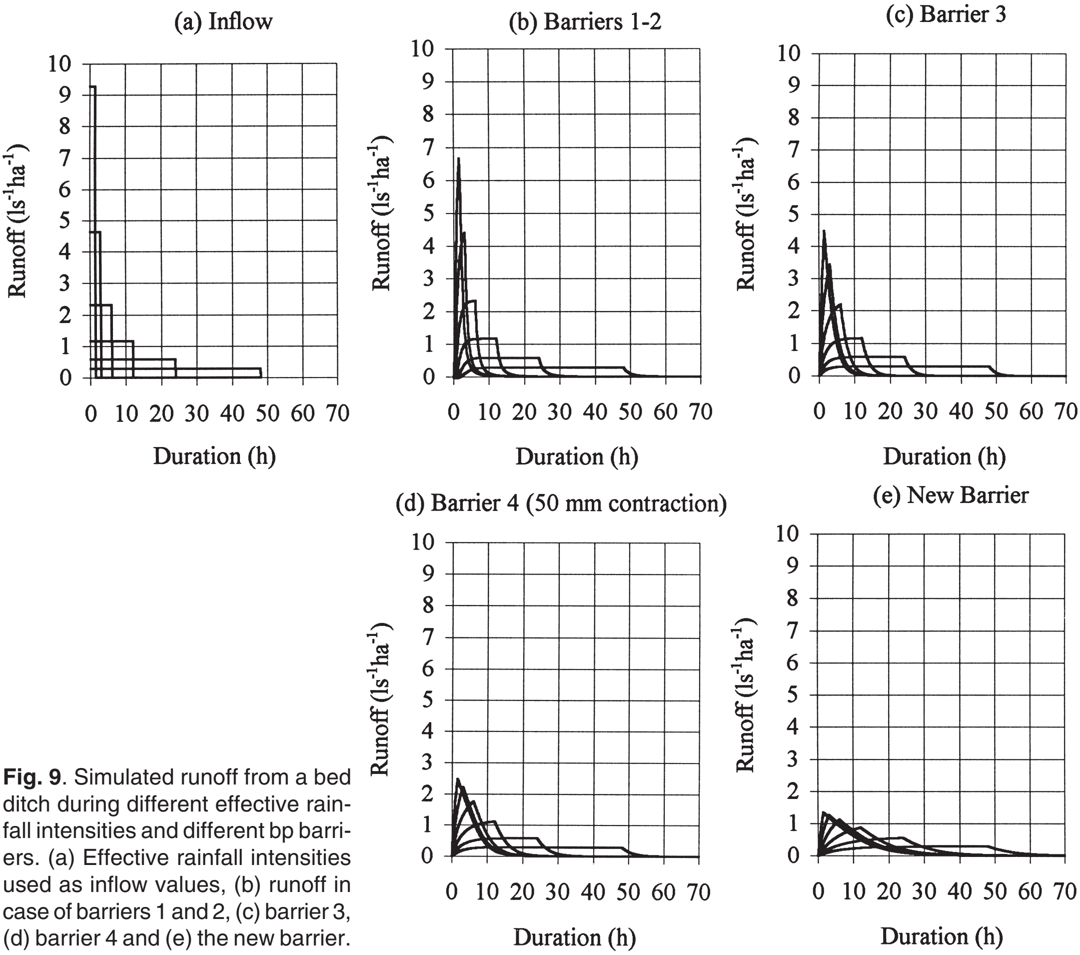

Fig. 9. Simulated runoff from a bed ditch during different effective rainfall intensities and different bp barriers. (a) Effective rainfall intensities used as inflow values, (b) runoff in case of barriers 1 and 2, (c) barrier 3, (d) barrier 4 and (e) the new barrier.

ceeds the effective rainfall. In new mines, the bed ditches alone can store an effective rainfall of 60 mm which occurs very seldom in Finland. However, runoff detention must be more carefully applied in older mines where the ditch volume is reduced. The final detention policy can be designed to take into account both peat production and environmental issues. Further information is needed on how this method affects the drainage and consequent drying of the soil in order to not affect peat mining.

Conclusions

The capacity of runoff detention is the main property of a barrier for controlling peat transport. No other characteristic have any significant effect. Experiments have shown that if the peak discharge can be reduced from 9.8 l s^{-1} to approximately 1.8 l s^{-1}, the peat transport is reduced by 57%. Such a reduction can be obtained with a new type of outlet structure. Simulations with different storm intensities show that the benefit of this new barrier is most significant during high intensity storms. When the new barrier is used, the maximum runoff would always be below 300 l $s^{-1}km^{-2}$ which is the design runoff for sedimentation ponds.

Barrier types 1 and 2, currently in use do not regulate the flow. Their usefulness is solely in preventing clogging of the bed pipe. They do not prevent the transport of suspended peat. The type 5 barrier which has already been used in some mines, should not be used because of the possibility of zero flow and therefore possible flooding during rain storms.

It is possible to considerably reduce peat transport from mines even with small technical changes. By using a barrier that retains water, the transport of peat into downstream waters can be much reduced. Compared to other water treatment alternatives used in peat mines, runoff detention is the only alternative that works well when pollution loads are high. Because the method is inexpensive it should be possible to include this method in the basic practises of all mines. This would greatly improve the quality of water from drained peatlands.

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