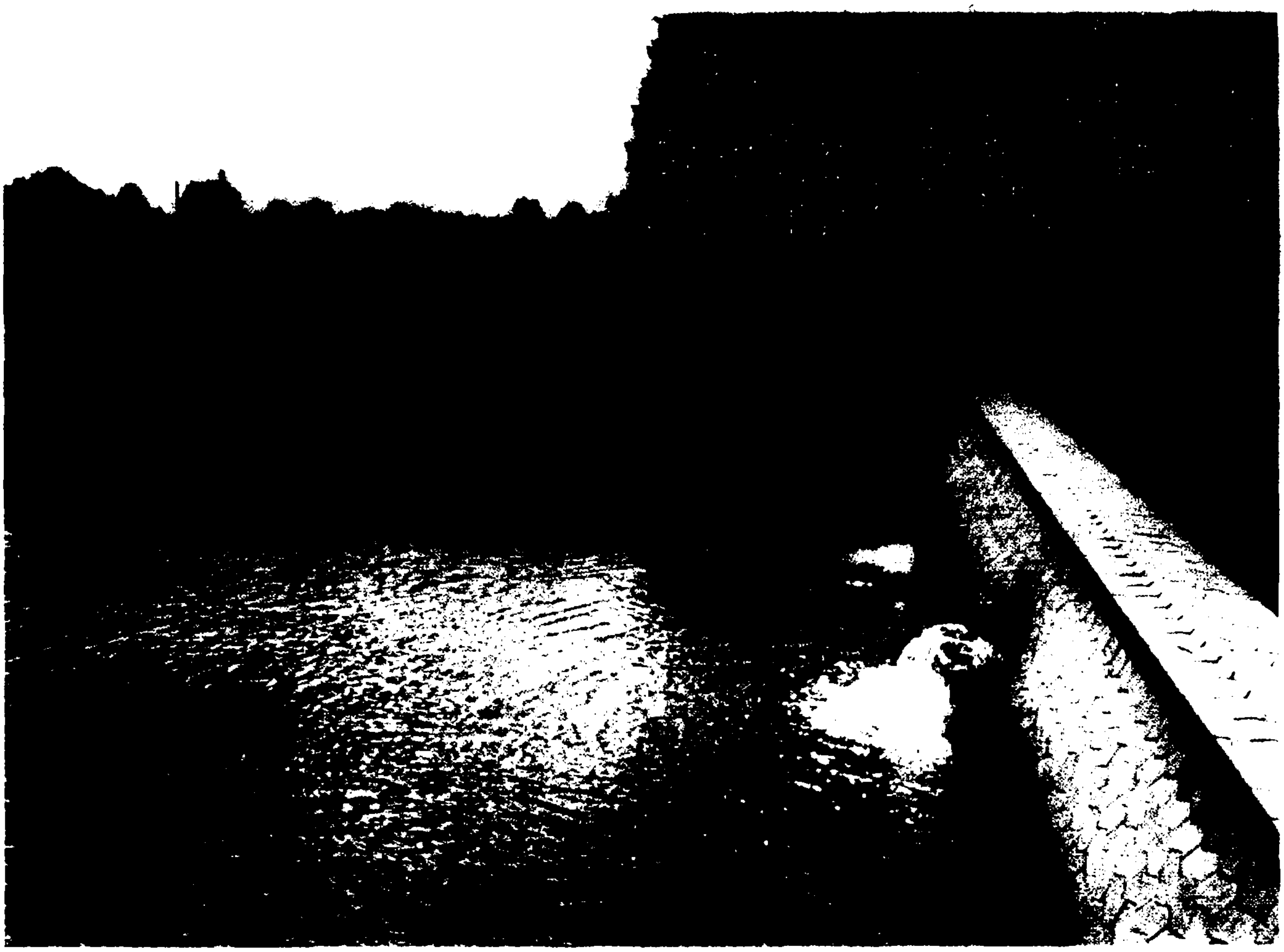
RE – INFILTRATION



A SIMPLE AND ECONOMIC METHOD
FOR TREATMENT OF GROUND WATER
WITH CONTENTS OF IRON, MANGANESE
AND ORGANIC MATTER.

VIAK AB

FACK
S-162 10 VÄLLINGBY
SWEDEN

RE-INFILTRATION*

A method for removing iron and manganese and for reducing organic matters in groundwater recharged by bank filtration.

by

TORGNY AGERSTRAND
VIAK AB, FACK, S-162 10 VÄLLINGBY,
SWEDEN

SUMMARY

Due to geological and climatological conditions in Scandinavia groundwater commonly will contain iron and manganese. When withdrawal of groundwater induces bank filtration from rivers and lakes the content of organic matters will increase and iron often occurs in humic complex. Treatment of such groundwater by oxidation and rapid filtration will normally necessitate the use of other oxidizers than air oxygen or the use of chemical precipitation.

Consulting engineers at VIAK in Sweden have developed a simple method called Re-infiltration for separating iron and manganese, even in humic complex forms, from groundwater. The method means that water is pumped to a suitable area of the aquifer where it is aerated in an overflow cascade and infiltrated to the groundwater reservoir through basins. The basin sandbeds are designed for a filtration rate up to 0.5 m/h to get a retention time for breaking humic iron complex and complete manganese oxidizing. When raw water contains large amounts of iron and manganese, >0.5 mg/l and >1.0 mg/l respectively, it is favourable to add a pre-filter stage before infiltration.

The infiltration will form a volume of purified water in the aquifer. This storage can be used directly for water supply by pumping from wells in the infiltration area.

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The system for infiltration, storage and recovery of water has to be adapted to the hydraulic properties of the aquifer.

Bank Filtration to Esker Aquifers

For municipal water supplies based on groundwater the esker aquifers are mostly used in Sweden. This is because glacifluvial deposits of sand and gravel in the form of eskers are very common and that other rich aquifers, e g sedimentary rocks, only are to be found in few parts of the country.

As shown in Figure 1 an esker is often situated near lakes and may be crossed by a river. Sometimes eskers run into lakes and can be followed as a row of islands. In these situations the esker will obtain a high groundwater recharge induced by bank filtration, when lowering the groundwater level by pumpage, see Figure 2.

Younger sediment (alluvial and postglacial) in Swedish lakes and rivers normally contain organic matters and when water percolates through these layers the oxygen contents will be consumed in processes, which cause carbon dioxide to be dissolved. Under these conditions iron and manganese dissolve from minerals and occur in the groundwater of the esker. Sometimes the iron contents will reach up to 20-30 mg/l and manganese to 5-10 mg/l. The contents of organic components will often increase similarly and measured as $KMnO_4$-consumption more than 40 ppm has been registered.

Due to the induced bank filtration to esker aquifers the groundwater quality at longer or shorter date will cause water treatment problems as a rule by increasing withdrawal. If a water plant is equipped with aeration and rapid sand filtration to remove iron and this changes to humic complex form the treatment will not be sufficient. In order to fulfill the oxidation process other oxidizer than air oxygen can be used but increasing iron contents will give shorter intervals between the backflushing of filtersand. When these intervals are too short it may be necessary to add a sedimentation stage with chemical precipitation, for example before the rapid sand filtration.

If bank filtration causes high contents of manganese (>1.0 mg/l) to the groundwater there can be a demand for other types of rapid filter combined with alkali to raise the pH-value.

Recharge to esker aquifers by bank filtration has consequently a positive side for the draft capacity and mostly a negative side of quality changing which will cause treatment problems.

Re-infiltration

Treatment of groundwater with high contents of iron even in humic complex form and manganese will be successful if the water after aeration is allowed enough retention time for the oxidizing processes to be fulfilled. Based on this thesis engineers at VIAK in 1958 started investigations on an esker auquifer which had deteriorated in quality. The main idea was to use infiltration to the esker in a way similar to artificial recharge. The groundwater was pumped to an aeration cascade and then led to an infiltration basin dug out in the sand-gravel of the esker and partly filled with a sandbed of slowfilter type. The esker water table was situated 2-3 m under the basin and the groundwater here contained Fe <0.05 mg/l and Mn <0.02 mg/l. The Cl-content in the raw water had a value about 20 mg/l and the groundwater at the infiltration place 8 mg/l. Thus the Cl-ions could be used as a tracer.

The first results of this 're-infiltration' were extremely good. All iron and manganese had been removed by the infiltration and the increase of Cl-ions in the vicinity of the basin indicated that a storage of treated water was formed in the esker. Even the $KMnO_4$-consumption was reduced by the infiltration. After two weeks about 10 000 m^3 had been infiltrated with results as shown in Table 1.

TABLE 1 RESULTS OF RE-INFILTRATION

		Raw water	Esker groundwater	
			Beginning	After 14 d
$KMnO_4$-consumption	ppm	12	5	8
Fe	mg/l	2.2	<0.05	<0.05
Mn	"	0.09	<0.02	<0.02
Cl	"	21	8	16

After two weeks the iron contents in the raw water was increasing and had after a month reached values over 3 mg/l. The sandbed surface became totally covered by iron precipitation and algae and iron bacteria were found. In a few days the bed was completely clogged and the experiment had to be discontinued.

The investigations were made in summer and in two days the bed surface had dried and the algae (and iron bacteria) could be removed as a paperlike sheet. The bed sand was rust coloured to a depth of 5-10 cm. After raking the bed surface the infiltration could be run again for a period of two weeks.

The main results of the re-infiltration investigation were:

- the retention time in slow sandfilter was sufficient to oxidize iron and manganese

- organic matter in groundwater could be reduced by using slowfilter sand

- iron contents of 2-3 mg/l were too high to attain sufficient running time

Pre-filter

To reduce high contents of iron in groundwater aimed to re-infiltration simple filters of coarse grained material e g macadam were tried. Several experiments during the early 1960's combined with investigations for re-infiltration applications indicated that by using aeration and a filter bed of 30-50 mm macadam with a retention time of 10-30 min 75-90% of the iron contents could be removed. The success of removal was always coupled to the 'personality' of the groundwater and the higher the contents of organic matter the longer retention time was needed.

Coarse grained macadam showed to be easy to clean out of iron precipitations. In the first oxidizing step iron hydrate will dominate and this voluminous precipitation was possible to wash out of the filter bed by rapid tapping.

Different types of coarse grained pre-filter have been designed and constructed. Some are equipped with perforated pipes on the bottom of the filter for blowing in compressed air during flushing. The efficiency of this is good but the compressed air will cause a more expensive plant. A simple type of pre-filter is shown in Figure 4.

Experiences of Re-infiltration

During the 1960's and 1970's some 40 re-infiltration plants designed by VIAK have been built in Sweden. Almost all are open-air plants of the type shown in Figure 3. When compressed air is used at the pre-filter this sometimes is placed in a building.

The aeration of raw water is in all plants except one accomplished by overflow cascades to pre-filters or direct to infiltration basins. The exception has a purger and spray aerator placed indoors.

By empirical experiences it is found that Fe >0.5 mg/l and Mn >1.0 mg/l requires prefiltering before basin infiltration. Higher values will require removal of the upper 5-10 cm of the sand bed more than 3-4 times/year. Shorter intervals will create problems during the long winter period.

To counteract too rapid clogging of the bed surface caused by precipitation of the iron and manganese and also by the growth of algae and iron bacteria an intermittent running of the infiltration has proved to be very effective. If the sand bed gets a drying time of 6-24 hours followed by a raking of the surface, the voluminous iron hydrate oxidizes to iron oxides and the conditions for algae growth are damaged. This means opening of the pores in the bed surface and prolonging of the time to sand removal.

When the basin water level rises to 0.5 m in a few days it is time to remove the sand. Depending on the quantities of iron and manganese in raw water different thicknesses of the upper part of the sand bed has to be removed. When iron dominates, it will be enough to remove about 5 cm. When the manganese contents are high the oxide precipitation will penetrate deeper and require removal of 10 cm or more. At a plant in southern Sweden, where the raw water only contains manganese the whole filter bed (0.7 m) has to be removed. This operation is however needed first after 3-4 years running time.

When operating with pre-filters it has been possible to use a higher infiltration rate than the normal 0.1-0.2 m/h at artificial recharge. In many cases 0.4-0.5 m/h is used without any problems. This will of course reduce the demand of infiltration areas.

The volume of purified water formed by infiltration to the esker has to be known in extension and depth so the well(s) for clear water can be placed properly. This means that the systems for infiltration, storage and recovery of water have to be adapted to the hydraulic properties of the aquifers. Normally the well(s) will be situated between 2 or 3 infiltration basins.

Bank filtration to esker aquifers often gives a short time (hours-days) for surface water to become groundwater, especially when a river crosses an esker and has eroded the coarse grained layers. In spite of this there have not been any problems of a bacterial kind for wells placed in the area of re-infiltration. It has always been possible to pump water from the clear water well to the municipal distribution net. Alkalization is of course often required.

As an illustration of re-infiltration treatment results three different types of groundwater are shown in Table 2.

Type A — Groundwater of medium hardness from esker aquifer in the Stockholm area (Haninge). The raw water contains small quantities of hydrogen sulphide.

Type B — Soft groundwater from a small esker island in western Sweden (Kristinehamn). (The aquifer is described in Mr G Gustafson's paper to this symposium)

Type C — Very soft groundwater from an esker aquifer in the highland of southern Sweden (Hässleholm). The esker is situated above the highest marine level in a moraine area with bogs and small lakes.

TABLE 2 DIFFERENT TYPES OF GROUNDWATER TREATED BY RE-INFILTRATION, I = RAW WATER, II = CLEAR WATER

		A		B		C	
		I	II	I	II	I	II
pH		7.0	7.1	7.3	6.9	6.3	6.5
$KMnO_4$-consumpt	mg/l	6	1	8	1	12	5
Fe	"	3.9	<0.05	<0.05	<0.05	0.7*	<0.05
Mn	"	0.21	0.01	0.45	<0.01	0.03	<0.01
NH_4	"	0.10	<0.05	0.14	<0.05	0.15	<0.05
NO_2	"	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3	"	0.35	0.88	0.22	0.93	<0.1	0.21
SO_4	"	70	42			10	14
HCO_3	"	63	59	68	61	20	18
Cl	"	11	8	27	28	18	19
Ca	"	34	31	13	13	9	8.5
Mg	"	3.8	3.9	3.4	4.0	1.6	1.9
Hardness	^{o}dH	5.6	4.6	2.6	2.8	1.4	1.7
(Free)CO_2	mg/l	15	1	7	17	28	15

* The iron has humic complex form. After aeration and rapid sand filtration the same value, 0.7 mg/l, remains

The treatment of A and C includes pre-filtering. B is led directly to a basin from an aeration cascade.

As seen in Table 2 not only iron, manganese and organic matters are oxidized by re-infiltration but even ammonia is oxidized to nitrate.

Re-infiltration Capacities and Costs

The 40 re-infiltration plants in Sweden have capacities from a few m^3/day to 7000 m^3/day. Higher capacities are quite feasible and will primarily be a question of the size of the bank filtration recharge. Suitable areas for infiltration basins are quite easy to find e g in former gravel pit areas.

Compared with other treatment methods re-infiltration has proved to be the cheapest regarding both the construction and running costs. In 1976 the construction costs for a re-infiltration plant with a capacity of 3000 m^3/day was only 1/4 of the calculated costs for a rapid sand filter plant. The lower running costs are mainly due to the fact that no other oxidizers than air oxygen is required.

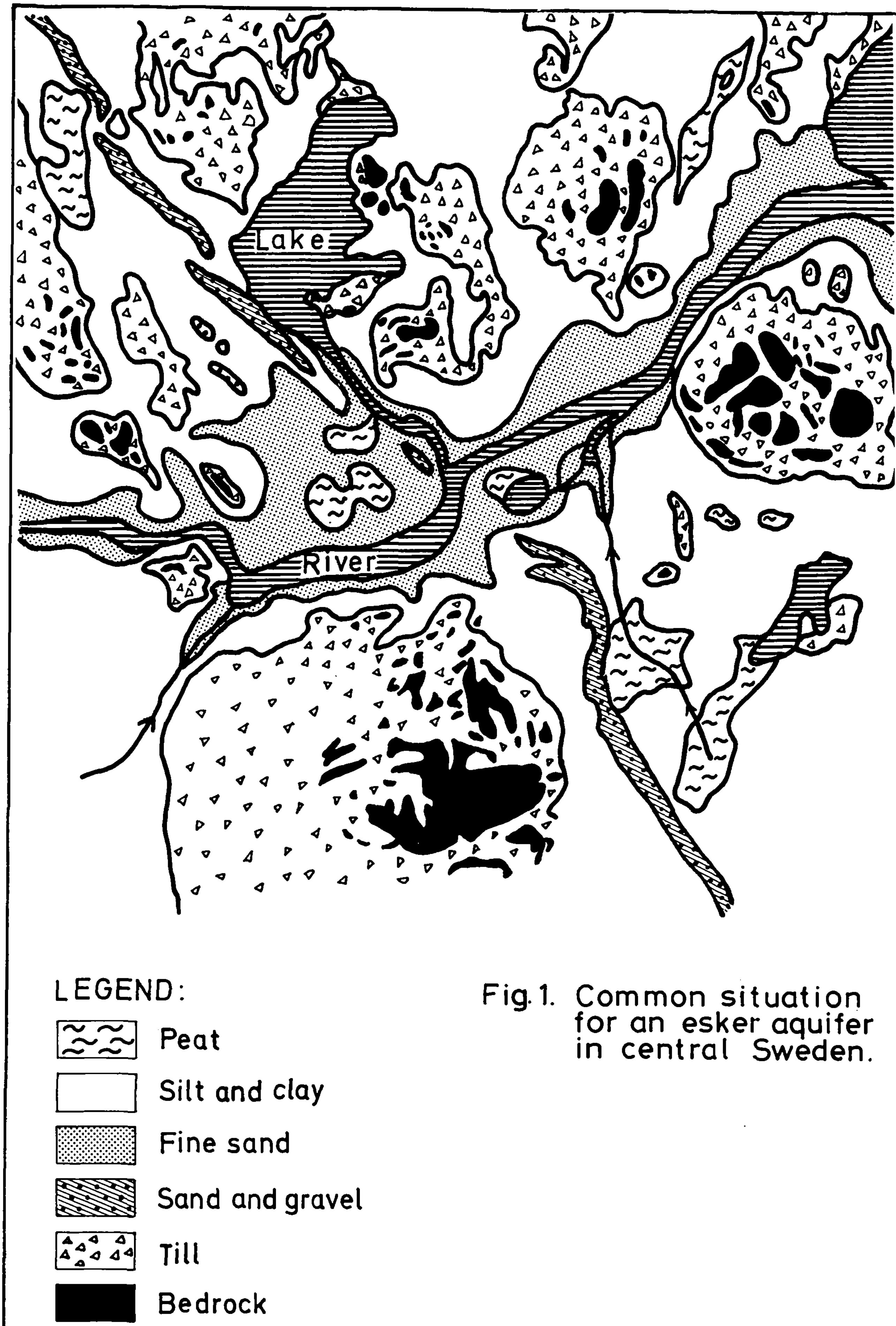

Fig. 1. Common situation for an esker aquifer in central Sweden.

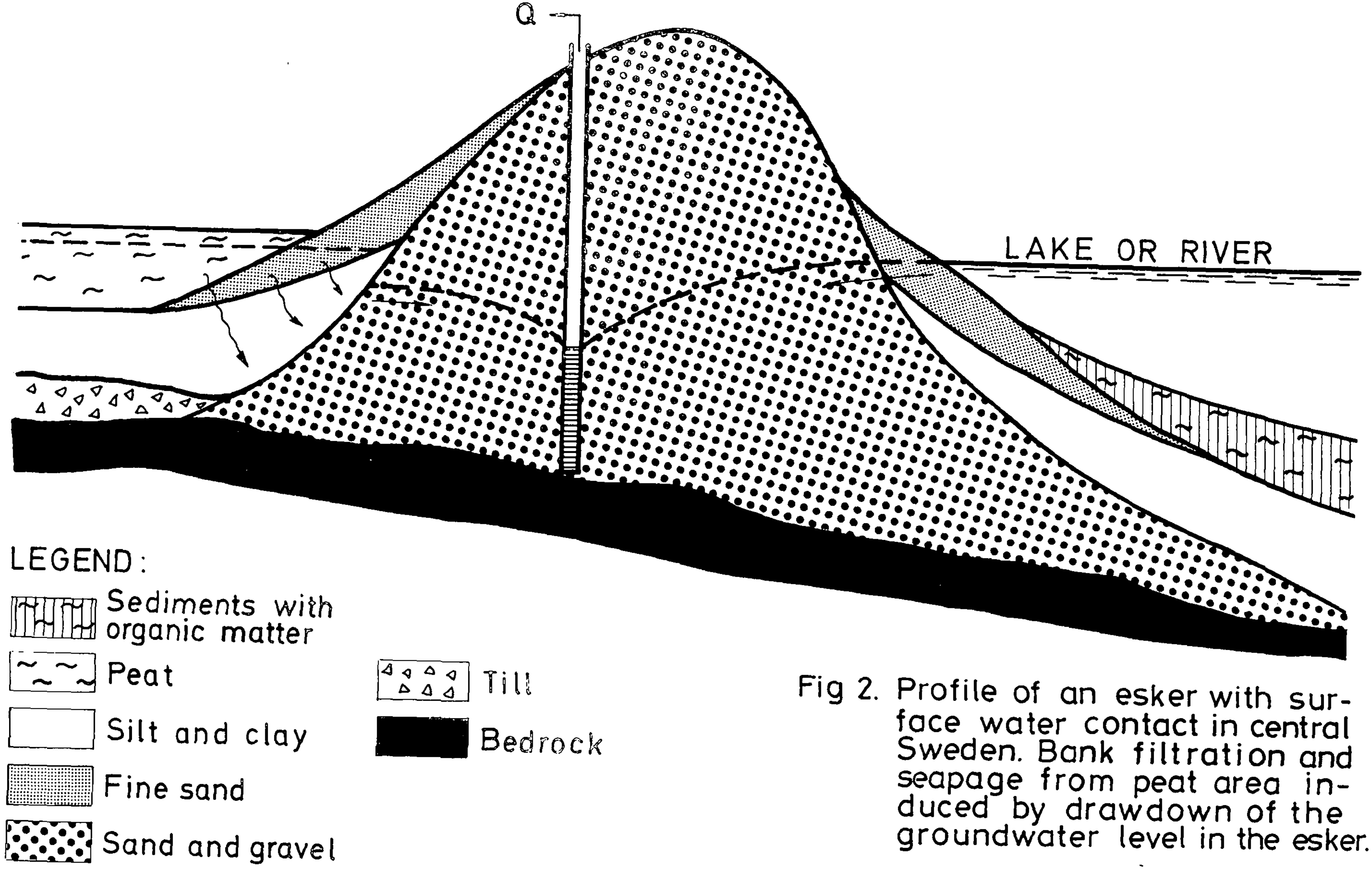

Fig 2. Profile of an esker with surface water contact in central Sweden. Bank filtration and seapage from peat area induced by drawdown of the groundwater level in the esker.

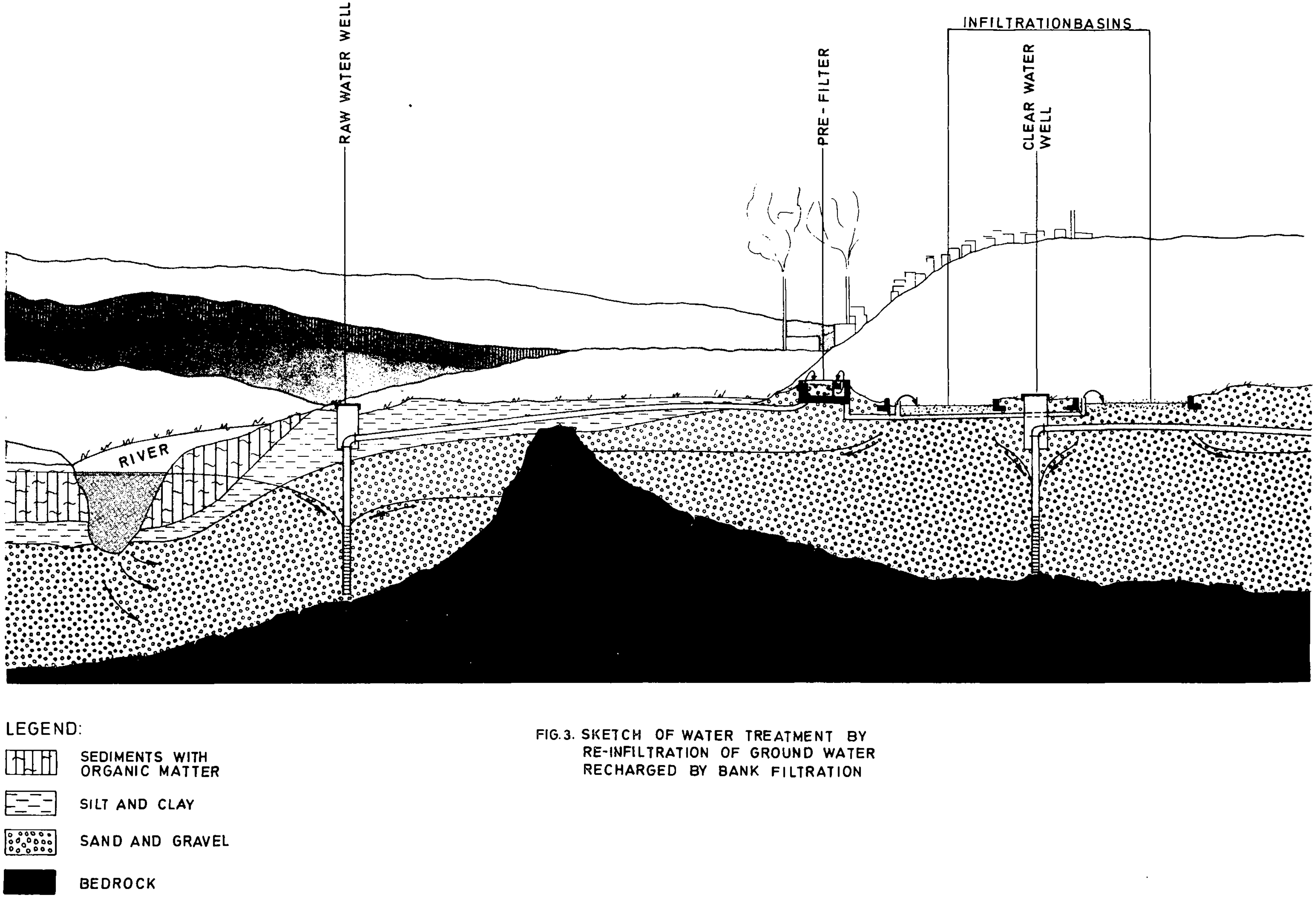

FIG. 3. SKETCH OF WATER TREATMENT BY RE-INFILTRATION OF GROUND WATER RECHARGED BY BANK FILTRATION

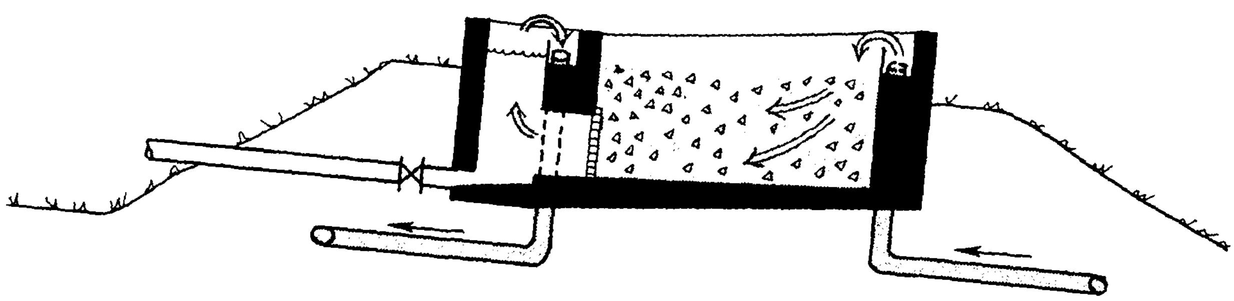

Fig. 4. Sketch of a pre-filter with filter bed of macadam. Flush-ability by rapid tapping.