Problems of Embankments

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Subgrade Failure

Three categories of subgrade failure associated with train loading can be distinguished based on the mechanisms of failure:

1) Massive shear failure.

2) Progressive shear failure (also known as general subgrade failure).

3) Attrition (also known as local subgrade failure).

In addition for tracks placed on embankments, massive failure of the earth foundation under the embankment weight must be avoided. Normally this possibility only needs to be considered for newly constructed embankments.

Massive Shear Failure

Massive shear failure is illustrated in Fig. 1 The driving forces are the weights from the train, the track superstructure and the unbalanced portion of the substructure. The resisting force is from the substructure layer shearing resistance. Because more of the failure zone is in the subgrade, then the subgrade strength properties have a big effect on the factor of safety against massive shear failure.

Progressive failure of the subgrade under repeated loading generally occurs at stress levels below that which will cause massive failure. Hence progressive failure should govern performance. Thus massive failure is likely to be a problem only when the subgrade strength diminishes because of increasing water content. This may occur for example at times of heavy rainfall and flooding. In such situations failure may occur even without train loading being present.

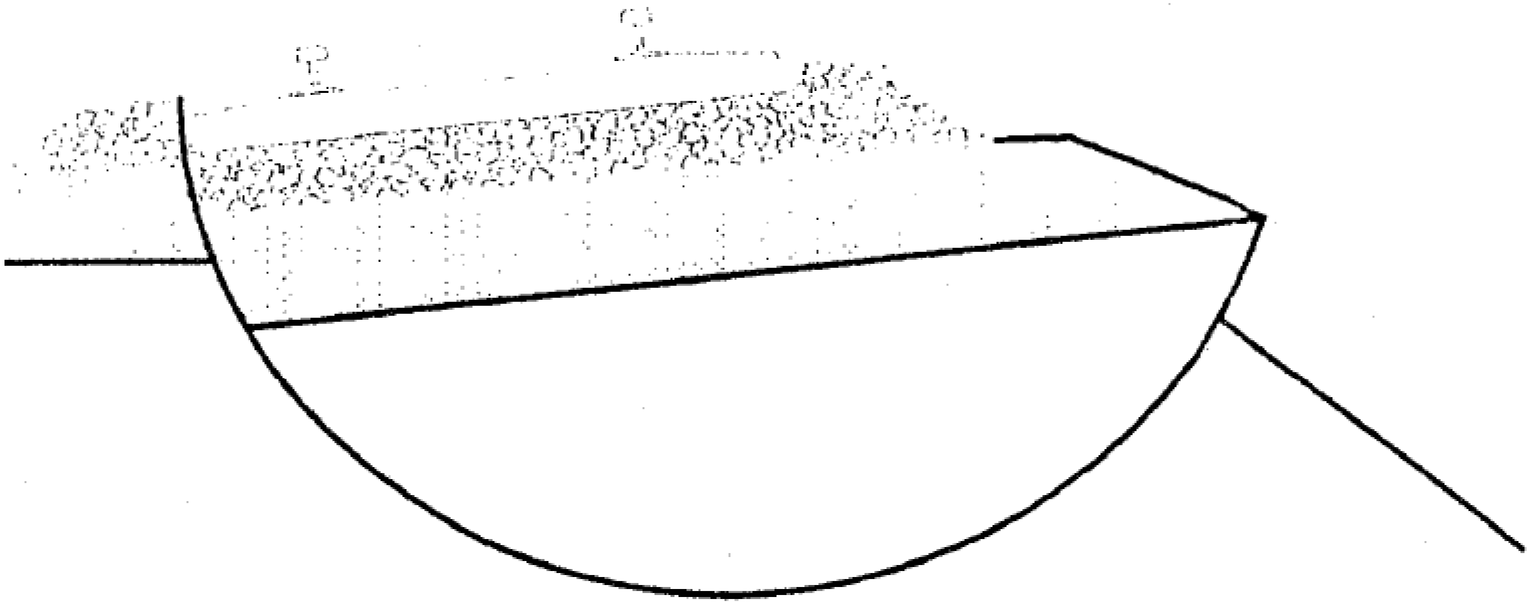


Fig. 1 Massive shear failure

Figure 2 shows cross-sections through a number of slopes that have sustained a slip failure in which the materials above and below the slip plane have moved with respect to each other resulting in shear. If the slip plane extends beneath the track, such movements will disturb the track geometry.

The prime requirement is the location of the slip plane. Once located, it is possible to confirm that the plane extends beneath the track, and thus, that the track movements being experienced are attributable to this cause. Simple, and widely used methods of directly locating a slip plane, and confirming that the slip is still active, are available.

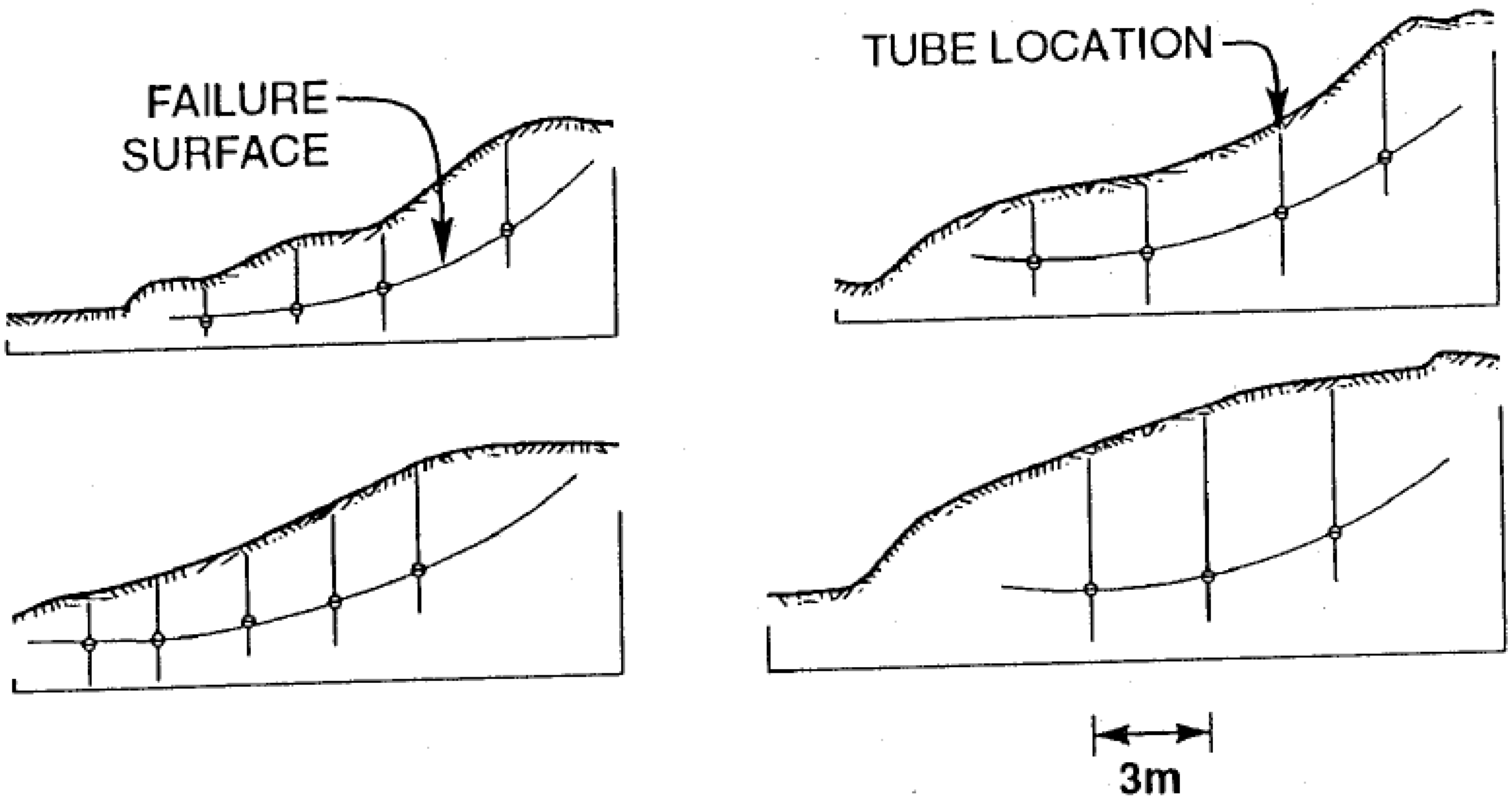


Fig. 2 Slip failure surfaces identified by tube method

For non-cohesive materials a driving dolly is used to drive a length of 19 mm (3/4 in.) diameter steel tubing, provided with an expendable point, vertically into the slope to a depth in excess of that at which it is considered the slip plane will be located. A length of plastic tubing (as used in domestic plumbing) is passed down the tube. The steel tubing is withdrawn, leaving the steel point in position.

For cohesive materials solid rodding, provided with a pointed end, is driven as described above. The rodding is withdrawn and the plastic tube is passed down the unlined hole formed by the rodding.

After a period of time, dependent upon the rate of movement of the slip, deformation of the plastic tubing will occur at the slip plane as a result of shear associated with relative movement of materials above and below the shear plane. This point is located by using a cord to lower a short steel mandrel down the center of the plastic tubing until the deformation point is reached-- the length of cord required being equal to the depth of the slip plane.

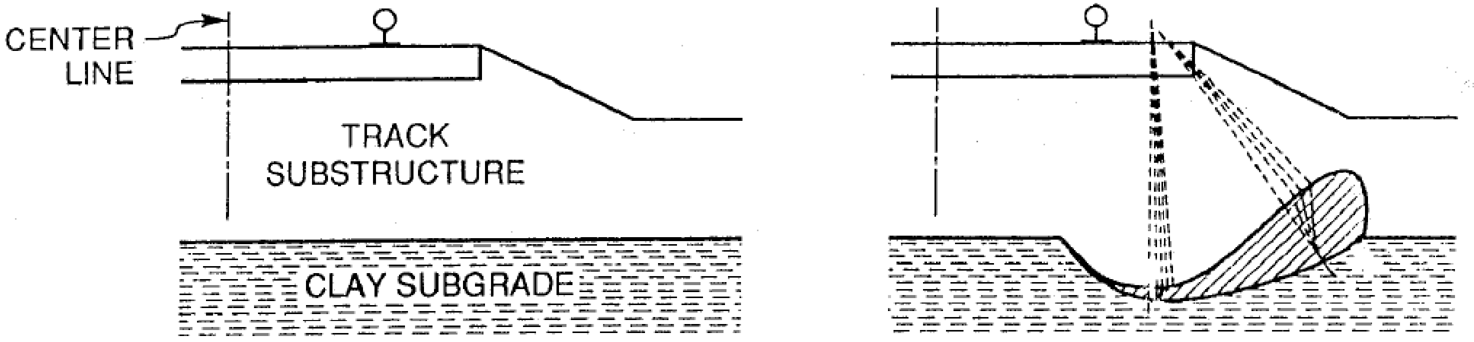
Figure 2 shows examples of circular and non-circular slip planes located in cut and embankment slopes by this technique, together with an indication of the points at which movement was detected.

Cut slope stability problems often arise because of ground water seepage into the excavated slopes. Other problems are weathering of freshly exposed soil and rock, and volume changes in expansive clays.

Progressive Shear Failure

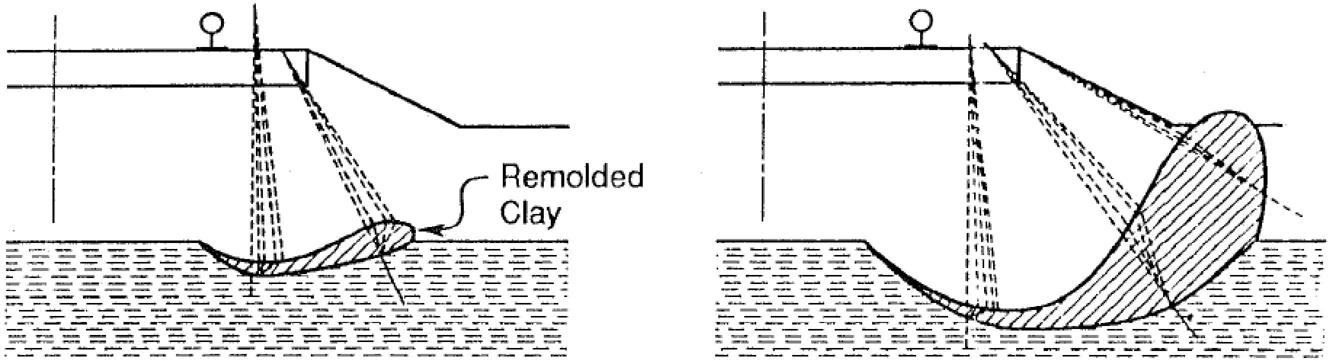
Stresses imposed on the subgrade by the axle loads may be large enough to caus progressive shear failure (general subgrade failure). This condition will most likely develop in the top part of the subgrade where the traffic induced stresses are highest. Overstressed soil will be squeezed sideways from beneath the track and upwards to give the bearin capacity failure known in the United Kingdom as 'Cess Heave'.

Figure **3** shows diagrammatically how overstressed clay is progressively squeezed sideways and upwards. Figure **4** is a photograph of a section through a cess heave during its formation. Figure **5** is a photograph of a section through a fully developed cess heave.



(A) STABLE SITE

(C) GROWTH OF HEAVE



(B) ONSET OF INSTABILITY

(D) SURFACE MANIFESTATION OF HEAVE

Fig. 3 Movement of overstressed clay

Fig. 4 Fully formed cess heave

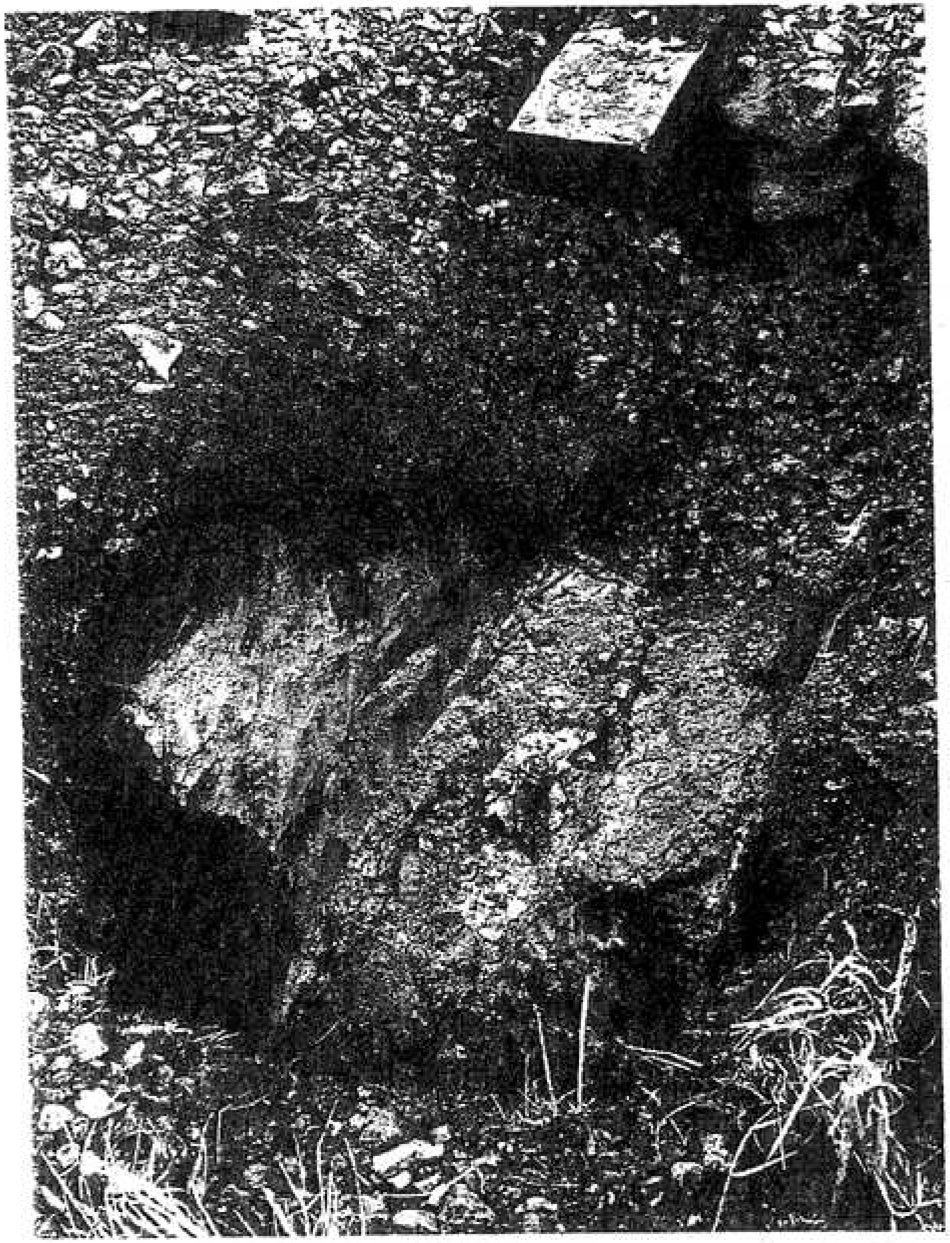


Fig. 5 Cess heave during formation

Figure 6 shows how three initially straight columns of segmented tubing have been distorted by the further development of a general subgrade failure. The columns of segmented tubing were initially installed by threading them onto a straight steel rod and then driving them into position

Fig. **6** Distorted columns indicating cess heave failure

Once in position, the rod was withdrawn, leaving the segmented tubing in position. After a period of several weeks, the trench was excavated alongside the tubes to expose them as shown in the figure.

From a study of this, and a number of similar observations, it became clear that in this mode of failure soil movements are as indicated in Fig. 3

The segmented tube technique described can also be used to establish whether or not a subgrade failure is taking place. To do this, columns of segmented plastic tubing are driven into the suspected failure site as described above. After a period of some weeks, the initially straight column of tube segements is probed with a straight rod. The location of an obstruction will indicate a distortion of the column of tube segments caused by an active 'cess heave'.

Figure 7 shows the disruption which is often caused to the track side drainage system as a result of cess heave. The heave can either physically destroy the track side drainage and/or, interpose an impermeable wall between the track and the drainage system, thus rendering it ineffective. Clearly, deprived of its drainage path, the water table within the track can rise resulting in an aggravation of the condition which originally gave rise to the cess heave.

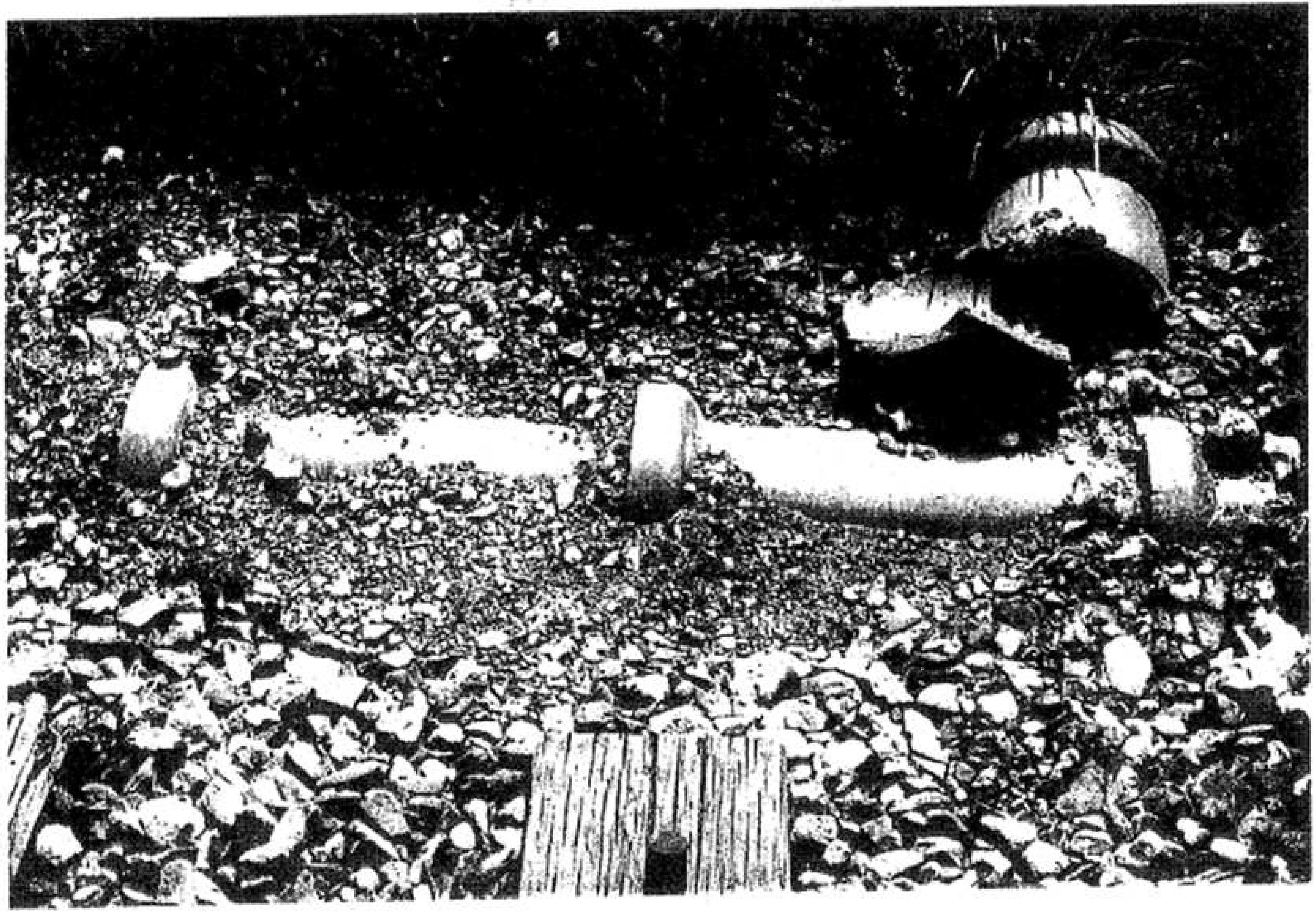


Fig. 7 Disruption of track drainage from cess heave