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EMBANKMENTS AND FOUNDATIONS—TORONTO-SUDBURY BRANCH C. P. R.

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(To be read at a meeting of the General Section, 1911.)

The Toronto-Sudbury Branch of the C. P. R. was constructed in the years 1905-1909, and as the standards were of a very high type they may contain some points of interest. No curves over four degrees were allowed, and the grades were limited to 3/10% compensated. These grades were successfully maintained, with the exception of a pusher grade of 8/10%, for some miles near Tottenham mile 37. This difficulty will eventually be obviated when traffic demands it, by the substitution for freight purposes of 8 miles of 3/10% track for the present 3 miles of 8/10%. Velocity grades were allowed within the limits of 10 and 30 miles per hour for freight trains.

The intention of the company was to insure a thoroughly solid road bed, rather than to keep initial expenses at a minimum, and as the greater part of its 225 miles ran through a rock and muskeg country, there was frequently some difficulty in attaining this result. This article, however, will deal only with the district between miles 22 and 182, north from West Toronto, from Bolton to Byng Inlet, as this was the part with which the writer became personally familiar during his four years' experience on the work.

The line may be divided into two sections, viz., the earth district and the rock district; the first running from mile 22 to 92, and the second north from mile 92 to mile 248.

On the south, or earth section, little difficulty was encountered either with foundations or embankments. Eventually all streams and gulleys will be bridged either by steel viaducts, or by concrete arches and embankments, but at the time a number of permanent timber trestles were built, several of them containing an average of 500,000 F. B. M. The bents of these trestles rested on piles driven to an average depth of 20 ft. or more, and the only settlement that has occurred has been on the ends of the trestles, where the bents rested on mud sills on the made embankment.

A curious instance of an over refinement of engineering occurred at the Nottawasaga River trestle. The trestle is about 700 ft. long with a maximum height of 110 ft., and is located on the short tangent between two reverse curves. The trestle itself has an average elevation of 10 or 15 ft. below the general track elevation in the immediate vicinity. This is overcome by the use of 2,000 ft. of velocity grade of 6 or 7/10%, resulting in a high rate of speed for the consolidated locomotive that passes over it. This will easily be remedied, however, when the trestle is replaced by a steel viaduct, either by building the viaduct higher or by slightly reducing the little summits adjacent to it. The curves also may be somewhat lessened by turning the new viaduct in a direction more nearly parallel with the tangents.

In the earth section water openings were either concrete or glazed tile pipes for small drainage areas, with concrete arches for larger ones. The pipes, on the whole, were very satisfactory, except that in a number of instances insufficient allowance had been made for their becoming reduced in area by being partially filled with water-washed sand; it was therefore necessary, under these circumstances, to replace 18 or 24-inch pipes with 4 ft. arches. The rule was to "camber" as high as the drop would allow, and the adjustment of the soil under the embankment was usually sufficient to take out quite a large curve, as "shrinkage" seemed to be due not only to the settling of the deposited embankment, but chiefly to the sagging of even firm clay in such a way as to cause a low spot in a pipe laid flat, and the consequent tendency of the pipe to clog. The culverts were the standard 1905 and 1906 types of concrete arches made in 20 ft. sections, to allow settlement. Piles were used in exceptional cases, a row under each side, but the general practice was to divert the stream far enough to secure firm soil.

In the rock country, practically all openings of eight feet or less were built up of the excavated rock and laid without mortar, those over four feet in width being made double, with the top constructed of flat lintel stones. These proved entirely satisfactory in the great majority of cases, as they were laid on solid rock a little to one side of the original stream.

We will now proceed to deal with the rock section, discussing particular points in the order of their mileage from the south end. At mile 102, near Buckskin, a rock embankment about 10 ft. high crossed a fairly dry muskeg, in which the rock was about 50 or 60 ft.

down. No cross waying was ever permitted, as the intention was to have the rock embankment cut its way through the thin mattress of the dry surface of the muskeg; in this case the rock remained on the surface for about a year, and then gave way during train filling. Some time was spent in filling it, as its depth allowed the train gravel to move sideways, but eventually bottom was reached after 3,000 Hart car loads of gravel had been placed in it. The only real objection to its sinking, when it did, was that the gravel used was high grade surface gravel which had to be hauled about 40 miles, as track laying had not then proceeded far enough to reach the more northerly, and thus more convenient, sand pits.

The only midway divisional point was at Muskoka, mile 126 from West Toronto. As this point was in the rock district the grading for it was rather heavy, the finished yard occupying an area, apart from the main passing siding, of about 3,000 x 300 ft., much of which was solid rock that had to be lowered about ten feet. Water was obtained from the nearby Stewart Lake, but, as it is not allowable to pollute the Muskoka waters, the sewers had to drain into the swamp on the other side of the track.

The general mode of procedure through the rock country was to make the rock cut only about a third of the embankment, as this quantity of rock would have sufficient weight to cut its way vertically through the mattress, and as soon as bottom was reached the remainder could be made by train filling. The efficiency of this method of forcing the sink holes through is shown by the fact that, train filling once completed, the percentage of derailments has been at least as low on this new road bed as on that of sections twenty years old or more. This brings up an important question. If the intention is to have the weight of the rock cut its way through the mattress, and as it is only when it has done so and reached solid bottom that the earth filling becomes really effective, would it not be advisable, in some instances, before placing the rock fill, to cut right through the mattress parallel to the centre line, for instance, in the case of a thirty foot embankment, to cut two longitudinal ditches forty feet apart, and thus allow that whole section to sink vertically without deforming the surface at the side? Almost every case of deformation is caused by the sand or gravel floating sideways, and it does not become solid for some time.

Depressed temporary grades of 3% were allowed. In many cases small hillocks of rock were cut away to allow the temporary grades to descend to the center of the larger gulleys.

At mile 124, during train filling, a low rock embankment, while carrying an engine, gave way suddenly, and the engine sank with such force as to shear the nuts in the track for a distance of 1,000 ft. or more. Between miles 112 and 142 a number of embankments were train filled from temporary trestles, and little trouble was experienced, although in many cases it was found necessary to lower the level of adjacent small lakes in order to give more solid bearing to the toes of the slopes.

At Richmond Lake, mile 101, south from Romford, the lake level was about fifty or sixty feet below the level of the track. A rock embankment rested firmly on the solid rock below, but was not carried up to grade, a trestle being used above water level. The water would probably seep through the rock fill, but, in the event of its not doing so, it would easily flow through the trestle at high water. At mile 76, south from Romford, occurred one of the heaviest train fills of the line, the depressed grade being no less than twenty-five feet at a maximum below the final grade, and as it was necessary in filling to cover the toes of a rock embankment up to thirty feet in height, at least a quarter of a million yards of earth must have been used in this one-half mile of fill.

At mile 75.5, south from Romford, a temporary trestle beside a lake had been train filled, but the water had apparently dissolved the embankment and caused lateral slipping. The lake was small, and the lowering of its level about four feet left the toe dry and firm.

In many instances where a comparatively dry muskeg was to be crossed, provision was made for thickening the dry supporting mattress by ditching and lowering the level of the water table. This was generally effective, provided there was solid soil in the mattress, but not invariably. At mile 70.5 from Romford, the track crossed a muskeg about two thousand feet long and from twenty to forty feet deep, with an embankment when completed about four feet high. A drainage ditch was dug, leaving the water table only about four feet below the level of the surface soil. The track crept very badly and made "sun kinks," elevations taken during the passage of a train showing track undulations of one or two-tenths. The track was made safe for traffic and prevented from creeping by the substitution of 14-ft. bridge ties; later it was diverted to a side hill of solid rock and made thoroughly solid.

At mile 66.7, south, in order to make secure a muskeg, which for its length gave considerable trouble, a depressed grade was built, with a rock embankment about 10 ft. high, the lowest point of which was a maximum of about 20 ft. below the intended finished grade. In this case, although soundings showed a depth of 50 ft. or more to bed rock, the weight of the rock embankment was not in itself sufficient to slice through the surface mattress. This was somewhat unfortunate, as it was always found that although earth alone would eventually reach a firm foundation, yet, owing to its specific gravity being so low, it had a great tendency when placed by train filling, to move horizontally rather than vertically, causing the mattress to bulge upwards for some distance out from the toes of the slope.

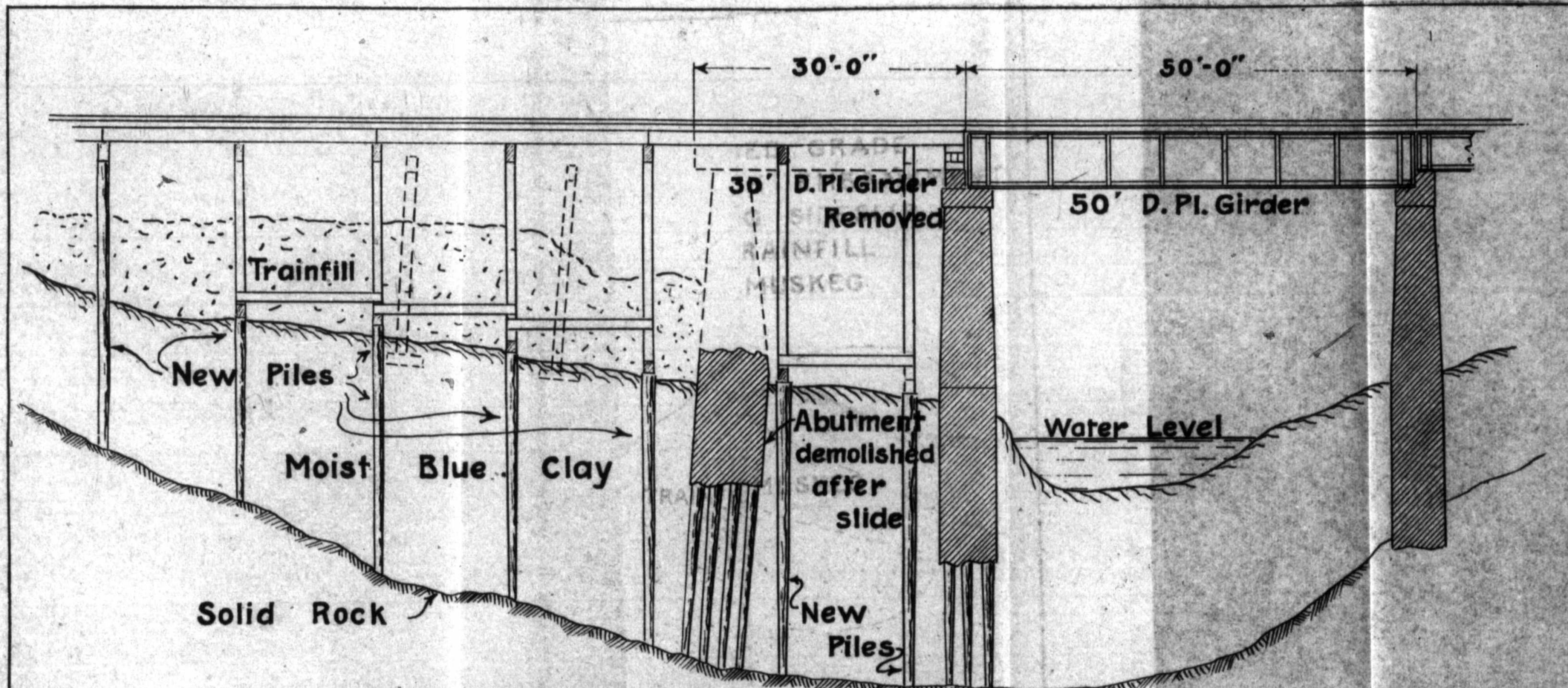
The writer was not present until the completion of the filling of this sink hole, but although it had a length of only 600 ft. and had to be lifted to a height of 20 ft. above the depressed grade, a fill of 30,000 yards had raised it only 3 ft. Fortunately, by the use of spreaders, the embankment while sinking retained a good surface and alignment, and no difficulty was experienced in running passenger trains over this temporary velocity grade.

The next large fill occurred at the crossing of the Magnetawan River, the valley of which was about 3,000 ft. wide. With the exception of three girder spans this valley was crossed by a timber trestle about 40 ft. high. In this case the length of the trestle helped to reduce the unit cost of filling, as it was possible to fill from temporary grades placed on each side of the trestle, and thus leave the main line open for traffic.

It might now be interesting to mention a few of the bridges, with reference to foundations. On this 160 mile section, with two exceptions, there were no steel bridges larger than plate girders; the exceptions were at the Severn River, where there was a 200 ft. through Pratt Truss, and at Parry Sound, where there was a viaduct 1,700 ft. in length. The largest span consisted of two Howe Deck Trusses of 165 ft. span. In the earth district all concrete was carried below frost line and rested on piles; while in the rock country the piers in almost every case rested directly on the rock itself.

During the construction of the Parry Sound Viaduct a simple method was adopted to eliminate delay. The track was paralleled at the points by the C. N. O. Ry., and running rights, or rather haulage rights, were given by that railway over a four mile section through Parry Sound. In this way it was possible to lay some twenty miles of steel north of the Sound during the construction of the viaduct, at the same time leaving the bridge contractors a mile or more of blind main line for bridge yard purposes. The only difficulty occurred at one of the abutments at the South Nascoutyong River. In this case the abutment was carried to a depth of 10 or 15 ft. below the surface of the ground, and piles were then driven to bed rock, about 20 ft. further. Back of the abutment was a temporary trestle about 30 ft. high resting on mud sills, the soil being an alluvial clay which was kept moist by the presence of a stream less than 100 ft. away. No trouble was experienced with the abutment until train filling had proceeded for some time on the temporary trestle, when the earth filling caused a flow of the clay sub-soil, and although the bases of the piles remained in their places on bed rock, the flowing of the clay caused the abutment to tilt forwards, necessitating its demolishment. No further attempt was then made to fill the embankment, but piles were driven and a trestle constructed, both in place of the temporary trestle, and also between the abutment and the next pier, the new trestle replacing a short girder span.

In this case, even if the pier had been constructed just as it was, had piles for the temporary trestle been driven at once, the clav might possibly have been so firmly anchored that there would have been little, if any, horizontal movement.



Bridge Abutment Resting on Piles
Demolished owing to Sliding of Blue Clay Soil
During Trainfilling

PLATE I.

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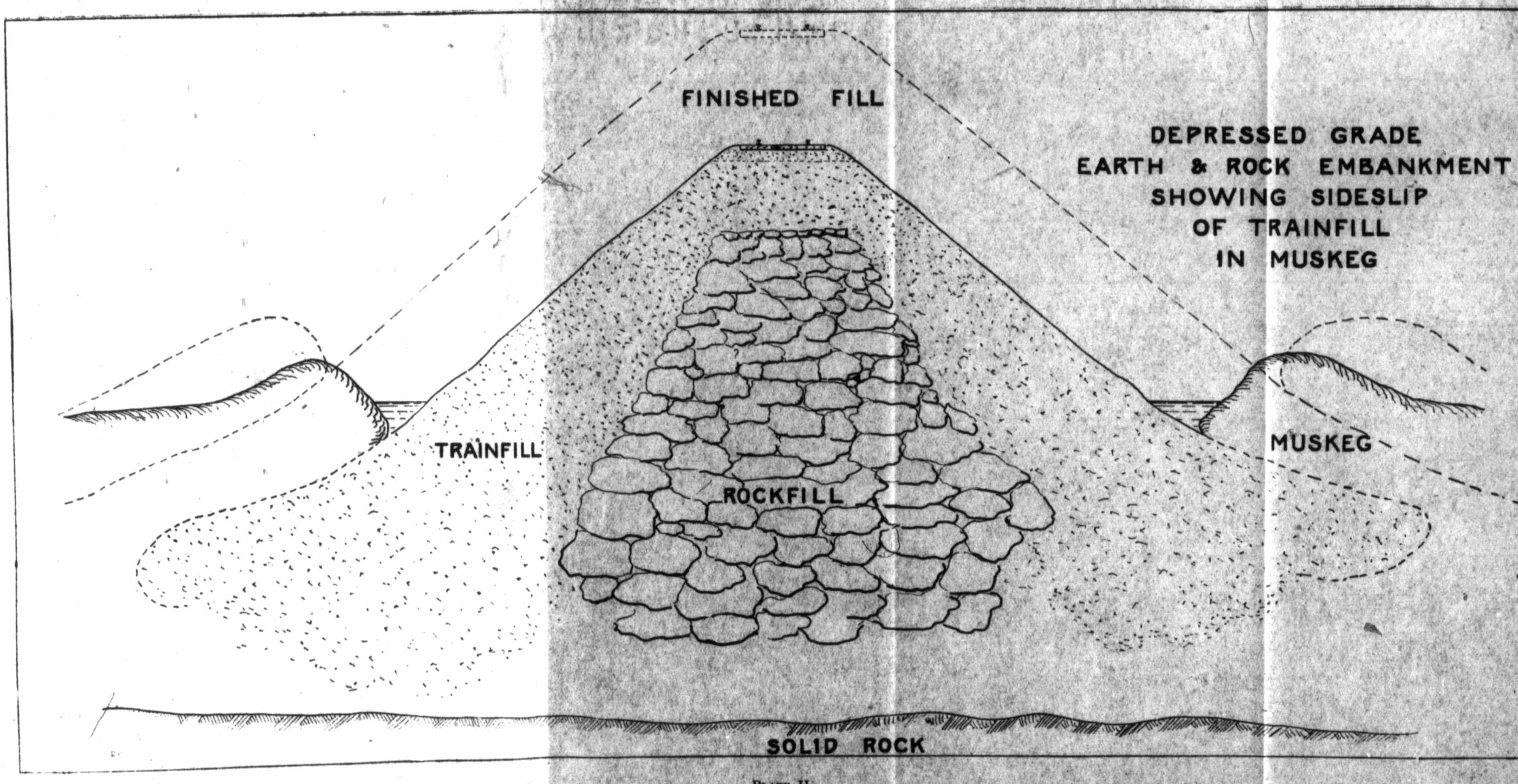
FINISHED FILL
DEPRESSED GRADE
EARTH & ROCK EMBANKMENT
SHOWING SIDESLIP
OF TRAINFILL
IN MUSKEG
TRAINFILL
ROCKFILL
MUSKEG
SOLID ROCK

Plate II.