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by

C.B. Crawford and W.J. Eden

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PREFACE

As an indication of the importance of landslides to building in Canada, the Associate Committee on Soil and Snow Mechanics of the National Research Council in 1953 formed a subcommittee on "Canadian Landslides". About the same time the Soil Mechanics Section of the Division of Building Research began a literature search on Canadian landslides, and field studies were begun on a modest scale. The Nicolet landslide of 1955 presented the first opportunity to study a "flow" type slide. A brief visit was arranged and this report presents the results of reconnaissance and soil tests.

Since this investigation was carried out, others have published papers listed in the references, on the Nicolet slide. The work of Hurtubise and Rochette in particular was carried out in much greater detail and was reported subsequent to the preparation of this report in a preliminary form in July 1956. The record which is now presented is substantially that of the earlier report, giving the comments and discussion which at that time seemed appropriate.

Ottawa,
August 1957.

N.B. Hutcheon,
Assistant Director.

REPORT ON THE NICOLET LANDSLIDE OF NOVEMBER 1955

by C. B. Crawford and W. J. Eden

Just before noon on November 12, 1955 a disastrous landslide occurred on the north bank of the Nicolet River at the village of Nicolet, about 2 miles upstream from the mouth of the river. Three lives were lost and damage was estimated at several million dollars. From even the first reports it was known that this was a "flow" type of slide common to the marine clay deposits of the St. Lawrence and Ottawa River Valleys. The last landslide of this type to attract wide engineering interest occurred in August 1951 at Rimouski, Quebec, but similar slides are recorded with alarming frequency in the geological literature of the last 100 years and innumerable slides have been recorded over the centuries by the scar-studded river banks of the St. Lawrence drainage system.

In view of the great engineering interest in determining the cause and understanding the mechanism of these "flow" slides, the Division of Building Research is anxious to accumulate precise historical records of every major slide occurring in the marine clay. Due to certain circumstances it was not possible to visit the site of the Nicolet landslide until several months after it had occurred. In the meantime three reports, had been prepared (1, 2, 4) on the landslide and these were made available to the Division by Brigadier J. P. Carriere, Chief Engineer of the Harbours and Rivers Engineering Branch, Department of Public Works. The reports were studied in advance of a visit to the site of the landslide by members of the Division of Building Research on May 25th, 1956.

The Slide

Fortunately, during the summer of 1955, aerial photographs of Nicolet were made and, just a few days after the slide, the area was rephotographed. This has made it possible to study features of the slide both before and after the failure. Figure 1 shows an aerial view of the slide and Fig. 2 is a sketch made from this photograph showing the crater, the relative position of structures and vegetation before the slide, the general outline of debris after the slide and the approximate distribution of structural and vegetal debris after movement.

In the one-day visit, it was impossible to make more than a general reconnaissance of the area and obtain a few soil samples. It was unfortunate that the visit was not possible until approximately 6 months after the failure since the significant features of the flowed material had been destroyed during this interval. The mode of failure however, can be inferred from a study of aerial photographs.

Site Investigation

Soil conditions at the site of the slide consisted of a cap of stratified fine sand about 8 feet thick overlying a stratified grey clay. This clay extends from about elevation 45 to elevation 18. At elevation 18 the clay becomes darker in colour with black mottling. The total thickness of clay is from 90 to 100 feet.

Boring No. 1 (see Fig. 2) was put down by the river's edge near the northeast edge of the mouth of the crater from elevation 28 to elevation 13. Boring No. 2 was located near the crest of the river-bank south of the crater. It extended from elevation 50 to elevation 35. A third boring was made in the slide crater to obtain a sample of the clay involved in the slide. Eight samples were obtained using a 3-in. Ø piston sampler.

The samples were transported by automobile to Ottawa and subjected to strength, consolidation and classification tests. Test results are summarized in Table 1. Generally the clays contain a high percentage of clay-sized particles and have a natural water content above the liquid limit. Sensitivity measurements place the clays in the "extra-sensitive" to "quick" class. The activity of the clays suggests that the clay fraction has a large amount of inert minerals or rock flour. Salt concentration in the pore water of the clays was measured to determine whether or not leaching of the salt could have been a contributing cause of the slide.

The salt concentration of the clays in hole No. 1 varied from $6\frac{1}{2}$ to 11 gr/l while that of holes 2 and 3 was less than 1 gr/l. A significant difference in salt concentrations was revealed but because no reliable estimate can be obtained as to the original salt concentration of the clays, it cannot be proved that leaching had taken place.

Dr. N. R. Gadd of the Pleistocene Section of the Geological Survey of Canada was consulted concerning this point. He considered that clays in the Nicolet area were deposited in brackish water of unknown salt concentration. Clays with black mottling were laid down in stagnant waters with a relatively high salt concentration. Stratified clays suggest a considerable influx of fresh water and could be expected to have a lower salt concentration. He did not rule out the possibility that leaching had taken place in the upper portion of the clays.

Consolidation tests show the clays to be lightly overconsolidated. Shear strength determinations indicate the upper clays (hole No. 2) to have a cohesion of about 550 lb/ft^2 and the lower clays about 1000 lb/ft^2. These results have been confirmed in general by recent vane and laboratory tests.

In summary two types of marine clay are present at the site of the landslide; an upper stratified clay with a very low salt concentration and a lower grey clay with black mottling and a salt concentration of about 8 gr/l. Both clays were slightly overconsolidated, extremely sensitive and have a liquidity index greater than one. The soil involved in the landslide appeared to be mainly the upper stratified clay although the failure plane may have been in the lower clay.

Mode of Failure

The delay in visiting the site has complicated the interpretation of the sequence of events which resulted in the landslide. It has not been possible to obtain eye-witness accounts, which would be of uncertain value anyway, because of the confusion at the time of the failure. There are indications that the initial failure occurred at the upstream end of the present throat of the slide and it is believed that the direct and immediate cause was probably due to the construction being carried out at that point. Probably the initial failure was similar to a conventional circular slip involving only a limited amount of material in the river-bank. Slides in this sensitive marine clay are known to retrogress by failure of successive slices until equilibrium conditions are reached. There is no reason to believe that the Nicolet slide did not fail in this manner. As a matter of fact, eye-witness accounts reported elsewhere have indicated that this type of failure did occur.

A study of the aerial photographs and of the debris in the river suggests a series of events which describe the progression of the slide. In Fig. 2 the original position of a grove of trees is shown and the final location of some of these trees is plotted in the debris. The approximate limits of the debris of the garage and school are shown. Of particular significance is the final location of rip-rap at the upstream extremity of the slide. The position of the moved rip-rap indicates a rotational movement like the opening of a gate. Also the orientation of large blocks of clay give some indication of the direction of movement. From these observations it is believed that the initial movement occurred at the upstream edge of the slide with material moving straight out into the river and flowing either way. This would be followed by retrogression until the grove of trees moved out into the river and was deflected downstream by previously flowed material. The final location of the debris of the garage suggests that it was swept away after part or all of the grove of trees had slipped into the river since it appears to have been confined to a path along the river-bank by previously flowed material. The school structure, located north of the garage, apparently followed the path of the garage until movement stopped. Finally, two occupied houses (Dr. Roy and Dr. Vigneault) and a portion of the Bishop's Palace which were destroyed by the slide, moved through a relatively short horizontal distance. Dr. Roy's house remained relatively intact as it came to rest (see Fig. 2). Other buildings involved in the slide were reduced to rubble.

Causes of the Slide

Landslide or "flow" slides of this type cannot be analysed by standard methods. As a matter of interest, one cross-section of the failed river-bank was analysed by two of the standard methods and was found to have a factor of safety of about 0.6. This cross-section at the foot of Avenue du Seminaire (Section H on DPW Plan 34-58 dated 1938) had a slope of about 45°. It is apparent therefore, that any theories on the failure of this bank must be open to question until the engineering properties of the marine clay are more fully understood.

The writers believe that a consideration of the geological history of the area will provide a general understanding of the failure. It must be remembered that following deposition and drainage of the depositional medium the surface of the clay was essentially horizontal with no external forces on it tending to cause lateral movement. The initial tendency for lateral movement probably began when the Nicolet River started to cut its channel. In most soil deposits the downcutting by a river is usually accompanied by a strength gain in the adjacent soil due to a lowering of the ground water table and desiccation. An exception to this normal phenomenon appears to occur in the marine clays of the St. Lawrence Valley as indicated by the large number of modern and prehistoric landslides in the region. The precise difference between this soil and other soils is not yet clear. Work in Norway has suggested that marine soils lose part of their strength due to a leaching of salt from the pore water. Preliminary tests suggest that this may be part of the reason for the Nicolet failure but the six-month delay in carrying out field work may confuse this feature of the soil. In any case, assessment of changes in the properties of the soil during its geological history is a long process which has not yet been satisfactorily evaluated. It is sufficient to say that slopes become potentially unstable by long-term natural processes.

It is reasonable then to believe that regional and local short-term effects become prominent. The weather cycle over a period of a few years may considerably affect the stability of slopes. Artificial infiltration of water from man-made structures may begin to play an important part. Very often the immediate cause of the failure may be due to a local disturbance which "triggers" the entire movement but cases of failure reported in the literature have not always indicated any obvious direct cause. A variety of circumstances can be cited for the immediate cause of failure. Heavy rains are a possibility. Vibrations may be a "triggering" action although, to the writers' knowledge, these failures in general have not been associated with major earth tremors. River erosion may be an immediate cause but this seems to be unlikely in the case of the Nicolet slide. The improper placing of fill, and excavating or bank steepening are possible causes. Construction operations could also have set off the failure.

Although the exact cause of "flow" slides cannot be determined by present knowledge, it is the study of this and other similar slides which will result in a more complete understanding of the process. The mode of failure has been inferred from the evidence and this suggests to the writers that the construction work being carried out at the river-bank created the "triggering" action which began the failure. Roadway construction and sewer excavation were proceeding at the time of the Nicolet failure and construction equipment was swept away in the slide. It should be noted that the basic cause of failure was probably a gradual weakening of the soil during geologic and recent history and the immediate cause was simply a chance occurrence.

It is thought that a complete explanation of this and similar failures in the St. Lawrence Valley must await further developments in our understanding of the physical properties, especially the shear strength, of this marine clay. Former reports have suggested that the stability of these and similar banks is dependent on a dried layer of soil on the slope (1, 4). This theory does not fit in with modern soil mechanics theory but it should not be discounted without further investigation since it is now apparent that modern theories cannot adequately account for this type of failure. Early writers on this phenomenon have strengthened their argument for the "natural retaining wall" theory by emphasizing the fact that material flows out through a narrow opening indicating additional strength along the bank. It has also been reported that a lip of stronger material lies beneath the throat resulting in a dish-shaped region of remoulding under the slide. These suggestions require further investigation.

References

1. Béland, Jacques, Nicolet Landslide - November 1955, Proceedings of the Geological Association of Canada, Vol. 8, Part 1, pp 143-156, Nov. 1956.

2. Hurtubise, J.E. and P.A. Rochette, Causes of Landslides as Revealed by Nicolet Disaster, Roads and Engineering Construction, Vol. 95, No. 3, pp 82-89, 1957.

3. Rochette, P.A., Experimental and Theoretical Investigations of the Engineering Properties of Canadian Natural Clay Deposits, Proceedings 10th Canadian Soil Mechanics Conference, National Research Council, A.C.S.S.M., T.M. No. 46, June 1957.

4. Bilodeau, P.M., The Nicolet Landslide, Proceedings 10th Canadian Soil Mechanics Conference, National Research Council, A.C.S.S.M., T.M. No. 46, June 1957.

TABLE I

Soil Properties at Nicolet

Boring	Sample	Depth (Ft)	Geodetic Elev. (Ft)	w/c %	LL %	PL %	Clay Size %	Activity	Salt Content g/l (1)	Sensitivity St (2)	Avg. Shear Str. Tons/Ft^2 (3)	Precon-solida-tion Load Tons/Ft^2
1	68-1	8.0	20.0	47.8	50.1	25.1	54	0.46	8.3	8.8	0.44	
1	68-2	9.8	18.2	52.7	44.4	24.4	50	0.49	10.2	13.8	0.65	2.0
1	68-3	11.4	16.6	52.9	45.9	22.4	47	0.50	6.6	12.1	0.45	1.3
1	68-4	12.9	15.1	52.6	51.0	23.1	47	0.59	11.0	16.3	0.62	
1	68-5	14.6	13.4	54.0	51.0	25.0	50	0.52	7.8	13.8	0.36	1.4
2	68-6	12.0	38.0	56.6	50.1	24.3	75	0.34	0.2	9.7	0.30	1.2
2	68-7	14.0	36.0	62.9	60.3	25.2	71	0.49	0.8	9.1	0.23	1.2
3	68-8	Clay Remoulded by Land-slide		57.7	44.5	23.3	69	0.31	0.9	79.0		

(1) grams of salt per litre of extracted pore water

(2) $St = \frac{\text{unconfined compression shear strength}}{\text{Laboratory vane shear strength (remoulded)}}$

(3) by unconfined compression test

(Photo by Spartan Air Services)

Figure 1 Airphoto of Nicolet landslide

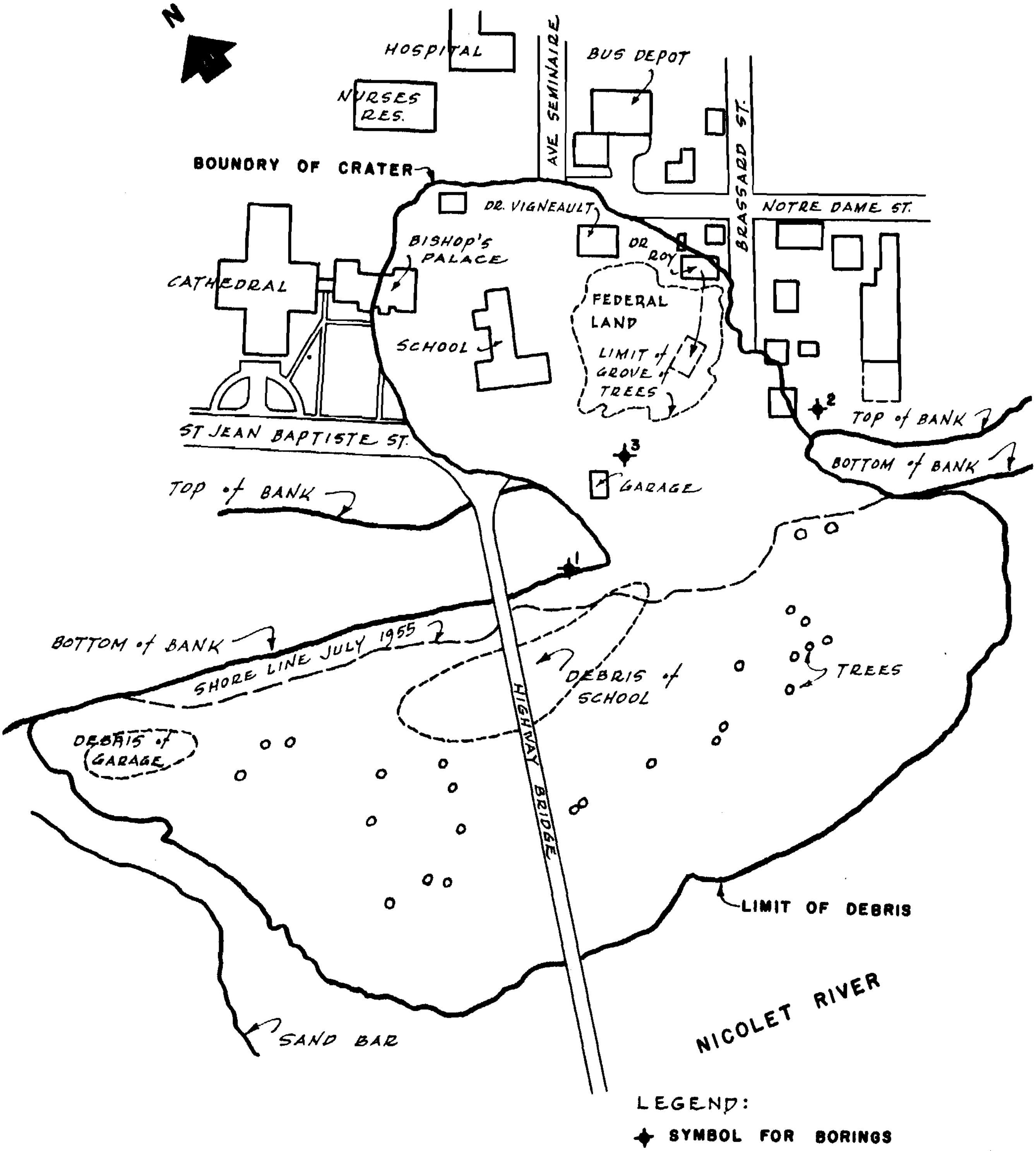

FIGURE 2

PLAN OF NICOLET LANDSLIDE – NOV. 1955