The Whitehorse escarpment

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NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

THE WHITEHORSE ESCARPMENT

(Prepared for the Advisory Committee on Northern Development, Department of Northern Affairs and National Resources)

by

R.F. Legget and G.H. Johnston

Report No. 136

of the

Division of Building Research

Ottawa

June 1959

Whitehorse Aerodrome and Town of Whitehorse - about 1944 (U.S.A.F. Photo)

LETTER OF TRANSMITTAL

Mr. R.G. Robertson,
Chairman,
Advisory Committee on Northern Development,
Dept. of Northern Affairs and National Resources,
Ottawa, Ontario.

Dear Mr. Robertson:

Whitehorse Escarpment

I have pleasure in submitting to you this report from the Division of Building Research of the National Research Council on the Whitehorse escarpment problem, as requested by the Advisory Committee on Northern Development at its meeting on 12 November 1956.

It has been a pleasure to keep you advised of the progress of our studies and to have had the opportunity of bringing before the Advisory Committee our conclusions and recommendations at its meeting of 12 January 1959. For your convenience and that of other readers of this report, our recommendations are presented on the page immediately following this letter.

Mr. Johnston and I have received every possible assistance from those whom we have approached and we are most grateful for this aid. We would record particularly the sense of our appreciation for the excellent report from the Forestry Branch of your own department on the vegetal rehabilitation measures and also for the way in which the Department of Public Works very kindly arranged to carry out the necessary supplementary drilling programme by contract.

It is the hope of my colleague and myself that this report may provide a sound basis for the complete rehabilitation of the beautiful Whitehorse escarpment which we have now come to know well in the course of our studies.

Yours faithfully,

Original Signed by

R.F. Legget,
Director.

RECOMMENDATIONS

If the Advisory Committee on Northern Development should decide that the escarpment should be rehabilitated, then the authors would recommend the following general procedures:

(1) Although it would be desirable to have no buildings anywhere near the crest of the escarpment, it is realized that this may now be impracticable, but it is, however, essential in the view of the authors that all buildings to the east of the road which runs near the crest of the escarpment should be completely removed or moved to other locations.

(2) Correspondingly, arrangements must be made to seal off effectively all connections to water mains and the sewers which now exist between this road and the edge of the escarpment.

(3) Arrangements must be made to ensure that under no circumstances whatsoever is water to be used in any quantity (such as for the washing of vehicles) anywhere in the area between the east runway and the crest of the escarpment.

(4) Arrangements should be made for the design and execution of a complete but relatively simple drainage plan to trap all surface water falling on the roofs of buildings, road-ways, and the runways adjacent to the escarpment, and using the natural grades to lead this as surface drainage away from the crest of the escarpment.

(5) A strong protective fence should then be erected along the crest of the escarpment for the full length of the affected area and at a suitable distance back from the edge as part of the measures which must be taken to ensure that there is no human interference whatsoever with the escarpment slope once rehabilitation work commences.

(6) With the fence in position and the buildings moved, the recommendations of the Forestry Branch of the Department of Northern Affairs and National Resources for the vegetal rehabilitation of the entire escarpment slope should be implemented as quickly as possible.

(7) Finally, when the rehabilitation work is complete, measures must be taken to ensure the proper maintenance of the rehabilitated slope, with provision for complete control over any interference with drainage arrangements, water, or sewage pipes, etc., anywhere near the crest of the affected part of the escarpment.

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by

R.F. Legget and G.H. Johnston

PART ONE

INTRODUCTION

Whitehorse, capital of the Yukon Territory, is fortunate in having adjacent to it a most convenient airport which formed part of the Northwest Staging Route and now constitutes one of the important air transportation centres of the Northwest. The airport is located on a large plateau located immediately to the west of the town but at an elevation of about 200 feet above the river flats on which Whitehorse itself is located. Between the airport and the town is a steeply sloped escarpment, once well wooded. This report is concerned with the damage which has been done to this escarpment in the last fifteen years, the report making certain recommendations regarding the rehabilitation of this important natural feature.

Damage to the vegetal cover of the escarpment appears to have started when the war emergency necessitated extensive construction work at the airport site and the construction of a new road on the face of the escarpment for access purposes. The first attention given to the escarpment damage was not until after the war but nothing was done until very serious sloughing of the face with consequent damage to roads and buildings in Whitehorse, and even to its graveyard, occurred in the spring of 1953.

The damage in 1953 was so serious that a number of special studies were made shortly after that time on behalf of the various Federal Government departments which by this time had an interest in the Whitehorse airport. The senior author of this report was jointly requested by Mr. R.G. Robertson, Deputy Minister of the Department of Northern Affairs and National Resources and Major-General H.A. Young, Deputy Minister of the Department of Public Works, if he would make a personal examination of the escarpment as representing an independent agency and in view of his own personal interest in soil studies and geology. A visit was therefore paid to Whitehorse in July 1954, as a result of which SPX report No. 12 of the

Division of Building Research was prepared and submitted in August 1954 to Mr. R.G. Robertson and Major-General H.A. Young.

Climatic conditions at Whitehorse during the next year or two were such that no further serious trouble took place on the escarpment. During this period, the Department of Public Works made further surveys and gave study to the carrying out of an extensive boring program, so that further information might be obtained regarding soil conditions beneath the surface of the plateau. Before this program was put into effect, the whole matter was brought up for review before the Advisory Committee on Northern Development. In view of the fact that several departments of the Federal Government were interested in the problem and concerned about necessary remedial action, the Advisory Committee requested the National Research Council, through its Division of Building Research, to make a complete study of the history of the damage to the escarpment and of other relevant information with a view to making recommendations as to how the escarpment should be rehabilitated, if this were considered to be desirable.

The junior author of this report, a member of the Northern Building Section of the Division of Building Research, took on this study as his special responsibility, beginning work in January 1957 and devoting approximately five months to a full-time study of the problem. He was greatly assisted by being given free access to the files of the Department of National Defence, the Department of Northern Affairs and National Resources, the Department of Public Works, and the Department of Transport. In all cases, he received much helpful assistance from members of the respective staffs. In May 1957, he paid a two-week visit to Whitehorse to study the problem on the site. Here he was assisted similarly by local officers of the departments mentioned.

In order to supplement the information thus assembled, the Royal Canadian Airforce through their resident staff at the Whitehorse airport, kindly carried out a test drilling program in September 1957 to delineate the surface of the silt which appeared to exist beneath the sand which forms most of the eastern surface of the entire airport area. The information so obtained was of great assistance.

When all the assembled information was carefully considered, it was clear that it would be necessary to carry out two further field projects before this report could be completed and final recommendations made. A request was therefore addressed to the Deputy Minister of the Department of Northern Affairs and National Resources on 28 March 1958 for an investigation by members of the staff of the Forestry Branch of his department into the possibility of successfully rehabilitating the vegetation on the escarpment, provided the drainage was improved, and soliciting some estimate of cost of such a procedure if practicable.

A second request was addressed to the Deputy Minister of the Department of Public Works, asking if a much more detailed test boring program could be carried out, to determine as accurately as possible the surface contours of the silt already mentioned, since quite clearly this information would confirm or disprove the opinion then formed that the trouble on the escarpment face was due to surface waters falling on the runway area and not to some deep-seated source of water as had been suggested.

Both these requests were implemented. A report was prepared by Messrs. W.M. Stiell and P.H. Jones of the Forestry Branch of the Department of Northern Affairs and National Resources dated August 1958 and entitled "Rehabilitation of the Whitehorse Airport Escarpment -- Yukon Territory". The main sections of this paper have been included in this report as Appendix C. Copies of the complete report, which includes useful coloured maps to illustrate the detailed recommendations, are available from the Department.

The Department of Public Works arranged to have the necessary test drilling carried out by a contract arranged for through the Development Engineering Branch, Mr. G.B. Williams, Chief Engineer. A contract was awarded to Warnock, Hersey and Co. Ltd., and G.S. Eldridge and Co. Ltd., jointly in August 1958. The authors were pleased to "brief" members of the two firms concerned on the Whitehorse problems before field operations started. Mr. Johnston visited the test boring work at Whitehorse while it was in progress in October 1958, following an earlier visit by H.B. Dickens, Head of the Northern Building Section of the Division of Building Research, who was in Whitehorse in September 1958. The consultants submitted their report in November 1958.

This report presented exactly the information on the silt contours required by the authors. These records have been carefully plotted and on the basis they provide, much more detailed contours of the silt surface have been prepared and are now shown on Figure 18 accompanying this report. The conclusions now included in this report were confirmed by this additional information. Excerpts from the consultants' report appear as Appendix D. The report itself went much further than giving the soil records requested but it was this information which was necessary for the completion of this report and the abstract therefore relates only to the levels of the silt. Complete information on the survey and borings program is available from the Development Engineering Branch, Department of Public Works.

With the information thus kindly made available through the assistance of the two departments mentioned, the authors were able to draw their conclusions and to prepare their specific recommendations. These appear at the end of this report which gives first a history of the development of the Whitehorse airport and an account of the gradual deterioration of the escarpment prior to a detailed study of the many factors which relate to this damage.

PART TWO

GENERAL DESCRIPTION

1. THE TOWN OF WHITEHORSE

Whitehorse is situated on the west bank of the Yukon River at latitude 60° 43' N and longitude 135° 03' W. The town was founded about 1900 as a result of the great influx of people to the Klondike gold country for it is situated at the head of the navigable section of the Yukon River. It is now the terminus of the White Pass and Yukon Railway from Skagway. During World War II it was a focal point of great activity in the Yukon with the building of a modern airfield, the construction of the Alaska Highway, and the Canol oil pipeline and road from Norman Wells, N.W.T. In 1953 the seat of government for the Yukon Territory was moved from Dawson City to Whitehorse.

The town has a population of about 5,000 approximately half of which are personnel of the Department of National Defence. A new townsite is being developed across the river from the present town. This new development was necessary because of the growth of the town over the past few years and the lack of room for expansion on the present site. The "old" town is located on a remarkable "river flat", its general elevation of about 2100 feet being from 10 to 20 feet above river level. The site is bounded by a swamp and the river to the north, a swift-flowing stretch of river to the east and the property of the White Pass and Yukon Railway extending to the river on the south. To the west, the level part of the townsite is bounded by an escarpment which is the subject of this report.

2. THE AIRPORT

The top of this escarpment, which is about 2 miles long (N-S), half a mile wide and was fairly level in its natural state, was the obvious choice for an airport site. The flight of four U.S. Army planes in 1920 from New York State to Nome, Alaska, marked the advent of aviation in the Yukon Territory. They landed on a grassy meadow about the centre of the present airfield as did the first commercial aircraft operating in the Yukon from about 1927 to 1940. It was not until the war, however, between 1941 and 1945 that the present modern airfield was constructed by the Department of Transport (D.O.T.) and the U.S. Air Force as part of the "Northwest Staging Route". Two main runways were built running N-S, with one short cross runway, approximately NE-SW. The Alaska Highway borders the airfield to the west.

With the exception of a short period following the war when operations were controlled by the Department of Transport, the Royal Canadian Air Force has had jurisdiction over the field. In July 1958, the operation and maintenance of the airfield was turned over to the D.O.T. The hangars and establishment of the R.C.A.F. are located on the west side of the airport, i.e., adjacent to the Alaska Highway and about half a mile from the edge of the escarpment. The offices and residences of the D.O.T. weather and radio services personnel and the Canadian National Telegraphs personnel are located on the east side of the field, as are buildings used by Canadian Pacific Airlines and Pacific Western Airlines. Canadian Pacific Airlines and Pan American World Airways use the field for regular domestic service while Pacific Western Airlines conducts a charter business. Several of the Department of Transport and Canadian National Telegraphs buildings are very close to the edge of the escarpment overlooking the Town of Whitehorse.

3. THE ESCARPMENT

The elevation of the airport is about 2300 feet above sea level. The rise of 200 feet from the general level of the town "flat" is effected by means of a steeply sloping bank. This terrace or escarpment stretches, as a well-defined topographic feature, from a point over a mile south of the town to well over a mile from the north end; it therefore dominates the local physiography.

Despite the steep slope, the face of the escarpment both north and south of the town is reasonably well wooded with spruce and the usual accompanying underbrush. There are some exceptions - one being the section overlooking the railway tracks just south of the town which is very steep and bare of any vegetation. The vegetation on that portion of the escarpment overlooking the town has been disrupted for a good part of its length by serious sloughing and mud flows that have occurred on the face. This report is concerned with a study of the damage to this part of the escarpment.

Two deep gullies penetrate into the escarpment, as they conduct natural drainage from the ground above to the river. Known respectively as "Baxter's Gulch" and "Puckett's Gulch" they provide vivid evidence of the natural process of erosion by water into the material which constitutes the escarpment.

4. GEOLOGY

The Town of Whitehorse and the surrounding area lie in the major physiographic division known as the Yukon Plateau province. This region is characterized by the remnants of a gently undulating upland which has been uplifted and dissected. Streams have cut valleys from 1500 to 4000 feet in depth into this upland (average elevation 5000 ft). "Rough highland" would be a more suitable description than "plateau". Glacial action has played an important role in shaping the topography as evidenced by U-shaped and hanging valleys and truncated spurs and, in many of the wider valleys, by the knob and kettle topography typical of ground moraines. The movement of the ice sheet, as deduced from the grooved and striated rock surfaces, was in the direction of the modern drainage, that is, to the northwest.

The deposits of the ice age consist mainly of boulder clays and silts (with lesser amounts of sand and clay) and are generally confined to the valleys and lowlands. The old pre-glacial valley of the Yukon River at Whitehorse is about 4 miles wide from base to base of the enclosing hills. The central portion of the valley is floored with silts and boulder clays and through these the river has cut its present narrow, winding secondary valley about 200 feet in depth. In the Whitehorse area these silts overlie the boulder clays or glacial till indicating that they were deposited after the retreat of the ice.

The escarpment overlooking the Town of Whitehorse consists, except for a surface layer of sand from 4 to 30 feet thick, of these stratified, light coloured and sometimes almost pure white, silts. They are usually stratified in beds from 1 to 3 inches thick but in most sections seem homogeneous throughout although occasional scattered pebbles and thin sand layers do occur.

These silt deposits represent accumulations of the fine material washed down by glacial streams and deposited when the current slackened sufficiently or still water was reached. At Whitehorse it would seem that the silts were deposited in a lake formed as the glacier retreated up the valley to the southeast. The water was ponded behind a dam of glacial debris (perhaps near Lake Laberge) which was cut through by streams, eventually draining the lake. The present course of the Yukon River at Whitehorse would seem to be along the eastern edge of this lake as suggested by the knob and kettle topography just east of the river. Just west of the airfield, rock outcrops occur here and there and these, together with the steadily rising ground elevation, suggest that the western edge of the lake was just west of the present location of the airfield. Thus a long, relatively narrow body of water was formed by melt water from the glacier in which fine material settled out in more or less homogeneous stratified layers.

5. CLIMATE

Largely as a result of the increasing height and breadth of the mountain systems on the southwest and northeast, the Yukon Plateau has a continental climate with relatively low precipitation and a large range of temperature. The climatic effects of the Pacific Ocean that manage to penetrate the remarkably effective barrier of the high and continuous mountain ranges along the coast do so through the depression which includes the White and Taku Passes south of Whitehorse.

Generally speaking, the climate is subarctic, characterized by relatively short summers and long dry winters. At Whitehorse, the monthly mean temperature is below 32°F in the five months, November to March, but not below 0° in any month. While extremes to -60°F and lower have been recorded, periods of intense cold do not last long. Summer comprises the three months, June, July and August, the monthly mean temperature reaching 56°F in July at Whitehorse. Temperatures of up to 90°F have occurred during the summer but frost has also been recorded in every month. The very large variability in temperature is a remarkable feature with the greatest range (e.g., -60° to +30°F) occurring during the winter months. The mean annual temperature at Whitehorse is 31°F.

With the exception of the high mountainous areas along the coast, the mean annual precipitation, including both rain and snow, is remarkably uniform over most of the Yukon Territory. The mean annual precipitation for Whitehorse is 10.3 inches (based on records from 1941-58) with about two-thirds of the precipitation falling in the summer and fall months. Almost all rainfall can be classed as light rain and drizzle with thunderstorms and heavier rains occurring infrequently. Snow accounts for approximately one-third to one-half the total precipitation averaging about 45 inches per year. Significant records for Whitehorse are given in Table I.

In summary, the climate of the Whitehorse area is milder than one might expect, in spite of the high latitude (60°N) and the extremely low temperatures recorded during the winter months, and is relatively dry.

6. PERMAFROST

Climatic conditions such as the long cold winters and the short, relatively dry, cool summers indicate that the existence of permafrost is possible in the Whitehorse area. The mean annual temperature of 31°F (based on records 1941 to 1950) suggests that the area is near the southern extremity of the permafrost region. None of the physiographic forms usually associated with the presence of permafrost were seen or have been reported in the Whitehorse area.

It is reported that permafrost was encountered (about 3 years ago) in an area near Ice Lake west of the airfield (1) but its existence cannot be definitely proved. The occurrence of permafrost on a few isolated sections of the Alaskan Highway south of Whitehorse has been noted (2) but none was reported in the immediate vicinity of the town. J.L. Robinson (3) states that permafrost was found at a depth of 25 feet at the Whitehorse airport; the basis of this observation is unknown. Several geological reports refer to areas in the Yukon Plateau (higher in altitude than Whitehorse) where difficulty was encountered in stripping and trenching the frozen soils covering bedrock.

Although it is reasonable to assume that isolated, but not extensive, small pockets or islands of permanently frozen ground may occur in the Whitehorse area it is not thought to be a contributing factor to the slope stability problem at the airfield. Certainly, had it been present originally at the airfield site, the stripping of the vegetation cover together with the sandy nature of the surface soil and, in general, the human activity in the area would have depressed the permafrost table below any level of present significance. No permafrost was encountered on the airfield during the recent drilling programs when several holes were drilled to depths exceeding 35 feet. Seasonally frozen ground may persist, however, well into the summer (possibly until July) and it is believed that this is a contributing factor to the instability of the slope.

PART THREE

DEVELOPMENT OF THE WHITEHORSE AIRPORT

On 16 August 1920, four aircraft of the U.S. Air Force landed at Whitehorse on their way to Nome, Alaska from Mineola, New York, marking the advent of aviation in the Yukon Territory. Earlier in the year, an advance party comprised of representatives of the U.S. Air Force and the Canadian Air Board had laid out a landing strip, 550 yards by 125 yards, on top of the escarpment west of the town which "was considered ideal for aviation purposes".

The landing field was located on a meadow about 1,500 feet back from the edge of the escarpment. With the exception of this meadow, which was grass covered, the whole top surface of the escarpment was covered with a moderately dense growth of pine and spruce and light underbrush that gave it a park-like appearance. Preparing the meadow as a landing strip necessitated clearing off a few willows and small pine on the approaches. It is said that in the spring of some years, water lay for short periods on this meadow. A trail (known locally as the "bridle path") had existed since about 1900 up the face of the escarpment from the town below (Fig. 1). It was very steep and was used mainly as a footpath although horses could be ridden up it. At the top of the escarpment, the trail connected with roads leading to the airfield and to mines and lakes to the west.

It was not until 1927, however, when the Yukon Airways and Exploration Co. Ltd. was incorporated, that commercial aviation got its start. Klondike Airways Ltd. began operations in 1928 initiating air mail service to Mayo. In 1929, it was announced by the Hon. Charles Stewart, Minister of the Interior, that ample land had been set aside (at Whitehorse) for aviation purposes. Some of the land required for the airfield was donated by the White Pass and Yukon Route. The sum of $1,000 collected by subscription from local residents at this time was used to clear some brush and level off parts of the airstrip. Additional clearing, though not extensive, was carried out adjacent to the airstrip during 1930 to 1936. Some gravel (decomposed granite) obtained nearby was used to level off bumps and hollows on the grassy meadow (Figs. 2 and 3).

The White Pass and Yukon Route began air operations from Whitehorse in 1935 flying to Mayo and Dawson City. The main access road to the airfield was by way of Puckett's Gulch. However, the White Pass Company constructed a road about 1937, on the face of the escarpment near the old trail to provide easier access to the airfield (Fig. 4).

In 1935, on recommendations by Mr. A.D. McLean, Department of Transport, following a survey flight in the Yukon, a government appropriation of $1,000 was used to make a survey of the airport property (see Plan No. F.B. 21863, Legal Surveys and Aeronautical Charts Division, Dept. of Mines and Technical Surveys, Ottawa) and improvements to the landing strip. Mr. Jeckell, Controller for the Yukon, reported in 1936 that "the ridge existing near the centre of the landing strip was removed and the dip towards the south end of the field was filled. Minor bumps and hollows were graded to uniform level for a length of 2,800 feet. The landing strip had been previously surfaced to a width of forty feet. This was widened to 80 feet. The surfacing material used was a fine decomposed granite which was raked and rolled".

During 1940, the British Yukon Navigation Co. (White Pass and Yukon Route subsidiary) had lengthened the runway somewhat and improved the grades by hauling fill material from the east side of the cleared area, which was at a higher elevation, to a low spot about the centre of the runway. They also had erected a hangar on the northeast side of the existing cleared area and one or two small buildings - workshop, office buildings, etc. - were located along the east edge of the airstrip.

It was in 1941 that the first major construction at the airfield took place. During the winter of 1940-41 the Department of Transport drew up plans and made arrangements for a relatively large construction program to be carried out during the summer of 1941. This work included:

(i) Construction of a stabilized runway about 5,900 feet long by 150 feet wide and associated taxi strip east of the runway

(ii) Construction of a road up the face of the escarpment. The road to the airport by way of Puckett's Gulch was unsatisfactory because of steep grades and the difficulty of keeping it open during winter and spring months

(iii) Erection of several buildings - residences, offices, etc., on the east side of the field (edge of the escarpment). The east side was chosen as the building area because it was close to the access road up the face of the escarpment, was convenient to a water supply from the Yukon River and meant a shorter connection to power facilities in the town of Whitehorse

(iv) Construction of a water supply main from a pump house at the Yukon River, up the face of the escarpment to the building area

(v) Clearing and grubbing of trees and brush from the proposed site except for a fringe along the edge of the escarpment.

This work was carried out by the White Pass and Yukon Route under contract to the D.O.T. during 1941-42.

Much of the fill required on the runway was borrowed from the building area to the east. Other fill material was removed from cuts along the line of the runway, namely, at the south and north ends. Difficult working conditions were encountered over the whole field owing to the existence of blow sand which was so clean and free from humus that it was impossible to fertilize and get a catch of grass. At a meeting on 17 June 1941, the Department of National Defence (Air Force), Aerodrome Development Committee, British Commonwealth Air Training Plan and Home War Establishment Plan recommended that the runway and taxi strip be hard surfaced with a bituminous coating. It was considered advantageous to do this because "of the arid soil conditions and extreme dust nuisance existing on this site".

The construction of the water line up the face of the escarpment just south of where the access road struck the crest of the escarpment proved to be a very difficult and costly operation because of the loose soil (sand) that was encountered. The line was laid about 8 feet deep in an open trench and then backfilled. This required a very large excavation to prevent sloughing of the loose material into the trench because lumber, which was scarce and expensive, could not be used for shoring the walls of the trench.

A gravelled cross runway NE-SW was also constructed. To get suitable grades on this strip a 10- to 15-foot cut was made through a knoll of silt at the southwest end. A wet swamp was partially filled at the extreme southwest end to complete this runway.

With the entry of the United States into the world conflict and the danger of invasion of Alaska, military air traffic increased tremendously and early in 1942, the U.S. Ferry and Transport Command recommended additional expansion of the existing airport and facilities. The construction, as requested by the United States, was to be carried out by Canadian contractors under D.O.T. supervision. This work consisted mainly of the erection of hangars, barracks, warehouses, workshops, etc., and the installation of water services including lines, pumphouses and a 100,000-gallon reservoir at the northwest corner of the field, with a few buildings, barracks, garages, etc. and a 150,000-gallon reservoir to be erected on the east side. Water supply for the American section at the northwest corner of the field was obtained from springs nearby (to the north at, or near Baxter's Gulch).

During the summer and fall of 1942 open drainage ditches were excavated to drain that section of the field west of the asphalt runway and adjacent to the cross runway, the drainage being directed to Puckett's Gulch to the north. Some trouble had occurred during the spring on the southwest end of the cross runway where frost action in the saturated soil softened the grade through the cut in the silt bank. There had been little or no airfield drainage work carried out the previous year since the sand provided a pervious cover over the field allowing any surface water to soak away.

Septic tanks and tile fields were laid for disposing of sewage in the east side building area (Canadian). Six units were installed, four of which were approximately 100 feet from the edge of the escarpment. Septic tanks and tile fields were also used in the American sector at the northwest corner of the field.

During the winter of 1942-43 and early spring, the requests from the U.S. Government for expansion of the airfield and construction of additional facilities increased to such an extent that an agreement was made at a meeting of U.S. and Canadian representatives on 18 May 1943, whereby U.S. authorities would assume responsibility for any unfinished construction including construction initiated by Canadian authorities as well as the new construction requested by the U.S. Government. Thus, all major construction on the airfield and in the surrounding area was carried out by U.S. military and civilian agencies from the spring of 1943 to the spring of 1945.

This work included the construction of a concrete N-S runway, concrete taxi strips, large hangars and an extensive development of the U.S. base (barracks, workshops, offices etc.) all on the west side of the airfield. In addition, drainage of the airfield area was attempted with the installation of perforated wood and metal pipes and closed systems along the west taxi strip and concrete runway, all draining to Puckett's Gulch where the water spilled out into the gulley. Storm sewers were also installed through the west camp area, particularly around the large hangars where foundation trouble was encountered with the saturated silt on which the buildings were constructed. These lines tied into the airfield drainage lines running to Puckett's Gulch. Domestic sewage from the west camp was carried in a sanitary sewer down Puckett's Gulch to connect with the sewer system (constructed by the United States) in the town of Whitehorse.

Inspection of the sewage disposal system in the east building area in 1944 by D.O.T. representatives showed that the septic tanks and disposal fields were not satisfactory because:

(a) the fine alluvial silt in the airport building area limited the effectiveness of soak-away dispersal beds

(b) the cold climate resulted in slow bacterial action in the septic tanks, and

(c) the increase in personnel had in some instances caused overloading of the existing sanitary facilities.

Subsequently, a collecting sewer system was designed by the D.O.T. connecting by means of a drop manhole and outfall sewer down the face of the escarpment near the top of the access road to the U.S. system of sanitary sewers in the Town of Whitehorse. At the same time, the R.C.A.F. drew up plans for a water distribution system for the east side to be connected into the U.S. distribution system on the west by means of a water-main skirting the north end of the airfield. The water line from the Yukon River up the face of the escarpment to the east camp and the septic tanks and tile fields for sewage disposal were therefore abandoned. Some confusion existed as to who was to do the work, the D.O.T. or the R.C.A.F. However, the Bennett and White Construction Co. Ltd. carried out the construction of both the sewage and water supply systems under contract to the D.O.T. The work was completed early in 1945.

It was recognized early in 1945 by both the D.O.T. and the R.C.A.F. that existing drainage facilities on the airfield were inadequate. Drainage of the airfield during the summer was satisfactory when moisture was able to drain away through the sand and gravel. During periods of sudden thaw, however, in the winter and spring months when fairly extensive runoffs occurred before the frost was out of the ground, water accumulated in some areas, notably between the concrete taxi strip and runway adjacent to the cross runway, and icing occurred where runoff water found its way across the taxi strip and runways. In addition, where cuts were made through the higher land adjacent to the concrete taxi strip and the cross runway, seepage water from these silt knolls caused further icing and also provided ideal conditions for frost action which heaved concrete slabs as much as 4 inches.

In March 1945, therefore, the North West Air Command, R.C.A.F., Edmonton, submitted a comprehensive outline of recommended major improvements to the Whitehorse aerodrome. This brief included major repairs to runways, taxi strips, etc., as well as drainage improvements at an estimated total cost of $2,114,879.

The proposed plans for drainage were as follows:

(i) advantage to be taken of local topography wherever field clearances would allow to install open interceptor ditches on the upgrade side of all traffic carrying areas

(ii) where field clearances were in effect perforated pipe was to be installed and backfilled with porous material at the bottom of all troughs or low spots so that surface water could be led to them

(iii) on side slopes a porous drain cover to be installed on the up-grade side of the pavement to intercept any flow onto the pavement

(iv) all pipe to have a minimum cover of 8 feet to protect against frost damage, and

(v) the existing inadequate American drain along the concrete taxi strip was to be salvaged and replaced with a larger capacity perforated pipe buried at least 8 feet below ground level to ensure interception of all seepage water and to protect against frost damage.

The total cost of this drainage was estimated to be about $213,000. Following discussion at previous meetings the Aerodrome Development Committee of the Department of National Defence (Air Force) at a meeting in June 1945 recommended that only sealing operations to runways and taxi strips plus such drainage as was required along the concrete taxiway be undertaken by the R.C.A.F. Construction Maintenance Unit, at a cost of approximately $470,000. It was not thought feasible to carry out the large construction program as proposed by North West Air Command since it was not known whether the airfield would be of continuing value. Specifically, with regard to drainage, clearances were so restricted on the field that in many cases open ditching could not be utilized. Attempts to drain the storm water by offtakes along the low side (east) of the field would also be restricted by the town of Whitehorse, the escarpment, access road, and railway requiring extensive, and thus expensive, piping of this water from the field to existing bridges and culverts on the railroad.

U.S. military traffic was reduced considerably when the War ended in 1945 and the American base (west side) was turned over to Canada. Construction carried out during the War on the airfield and associated facilities by American forces and contractors was on a "piecemeal" basis. When Mr. W.J. Johnston of the Department of Public Works inspected the buildings and services at the American base prior to acceptance by Canada he reported, with regard to the water and sewage installations, that the "situation was very confused with no proper plan of complete system". Similarly, little was known regarding construction of the concrete runways and taxi strips, drainage, etc., i.e., the kind of subgrade material used and location and types of drain pipe.

The Department of Transport carried out a survey of water and sewage installations during the latter part of 1945 and a plan of the complete airfield showing all the installations was completed in February 1946 (see Department of Transport, Civil Aviation Division, Plan No. R-YU-18).

After the withdrawal of American forces from the area in 1945, the R.C.A.F., who had operated from the east side of the camp during the War, took over the base on the west side of the field. Subsequently, in the fall of 1946, the east side area, with the exception of a few buildings, was turned over to the D.O.T. who controlled operations at the field from that time until late 1947. From 1947 until July 1958, when the D.O.T. again took over operation and maintenance of the airfield, the R.C.A.F. had jurisdiction over the airport at Whitehorse.

The D.O.T. maintenance staff had difficulty in keeping the water and sewage services operating during the winter of 1946-47. With the decrease in personnel at the east side camp, several buildings were not in use - particularly in the southern end - and consequently, during the severe cold weather many lines froze. Continuous maintenance of service lines was necessary.

Maintenance of utilities (sewer, water, and power) and roads, etc., was again of concern during 1948-49 for evidently neither the D.O.T. nor the R.C.A.F. had the staff to carry out the work which was urgently required. For both organizations to set up maintenance units and facilities meant duplication of services. Ultimately, the R.C.A.F. took over maintenance of the airport because they were official operators of the field.

Plans for drainage improvements, in an attempt to alleviate serious sloughing on the face of the escarpment and generally poor airfield drainage conditions, were submitted by both R.C.A.F. and D.O.T. staff to their respective headquarters in 1948 and 1949. The cause of the escarpment problem was attributed to water seepage from swampy areas west of the airfield and it was proposed to divert this water by deep underground drains along the Alaska Highway and on the airfield to a closed drainage system to Baxter's Gulch.

A few hand borings made by D.O.T. personnel in 1949 and a few test pits dug with excavating equipment by the R.C.A.F. in 1950 seemed to indicate a "saucer-shaped" depression under the sand layer on the airfield leading water across the field to the edge of the escarpment.

No corrective measures were started until mid summer of 1950. At that time, existing airfield drainage lines (constructed by U.S. forces) were cleaned out, subsurface drains and manholes were installed along both sides of the cross runway west of the concrete taxi strip, and a deep ditch was excavated along the Alaska Highway which carried water to storm sewers through the west camp (R.C.A.F.). A ditch was excavated due south to the edge of the escarpment from the junction of the concrete taxi strip and runway at the south end of the field to drain the south half of the west edge of the taxi strip, and grading of slopes and shoulders along the concrete runway and taxi strip to direct surface runoff into the existing drainage channels was carried out. This work, started in 1950, was completed in 1951 by Poole Construction Co. under contract to the R.C.A.F. At the same time, the storm water sewer, previously emptying into Puckett's Gulch, was reconstructed so that water is now carried north of the airfield in a buried line to the bottom of Baxter's Gulch.

Considerable leakage of the water lines in the east camp was reported in 1950. The whole system was tested and leaks were repaired with new lengths of pipe by recaulking joints and by replacing valves, etc. Dead end lines were eliminated where possible. The major water-main leaks were located at the south end of the camp. The work was carried out by Northern Construction Co. and J.W. Stewart Ltd. All repairs made and all revamping of lines carried out are indicated in detail on a "Plan Showing the Water Distribution System and Sewer System on East Side of Whitehorse Airport" as filed in the Department of Transport, Civil Aviation Division, Architectural Section, under No. F3320.

Since 1951, no major construction other than routine maintenance work has been carried out at the R.C.A.F. Station, Whitehorse.

PART FOUR

SLOUGHING OF THE ESCARPMENT

The access road to the airport, constructed in 1941 by the White Pass and Yukon Route under contract to the Department of Transport, carried heavy traffic, mostly military but some civilian. Minor sloughing had occurred on the road each year following construction, but was not extensive enough to warrant major repairs. It is reported by Whitehorse "old timers" that mud flows, similar to those that occur now, did not exist on the slope previous to this time. In the fall of 1944, however, the road was closed for about one month by the R.C.A.F. to carry out maintenance and repair work on "the sandy portion of the east hill".

Mr. H.V.G. Wheeler (then Department of Transport airway engineer at Whitehorse) reported to D.O.T. district headquarters at Edmonton in August 1948 that storm water from the airfield had recently flowed down the face of the escarpment (A, Fig. 17) through a culvert installed by the R.C.A.F. that spring in the road around the north end of the field. The culvert was (and is) located just north of the northeast end of the cross runway. Although there was not a large quantity of water it washed a great deal of material down the slope silting up portions of the cemetery, some yards, and one basement. Mr. Wheeler also reported that "this water came from a point at the edge of the hill where the road around the airport had been washed out several springs to the writer's knowledge". At the same time the storm water sewer emptying at the head of Puckett's Gulch had undermined itself and the sanitary sewer. The sanitary sewer consequently broke, emptying raw sewage down the slopes and eroding the head of the gulch. Other minor slides occurred along the face of the escarpment during this year. Mr. Wheeler's observations were passed on to D.O.T. headquarters in Ottawa this same year.

In a detailed report (July 1949) to the Director of Air Services, Department of Transport, Ottawa, the occurrence of two serious slides was described by the District Controller of Air Services, Edmonton, and recommendations suggested for corrective drainage, exploratory field work to determine the profile of the relatively impermeable strata underlying the surface sand layer on the field and the possibility of calling in a consultant. The most serious slide had occurred adjacent to the D.O.T. garage (B, Fig. 17) where the top of the bank was within 30 feet of the building with indications (fissures) of further slides. The second major slide occurred at the point (C, Fig. 17) where the outfall sewer dropped down the escarpment. Other minor slides had occurred along the length of the escarpment overlooking the town.

Further slides were reported during the summer and fall of 1949 which blocked the access road for short periods. Also, seepage water flowing from the interface of the sand and silt layers caused icing of the road in late fall with the result that the R.C.A.F. finally closed the road. This created some ill feeling among the local people who cleared the debris off and traffic continued to use the road bypassing the barricades. The R.C.A.F. recommended closing the road permanently since large cracks were opening at the edge indicating further slides would occur.

In 1950, further sliding of the slope around the outfall sewer necessitated cribbing and backfilling to prevent freezing and further damage to the line. The occurrence of more slides (D, Fig. 17) along the escarpment was endangering several dwellings in the Town of Whitehorse at the base of the slope. A preliminary engineering investigation by D.O.T. engineers indicated the need for considerable study of the problem before remedial measures could be taken.

Extensive slides occurred along the escarpment in 1951. The access road was continually blocked and continuous maintenance by the R.C.A.F. was required to keep it in service. R.C.A.F. vehicles no longer used this road as they travelled from Whitehorse to their base by way of the Two Mile Road north of the airfield.

Concern for the safety of the buildings at the top of the slope and the condition of the access road resulted in an inspection trip by representatives of the D.O.T. and the R.C.A.F. who submitted a joint report in September 1951. Remedial measures such as trimming the slope were not considered feasible because of the proximity of the buildings to the edge of the escarpment. It was recommended that an exploratory program be carried out to determine the location and contour of the impervious layer which, it was thought, was channelling water to the face of the escarpment.

The most serious slides occurred (A and E, Fig. 17) in 1953 when large quantities of "soupy" material flowed down into the Town of Whitehorse causing considerable damage to private property. Light snowfall (and thus deep frost penetration) and excessive rainfall in the preceding winter and during the spring respectively were thought to have been a major contributing factor. Sloughing and mud flows, varying in degree of seriousness, have occurred each year since, on the face of the escarpment (F, Fig. 17).

Several auger holes were bored on the airfield by D.O.T. personnel in 1954 and the results of this investigation were reported by Mr. E.B. Wilkins, District Airways Engineer, Department of Transport, Edmonton in 1954. In 1955 a more detailed examination of the escarpment was carried out by Mr. S.J. Brander of Department of Public Works, who made a topographic survey of the slope and put down a number of test borings along the edge of the escarpment. Both Department of Transport and Public Works engineers, however, suggested that a much more detailed program was required to establish definitely the contours and soil types of the material underlying the whole airport area. As a result, a comprehensive program of test borings was drawn up by the Department of Public Works to be carried out during the summer of 1956 by a private contractor. The work covered the drilling of about 65 holes of which three would be to a depth of 250 feet as suggested by personnel of the Geological Survey of Canada. This program was held in abeyance pending recommendations of the Construction Subcommittee of the Advisory Committee on Northern Development of the Department of Northern Affairs and National Resources.

At a meeting of the Advisory Committee on Northern Development in November, 1956 approval was given for a full-scale study of the history of the development on the Whitehorse escarpment. This would include the collection of information on the condition of the escarpment prior to construction and a review of all developments that had taken place since then.

This study, begun in January 1957 by the authors of this report, pointed out the need for an exploratory borings program to determine the extent of the silt deposit over the whole airfield. In September 1957 the R.C.A.F. made a number of borings (45) at intervals of 500 feet over the airfield. The extent and depth of the surface sand deposit was thus delineated and a general picture of the subsurface elevation of the silt was obtained. Details of the contours of the upper surface of the silt were, however, lacking in several critical areas.

To obtain the desired information, a more extensive borings program was required. In September 1958 the firms of Warnock, Hersey and Company Ltd. and G.S. Eldridge and Company Ltd., together carried out, for the Department of Public Works, a study which consisted of boring approximately 520 holes on a grid pattern of 200 feet over the airport.

In June 1958 an investigation concerned with the feasibility and cost of reforestation of the escarpment slope and the obtaining of a grass cover on the airfield was conducted by Mr. W.M. Stiell and Mr. P.H. Jones, Forestry Branch, Department of Northern Affairs and National Resources at the request of the authors of this report. The results of this study are described in their report dated August 1958 (included in this report as Appendix C).

PART FIVE

DISCUSSION

A review of pertinent aspects of the development of the Whitehorse airport is contained in the following sections. Observations made by the authors during visits to the site, information collected from several sources, and the results of tests carried out are included. Finally, the probable causes of the escarpment instability are discussed.

(1) The Escarpment

In contrast with what is shown on old photos (Figs. 1 and 4), which show the face of the escarpment in a relatively well-wooded condition, the vegetation today (Fig. 5) has been totally destroyed or at least badly disrupted on that portion from the southern extremity of the building area on the top of the escarpment to approximately a point in line with the cross runway or about 1,000 feet north of the northern limit of the building area. The total length of escarpment involved is about 4,000 feet.

It can be seen from Fig. 1 (June 13, 1913) that those parts of the slope which then had no trees or standing vegetation had a surface cover of grass, which no doubt, is the same as the grass cover existing on similar slopes in the vicinity today. It will also be noted that what appear to be mud flows were even then taking place on the face of the escarpment but were minor and much less extensive compared to those occurring at the present time.

An examination of portions of the escarpment slope, not covered by mud flows, was made in July 1954 for the Yukon Forestry Division, Department of Northern Affairs and National Resources. This indicated that the area had been cut over and burned just prior to the establishment of the present stand of vegetation. Samples of the existing tree growth (white spruce and lodgepole pine) were examined and found to be between fifty and sixty years of age. A more detailed report of vegetation conditions on the escarpment face is given in the report by W.M. Stiell and P.H. Jones, Department of Northern Affairs and National Resources, dated August 1958 (see Appendix C).

Each year, in the spring, with the melting of the snow and thawing of the ground, a "soupy" mixture of sand and silt flows down the face of the escarpment surrounding homes at the base and running as far as 500 to 1,000 feet along the streets of the town of Whitehorse. A large part of the cemetery at the west end of Main Street has been covered, drainage ditches have been filled, flows have covered the railway Y-yard at its northern end, and are encroaching at its southern end, and two oil tanks adjacent to the railway Y are surrounded by "mud". The access road on the face of the escarpment (which has been closed for several years) is completely obliterated at its upper end and provides a path for the mud flows above its lower section, directing them down onto Main Street and the adjacent areas of town.

At the time of the junior writer's visit (29 April to 10 May 1957) sloughing of the escarpment was taking place along the whole face. Large drifts of snow still remained at the tops of two of the large scalloped portions north of the building area (Fig. 9). The face of the escarpment, wherever flows were occurring, was found to be frozen. Melt water from the snow-drifts and the frozen face picked up material as it trickled down the slope. The soupy mixture dammed up at obstructions on its way down the slope until a sufficient quantity accumulated so that 2 or 3 cubic feet of material would then slide as a mass increasing in velocity and aided by the slippery surface of the frozen face. By the time it reached the bottom of the slope, the material was flowing in a relatively large stream which decreased in velocity as it spread out on the flats below. At night, because of cooler air temperatures, the flows diminished greatly, in some cases ceasing altogether, indicating that this first sloughing was caused primarily, if not totally, by melt water.

The top edge of the terrace has been badly affected by erosion notably near the Department of Transport garage at the northern end of the building area and also for a stretch south and north of the outfall sewer line down the face of the escarpment. At the garage, gullying has proceeded to within 30 feet of the building, and the edge of the escarpment behind the Department of Transport fire hall and barracks has sloughed to within 10 feet of the buildings.

Refuse has been thrown over the edge in two or three places. Ashes and cinders have been dumped behind the Department of Transport barracks and waste oil plus other material such as automobile axles and springs, have been cast over the edge near the garage.

Surface run-off from the airfield had caused gullying in two places adjacent to the east end of the cross runway (one being opposite the culvert through the road to the west side of the field). Both had dried up but had evidently carried a good deal of material down the slope to the town. A shallow ditch had been dug (by hand) to the face of the escarpment, at a point just south of the outfall sewer line, which drained surface water from a low spot. This, although dry at the time of inspection, had caused the bank to erode back 10 to 15 feet and had also carried a good deal of material down the slope.

The outfall sewer line serving the building area at the top of the escarpment has had to be suspended above the face from steel cables tied to towers - one at the top and one at the bottom of the slope. Power lines also have been supported or strengthened by steel cables. This has been done in an attempt to prevent breakage of these lines when caught by material sloughing down the slope.

At two or three places along this disturbed section of the escarpment, the silt and sand layers stand with almost vertical faces and are bone dry with only minor sloughing of the dry material taking place. At no place on other escarpments in the Whitehorse area (down river and across the river from town) were mud flows evident similar to those on the airfield escarpment, although dry natural sloughing has taken place on most of the slopes.

Cracks along the edge of the escarpment and leaning trees indicate that further soil movements are to be expected at different locations along the slope.

(2) Escarpment Soils

The escarpment consists almost wholly of a very fine sandy silt or silt which appears to be well bonded and is quite stable in the dry state as shown by the almost vertical faces standing on some sections of the slope. It is stratified, as a rule, but appears to be homogeneous throughout. Some of the strata have undergone some distortion.

Undisturbed samples of the silty material were obtained from a borehole put down by the junior writer (May 1957) near the edge of the escarpment behind the Department of Transport residences. The samples were taken just below the intersection of the silt and sand layers at a depth of about 11 feet. Examination showed that fine sand layers (1/16 to 1/4 inch thick) separated the silt strata which were from 1/4 to 1 inch thick. Distortion of a 3-inch section of the silt and sand strata occurred about 6 inches below the sand and silt intersection. The junior writer also examined a dry, vertical slope along the railway just south of the Y-yard and another about half way down the access road on the escarpment. At these points, the stratification was seen to be layers of silt, from 1 to 3 inches or more thick, separated by very thin layers of fine sand. No evidence of clay layers or strata was noted in these sections.

Overlying the silt and extending to the surface of the airport is a layer of clean, medium to coarse sand which varies in depth from 4 to 30 feet. In an attempt to alleviate the dust nuisance, gravel was spread up to 6 inches in depth over virtually all the infield area as well as on the other sections of the field.

No preliminary investigations were carried out, prior to construction of the airport, to determine the extent of this surface sand layer, and with the grading of the top of the plateau and moving of soil back and forth, all indications of original conditions have been obliterated. Portions of the concrete taxi strip and the west end of the cross runway were constructed in cuts made through silt knolls on the west side of the field. Aerial photos taken during the war show this construction taking place and seem to indicate that these knolls tapered off between the taxi strip and the concrete runway. It is said that the silt came to the surface near the southern end of the field. Some material from the cuts on the west side was wasted in the area south of the runways.

It was thought important that the depth and extent of this sand layer on the airfield should be determined so that an intelligent appraisal of possible causes of the slope stability problem could be made. Therefore, a boring program was initiated during the summer of 1957 to determine the subsurface contours of the silt. This work was kindly carried out by R.C.A.F. personnel at the Whitehorse base during September 1957

The results of this exploration work plus records obtained from boreholes put down by the junior author in July 1957, by Department of Public Works personnel (S.J. Brander) in May 1955, and by Department of Transport personnel (E.B. Wilkins) in June 1954 were then plotted to determine the upper contours of the silt deposit. The extent of the sand layer was thus defined but more detailed information was required to define the silt-sand interface. Subsequently, a more extensive boring program was carried out in September 1958 by the firms of Warnock, Hersey and Company Limited and G.S. Eldridge and Company Limited under contract to the Department of Public Works. A contour plan of the silt surface (Fig. 18) was drawn from the detailed information obtained from approximately 520 holes drilled on the airport. It appears from an examination of this plan that the main cause of the escarpment sloughing is due to surface waters falling on the runway and east side building areas and not to a deep-seated source of water under the airport as had been suggested. Although ponding of water may occur on the silt surface at one or two isolated locations, no direct connection between these and the areas of trouble on the escarpment face can be established.

Additional interesting information is included in the consultants' report but only relevant material has been included in Appendix D which is an account of the work carried out.

An undisturbed sample of the silty soil obtained by Mr. R.F. Legget in 1954 was sent to the Engineering Laboratories, Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado for microscopic analysis. The sample was found to slake rapidly in water to a loose silt but when dry was coherent but weak and pulverulent. Under the microscope, the analysis revealed: "the matrix is composed of angular particles in very fine sand and silt sizes. Angular particles of fine sand are distributed sparsely through the matrix. The grains constituting the bulk of the matrix are about 0.015 mm. in diameter. The interstices are partially or completely filled by clay and clay-like minerals. The particles of very fine sand and silt are predominantly calcite, dolomite, quartz, feldspars, and leucoxene. Particles of amphiboles, epidote, zircon, and miscellaneous other minerals are present in small amounts. The particles of fine sand are feldspars, quartz, chalcedonic cherts, shale, limestone, and granitic rocks. The interstitial material is a mixture of micas, hydro-micas (illite), and small amounts of a montmorillonoid."

Soil classification tests were carried out by the Department of Transport and the Division of Building Research Soil Mechanics Laboratory on samples obtained in 1954 and 1957. A summary of the soil test results and curves of grain size distribution limits are shown in Appendix E. The tests show the material to be a light grey, inorganic silt, with some (5 to 20 per cent) fine sand and clay and of low to medium compressibility. The grain-size curve of one sample (XY#2), which deviates somewhat from the limits of 11 others, is seen to lie almost wholly within the silt range and consist predominantly (75 per cent) of coarse size particles.

The layer of clean, medium to coarse sand which covers the airfield is very permeable and allows water to percolate downward rapidly. The underlying silt, however, is relatively impermeable; samples tested in the Division of Building Research Soil Mechanics Laboratory showed that the permeability coefficient of the silt is about 8×10^{-6} centimetres per second (i.e. almost impermeable).

(3) Sewage Disposal

Septic tanks and disposal fields installed in the east side building area in 1941 did not function properly and were abandoned in 1944 when a collecting sewer system was constructed. It is not known whether the septic tanks were actually removed. The collecting sewer system is connected to the town of Whitehorse sewer by means of an outfall line down the escarpment near the south end of the building area. It was very difficult to install this outfall line and sloughing of the slope has caused a great deal of trouble each year since. The pipe, which was previously buried 8 feet deep is now exposed and is supported by steel cables from two wood towers, one at the bottom and one at the top of the slope. The only building at the present site served by a septic tank is a one-family dwelling adjacent to the guest house at the extreme south end of the area. No difficulties have been reported with the present sewer system, other than those encountered on the outfall line with sloughing of the slope material; it is believed it has contributed little to the erosion of the escarpment face.

(4) Water Supply

A water main constructed in 1941 from a pumphouse at the Yukon River up the face of the escarpment at the location of the present outfall sewer line supplied water to the east camp. In 1944, a line from the American base on the west side, which is supplied by a pumphouse on McIntyre Creek, was constructed around the north end of the field and the main from the Yukon River was abandoned (pieces of the 2 1/2-inch pipe can be seen on the slope).

Minor leaks have occurred in the system nearly every year due mainly to freezing of lines, but these have generally been repaired without delay. A large maintenance program was carried out in 1950 when many leaks were reported. The whole system was thoroughly checked and sections of the line excavated and replaced with new pipe. The most serious leakage occurred in the mains just west of the top of the access road where pipes had frozen and cracked (see Plan No. F3320 Department of Transport, Civil Aviation Division, Architectural Section). The existence of a valve on the water supply main to the east side at the northeast corner of the cross runway has been noted on this plan. From this valve a 2-inch diameter drain line leads to the edge of the escarpment immediately above Main Street in the town of Whitehorse. The location of this valve and drain line should be verified and precautions taken to ensure no water loss occurs at this point. Had water leaked or been allowed to flow from this valve to the side of the escarpment, then it would account for much of the trouble at this most critical point.

An 8-inch main which ran to the guest house at the south limit of the east camp generally froze up each year (reported to G.H. Johnston by R.C.A.F. plumbers who have been at the airbase since the end of the war), because buildings in that area were used only occasionally. This line, in part, was reduced to 2 1/2-inch pipe during 1956. The R.C.A.F. carry out maintenance and repair work on the water and sewer mains and also house lines depending on the nature of the repairs. The repair work in 1950 was carried out by a contractor for the Department of Transport.

According to D.O.T. personnel at Whitehorse, freezing of house connections has occurred but breaks are repaired almost immediately (matter of hours) and are generally of a minor nature. Maintenance crews of the R.C.A.F. reported that any leaks in the water mains are repaired as soon as possible. The large 150,000-gallon concrete reservoir situated in the east side area has never leaked. It is kept full at all times for fire protection and the water level remains unchanged except for natural evaporation.

The breaks that have occurred in the water lines through the years have certainly contributed, in varying degrees, to the slope problem but are not a major source of the water appearing on the escarpment face.

Water samples were taken by the junior writer (May 10, 1957) in an attempt to determine a possible source of the seepage water on the face of the escarpment. Three samples were obtained: (i) from the face of the slope at the east end of the cross runway; (ii) from a swamp west of the Alaska Highway; and (iii) from the domestic water supply. No conclusive results were obtained following analysis of the samples (by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys) to show whether the seepage water was from any of the sources or a mixture of all three.

(5) Airfield Drainage

No large-scale drainage system has been installed on the airfield. The whole airfield area has little or no vegetation cover; the grassy growth that does exist is very sparse. Because it was virtually impossible to get vegetation to grow, gravel was spread over the surface in an attempt to keep down the dust. During the summer, normal light rainfall soaks away quickly through the sand and gravel surface cover. R.C.A.F. personnel at the base report that they have never known ponding of water to occur during the summer. At the time of the junior writer's visit (1 May 1957) surface melt-water was running into the underground drain between the concrete runway and taxi strip, although some minor ponding was occurring in the area along the south side of the cross runway, between the concrete runway and taxi strip, because of poor gradients on the ground.

Surface water from the very occasional heavier rains in the summer and the melting snow in the spring, which accumulates on the west side of the field, drains off through the airfield drainage system (Fig. 17) between the runways to Baxter's Gulch.

Surface water which accumulates on the east side of the field near the end of the cross runway is directed to the edge of the escarpment by the ground contours through culverts. Perforated subsurface drains which were installed 8 to 10 feet deep west of the concrete taxi strip and along the west end of the cross runway to catch seepage water, do not perform satisfactorily, if at all, as they silt up quickly and also freeze during the winter. A large drainage ditch excavated on the west side of the Alaska Highway to intercept water from the swamps to the west is not effective.

Considerable seepage water, particularly during the spring, has flowed from the silt knolls along the west taxi strip, to such an extent that sections of the subgrade under the pavement have been badly eroded in some years north and south of the cross runway and that a great deal of difficulty has been caused with foundations for the hangars and adjacent buildings on the west side.

Between the time of construction of the airport and 1948, the water level of Ice Lake (southwest of the airport), which has no visible inlet or outlet and presumably is fed only by run-off from adjacent hills, dropped about 2 feet. Since 1948, the lake has been used as a water supply for a nearby R.C.A.F. installation. In July 1957 it was reported that the water level was approximately 10 feet below its original mark and was steadily dropping. Adjacent areas have been tapped by connecting ditches in an attempt to maintain the water level, but with little success. Smaller lakes in the area have exhibited the same effect. It is thought by some that this whole area is providing a source for the water appearing on the face of the escarpment. It is reported that a little further west small streams disappear into the ground and that they too may provide a source for some of the water. Springs flow in Baxter's Gulch and were also encountered in road construction on the Two Mile Hill in 1956.

PART SIX

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1) Following the detailed study of the escarpment problem at Whitehorse by the authors of this report, aided by their study of all other reports dealing with the problem, and in the light of the information recently revealed through the extensive drilling program kindly carried out by the Department of Public Works, it appears that the damage which has been done to the face of the Whitehorse escarpment has been caused by lack of control of water in the vicinity of the crest of the escarpment and that it is not due to some underground stream or ponding, as has been suggested.

2) Accordingly, it should be possible to rehabilitate the escarpment and, in the course of time, to restore it to its state prior to the construction of the air field if appropriate measures are taken to ensure absolute control over all operations in the vicinity of the crest of the affected section of the escarpment.

3) The cost of this rehabilitation procedure cannot be estimated accurately until it is known which of the buildings must be removed, cannot be abandoned, or must be moved to other locations. Assuming, however, that the total estimate of cost includes only the moving or removal of existing buildings and not their replacement, the authors see no reason why the total cost should exceed $250,000.

Recommendations

If the Advisory Committee on Northern Development should decide that the escarpment should be rehabilitated, then the authors would recommend the following general procedures:

1) Although it would be desirable to have no buildings anywhere near the crest of the escarpment, it is realized that this may now be impracticable, but it is, however, essential in the view of the authors that all buildings to the east of the road which runs near the crest of the escarpment should be completely removed or moved to other locations.

2) Correspondingly, arrangements must be made to seal off effectively all connections to water mains and sewers which now exist between this road and the edge of the escarpment.

3) Arrangements must be made to ensure that under no circumstances whatsoever is water to be used in any quantity (such as for the washing of vehicles) anywhere in the area between the east runway and the crest of the escarpment.

4) Arrangements should be made for the design and execution of a complete but relatively simple drainage plan to trap all surface water falling on the roofs of buildings, road-ways, and the runways adjacent to the escarpment, and using the natural grades to lead this as surface drainage away from the crest of the escarpment.

5) A strong protective fence should then be erected along the crest of the escarpment for the full length of the affected area and at a suitable distance back from the edge as part of the measures which must be taken to ensure that there is no human interference whatsoever with the escarpment slope once rehabilitation work begins.

6) With the fence in position and the buildings moved, the recommendations of the Forestry Branch of the Department of Northern Affairs and National Resources for the vegetal rehabilitation of the entire escarpment slope should be implemented as quickly as possible.

7) Finally, when the rehabilitation work is complete, measures must be taken to ensure the proper maintenance of the rehabilitated slope, with provision for complete control over any interference with drainage arrangements, water, or sewage pipes, etc., anywhere near the crest of the affected part of the escarpment.

ACKNOWLEDGMENTS

To carry out this study of the development of the Whitehorse aerodrome, files of various Government Departments, geological reports and other sources were reviewed for relevant information. In addition, contacts were made, both in Ottawa and at Whitehorse, with people who had knowledge of the escarpment problem, the airfield construction, and the general history of the area. The writers are indeed grateful to those people, with whom they were in touch, for their advice and co-operation during this study. In particular, the assistance provided by Commissioner F.H. Collins; Mr. G.W. Smith, Department of Transport; Mr. H.A. Davis, Department of National Defence; W/C J.D. Shannon, Royal Canadian Air Force (now retired); Mr. C.J. Marshall, Department of Northern Affairs and National Resources (now of the Department of External Affairs) and Mr. G.B. Williams and Mr. E.L.M. Gordon of the Department of Public Works is gratefully acknowledged.

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TABLE I

Whitehorse, Y. T.

Records of Monthly Precipitation (in inches)

	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Totals Rain Snow	Year *
1941	0.31	0.08	1.55	0.03	0.90	0.81	1.07	0.73	2.94	1.27	0.90	0.55	6.66 44.8	11.14
1942	0.35	1.13	0.10	0.12	0.51	1.58	2.24	0.75	1.38	0.42	1.09	0.60	6.07 42.0	10.27
1943	0.14	0.35	0.76	0.14	1.07	2.58	1.33	1.63	0.66	1.11	0.77	0.88	8.16 32.6	11.42
1944	0.66	0.36	0.91	0.20	0.31	1.06	1.98	2.18	1.68	1.60	2.03	0.64	8.04 55.7	13.61
1945	0.48	0.46	0.79	0.86	0.13	1.12	1.45	0.05	1.56	0.91	0.99	0.67	4.72 47.5	9.47
1946	0.77	0.18	0.22	0.39	0.50	0.42	2.84	1.67	1.62	0.70	0.27	1.56	6.69 44.5	11.14
1947	0.51	0.28	0.12	0.71	0.37	0.56	1.07	1.24	0.68	0.06	0.48	0.62	4.05 26.5	6.70
1948	0.97	0.92	1.43	1.18	0.99	0.53	1.92	2.82	1.67	0.04	1.15	0.22	7.79 60.5	13.84
1949	0.61	0.36	0.10	0.18	0.68	0.91	0.78	3.33	0.61	0.91	1.22	0.51	7.03 31.7	10.20
1950	1.55	0.61	0.06	0.32	0.27	0.40	1.61	0.90	0.55	0.10	1.06	1.47	3.76 51.4	8.90
1951	0.45	0.33	0.70	0.16	0.63	1.04	0.38	0.67	0.36	0.71	1.13	0.70	3.56 37.0	7.26
1952	1.57	0.68	0.85	1.49	0.47	1.32	1.18	1.52	1.42	1.05	0.47	0.73	5.95 68.0	12.75
1953	0.37	0.13	0.65	0.23	0.52	3.62	1.89	2.54	0.44	1.44	0.68	0.83	9.38 39.6	13.34
1954	0.52	0.22	0.68	0.32	0.69	0.65	1.27	0.63	1.35	0.52	1.38	0.80	4.97 40.6	9.03
1955	0.55	0.75	0.75	0.02	0.10	0.42	1.32	1.10	0.46	0.26	1.02	0.66	3.25 41.6	7.41
1956	0.84	0.77	0.39	0.14	0.14	1.29	0.93	0.96	1.71	0.92	1.17	0.95	4.15 60.6	10.21
1957	0.51	1.46	0.17	0.43	0.52	0.84	1.28	0.93	0.55	0.41	0.25	0.82	4.08 40.9	8.17
1958	0.73	0.50	0.27	0.70	0.18	0.34	0.50	1.15	0.59					
										Mean Annual =				10.3 "

* 10 inches snow = 1 inch precipitation

Figure 1. Whitehorse - June 11, 1913. Note "bridle path" on face of escarpment. (Photo taken by E.J. Hamacher; original print loaned by W.D. McBride, Whitehorse.)

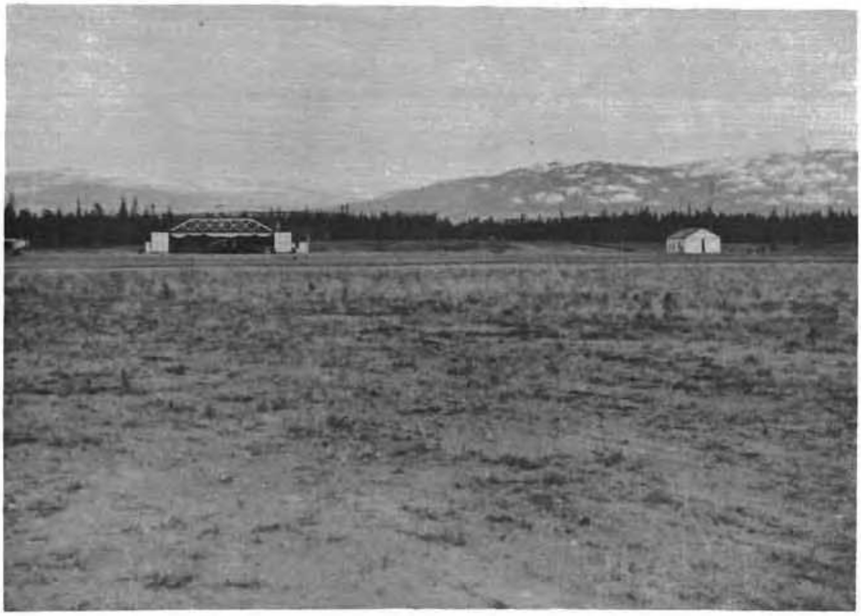


Figure 2. Whitehorse Airfield, 1939, looking east. (Geol. Survey of Canada photo No. 86836)

Figure 3. Vertical air view of Whitehorse Airfield, 1939, (north on right side of photo). (Geol. Survey of Canada photo No. 86838)

Figure 4. Town of Whitehorse and escarpment, 1938. (Note "bridle path" and Whitepass and Yukon route access road to airfield.) (Geol. Survey of Canada photo No. 84601)

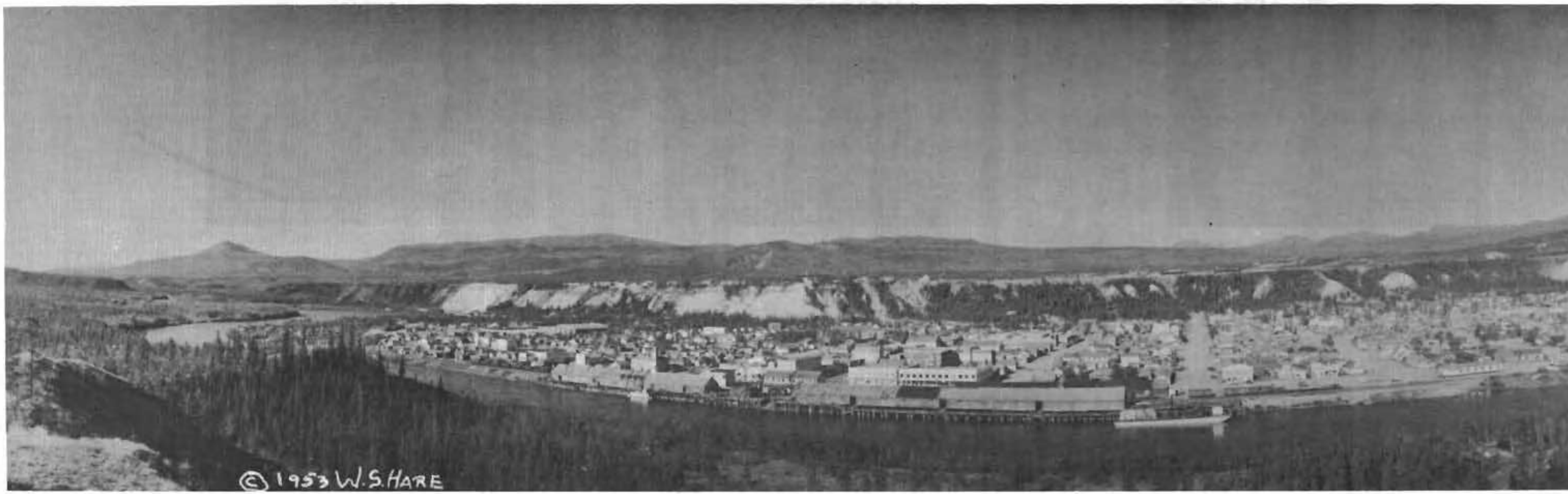


Figure 5. Whitehorse, 1953 (Photo by W.S. Hare)

Figure 6. Mud flows on escarpment, east end of cross runway, May 1957. (Note snow drift at top of scalloped portion (DBR photo BR 6762)

Figure 7. Sloughing on slope at DOT garage (at top of bank), May 1957 (DBR photo BR 6763)

Figure 8. Sloughing near DOT garage, May 1957. (DBR photo BR 6764)

Figure 9. Snow drift on scalloped area east of cross runway. Gully caused by surface runoff from airfield can be seen at edge of slope in line with gullying on face, May 1957 (DBR photo BR 6765)

Figure 10. "Mud" streams flowing down lower sections of abandoned access road, May 1957 (DBR photo BR 6766)

Figure 11. Erosion of bank behind DOT residences (at top of slope), May 1957 (DBR photo BR 6767)

Figure 12. Dry face of escarpment immediately behind DOT residences (at top of slope), May 1957 (DBR photo 6768)

Figure 13. Another view of dry face of escarpment, May 1957 (DBR photo 6769)

Figure 14. "Mud" runs flowing around oil storage tanks and down into town over railway Y tracks, May 1957 (DBR photo BR 6770)

Figure 15. Extensive sloughing on slope has completely obliterated access road at its upper end, May 1957 (DBR photo BR 6771)

Figure 16. Steep, dry slope adjacent to railway south of Whitehorse, May 1957. Note occurrence of some gullying on face and also soil stratification on right side of photo (DBR photo BR 6772)

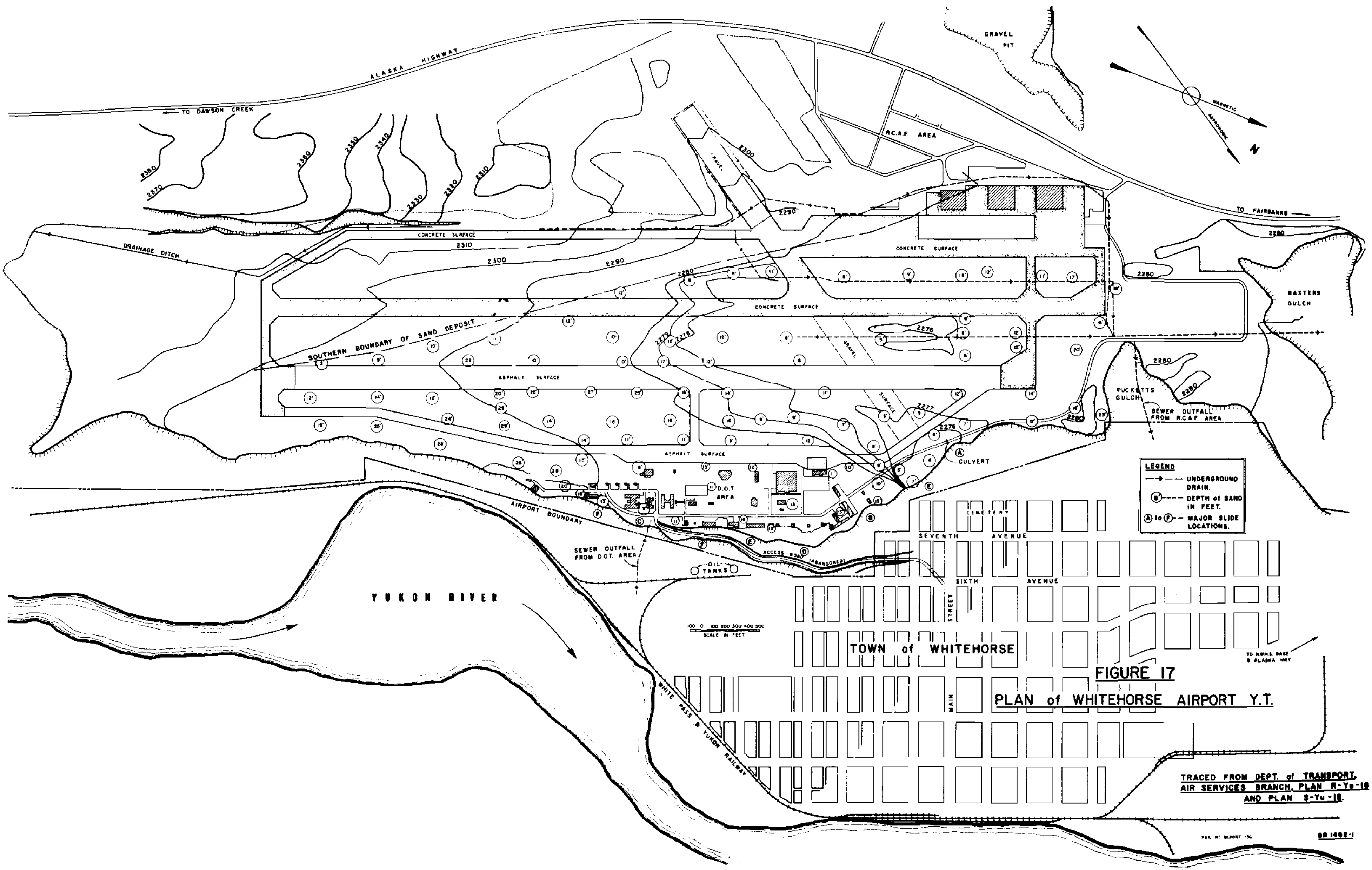
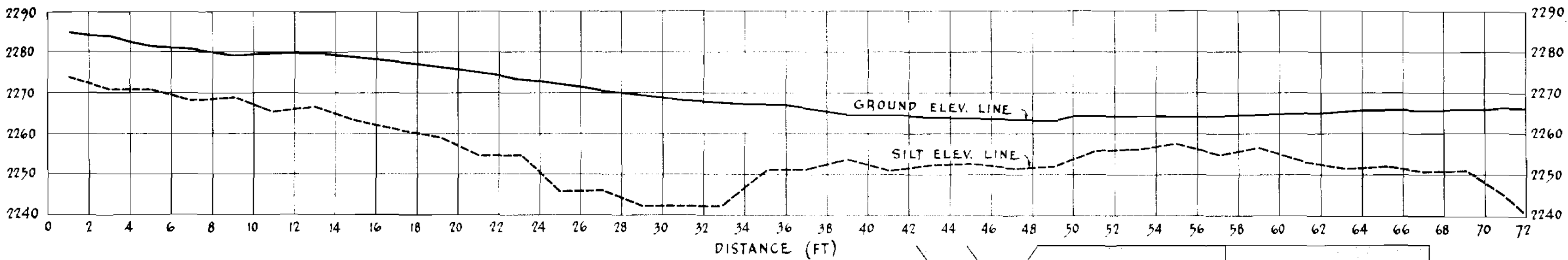
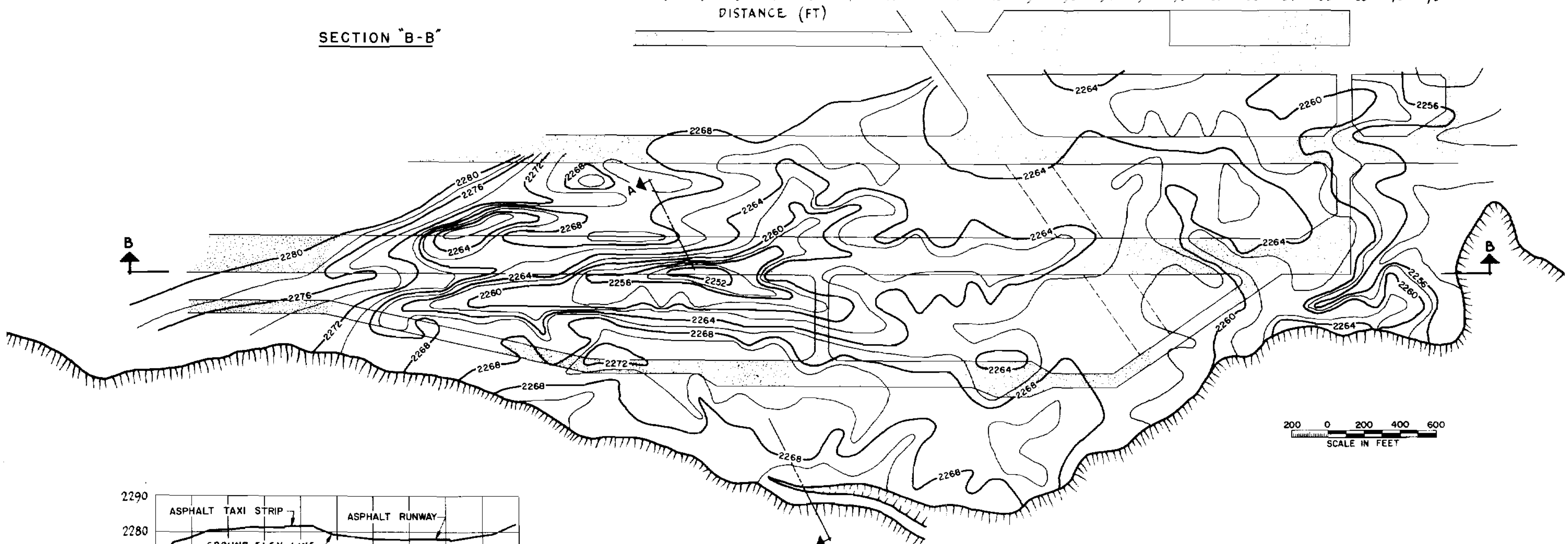


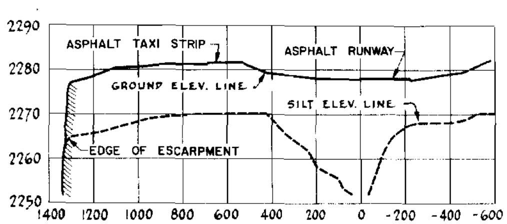
FIGURE 17

PLAN of WHITEHORSE AIRPORT Y.T.



SECTION "B-B"





SECTION "A-A"

FIGURE 18

WHITEHORSE AIRPORT YUKON TERRITORY

PLAN SHOWING SUBSURFACE SILT CONTOURS

DRAWN FROM BOREHOLE LOGS OF INVESTIGATION CONDUCTED
BY THE DEPARTMENT OF PUBLIC WORKS - SEPTEMBER 1958

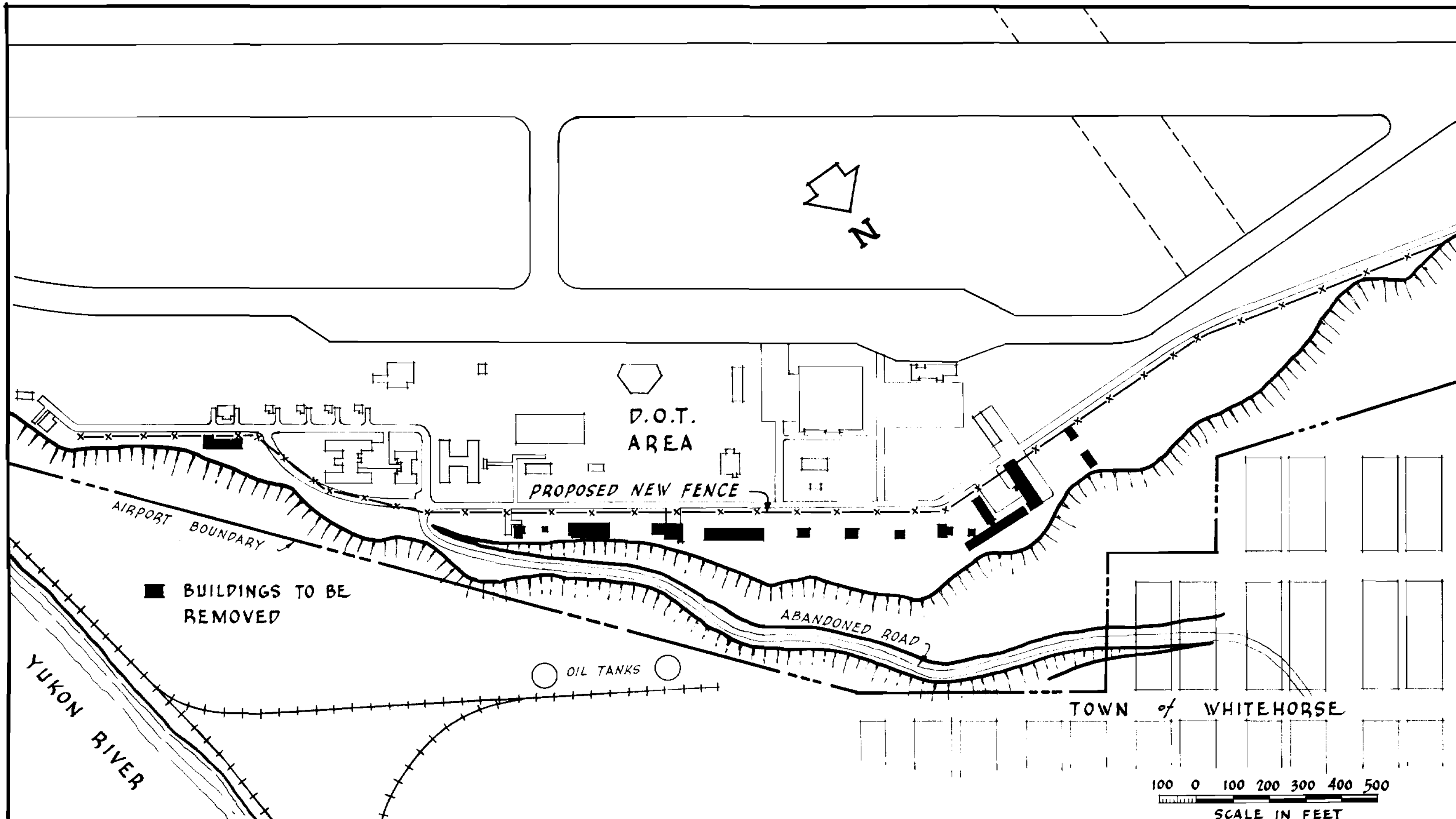


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FIGURE 19 PLAN SHOWING LOCATION OF PROPOSED PROTECTIVE FENCE AND BUILDINGS TO BE MOVED

APPENDIX A

DEPARTMENTAL FILES REVIEWED (OTTAWA)

1. Department of Transport,
   Air Services, Construction Branch

   (a) 5158-702 - Construction and Maintenance, Aerodrome Development

   (b) 5168-702 - Sites

   (c) 5173-702 - Roads

   (d) 5176-702 - Drainage and Sewerage

   (e) Whitehorse Soils File

   (f) Whitehorse Miscellaneous Contract and Specifications, etc.

2. Department of National Defence (Air),
   Construction and Property Section

   (a) Whitehorse Escarpment

3. R.C.A.F. - Construction Engineering Branch

   (a) H.Q.'s File No. -087-5/70-10- Investigation into landslide at R.C.A.F. Station, Whitehorse, Y.T.

   (b) Flimsy folder - Whitehorse Construction Projects.

4. Department of Public Works

   (a) 752-896-1 - Building Construction, Development of Townsite, Whitehorse, Y.T.

5. Department of Northern Affairs and National Resources

   (a) 301-1/2 - Floods in Yukon Territory

   (b) 331-2/200 - Conditions at Whitehorse - Water Supply, Sanitation, Sewage, Fire Protection.

   (c) 333-3/200 - Sanitation, Whitehorse, Y.T.

   (d) 1000/200 - Whitehorse General

   (e) 1000/200-1 - Townsite Expansion - Whitehorse, Y.T.

   (f) 332-1-3 - Hydro-Electric Power Project, Yukon River.

   (g) 352-2/200 - Airport - Whitehorse, Y.T. (including access roads)

APPENDIX B

REPORTS SUBMITTED ON WHITEHORSE SLOPE STABILITY PROBLEM

Representatives of various government departments have investigated the slope stability problem at Whitehorse and have submitted reports dealing with possible causes and recommendations for remedial measures. Those carrying out the investigations are noted in the following list:

1. 1948 - H.V.G. Wheeler, Airway Engineer, Department of Transport, Whitehorse
2. 1948 - J.R.K. Main, District Controller of Air Services, Department of Transport, Edmonton
3. 1949 - J.R.K. Main, District Controller of Air Services, Department of Transport, Edmonton
4. 1951 - O. Kelly, District Airways Engineer, Department of Transport, Edmonton,
   and
   S/L E. Hurry, Tactical Air Group, R.C.A.F., Edmonton
5. 1953 - C.V.F. Weir, Chief, Engineering and Architectural Division, Department of Public Works, Ottawa
6. 1953 - Dr. J.O. Wheeler, Geological Survey of Canada, Ottawa
7. 1954 - Col. B.B. Campbell, Special Advisor on Properties, Department of National Defence (Air) Ottawa;
   Capt. S. Thomson, R.C.E., N.W.H.S. Whitehorse;
   F/L A.G. Hoyt, R.C.A.F.;
   and F/O H.W. Cameron, R.C.A.F.
8. 1954 - E.B. Wilkins, District Airway Engineer, Department of Transport, Edmonton
9. 1954 - R.F. Legget, Director, Division of Building Research, National Research Council, Ottawa
10. 1955 - S.J. Brander, Engineer, Department of Public Works, Vancouver, and
11. 1955 - R.B. Campbell, Resident Geologist, Geological Survey of Canada, Whitehorse, Y.T.

APPENDIX C

EXTRACTS FROM

REPORT ON REHABILITATION OF THE WHITEHORSE AIRPORT

ESCARPMENT, YUKON TERRITORY

by

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Forest Research Division

and

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Forest Economics Section

of the

Forestry Branch, Canada, Department of
Northern Affairs and National Resources

Ottawa

August 1958

PREFACE

This report deals with the problem of restoring a forest cover to the eroded slopes of the Whitehorse airport escarpment. It includes estimates of cost for the reforestation work, and while the problem of bringing a grass cover to the airport did not strictly fall within the scope of this investigation, some attention is devoted to the methods and probable costs of bringing this about.

This investigation was prompted by a letter from the Director, Division of Building Research, National Research Council, to the Deputy Minister of Northern Affairs and National Resources. The letter stated in part that almost all serious erosion of the slopes could be checked by improving the airport drainage system and that, since this alone could not be expected to restore the escarpment to its original condition, it should be followed by a reforestation programme. The Forestry Branch was asked to study the problem and to estimate the costs of such an operation.

The investigation included a study of the relevant documents available to us, of which the most useful were reports by R.F. Legget (1) and by G.M. Wilson (2) and a large-scale topographic map of the escarpment prepared by S.J. Brander (3). First-hand information was obtained during a 10-day visit to Whitehorse in June, 1958, when a thorough examination was made of soil and vegetation conditions on the escarpment and airfield, plant specimens were collected, and the location of eroded areas and the distribution of vegetative cover were mapped in detail. At the same time interested and experienced parties were interviewed concerning various aspects of the problem. Thanks are due to Colonel F.H. Collins, Commissioner of the Territory, and his staff for transport and facilities for work at Whitehorse; to Mr. G.M. Wilson, Yukon Forestry Division, for the loan of maps and equipment and for a preliminary tour of the escarpment; to Mr. J.Y. Tsukamoto, Agronomist, Whitehorse Experimental Farm, for advice on seeding the airfield; and to Mr. McBride, White Pass and Yukon Railway, for the loan of an old photograph of the escarpment from the Whitehorse Museum.

THE NATURE OF THE PROBLEM

Introduction

Whitehorse is located on a broad terrace on the west bank of the Yukon River. The airport is situated on a plateau immediately to the west of the town, and about 200 feet above it at the top of a steep escarpment. The erosion problem is caused by springtime mud flows which originating in the face of the escarpment, cause damage by undermining standing trees, undercutting the bank above, burying part of the old airport road, and depositing layers of silt at the foot of the slope.

Airport and Escarpment

The elevation of the plateau is about 2,280 feet above sea level. It is aligned approximately north and south and is about two miles long. The escarpment, while following a somewhat sinuous course and thus forming a number of shoulders and re-entrants, trends generally northwest-southeast with an average slope of 36 degrees. Used periodically as an airstrip since the early 1930's the plateau became the site of a large airport with paved runways, hangars, and administrative buildings in 1942 as part of the Northwest Staging Route.

Soils and Vegetation

The body of the plateau appears to be a remnant of a very extensive lacustrine deposit composed of fine silt with occasional narrow bands of silty clay. This deposit is capped with uniformly stratified sand, varying in thickness from about 2 to 15 feet, at least along the escarpment face. The sand is mainly fine textured, and some layers are firmly compacted. Whereas the sand cap which forms the surface of the airfield is of uneven thickness, the surface of the underlying silt may well be level along the entire length of the escarpment face.

In its natural state the surface of the plateau appears to have supported stands composed predominantly of lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) with small amounts of white spruce (Picea glauca (Moench) Voss), trembling aspen (Populus tremuloides Michx.), and balsam poplar (Populus balsamifera L.), interspersed with grassy openings. Remnants of this cover still occur at the north end of the plateau beyond the airfield. Today, the surface of the airfield, apart from the paved runways, is composed chiefly of bare sand or fine gravel. Scattered herbs and grass, with occasional small aspen and willow (Salix spp.) occur sporadically, but except for local areas there is nothing approaching a continuous cover. The most successful and aggressive species present, and the one showing the best tendency to colonize and spread, is smooth brome grass (Bromus inermis Leyss.).

The escarpment formerly supported forest stands composed chiefly of white spruce with lesser amounts of the other tree species listed above. It is not believed that this cover was continuous throughout the length of the slope, however, but was confined to north, northeast, and east exposures. Slopes facing the south or southeast were generally devoid of vegetation, or supported only sparse grasses. This is the present distribution of vegetation on the non-eroded portions of the escarpment, and on similar slopes in the vicinity of Whitehorse. That this situation prevailed in the past is confirmed by an old photograph of the escarpment taken in 1900. Shoulders and faces of the slope devoid of vegetation can easily be discerned, and match exactly with the same areas in a 1958 photograph. Denuded areas in the latter are much more extensive, however, owing to slide action. The residual spruce stands on the slope are well-stocked, about 60 feet tall, and with an average age which exceeds 70 years. There is little underbrush.

The total annual precipitation at Whitehorse averages 10.6 inches, of which only 6.3 inches fall as rain. It is this dry climate that prevents the establishment of vegetation on steep southerly exposures, and also permits unvegetated slopes of such a readily erodible material as silt to remain firm and stable - there appears to be little surface erosion from direct precipitation although there is obviously some damage caused by prolonged wet weather.

REHABILITATION

Interrelation of Erosion and Vegetation

Vegetation and Slides

Surface erosion has been shown to be a relatively minor factor compared to the subterranean movement of water and its damaging effects on tho Whitehorse escarpment. Hence it must follow that the restoration of vegetation alone cannot be relied on to prevent further erosion of the slope. We have only to look at the remaining climax forest stands (usually considered the ultimate in soil protection value) to see that they are being undermined and destroyed. Thus there would be little value in restoring vegetation before the erosion has been brought under control by other measures.

This has been clearly stated by Legget (1954) who recommended that control be achieved by (a) capturing all airport drainage in a closed system before it reaches the escarpment, and diverting it for discharge elsewhere; and (b) seeding the airfield between the runways, to provide a grass cover for delaying and reducing infiltration of water into the soil. These complementary measures seem very reasonable to us, and the question of seeding the airfield is referred to later.

When the drainage has been placed under control, and the water and silt discharge from the escarpment checked, attention can be turned to restoring vegetation to the slopes. The sand cap, which is easily shifted and may be subject to mechanical disturbance, will be most in need of stabilization. Apart from this thin layer at the top of the slope, however, the escarpment is composed of silt, which is comparatively stable under the prevailing climate.

Problems of Vegetal Rehabilitation

The appearance of some vegetation on the less active slides has been mentioned. Eventually a good deal of the eroded area might be covered naturally in this manner, but it would be an extremely lengthy process, and distribution would be patchy. Further, the cover would be composed almost entirely of grasses and herbs, shrubs, and deciduous tree species; the appearance of any quantity of coniferous seedlings would be deferred even longer. Therefore artificial means would be required to establish a uniform plant cover on the escarpment within a reasonable time.

We believe that conifers can be established on the escarpment, but only with difficulty, and not in a single planting operation. The sites are too dry and exposed for the direct establishment of spruce seedlings. Rather, a preliminary cover of willow and poplar should be provided first, and the spruce planted several years later under the protection of these pioneer species. This is the natural plant succession for these sites, and most likely the way in which the spruce became established originally. In addition, special measures would be required to stabilize some of the sandier slopes, and to protect the edge of the escarpment.

The total area to be treated is about 18 acres, and this includes only the eroded slopes which at one time supported a forest cover. We do not recommend planting trees on the southerly exposures (totalling about 12 acres) where trees did not grow before. As indicated above, treatment will vary with conditions on the slope.

Site and location combine to give unique growing conditions on the escarpment, and we admit that there are a number of points on which we would like more definite information. We believe that experimental work on the more stable slopes, to test planting methods and early survival and performance on various slope positions and aspects, could be carried out to great advantage before the planting program begins. There should be plenty of time for this since it appears that engineering measures to control airport drainage will not be completed before 1959. Even if immediate slope stability results, this fact could not be determined until late spring of the following year. Thus planting could not begin before the spring of 1961 at the earliest. Applied research carried out in the 1959 and 1960 growing seasons could provide important data to guide the main operation.

In the section dealing with rehabilitation costs it was thought necessary to work out estimates for two alternative measures which could be used to reforest the affected portions of the escarpment edge and slope. These are presented as Alternatives I and II.

Briefly, Alternative I assumes that hardwood shrubs, grown from poplar and willow cuttings, together with a shelterbelt of lodgepole pine (planted on the edge of the escarpment) will offer adequate protection to the slope.

Alternative II goes a step further and assumes that conifers will be planted to replace the initial cover of hardwood shrubs.

The protection value of either type of cover would be comparable in the short run, although the restoration of a coniferous cover would assure long-term protection. A primary advantage of a coniferous cover would be the more effective interception of rain during the critical period in the spring when erosion is at its height, and before the hardwood leaves emerged.

The success of planting will depend to some extent on the effectiveness of the drainage improvement measures. It is unlikely that the original moisture regime of the undisturbed slope will again prevail. However it is assumed that the moisture escaping the drainage system together with the normal precipitation will be sufficient to maintain satisfactory tree growth on the escarpment.

Planting Procedures

Supervision

Planting and similar operations should be directed by a professional forester. The efficient organization of labour crews and the proper handling of plant materials will be essential for optimum results. Since much of the following deals with standard procedures familiar to a forester, technical directions have been kept to a minimum.

Sequence of Operations

The tentative program is as follows:

1959 or 1960 - autumn - collect and process conifer seed.
1961 - spring - (a) collect and plant willow and poplar cuttings on escarpment,
- (b) place wattles on loose sand,
- (c) erect escarpment fence,
- (d) sow conifer seed in nursery.
1963 - spring - transplant 2-0 conifer seedlings.
1965 - spring - lift 2-2 conifers and plant on escarpment.
1966 - spring - refill conifer failures.

The above dates depend on how soon and how effectively the airport drainage is placed under control, and also on the occurrence of the next seed crop.

The various operations are described below.

Planting Cuttings

About 17,500 cuttings of willow and 7,000 of balsam poplar will be required for planting on the silt and sand portions of the escarpment respectively. The willow already growing on the slopes can be used to provide some of the material, but not more than half of the stems in a clump should be utilized for this purpose. Otherwise, there is plenty of willow brush available locally - specifically there is a good supply source, sufficient for the entire project, growing immediately to the west of the Alaska Highway at a point 1.6 miles north of the Whitehorse traffic circle. While glaucous willow is to be preferred, any species of willow occurring on well-drained sites will be satisfactory. A supply of balsam poplar was noted to the east of the Highway, 3.6 miles north of the traffic circle.

Cuttings should be obtained in the early spring of the year in which they will be planted, well before growth begins. A cutting should be not less than 12 inches long or one-half an inch in diameter. The butt ends should be pointed to facilitate inserting them into the ground and the tops should be trimmed about an inch above a bud. Cuttings should be tied up in bundles, and buried in moist soil until required; they must not dry out.

Cuttings should be planted by inserting almost their full length into the ground with the buds pointing upwards, and only about two inches protruding. If the soil is sufficiently moist, the cuttings can be driven or pushed in without difficulty. However, if the ground is hard enough to strip the bark or cause splitting, holes should be prepared with a pick or planting bar. During planting, cuttings can be carried with the butt ends in water. Spacing should be fairly regular, averaging 5x5 feet (1,742 cuttings per acre).

Wattling

In several places at the top of the slope where the sand cap is thickest, the sand tends to run down over the silt. Wattles of coniferous brush will have to be staked along the slope in these locations to prevent movement of the dry sand until the cuttings have rooted.

Wattles should be laid out in two rows, one just above the sand-silt interface, and the other about half way between the first row and the top of the slope. Wattles should consist of a double layer of young, long-crowned lodgepole pine, 7 or 8 feet tall. Each tree should overlap the next one by about half its length, and should be settled well down into the sand. If these rows are supported about every three feet on the downhill side by stakes three and one-half feet long by one and one-half inches in diameter, driven about two feet into the slope, they will provide an effective barrier to sliding sand. Cuttings should be planted above and between the rows of wattles in the normal manner. It is stressed that success of the wattling operation will depend on the treated areas remaining free from mechanical disturbance.

Escarpment Fence

If the escarpment edge, wattled areas, and young trees are to be protected, trespassing and the disposal of rubbish on the slope must be discouraged. For this purpose a fence should be erected along the edge of the airport from the R.C.A.F. guest house to Puckett's Gulch. The fence will serve also as an excellent windbreak for the young seedlings of the shelterbelt which is referred to later. The fence should be located as far from the escarpment edge as the location of the existing buildings and airport road permit. Ordinary 48-inch snow fencing, with posts at 16-foot intervals, should be suitable.

Planting Conifers

Both of the alternatives suggested to rehabilitate the escarpment will involve the planting of conifers. Under Alternative I the shelterbelt will require approximately 10,000 lodgepole pine seedlings, while Alternative II will require, in addition to the seedlings for the shelterbelt, the planting of approximately 33,000 spruce seedlings.

The establishment of young conifers involves a number of steps. The first of these is the collection of seed in the vicinity of Whitehorse or in the southern portion of the same forest region, to ensure a suitable provenance. In order to obtain the 1.5 pounds of white spruce seed and 0.7 pounds of lodgepole pine seed required, it will be necessary to collect about 100 pounds of spruce cones and 25 pounds of pine cones. Collection should be completed in a few days by felling the cone-bearing trees. The cones should then be shipped in sacks to the Forest Nursery Station, Indian Head, Saskatchewan (or the Petawawa Forest Experiment Station, Chalk River, Ontario), for extraction, dewinging, cleaning, and germination tests.

The raising of planting stock from seed should be undertaken as close to the planting site as possible. The most suitable location, by reason of available facilities and trained personnel, would be the Whitehorse Experimental Farm, Haines Junction, Yukon Territory. If possible, arrangements should be made with the Department of Agriculture for production of the planting stock at the Farm. Failing this, a small nursery should be set up at Whitehorse.

Seed should be sown to produce about 120 spruce seedlings per square foot and 75 pine seedlings per square foot. At the end of the second year the 2-0 seedlings should be transplanted to a density of about 10 seedlings per square foot. Two years later the 2-2 stock should be ready for planting in the field. Of the 33,000 spruce and 10,000 pine transplants required, two-thirds of each should be planted out as 2-2 stock, and the remainder held over one year for refilling failures.

At the planting site the stock should be heeled in, shaded, and watered. During planting the trees can be carried in pails with their roots in water. It is suggested that planting be carried out by 2-man crews, with one man carrying the trees and the other digging the holes with a grub hoe. Trees should be planted at 5x5 feet, the spruce in the silt and the pine in the upper sandy portion.

Shelterbelt

A belt of 5 or 6 rows of lodgepole pine should be planted along the top of the escarpment to reinforce the edge, limit wind erosion, and discourage human activity in its vicinity. The shelterbelt would occupy the space between the escarpment edge and the proposed fence or buildings. The trees should be set out at 5x5 feet, at the same time as the escarpment planting. No preliminary cover of cuttings will be required.

Airfield Seeding

This operation is closely related to the reforestation of the escarpment. According to the agronomist at the Whitehorse Experimental Farm, intermediate wheat grass (*Agropyron intermedium*) is the species best suited to conditions on the airfield. This grass has been tested at Haines Junction and found both hardy and drought-resistant under the prevailing climate. The seed may be sown in the spring or the fall. If in the spring it should be sown at least before July, at the rate of 10 to 15 pounds per acre. With a tractor-drawn drill, 20 to 30 acres could be covered in a day. It might be possible to borrow a drill from the Farm.

It was thought advisable, but not essential, to apply a nitrogen fertilizer (16-20-0 or 33.5-0-0) at a rate of 100 pounds per acre.

REHABILITATION COSTS

This discussion of the costs of reforesting the Whitehorse airport escarpment is at once conditioned by the methods used, the timing of the many operations, and the possible economies which could be made through the loan of equipment by various government departments in Whitehorse to the group undertaking the work.

Two Alternative Measures

It has been stated earlier that the forest cover which might grow from hardwood cuttings would probably afford sufficient protection to the escarpment, particularly if supplemented by a shelterbelt and a fence, both of which would run the entire length of the airport escarpment. This measure we have called Alternative I. Its long-term function of stabilizing the slope and its usefulness in providing a suitable environment for coniferous growth, either natural or artificial, have been mentioned.

Alternative II goes a step further than Alternative I and is the method which could be used to restore a coniferous cover to the escarpment. The costs of the two Alternatives are given below according to the items involved.

Schedule I - Nursery at Whitehorse

Cost Item	Alternative I	Alternative II
1. Cone collection and shipment	$ 50	$ 100
2. Nursery work at Whitehorse	1050	3100
3. Planting cuttings	2100	2100
4. Wattling	250	250
5. Escarpment fence	1300	1300
6. Pine shelterbelt	400	400
7. Spruce planting	-	2250
	$5150	$9500

Schedule I for Alternative II is broken down in further detail in Appendix C-1 showing the expected yearly expenditures for the six years required to carry out the project, under the assumption that the nursery work would be done at Whitehorse. It will be noted that Item 2 of Schedule I for the nursery work represents a large proportion of the over-all cost for either Alternative. The cost of producing this relatively small number of seedlings at Whitehorse including the collection of cones and the establishment and care of a small nursery, would amount to something over $100 per M seedlings for Alternative I and $70 per M for Alternative II. These figures appear particularly high when compared with the charge made by the Ontario Department of Lands and Forests of $15 per M seedlings for four-year-old planting stock. This would strongly indicate that considerable savings could be made by having the stock grown at an established nursery or experimental farm outside Whitehorse. In this context it has already been suggested that the Department of Agriculture Experimental Farm at Haines Junction, Y.T., could probably be relied upon to take on this work. Assuming, then, that the department or agency which undertook to raise the seedlings charged them to the project at $30 per M seedlings for both pine and spruce, including shipping costs, the estimates in Schedule I, Item 2, could be reduced to $300 and $1300 bringing the total costs down to $4400 and $7700 for Alternatives I and II respectively as shown below.

Schedule II - Nursery outside Whitehorse

	Cost Item	Alternative I	Alternative II
1.	Cone collection, etc.	$ 50	$ 100
2.	Seedling purchase at $30/M	300	1300
3.	Planting cuttings	2100	2100
4.	Wattling	250	250
5.	Escarpment fence	1300	1300
6.	Pine shelterbelt	400	400
7.	Spruce planting	-	2250
		$4400	$7700

Each item for Alternative II has been broken down into labour and materials, including freight, in Appendix C-1. The cost of the planting operations is largely comprised of labour costs while the major portion of Item 5, the escarpment fence, is made up of the purchase price of the fence. It should be remembered, too, that planting costs, i.e. Items 3, 5 and 6, include truck rental costs for moving personnel and equipment. This is important when considering the possible economies which could be made through the loan of equipment and supplies.

Timing of Operations - Costs

The costs of either alternative measure will be spread over six or seven years from the time the project begins. It has been mentioned that the forestry rehabilitation measures should be held up until the airport has been seeded with grass, and a successful cover obtained, and the drainage improvements made. This is important from the standpoint of costs just as it is in assuring the success of the whole operation.

The cost outlays, by years, are presented below, in Schedule III, for both alternatives. It will be seen that the costs over the first three years for either alternative are almost identical. The major differences, of course, occur in the sixth and seventh years where under Alternative I there is only the shelterbelt to be planted whereas, in Alternative II, in addition to the shelterbelt, there is the planting of spruce on 14 acres of the escarpment, where presumably the hardwood cuttings are now well established. In addition, replanting of conifers will have to be carried out in the seventh year under both alternatives to allow for failures. And again this is a large item for Alternative II.

Schedule III - Cost Summary - By Years

Year		Alternative I	Alternative II
1st	Seed collection, etc.	$ 50	$ 100
2nd	Planting cuttings and erecting fence	3450	3450
3rd	Replanting cutting failures	330	330
6th	Seedling purchase and shelterbelt planting (I and II), and spruce planting (only II)	380	2550
7th	Seedling purchase and replanting failures	190	1270
		$4400	$7700

The above schedule assumes, of course, that the seedlings will be grown at a nursery outside Whitehorse.

Labour Supply and Wages

No difficulty is foreseen in hiring labour at Whitehorse. In the early spring of 1958 there were 500 unemployed persons registered for unemployment insurance benefits. By June the number had been reduced by only 200. The reforestation of the escarpment could in no sense be considered a project to relieve any future unemployment in Whitehorse. Perhaps the measures designed to improve the drainage system could do this. However, it is suggested that because this surplus labour situation exists, no attempt should be made to enlist the free services of the Boy Scouts or similar bodies. At no time would the project require more than 12 workers on the escarpment, and this would be for a period of three weeks at most, for any specific operation.

The base rate in the Whitehorse district is governed by the D.N.D. Army rate of $1.48 + 30 cents Northern Living Allowance, or at present, $1.78 per hour. In the estimates for the labour costs of each operation an average rate of $2.00 per hour has been allowed. This is expected to be the average hourly rate for the whole project at today's rates to allow for the higher wages paid for supervision. For instance, the planting of cuttings will require three two-man crews and a foreman over the whole operation. The average hourly wages paid in this instance would closely approximate $2.00 per hour. An adjustment, according to wage increases in the Army rate, would serve as a basis for extimating the labour costs at the time the project begins. In other words, a 5 per cent increase in wages would increase the cost of labour under Alternative I, excluding nursery work at Whitehorse, by $100 and increase it under Alternative II by about $200.

Productivity

Productivity rates for the major operations were based on experience, taking into consideration the difficult terrain, the variation in soil hardness, and inexperienced labour. The productivity rates used in the estimates are set out below:

Major Operations - Productivity Rates

Item	Rate per man-hour
Making and bundling cuttings	
Willow cuttings (no.)	250
Poplar cuttings (no.)	200
Planting cuttings (no.)	81
Wattling (lineal feet)	82
Cutting, pointing and loading fence posts (no.)	4
Erecting fence, driving posts (lineal feet)	20
Planting conifers -	
Spruce seedlings (no.)	50
Pine seedlings (no.)	75

Man-Days and Total Labour Costs

It is estimated that a total of 231 man days will be required to complete the entire project of coniferous rehabilitation, assuming the nursery work can be done outside Whitehorse. This will amount to approximately $3,700 spread over seven years at the straight time rate of $16 per day for labour with no allowances for an increase in wages during that period. This total represents the labour cost for Alternative II with the nursery outside Whitehorse. With a nursery at Whitehorse, under Alternative II, the total man-days required would be 344 at a cost of $5,400.

For Alternative I the man-days required would be 132 at a cost of $2,110, with the nursery outside Whitehorse, or 166 man-days at a cost of $2,660 with the nursery at Whitehorse as shown in Schedule IV.

Schedule IV - Labour Costs and Man-Days

	Alt. I - Hardwood Rehabilitation		Alt. II - Coniferous Rehabilitation	
	Man-Days	$	Man-Days	$
Nursery at Whitehorse	166	2660	344	5400
Nursery elsewhere	132	2110	231	3700

It may be seen from the table that there would be an obvious saving in the labour element to have the seedlings grown at a nursery outside Whitehorse.

Cost of Materials

The costs of material and equipment, as with other commodities and services, are comparatively high in Whitehorse. This is largely due to the location of Whitehorse and the fact that it is not connected with the transcontinental railway system. It is served instead by the White Pass and Yukon Railway which runs from Skagway, Alaska, on the Pacific coast, and also by the Alaska Highway, and, as may be imagined, freights are high. This has been taken into account in the estimates; the assumption being made that materials will be purchased at Edmonton and also that they will include the road freight from that city to Whitehorse. Such items as lumber could probably be obtained more cheaply locally.

The cost of materials for either alternative will not differ appreciably according to whether the nursery is located at, or outside, Whitehorse; however there is a significant difference between Alternatives I and II as shown below in Schedule V as far as the over-all costs are concerned.

Schedule V - Cost of Materials

	Alternative I	Alternative II
Nursery at Whitehorse	$ 2490	$ 4100
Nursery outside Whitehorse	2290	4000

The reason why these costs do not differ appreciably between the two possibilities of having the nursery at Whitehorse, or outside it, is because the costs of purchasing seedlings is more or less equivalent to the cost of materials required to set up a nursery at Whitehorse.

The cost of materials includes such items as tools, freight, truck rental, snow fencing and materials to construct a storage tank for seedlings prior to planting and a shed for the nursery. The estimates are based on prices of material in various Canadian and U.S. price catalogues which would apply to Edmonton with appropriate allowance for freight to Whitehorse.

Possible Economies

Reference has already been made to the possible economies which could be made through the loan of equipment and supplies by various government departments to the group conducting the work. It is not possible to make an accurate estimate of these savings as it will depend largely upon the efficiency of the co-ordinating body. It is suggested however that these may amount to $1,000 for Alternative I and almost $2,000 for Alternative II, assuming the nursery is located outside Whitehorse.

The major items where economies are possible are in the loan of trucks for transporting men and equipment, the loan of tools by the Yukon Forestry Division and the loan of snow fence not presently in use.

Airport Seeding

At the end of the section dealing with rehabilitation some information was presented which related to the possible means of establishing a grass cover on the airport using fertilizer.

In estimating the costs of such an operation, which we believe vital to the rehabilitation of the escarpment, the following data were used.

Area requiring treatment	575 acres
Delivered cost of seed	70 cents per pound
Delivered cost of fertilizer	$140 per ton

The total cost of this operation, excluding the machine rental for fertilizer and seeder (which presumably could be borrowed from the Haines Junction Farm) would be almost $10,500. In discussing this problem with personnel of the Department of Agriculture in Ottawa, it was mentioned that the species recommended would probably be suitable but that the supply of the required 9,000 lbs. may be a problem.

The methods used by the Ontario Department of Highways to "fix" soil by spraying a mixture of mineral oil, seed, straw and fertilizer were investigated. It was found, however, that the costs of this method would be far in excess of those referred to above.

REFERENCES

(1) Legget, R.F. 1954. Slope stability at Whitehorse, Y.T. Special Report No. 12 of the Division of Building Research, National Research Council.

(2) Wilson, G.M. 1958. Memorandum for F.H. Collins, Commissioner, re: Whitehorse escarpment problem. March 26.

(3) Brander, J.S. 1956. Topographic plan of airport escarpment, Whitehorse, Yukon Territory, sheet 1 of 1, scale 1 inch to 50 feet. Public Works of Canada.

APPENDIX C-1

WHITEHORSE AIRPORT ESCARPMENT REHABILITATION

SUMMARY OF ESTIMATES - ALTERNATIVE II
(With Nursery at Whitehorse)

		Man days	Labour	Materials	Sub-totals	Total
1.	Cone collection	3 1/2	$ 56	$ 10	$ 66	
2.	Cone shipment	-	-	20	20	
3.	Seed extraction, etc.	not available				
4.	Nursery establishment	3	48	1200	1248	
			FIRST YEAR TOTAL			1334
5.	Nursery establishment and care, etc.	27	432	5	437	
6.	Planting cuttings	58	928	994	1922	
7.	Wattling	14	224	-	224	
8.	Escarpment fence	30	480	826	1306	
			SECOND YEAR TOTAL			3889
9.	Replanting cutting failures	10	160	170	330	
10.	Nursery-Transplant beds	24	384	207	591	
			THIRD YEAR TOTAL			921
11.	Nursery-Seedlings to Trsp. beds	27	432	-	432	
			FOURTH YEAR TOTAL			432
12.	Nursery-Care and Maintenance	12	192	-	192	
			FIFTH YEAR TOTAL			192
13.	Nursery-Seedlings to Escarpment	13	208	-	208	
14.	Conifers Planting Escarpment	67	1072	600	1672	
15.	Conifers Planting Shelterbelt	14	224	100	324	
16.	Replanting Conifers failures	33	528	60	588	
			SIXTH YEAR TOTAL			2792
	TOTALS		5368	4192		9560

Supplementary Estimates

		Man days	Labour	Materials	Sub-totals	Total
17.	Airport Grass Seeding	12	192	10248	10440	10440
	GRAND TOTALS		$5560	$14440		$20000

APPENDIX D

PERTINENT EXTRACTS FROM THE REPORT ON WHITEHORSE AIRFIELD SLIDES INVESTIGATION YUKON TERRITORY

NOVEMBER, 1958

Warnock, Hersey and Company Ltd., Montreal, P.Q.

G.S. Eldridge and Company Ltd., Vancouver, B.C.

INTRODUCTION

In August 1958, the two firms of G.S. Eldridge and Company of Vancouver, and Warnock, Hersey and Company of Montreal were called in to carry out a comprehensive exploratory survey of the airfield on behalf of the Department of Public Works. The appended report summarizes the conclusions to be drawn from their findings. The evidence revealed is much wider than was available to the Division of Building Research in 1954. The general conclusions in the earlier report, however, appear to be substantially correct, the main difference being that Mr. Legget's report approaches the problem as being one of slope stability, whereas, in the following report, the standpoint has been taken that the problem is mainly one of internal erosion of the silt surface.

DRILLING PROGRAM

A total of 517 auger-holes were sunk on the airfield in accordance with a 100 ft grid staked out by the Department of Public Works, who gave ground elevations for each grid point. Some difference between (these ground) contours and those of the original drawing, R-YU-18, is evident. As it is out of the question for the entire airfield surface to have been lowered to the extent that this difference would indicate, it must be assumed that there is a difference in the bench mark used. Drain elevations should therefore be referred to the same bench mark as used in the setting out of the grid. To sink these auger-holes, a 6-inch power-auger, mounted on a bombardier chassis was employed. Drilling started on 25 August, and the program was finished on 14 October, averaging approximately 11 holes per day.

To interfere as little as possible with air traffic, a rig with limited headroom had to be employed, and 5 ft flights of spiral auger were used with the short mast on the rig. Changing flights frequently made drilling slower than would have been possible had a rig with a tall mast been used. Occasional disturbed samples of sand were extracted for field laboratory mechanical analysis and moisture content determination. Three hundred and sixty one disturbed silt samples for the same purpose were also taken, as well as four undisturbed Shelby tube samples for more elaborate laboratory study in Victoria laboratory. Depth of sand could be logged with fair accuracy as soon as the silt was reached, enabling spot levels of the silt surface to be plotted and silt contours drawn in.

As drilling progressed, in order to establish where closer detail was needed, a plot was made of silt moisture contents at the contact with the sand, and isopleths of moisture content drawn in. This served the additional purpose of giving a lead on the source of moisture reaching the silt surface and engendering the mud-runs during the critical thaw period.

In no case were silt lenses encountered in the sand layer, and although the holes were carried down into the silt for a depth of approximately 5 to 10 feet, no sand lenses were encountered in the latter. The silt, therefore, appears to be consistently homogeneous, although the grading curves show slight differences in grain size.

APPENDIX E

SUMMARY OF SOIL TEST RESULTS

Soil samples of the silt in the Whitehorse Escarpment were obtained during the course of various investigations carried out by the Department of Transport (1954), the Department of Public Works (1955) and the Division of Building Research, National Research Council (1954 and 1957). The results of classification tests on these samples are summarized in Figs. E-1 and E-2.

Soil samples were also obtained and tested by the consultants for the Whitehorse airfield borings program completed in 1958. The results of the various tests carried out by them are included in their report entitled "Whitehorse Airfield Slides Investigation".

SOIL TEST SUMMARY RECORD - CLASSIFICATION

PROJECT: P-158	REMARKS:
LOCATION: Whitehorse Airport	

SAMPLE Nº	SOIL DESCRIPTION	DEPTH (FEET)	GEODETIC ELEV. (FEET)	NATURAL W/C (%)	L.L. (%)	P.L. (%)	P.I. (%)	GRAIN SIZE PERCENTAGES GRAVEL	SAND	SILT	CLAY	G			REMARKS Testing By
XY-1	Light grey silt	11.6		27.3	28.6	22.5	6.1	-	7	88	5				DOT 1954
XY-2	do	12.0		28.4	28.4	23.9	4.5	-	4	91	5				do
XY-3	do	9.0		28.4	30.1	23.7	6.4	-	6	87	7				do
XY-11	do	7.5		27.5	29.2	24.1	5.1	-	5	83	12				do
#16	do	15		26.2	27.2	20.6	6.6								DPW 1955
52-2	do	1.0			26.3	19.2	7.1	-	15	68	17	2.74			DBR-NRC 1954
52-4	do	2.5			23.3	18.4	4.9	-	26	60	14				do
52-5	do	3.5			19.4	16.5	2.9	-	21	65	14	2.73			do
52-6	do	6.0			26.0	20.9	5.1	-	9	75	16				do
52-7	do	10.5			32.6	22.0	10.6	-	15	71	14				DBR-NRC 1957
WH7-28	do	28			31.6	21.9	9.7								do
WH21-18	do	18			27.7	21.8	5.9								do
WH31-4	do	4.0			34.3	23.8	10.5	-	4	75	21				do
WH37-10.5	do	10.5			30.8	23.1	7.7	-	13	70	17				do
WH43-9.3	do	9.3			34.3	24.5	9.8	-	2	81	17				do
WH13-26	do	26.0			32.2	19.2	13.0								do

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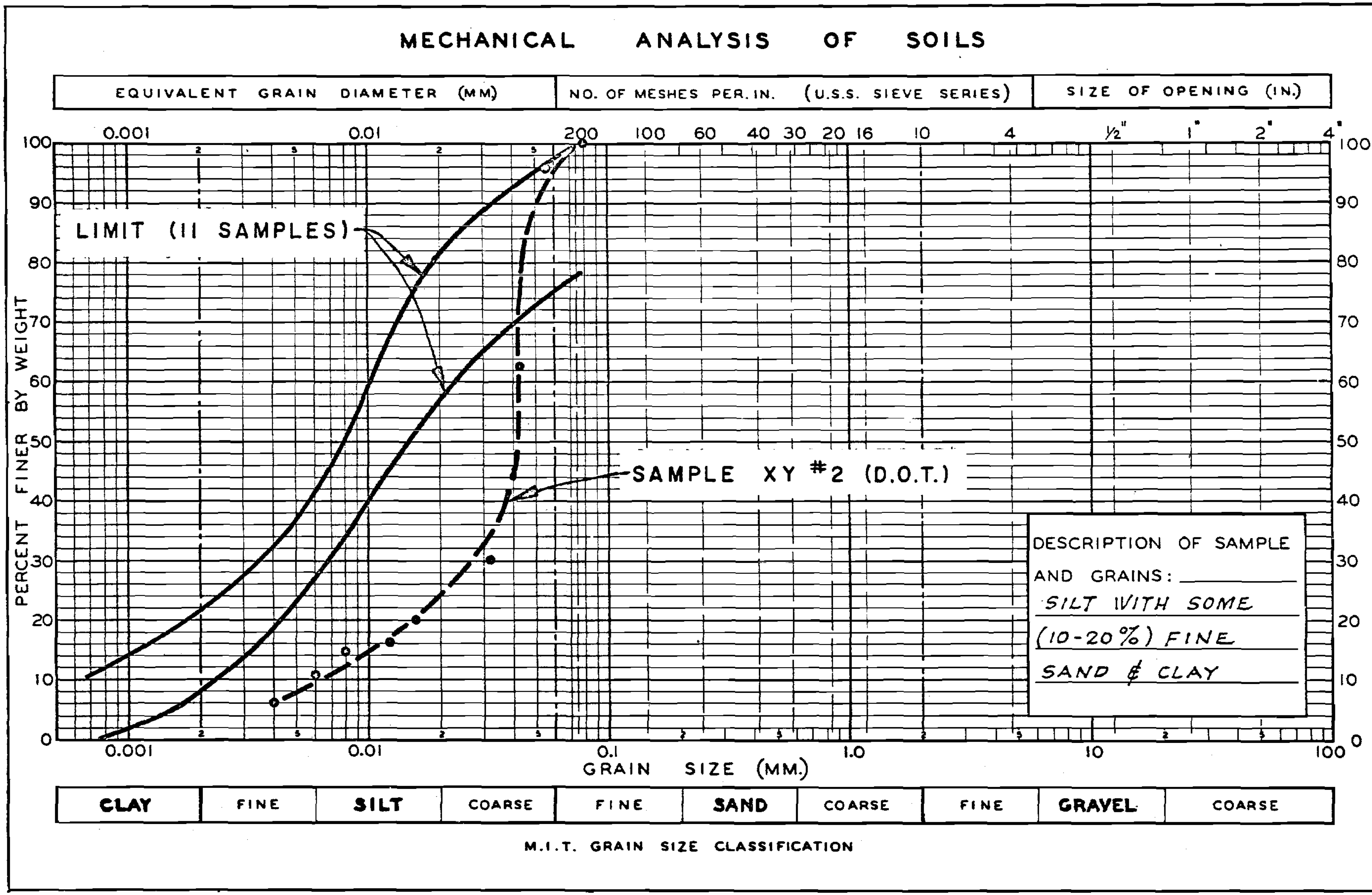
Figure E-1 Soil Test Record Summary, Whitehorse Airport

BR 1882



WHITEHORSE SILT - GRAIN SIZE DISTRIBUTION LIMITS.

FIGURE E-2

BR 1509