# Comprehensive Airport Pavement Surface Profile Collection and Analysis

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# 1.0 INTRODUCTION

The Iqaluit International Airport, located in Iqaluit, Nunavut is a facility constructed in a region of pervasive permafrost. In recent years, Runway 16-34 has developed significant pavement surface distortions of possible concern to aircraft operations. These distortions present increasing more complex maintenance and planning challenges for the facility pavements. In order to assess the Runway 16-34 pavement surface, an extensive field data collection program was undertaken, which included geo-spatially referenced high-resolution pavement profile data over the entire surface of the runway. Long wavelength post-processing allowed the compilation of the collected inertial longitudinal profiles to create an accurate high-resolution surface elevation map for the entire pavement surface. This surface elevation map provided the ability to interpret changes in runway profile and localized surface undulations. This comprehensive pavement surface elevation data, combined with other field data was compiled into a Graphical Information System (GIS) for client visualization and presentation. The entirety of the collected field data represents the foundation for a comprehensive pavement condition evaluation.

This profile data also provided an alternative perspective into the Airport's unique underlying geophysical conditions associated with the complex network of ice wedges and lenses. This data, when analyzed with detailed information pertaining to the active layer depth and subsurface thermal profiles, provided a method for quantifying the effect these sub-surface anomalies had on runway surface condition and ride quality. Ultimately, the results from this analysis were used to quantitatively identify pavement sections with the potential for airframe damage or other safety concerns during aircraft operations, and provided a means for selecting the most appropriate remedial action for restoring the long term integrity of the runway surface. The paper presents the collection, analysis and presentation of high resolution pavement profile data for Runway 16-34 at the Iqaluit International Airport.

# 2.0 BACKGROUND INFORMATION

## 2.1 Airport History

The Iqaluit International Airport (Airport), often referred to by its International Civil Aviation Organization (ICAO) code CYFB, is a single airstrip airport located adjacent to the City of Iqaluit at the land end of Frobisher Bay, Nunavut, Canada. The Airport serves not only the City of Iqaluit, but also acts as an essential hub in the development of Canada's north. The Airport is owned by the Government of Nunavut (GN) and operated by the Iqaluit International Airport Division Authority.

The Airport itself was originally founded as the Frobisher Bay Air Base in 1942 by the United States Air Force, and was used throughout the 1940s and 1950s by both Canada and the United Sates for transportation purposes. The base was eventually closed in 1963 and converted into a civilian airport.

The general geographic location of the Airport is provided in Figure 1.

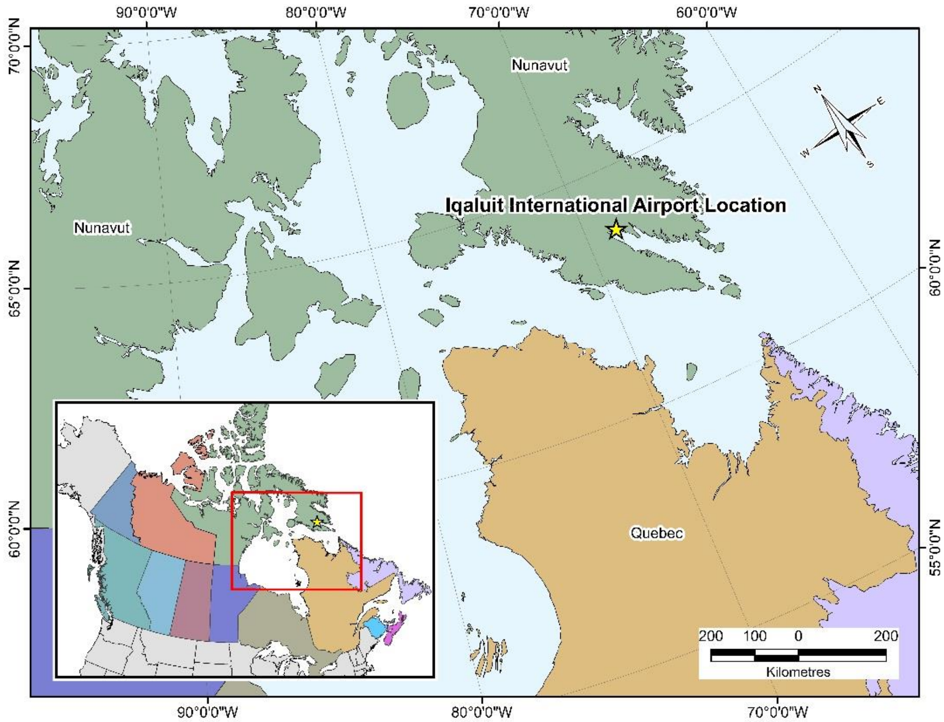


**Figure 1 – Iqaluit International Airport Location**

Presently, the Airport hosts regularly scheduled passenger air traffic from Montreal, QC, Ottawa, ON, and Yellowknife, NWT as well as supporting regional air traffic from a number of neighbouring Nunavut municipalities. In total, the Airport experiences over 19,000 annual aircraft movements, providing service to more than 120,000 passengers. In addition to civilian air traffic, the Airport is used as a forward operating base by both the Canadian and United States of America, and receives air traffic from both countries. The Airport in experiencing a rise in air traffic, which has been estimated to be increasing at a rate of five percent per year since 2000.

Airport facilities presently include one 9000 ft. (2740 m) runway (16-34), five taxiways, and four Aprons. The Airport can accommodate nearly all military and commercial aircraft, as is often used for cold weather testing/certification for aircraft manufacturers.

## 2.2 Iqaluit International Airport Improvement Project (IIAIP)

In 2009, the Canadian Federal Government announced its integrated Northern Strategy, which is based on four equally important and mutually reinforcing priorities: 1) Exercising our Arctic Sovereignty; 2) Promoting Social and Economic Development; 3) Protecting our Environmental Heritage, and 4) Improving and Devolving Northern Governance. This initiative included a commitment to both exercising Canada's arctic sovereignty as well as strengthening Canada's arctic presence through investment and development.

In 2012, the Canadian Federal Government, in conjunction with the Territorial Government of Nunavut and Partnerships Canada announced a commitment to fund a major construction initiative to upgrade and improve the airport facilities at the Iqaluit Airport. The project, dubbed the Iqaluit International Airport Improvement Project (IIAIP), was procured through the Private-Public-Partnership (P3) alternative delivery model. Many public agencies are starting to utilize the P3 model to finance the expansion and rehabilitation of existing infrastructure that would have otherwise been completed through traditional project development. One of the primary reasons public agencies consider the P3 model is the expanded economic capacity generated from the upfront financing through private equity and the commitment of federal investment (i.e., Partnerships Canada). Diversifying the potential source of funding has allowed public agencies to pursue large infrastructure projects that otherwise may have been unaffordable.

The project includes the Design, Build, Finance and Operation (DBFO) of the upgraded facilities, with a total capital investment estimated at $298.5M. The IIAIP project includes:

- A new 100,000 square feet (9,000 square metre) Air Terminal Building (ATB);
- Retrofitting the existing terminal which will become solely an administration building and control tower;
- Expanding parking lots;
- A new access road for future City's development (North Commercial Road)
- A new Combined Services Building to house all airport and safety vehicles;
- Reconstruction of existing Taxiway A;
- Construction of two new Taxiways (G and F);
- Widening of Apron I;
- Rehabilitation and repaving of runway 16-34;
- Construction of a new fuel dispensing system, and
- Replacement of airfield lighting system (including a new Field Electrical Center)

A rendering of the proposed Apron I expansion and the new ATB is shown in Figure 2.


**Figure 2 – Future Iqaluit International Airport Apron and Air Terminal Building**

In 2013, The Government of Nunavut selected a consortium led by Arctic Infrastructure Partners to design, build, finance, operate and maintain the IIAIP project. The consortium includes InfraRed Capital Partners, Bouygues Building Canada, Sintra Inc. and the Winnipeg Airport Authority. This team will coordinate the design, construction and operation of the Airport for the next 34 years. Bouygues Building Canada and

Sintra Canada will jointly manage the design and build aspects for the project. The Winnipeg Airport Authority will provide the airport services.

## 2.3 Basis for Performance Based Design

The P3 project delivery model has introduced the concept of performance-based design. A performance-based design approach is founded on the principal where the design and construction of an asset is completed to achieve a set of prescribed performance results. This is fundamentally different when compared to the traditional design approach which would specify a way and method to the design and construction process. In a performance-based approach, the focus of all decisions is on the level of service requirements and on the minimum required performance in use. This approach encourages the development of tools and methods that incorporate a whole life-cycle design and construction process, from the procurement and construction phases to the quantification and evaluation of results.

The four primary components to the performance-based design process are:

1. Identifying and formulating the relevant user requirements (i.e. runway condition and smoothness);
2. Transforming the user requirements into performance requirements and measureable performance criteria (i.e. Structural Condition Rating, Riding Comfort Index);
3. The development of reliable design and evaluation tools that can measure whether potential design alternatives meet the stated criteria at a satisfactory level; and
4. Accurate and reliable evaluation of the completed infrastructure to verify compliance with the stated performance criteria.

As such, the performance-based approach focuses all stages of procurement, design, construction, and operation and maintenance, on the required performance in use and on the evaluations and testing of the constructed infrastructure.

The airside pavements components of the IIAIP project follows the performance-based design approach. Initial pavement design/rehabilitation must be completed to meet certain initial structural requirements, as well as ongoing performance (surface distress and smoothness) requirements. The means the designer has to not only consider the as-constructed condition of the pavement, but also the ongoing condition throughout the 34-year concession period. Future interventions (typically maintenance activities and rehabilitation treatments) are forecasted using pavement performance modelling to ensure compliance with the project performance specifications

## 2.4 Context of this Paper

This paper focuses on the pre-construction runway condition. The constructor was interested in establishing a base-line total runway smoothness condition assessment for the purpose of identifying and quantifying existing runway distresses and distortions how they contribute to the overall runway ride quality. This base-line information could be used for primarily two purposes:

1. Assist in quantifying the adverse impact on runway ride quality of existing pavement surface distresses/distortions, and

2. Assist in the estimating the design life of future runway surface repairs, and how they will contribute to the restoration of runway surface profile.

The IIAIP 30-year Concession has specific runway ride quality performance requirements during the Operations, Maintenance, and Rehabilitation (OM&R) period. Specifically, the runway must be constructed, maintained and handed-back in compliance with the following requirements:

- The level of Runway performance at the commencement date shall have and Ride Comfort Index (RCI) greater than 7.2. This is approximately equivalent to an IRI of 1.30 m/km;
- The Runway pavements are to be maintained for the duration of the agreement with a minimum RCI rating of 5.0. This is approximately equivalent to an International Roughness index (IRI) of 2.7 m/km; and
- Airfield pavements shall have a minimum RCI rating of 6.0 at handback. This shall apply only to the Runway. This is approximately equivalent to an IRI of 2.0 m/km.

There are however, additional advantages to maintaining a smooth and serviceable runway surface. Large surface depressions or pavement distresses can impact not only user comfort, but also result in elevated stress on aircraft structural elements, and in some cases require emergency repair to restore runway safety. The Federal Aviation Administration (FAA) and others have produced other tools for evaluating runway profile as it relates to the safety and operation of aircraft, including the Boeing Bump Index (BBI). This paper attempts to address some of these additional methods for analyzing runway surface profile.

# 3.0 EXISTING GEOLOGICAL CONDITIONS

## 3.1 Summary of Existing Geological Conditions

The existing surficial geology at the Airport consists of sandy and gravelly glaciofluvial and glaciomarine sediments that extend under the airport and its surroundings. As a result of its Arctic geographic locations, the area is underlain by continuous permafrost. In addition, a large network of patterned frost cracks have manifested throughout the Airport area. Review of historical aerial photography shows a large network of surface water that has since been filled/diverted to accommodate the construction of the various airport facilitates. The migration of surface water during freeze/thaw periods has resulted in the evolution of many of these frost cracks into large ice wedges. Over time, airport pavements constructed over these ice wedges have experienced poor performance as a results of the gradual erosion of the ice wedges themselves and the resultant settlement of the pavement structure above them. Figure 3 shows two areas of pavement surface distress/settlement over an area of anticipated ice wedges.

**Figure 3 – Surface Distresses/Settlement Associated with Underlying Ice Wedges**

### 3.2 Geological Impacts on Existing Runway Conditions

The unique geological conditions found throughout the IIAIP present technical challenges for the maintenance of future infrastructure. Over the past few centuries, the existing ground within the general area of the airport have experienced cyclical freeze/thaw pattern that has resulted in an extensive network of subsurface ice wedges. It is this network of subsurface ice wedges that are a particular concern. The historical construction of the runway, and the systematic impact on the subsurface active layer profile/depth has led the gradual erosion of these ice wedges. The result of this is evident in the localized runway settlement and surface distresses within proximity of ice wedge locations. These settlements, and the localized impact loading they present have a detrimental effect on aircraft airframes and landing gear. In addition, the localized pavement surface wavelength and amplitude contribute significantly to the runway IRI (which is directly correlated to RCI). This is of particular concern, as one of the runway performance measures during the Concession is specified in terms of IRI. It was a significant challenge to develop a method to repair the distressed runway areas in a manner that most appropriately addresses the potential for future settlement during the runway rehabilitation design. The estimated performance of the finalized repair methods were used to predict future runway surface profile condition, and the potential impacts on overall RCI (and IRI).

## 4.0 RUNWAY SURFACE PROFILE DATA COLLECTION

### 4.1 Standard Industry Practice

Typically, due to the long-wave nature of the bumps which negatively affect aircraft, visual observations or high-speed car runs cannot identify the roughness. Any practical evaluation of roughness requires profile elevation surveys over the entire high-speed portion of the runway under investigation. Transport Canada's Aerodrome Standards and Recommended Practices TP312 4th Edition (Section 4.1 of Attachment

A) suggests that the finished surface should have no deviations which exceed 3 mm when tested with a 3 m straightedge, or FAA's guidelines of 0.25 inch over a 16 foot straightedge. FAA's Guidelines and Procedures for Measuring Airfield Pavement Roughness Advisory Circular 150/5380-9 recognizes the difficulty in quantifying roughness for airplane operations. Highway roughness measures reflect the performance of passenger car vehicle suspensions, and would not reflect the impact of surface roughness on airframe components due to excessive vertical accelerations or g-force nor cockpit vibrations. This is true for single bump events or continuous profile roughness. From an analysis standpoint, AC 150/5380-9 suggests bumps longer than 120 m do not contribute to damaging dynamic aircraft responses or otherwise negatively impact aircraft.

Due to access limitations for typical active runways, profile surveys are, as a minimum, conducted along the centerline of the runway. If access limitations permit, survey lines are also collected at centerline offsets corresponding to the main gear locations for the predominant aircraft using the runway. The main gear tracks are normally about 3 to 3.5 m left and right of the centerline.

Manual surveys, performed with an ordinary surveyor's level and rod or by total station are often done on 10 to 20 m stations and represent a trade-off between speed and profile wavelength completeness. These coarse, longer wavelength surveys can miss significant shorter wavelength surface roughness affecting aircraft. Manual surveys at 10 m stations would produce true elevation profiles with a wavelength (bump length) content range from 20 m to one half of the survey length. Other continuous true profile measuring devices, like the walking SurPRO profiler (shown in Figure 4), are self-contained and are capable of acquiring elevation measurements every 10 mm. A SurPRO profiler can complete three 2700 m survey tracks in about four hours. Both of these manual survey methods require additional referencing procedures to reference the measured profiles absolutely to either locate profile defects in the field or allow the temporal comparisons of subsequent surveys. The accurate comparison of subsequent surveys is critical to the assessment and management of any pavement assets.

**Figure 4 SurPRO Walking Profiler**

It is apparent that a self-contained continuous profile measuring device is more proficient at measuring profiles, but the significant advantage is that elevation data can be recorded at intervals as small as 10 mm. These devices produce true elevation profiles with a wavelength content range from 20 mm to one half of the survey length, and therefore, provide elevation data with much broader roughness analyses capabilities. Both of these manual techniques use survey equipment which is portable and accurate.

Another surface profiling technology which is available and widely used are inertial profile systems. These vehicle-mounted profilers combine integrated laser height sensors, with high-performance accelerometers and distance measuring devices to produce accurate short to medium-long wavelength elevation profiles. If a high quality inertial profiling system is used which incorporates high-performance accelerometers, and surveys are conducted following data collection protocol recommendations from TAC's 'Standardization of IRI Data Collection and Reporting in Canada' for dead start/dead stop surveys, then it is possible to acquire data with a wavelength content from 50 mm to greater than 300 m. This range is desirable since it covers all wavelength content of interest for aircraft roughness analysis as specified for the Boeing Bump analysis methods identified in FAA AC 150/5380-9, as well as the content required for additional roughness indices such as IRI, PrI, RN, etc. Figure 5 shows the elevation slope Power Spectral Density analysis of one of the pavement profile datasets collected on Runway 16/34 confirming the ability of the profiler to measure wavelength greater than 250 m. Inertial profilers also typically integrate GNSS (Global Navigation Satellite System) during survey activities to provide absolute spatial referencing to all collected profile data.

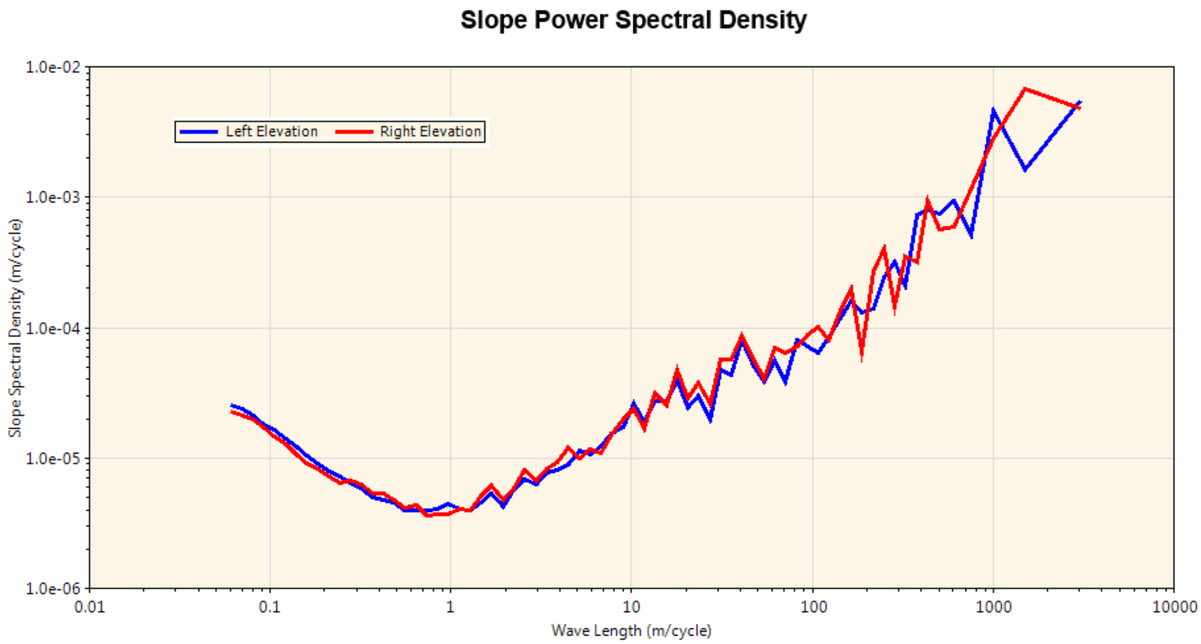


**Figure 5 Slope Power Spectral Density for the PSP-2000 Profiler**

Due to the significant and complex (longitudinal and transverse) roughness of the paved runway surface for the Iqaluit Airport facility, a roughness assessment program was required that 1) Substantially covered the entire 60 by 2740 m paved surface; 2) Collected profile data that was capable of producing the IRI roughness measure; 3) Allowed surveys be conducted on an active runway with a minimum impact to ongoing air traffic; 4) Allowed surveys to be conducted during the early winter months, and 5) Produced accurate, repeatable and fully referenced baseline profile elevation data for current and ongoing future engineering and asset management activities.

## 4.2 Data Collection Overview

In order to meet these survey requirements, full coverage runway pavement surface profiles were collected with a spatially referenced inertial profiler system. Due to the remote runway location, a portable Pavement Surface Profiling system (PSP-2000) was mobilized to Iqaluit and integrated onto the front bumper of one of the airport operators' onsite service vehicles. The profiler was mounted on the front of the vehicle to avoid the possibility of profile elevation errors caused by any pavement surface snow and ice thrown up from the rear tires obscuring the laser height sensor during surveys. The PSP-2000 system is fully AASHTO M328-10 Inertial Profiler Specification compliant and are capable of producing high resolution longitudinal pavement profiles from which all standard roadway roughness measures can be calculated (PrI, IRI, MRI, RN etc.).


**Figure 6- PSP-2000 Dual Wheel Path Inertial Profiler Integrated onto a Standard Service Vehicle**

The integration included the inertial profiling system, a high resolution distance measurement system and a real-time differentially corrected GNSS receiver. Special considerations were given to the thermal preparation necessary to ensure the accurate operation of all active profile measurement components at the ambient air temperatures of -10 to -17 °C experienced during surveys which were below the manufacturer operational limits. These thermal preparations included individual 1000 W matrix heating components and insulating wraps for each of the separate wheel path sensors, and heating elements for the control and data storage electronics.

Field surveys were completed following the AASHTO R 57-10 Operating Inertial Profiling Systems survey methodology guidelines, and TAC's 'Standardization of IRI Data Collection and Reporting in Canada' for dead start/dead stop survey protocols guidelines. Following installation, static block and bounce tests were used to ensure correct system operation following warm-up at ambient air temperatures. A PSP-2000 instrumented onto one of the airport operators' vehicle is shown in Figure 6.

At the time of survey, the runway pavement surface was clear of snow and dry in all but a few locations at the very edges of the runway with some slight snow accumulation. Multiple parallel surveys were conducted at approximately 2.5 m offsets from both sides of the Runway 16-34 center line, for a total of 24 parallel survey lines. Surveys were conducted in the northbound direction for surveys east of the centreline and southbound for surveys west of centreline. All surveys started and ended on the corresponding thresholds with significant acceleration to 50 km/h and then gradual controlled acceleration to 90 km/h and then a gradual deceleration to approximately 50km/h from 2400 to 2580 m and a sudden stop at approximately 2600 m, producing surveys of approximately 2600 metres in length. Using this approach, 50 to 60 m from each end of the surveys should be viewed as transient elevation profile zones and should not be used for medium to long wavelength analyses. All 24 survey lines were completed in 3.5 hours, including three 30-minute delays associated with landing and departing aircraft operations. A total of 24 survey lines were surveyed, resulting in 48 elevation profiles being acquired, one in each wheel path for each survey. The survey alignments for Runway 16-34 are shown in Figure 7.

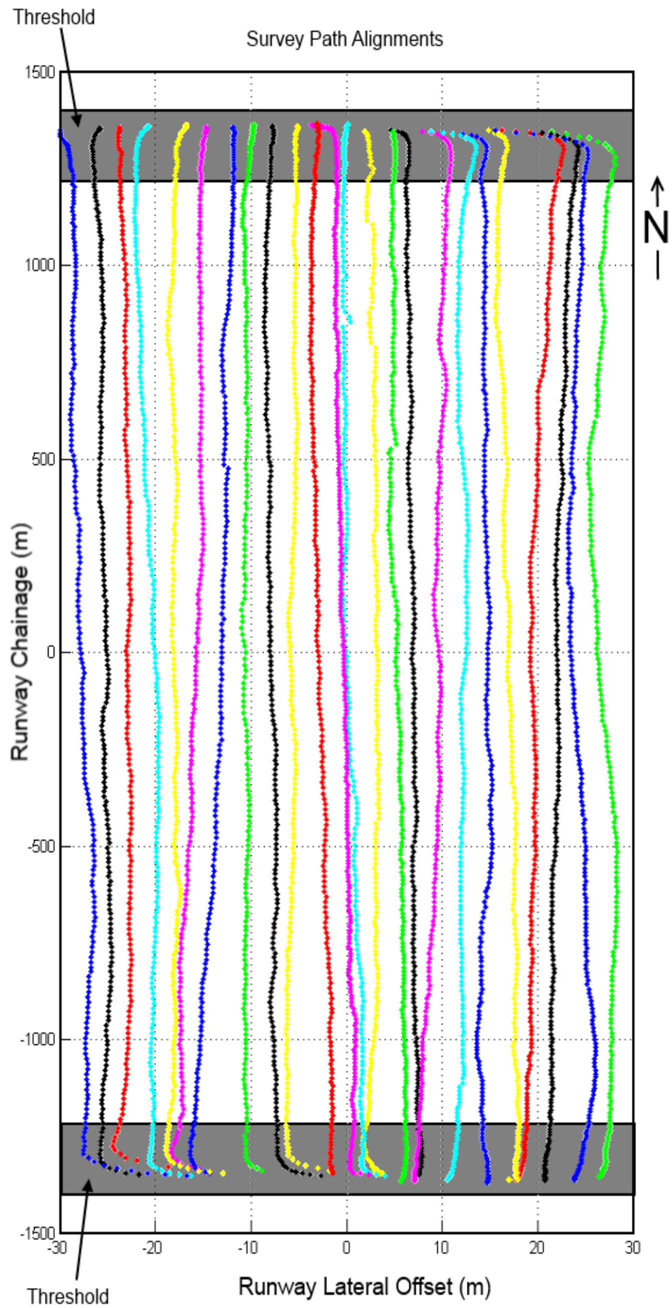


**Figure 7 Individual Survey Alignments for Runway 16-34**

All surveys was referenced, aligned and subsequently reported using the linear and spatial reference data that was synchronously collected at the time the pavement surface profiles were collected. Following the surveys, the measured true wheel path longitudinal profiles were post-processed, analyzed and reported using a combination of both proprietary profile analysis software and FAA's ProFAA software package.

## 4.3 Summary of Results

Post-processing and analysis was performed on individual elevation profiles, and the corresponding calculated output data were populated into a matrix representing the runway surface. For all analysis data sets, a total of 48 elevation profiles were analysed and reported, representing 24 surveys with separate elevation data measured in each wheel paths. Each analysis or output data point was placed into a sparse matrix corresponding to the actual runway input measurement location. The final output surfaces were then generated using 2D surface interpolation techniques. Because all source elevation profile data, and the corresponding post-processed output data are fully spatially referenced, all data can be rendered as GIS layers for graphic display and further spatial analysis.


**Figure 8 Runway 16-34 High Pass (160 m) Filtered Elevation**

### IRI Analysis

The International Roughness Index is a universally accepted roughness measure for roadway pavements, and although not as widely accepted for runway surfaces, IRI has been specified as the operational smoothness index for the Iqaluit Airport Runway 16-34. The IRI represents the simulation of a passenger vehicle suspension system response driving on the measured pavement profile at a speed of 80 km/h. The IRI Quarter Car Model used for this analysis has a waveband of significant influence on reported roughness ranging from 0.6 to 70 m. Although the IRI response is insensitive to the longer wavelengths (70 to 120 m) identified by Boeing as potentially having negative effects on aircraft, it is sensitive to a significant portion of pavement bump wavelengths. The elevation profiles were processed using a continuous 10 m averaging length and the Average 10 m IRI surface is presented in Figure 9. The IRI surface map for Runway 16-34 validates the need for a complete coverage survey of the runway surface. Significant variations in pavement elevations are seen both transversely and longitudinally as shown in Figure 8.

## Federal Aviation Administration Analyses

FAA's free elevation analysis software, ProFAA, provides the means to conduct numerous analyses on pavement profile data. These analyses can be loosely identified as static single bump analyses, reference frame based analyses or aircraft (vehicle) simulations. The rolling reference frame analysis includes the California Profilograph (25 ft. reference frame) and the Rolling Straight Edge analyses. Straightedge based pavement surface analysis are neither practical for a large pavement surface with significant lateral profile variations, nor representative of anticipated aircraft response to measured roughness reported using a short straightedge length. Figures 10 and 11 show the results of the ProFAA based straightedge analyses presented as GIS layers overlaid on an aerial photo of Runway 16-34. As is expected, the longer the straightedge length the more significant the roughness as calculated by the corresponding index. Figure 9 presents the results of the maximum absolute scallop heights in the inertial profiler measured pavement elevations calculated for a rolling 25 ft. (7.62 m) straightedge in the California Profilograph simulation. Figure 10 presents the results of the default ProFAA 5 m straightedge index calculating vertical deviations from a 5 m straightedge for all runway surface elevation data. Current Transport Canada smoothness guidelines for new runway pavements are no deviations of more than 3 mm anywhere under a 3 m straightedge. The effect of straight edge length on reported index can be seen by observing the roughness events at chainage 6+800 and 6+900. The roughness on the left side of the centreline has a shorter longitudinal length and is detected by both the profilograph and the 5 m straightedge. The same roughness on the right side of the centreline is longer and therefore is undetected by either straight edge index.

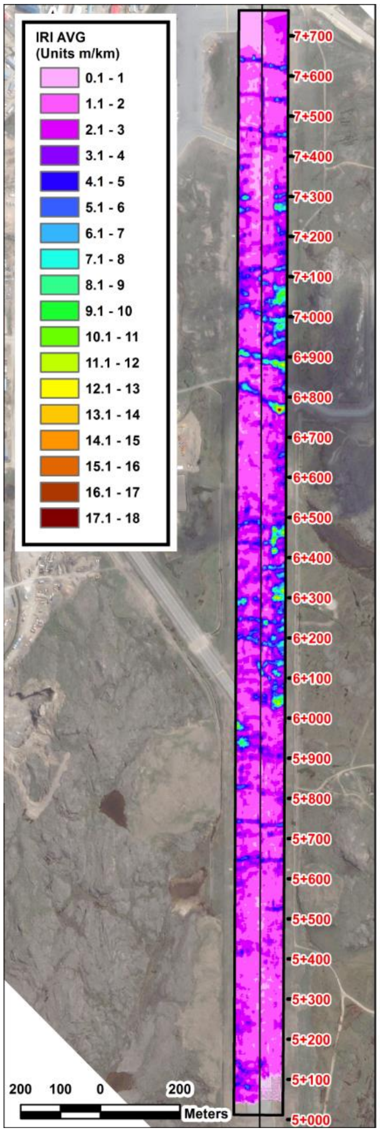


Figure 9 Runway 16-34 IRI

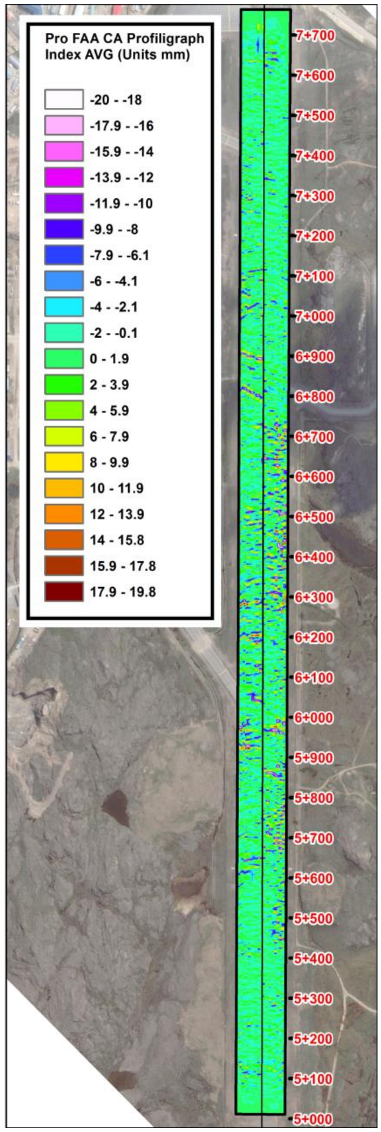


Figure 10 California Profilograph Simulation

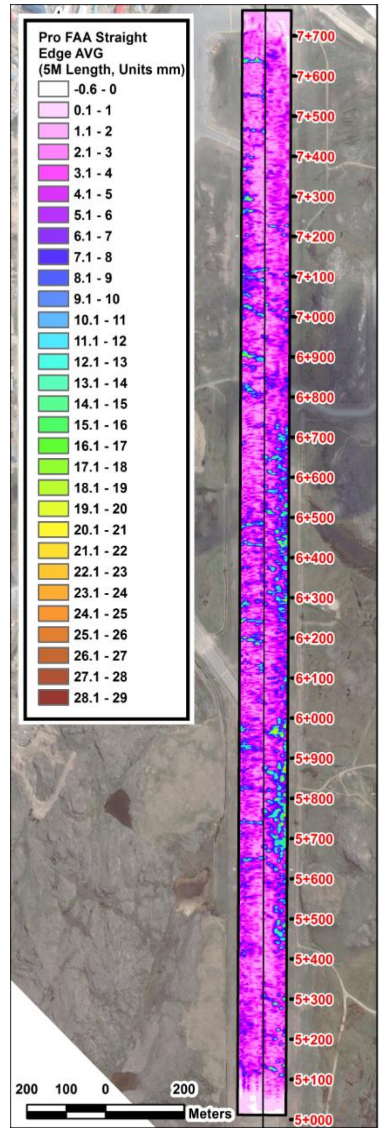


Figure 11 Rolling Straight Edge

## FAA Aircraft Simulations

ProFAA includes numerous advanced aircraft simulation methods. All of the simulations require the specification of a design aircraft and pavement elevation profiles. For Runway 16-34, the closest design aircraft available in the provided ProFAA libraries was selected as the Boeing 727-200 Standard. The size and weight of the B-727-200 is representative of the aircraft using the Iqaluit airport. The available aircraft simulations are capable of calculating; the RMS vertical acclerations at the aircraft center of gravity, the RMS vertical accelerations calculated at the cockpit, the RMS dynamic force coefficients on the nose strut, and the RMS dynamic force coefficients on the main strut. These calculated parameters are shown diagramatically in Figure 12.

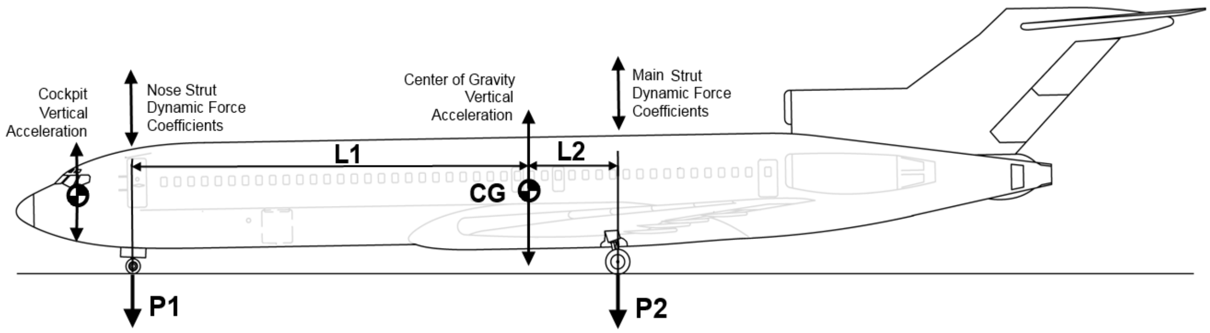


**Figure 12 ProFAA Aircraft Simulation Parameters for the B-727-200 Standard Design Aircraft**

The ProFAA aircraft simulation are well suited for the detailed elevation profiles produced by inertial profilers. In the case of the inertial profiler used for the Runway 16-34 surveys, the profiler bandwidth is capable of generating the wavelength content required to produce meaningful aircraft response simulations. From a long term runway pavement management perspective, the importance of considering dynamic aircraft response during pavement roughness analyses cannot be overstated. Dynamic loading, caused by the response to localized roughness by the strut assemblies on loaded aircraft can impart pavement loads which significantly exceed static loads and dramatically shorten the design life of the pavements.

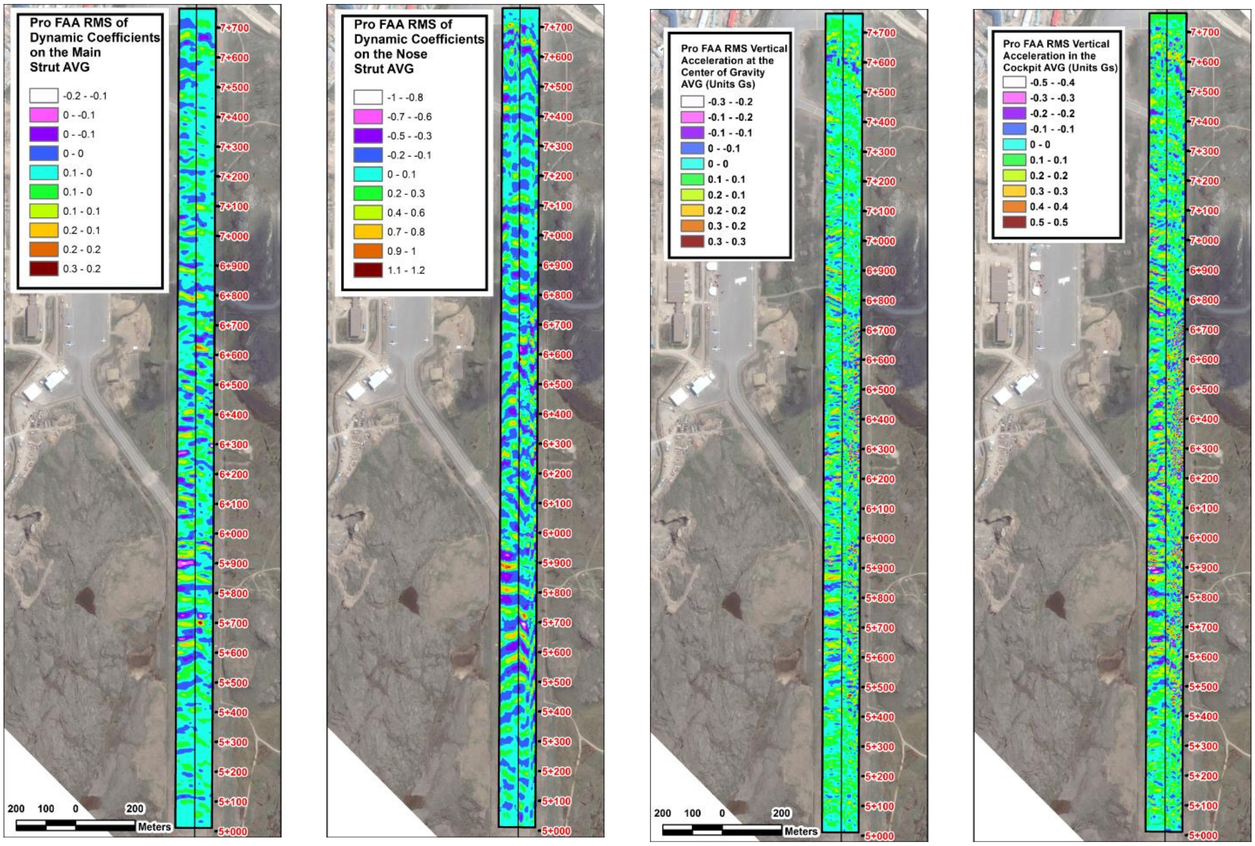


**Figure 13   Simulated Aircraft Dynamic Response for Strut Force Coefficients and Vertical Acceleration**

The dynamic response to the pavement roughness is shown in Figure 13. While not exceeding Boeing's airframe limits, the dynamic roughness will affect cockpit comfort, and have long term detrimental affects on pavement performance.

## Boeing Bump Index

The Boeing Bump Index is used to identify pavement elevation changes that will increase stress on airplane components, reduce braking action, and cause discomfort to pilots or passengers. Typically, it is long wavelength bumps, not usually visible to the naked eye, that are the most problematic. The Boeing Bump method is based on fully loaded aircraft operating at near-rotation speeds (130 to 200 knots), and is significantly influenced by the simulated aircraft type. For the analysis undertaken for Runway 16-34, the design aircraft was the Boeing 727-200 Standard, representative of air traffic in Iqaluit. The Boeing Bump method considers wavelengths up to 120 m, which represents a wavelength range contained in profile elevation data collected with the PSP-2000 inertial profiler.

The results of the analysis suggest that there are locations along the edges of the runway that have significantly higher bump indices that along the runway centerline. The apparent high bump index readings at the south end of the runway (station 7+700) are attributed to the inertial profiler start/end transients and should be discounted. In areas where the Boeing Bump Index value is below 1.0, the bump criteria is in the acceptable zone. Boeing Bump Indices greater than 1.0 and less than 1.25 represent excessive bump locations and values greater than 1.25 represent unacceptable zones.

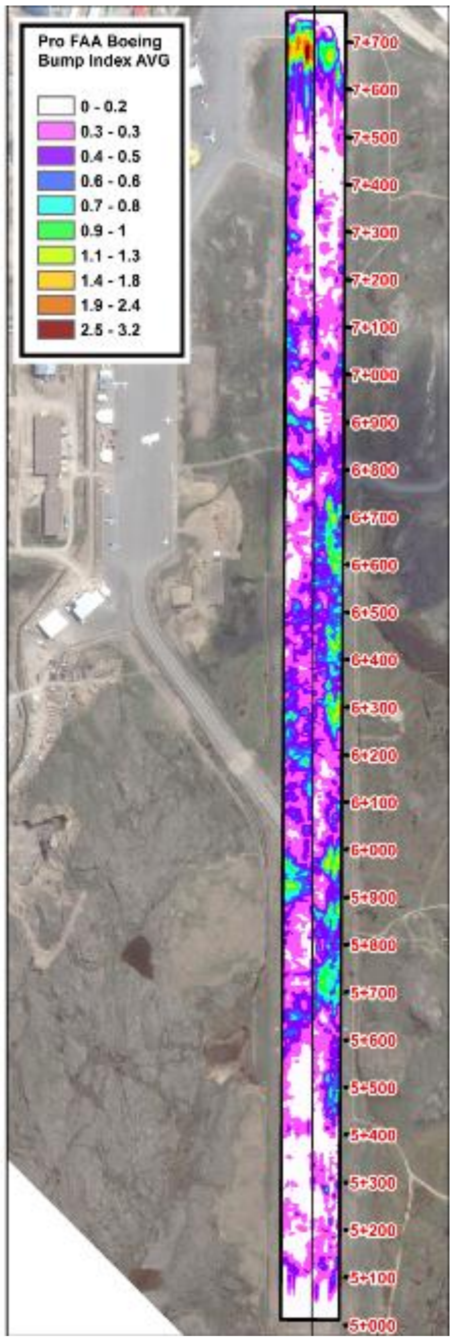


**Figure 14 Boeing Bump Index**

## 5.0 CONCLUSIONS

The content of this paper is intended to provide the reader with an alternative method of collecting, analyzing, and reviewing airport runway profile data. Through the use of innovative runway data collection technologies and interactive GIS software tools, it is possible to collect and interpret existing runway surface conditions that ultimately provide a greater overall runway ride quality summary. With the assistance of the variety proprietary and publically available FAA profile analysis tools, it is possible to view the overall runway profile in a manner that potentially better assesses the impacts of pavement roughness on aircraft airframes and user comfort. This may in time, lead to alternative methods for assessing runway performance in both the design of new runway surfaces, as well as the monitoring the condition of existing runways.

This runway profile investigation demonstrates that it is possible to collect high quality runway profile data with a portable laser based inertial profiler in remote geographic locations with sub-zero temperatures. The information collected can be used to provide valid data for nearly all runway profile based indices, and is not limited to the conventional straight edge/IRI/RCI based indices typically used for Canadian airfields. The generation and interpretation of runway profile dynamic algorithms and indices such as the Boeing Bump Index, aircraft strut dynamic force coefficients, and cockpit and center of gravity vertical accelerations provides invaluable information in the field of performance based design and pavement management. With the ability to quantify both the extent and severity of relative runway profile information, pavement management systems can better predict the rate of deterioration and reduction of pavement serviceability. In turn, this information provides the designer the opportunity to optimize both the treatment locations and types required to best maintain a required level of service through predicating performance while limiting ongoing maintaining and rehabilitation costs.

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