DNV·GL

BALSAMS SKI DEVELOPMENT

Wind Turbine Ice Throw Modeling and Operating Protocol Review for Balsams Ski Development

Dixville Capital, LLC

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Task and objective:

Review of operating protocol of Balsams Ski resort for planned development in the neighborhood of Granite Reliable Wind Farm. The analysis is to provide a better understanding of the risks and therefore help in establishing adequate and site-specific setbacks between the operating wind turbines and ski slopes.

Prepared by:	Verified by:	Approved by:
D. Faghani, Eng. Senior Engineer	S. Dokouzian, Eng. Senior Project Manager	D. Eaton, P. Eng. Team Leader, Engineer

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EXECUTIVE SUMMARY

Dixville Capital, LLC retained DNV GL to assess their risk-based protocol designed to manage the operation of the Balsams Ski Development given the proximity of operational wind turbines. DNV GL reviewed the efficacy and robustness of the proposed protocol as described below.

Efficacy of the proposed risk-based operating protocol

DNV GL modeled the risk of ice throw by turbine blades on planned ski trails and ski lifts in order to quantify the residual risks of ice fragment hit, assuming a full and perfect application of the proposed operating protocol.

DNV GL concluded that the residual risks, after the application of the proposed protocol, were somewhat higher than the thresholds suggested by its analysis. Consequently, DNV GL proposed modifications to the proposed ski trail setbacks and ski lift tracks to reduce the residual risks. The residual risks, assuming a thorough and successful application of the operating protocol, are presented in the table below. For the sake of comparison, this table also presents national risks of injury at US ski resorts and the odds of being hit by lightning, the latter being considered as a typical societal risk for outdoor activities.

	Residual ice fragment hit risk (Original Balsams protocol)	Residual ice fragment hit risk (DNV GL Scenario 1/Option 2)	Reference US Statistics
Overall Resort Risk			Fatal or serious injury at a ski resorts
Risk Level	1 hit in 19-20 years	1 hit in 33+ years	1 per year[(1)]
Risk to individual guests (societal risk)			Odds of being struck by lightning
Risk Level	1 hit in 1,000+ years	1 hit in 500,000+ years	1 in 960,000 years[(2)]

1: Fatal or serious injury at US ski resorts accepting the same number of guests as Balsams – Source: National Ski Areas Association.
2: Odds of being struck by lightning in a given year according – Source: NOAA.

Robustness of the proposed risk-based operating protocol

DNV GL reviewed the critical elements of the operating protocol and provided minor comments to enhance its robustness, notably with respect to turbine blade ice detection means.

DNV GL notes that reducing the risk of ice throw by employing wind turbine ice detection hardware and/or wind turbine icing event operation protocols (such as pre-emptive shut downs, de-icing, start-up with no ice present on blades, etc.), provide enhanced risk mitigation.

1 INTRODUCTION

Dixville Capital, LLC (or the "**Dixville**") is considering the expansion of the Balsams downhill ski resort ("**Balsams**") located near Dixville Notch, New Hampshire. The expansion project known as Balsams Ski Development is planned around Dixville Peak where seven (7) Vestas V90-3MW wind turbines at a hub height of 80 m are operating along the ridge. These wind turbines are part of the Granite Reliable ("**GR**") wind farm, a 99 MW wind farm operated by Brookfield Renewable Energy Partners ("**Brookfield**"), commissioned in 2011 in Millsfield and Dixville, Coos County, New Hampshire. An aerial view of the existing Balsams ski resort and the seven (7) GR wind farm turbines where the Balsams development is planned is presented in Figure 1-1.

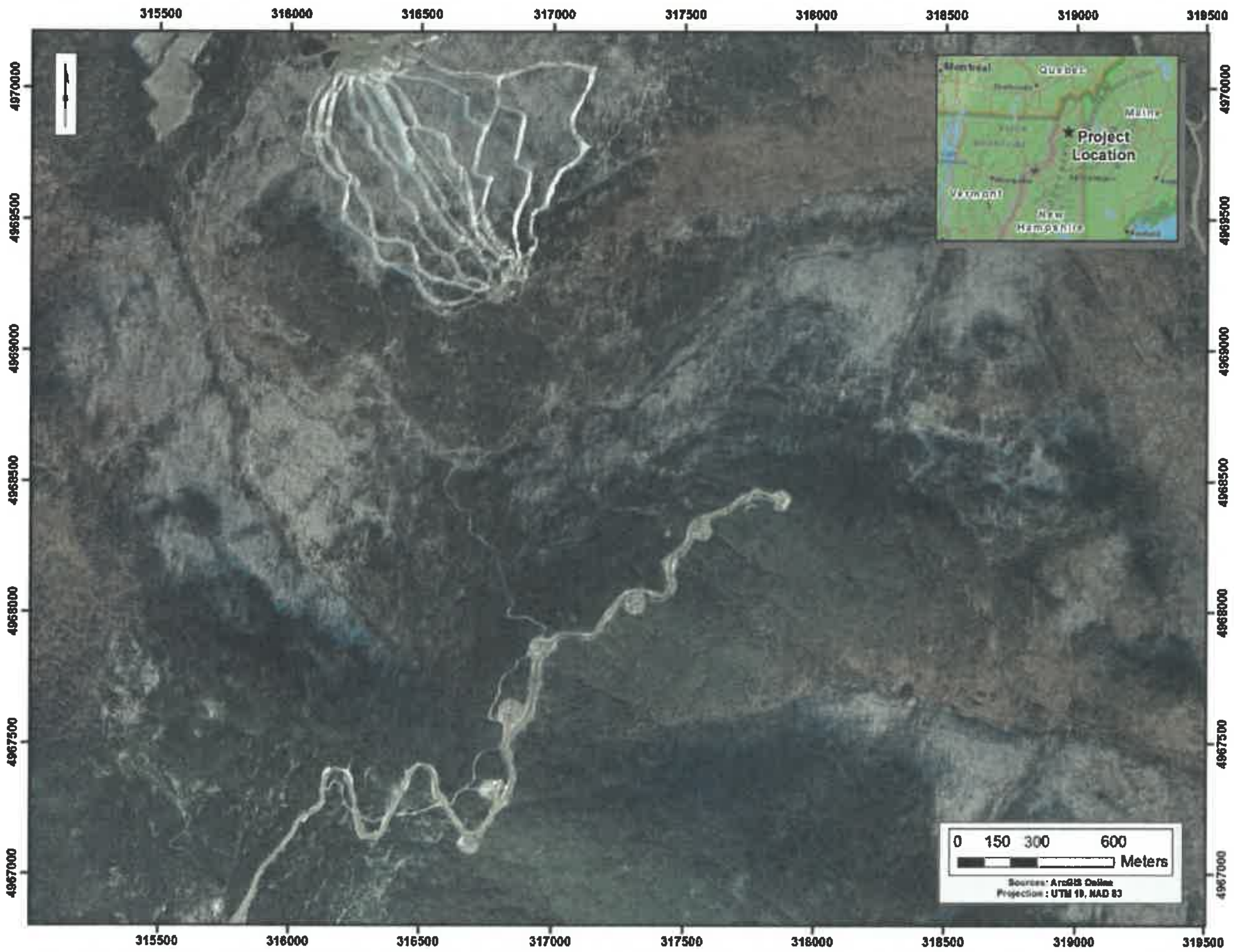

Figure 1-1: Partial aerial view of Balsams ski resort and GR wind farm.

Dixville is currently developing a risk-based protocol (Balsams Operating Protocol) to manage the operation of the Balsams Ski Development given the proximity of the wind turbines.

Garrad Hassan America Inc. ("**DNV GL**") performed an independent review of Dixville's development plans and Balsams Operating Protocol. First, DNV GL quantified the risk of ice fragment throw on the ground and ice fragment hits to Balsams guests at a given distance from the turbines to help define areas at risk and their corresponding risk levels. Then, DNV GL reviewed Dixville's proposed risk-based operating protocol in light of industry practice and national risk statistics.

This report presents the results of DNV GL analysis and is organized as follows:

- Section 2: modeling and assessment of the risk of ice fragment hit at Balsams;
- Section 3: review of industry practice and selection of acceptable risk management approaches;
- Section 4: review of the proposed Balsams Operating Protocol and assessment of its residual risks;
- Section 5: suggestions for modifications to Balsams Operating Protocol; and
- Section 6: conclusions.

2 ASSESSMENT OF RISKS

As a first step, and in order to establish the base case, the risk of ice fragment hits to Balsams guests was assessed assuming no risk management or specific operating protocols to mitigate the risks. DNV GL's risk assessment was based on modelling the following probabilities:

- Probability of ice throw by wind turbines, defined as the probability of an ice fragment thrown by a turbine blade hitting a unit area on the ground at any time during the winter season; and
- Probability of ice fragment hit, defined as the probability of a Balsam's guest being hit by an ice fragment thrown by a turbine blade; which requires the presence of the guest at the same time and location as the ice fragment bound to hit the ground.

Figure 2-1 below presents the approach used to determine the risk of ice fragment hits and the methodology used to provide recommendations to mitigate said risks.

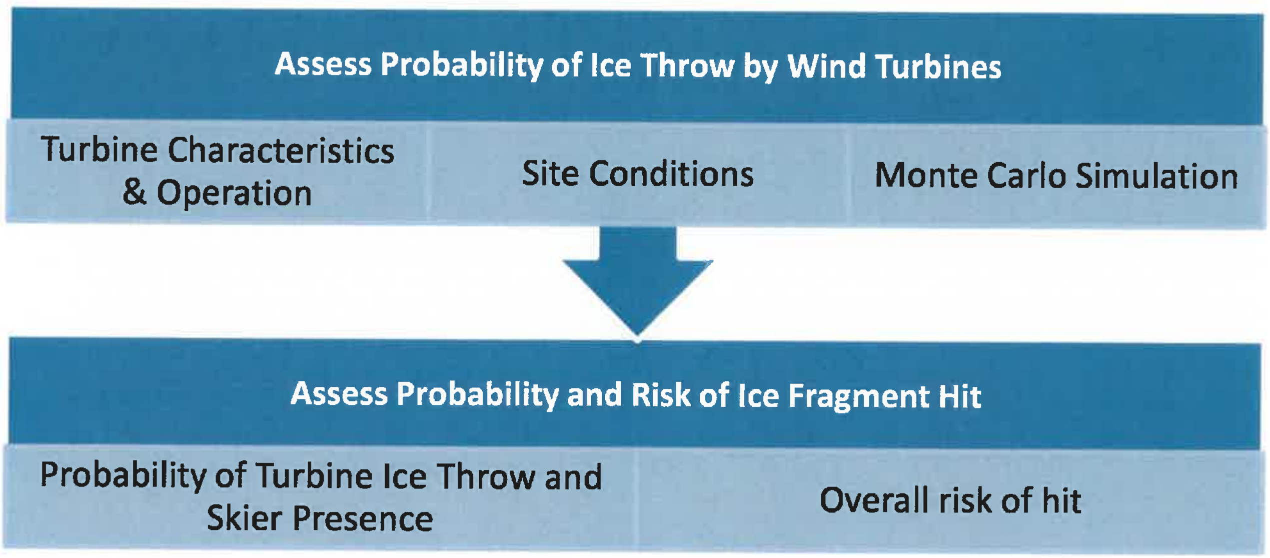

Figure 2-1: Methodology

The following sections provide the details of each step in the risk assessment methodology.

2.1 Probability of ice throw by turbines

2.1.1 Turbine characteristics and operation

Ice throw by the wind turbines is driven by their dimensions, characteristics and operational protocol. Turbine characteristics reported in

Table 2-1 were based on technical specifications; while the operational protocol was provided by Brookfield [1].

DNV GL understands that there is no specific hardware means of detecting ice build-up on the GR wind turbine blades. Icing is detected by monitoring the aerodynamic performance of the blades through examination of expected power output versus actual power output as reported by the wind farm SCADA.

DNV GL also understands that the wind turbines are *occasionally* paused and restarted after on-site inspection. DNV GL notes that the probability of ice throw, as opposed to ice fall, is present at GR and may be increased at turbine restart.

Based on the above information; DNV GL assumed that the risk of ice throw is not significantly mitigated by the current GR wind farm operational protocol.

Additionally, assuming that the turbines may only be paused and restarted during regular working hours, the probability of ice throw is assumed to generally occur during the day, which coincides with the operating hours of Balsams. This assumption is motivated by the fact that heating by the sun may promote local ice melting and detachment during the day. It is expected that this assumption could be revisited after some operational experience is gathered on site.

The main assumptions on turbine characteristics and operational protocol are summarized in Table 2-1.

2.1.2 Site conditions

Ice throw at a given site is also governed by the meteorological conditions. Hence, meteorological data were considered using data from two met masts erected during the preconstruction phase of the GR wind farm, provided by Brookfield [2]. Industry-practice procedures were used to extrapolate meteorological and wind resource conditions at turbine locations. Based on the gathered information and performed analyses, and DNV GL's general experience and knowledge of the area, DNV GL concluded that typically, from October to April, up to a total of seventy-five (75) days of wind turbine blade icing could be expected for turbines on Dixville Peak.

Although GR provided SCADA data from the operating turbines on Dixville Peak, the data were deemed insufficient to modify the estimated long-term site conditions.

Following this analysis, a representative hub height long-term winter wind speed and wind direction distribution was developed by DNV GL for the period when ice accretion is deemed to occur on site (October to April). This distribution, presented graphically in Figure 2-2, was used as the primary meteorological input for this analysis.

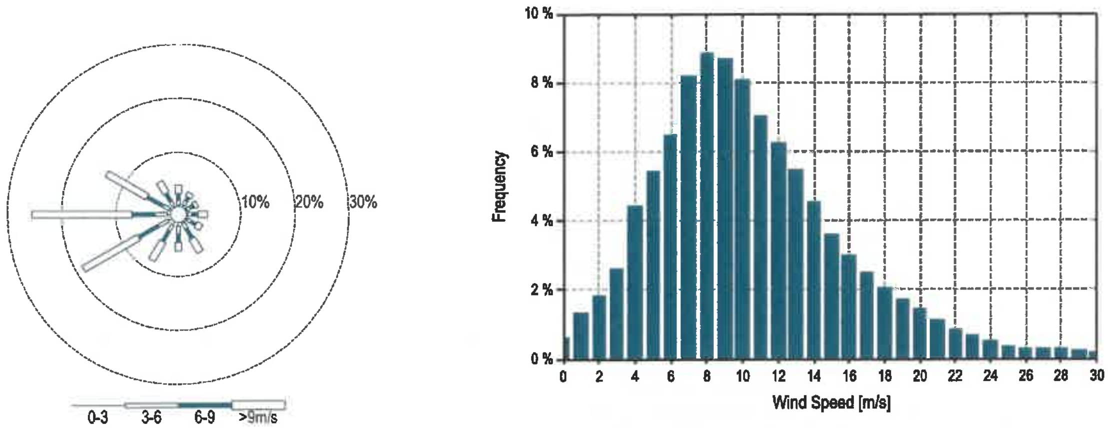

Figure 2-2: Long-term winter wind characteristics at turbine hub height.

The main site conditions assumptions are presented in Table 2-1.

2.1.3 Main assumptions and modeling

The assessment methodology used is based on the approach developed by DNV GL in conjunction with the Finnish Meteorological Institute and Deutsches Windenergie-Institut (DEWI) as part of a research project on the implementation of Wind Energy in Cold Climates (WECO). This research project was primarily funded by the European Union and also supported in part by the United Kingdom Department of Trade and Industry [3]. The guidelines for safety assessments related to ice throw were developed by DNV GL in the context of the WECO project and the work was summarized in a series of conference papers [4][5][6]. These guidelines have been applied to the Project site by considering the proposed turbine type, the terrain of the site and surrounding area of the study.

The overall approach is based on the following staged approach:

- Determine the periods when ice accretion on wind turbines are likely to occur, based on historical climatic observations.
- Within those periods, determine when the wind speed conditions are within the operational range of the wind turbines.
- Within the resulting periods, if applicable, exclude those periods when the wind turbines will be shut down automatically by the wind turbine control system or by remote operators. As discussed in Section 2.1.1, such automatic shutdown occasionally occurs at GR, and has therefore not been considered in the probability computations herein.
- Based on the estimate of icing occurrence described above, use Monte Carlo simulations to derive the probability of fragments landing at distances from the turbines of interest, at actual terrain elevation based on digital topography maps.
- Derive an estimate of the total probability of any unit area (1 m^2) struck by ice fragments.

Table 2-1 presents the main assumptions used by DNV GL to model the cumulative probability of ice throw on the ground by the seven (7) wind turbines of the GR wind farm considered in this study.

Table 2-1: Turbine Ice Throw Assumptions.

Item	Assumption used	Source
Turbine Characteristics	• Vestas V90 3 MW machines at 80m hub height • Blade length: 45 m • Cut-in/Rated/Cut-out wind speed: 4/15/25 m/s • Rotor start/rated speed: 8.6/18.4 rpm	Vestas technical specifications
Site conditions	• 75 days of blade icing from October to April • Air density (at 1000 m amsl[1]): 1.14 kg/m^3	DNV GL
Ice throw diurnal profile	• All ice shed/thrown during daytime operation hours of the ski resort	DNV GL

2.1.4 Comments on model assumptions

It is noted that the DNV GL model includes a number of conservative assumptions as follows:

- The ice fragment mass is assumed to be 1 kg; which represents the longer range fragments thrown by turbine blades. In practice, some fragments will have different masses and will fly shorter ranges than modelled. However, in the absence of onsite data, the conservative mass of 1 kg was used.
- All ice accreted on the blade is thrown by the model. In practice, some fraction will fall as opposed to be thrown.
- Wind turbines are considered to be operational during all icing events.
- The blade ice density is assumed to be 970 g/m^3 which corresponds to very dense ice without air bubbles. In practice, it is expected that the actual ice accreted on the blades will contain some amount of air bubbles (e.g. rime ice) with a lower density. Should DNV GL model be used with a lower ice density, fewer ice fragments would be thrown. However, in the absence of onsite data, the conservative ice density of 970 g/m^3 was used.

DNV GL did not perform any sensitivity analysis to estimate the potential impact of these conservative assumptions.

2.1.5 Results

Figure 2-3 represents the results obtained by DNV GL for the cumulative probability (i.e. combining all wind turbines) of ice fragment strikes per unit area (1 square meter) at ground level by the 7 wind turbines considered. The various risk levels are presented in shades of blue from one strike in 10 years close to wind

[1] Above mean see level.

turbines down to one strike in 10,000 to 1,000,000 years farther away[2]. The map also presents the turbine topple risk areas (dotted yellow line) and the generic setback historically used to mitigate ice throw risks without detailed modeling (dotted green line) for information [5].

The purple areas represent the proposed new ski trails, while the blue indicates the proposed new skier chairlifts.

DNV GL typically considers that probabilities of 1 in 500,000 years per unit area represent low enough risks which not require particular mitigation measures. As seen in Figure 2-3, the generic setback (dotted green line) does not ensure such low-level risks; which is partly due to site topography and the relatively high number of icing days at the site.

It is noted that the probability map in Figure 2-3 does not directly represent the risk levels for skiers; although it is a major driver for such risks. Indeed, risk levels for skiers are based on the combined probability of ice throw and skier presence as further discussed in the next section.

[2] DNV GL considers that risk levels below 1 in 1,000,000 years are not significant and can be neglected.

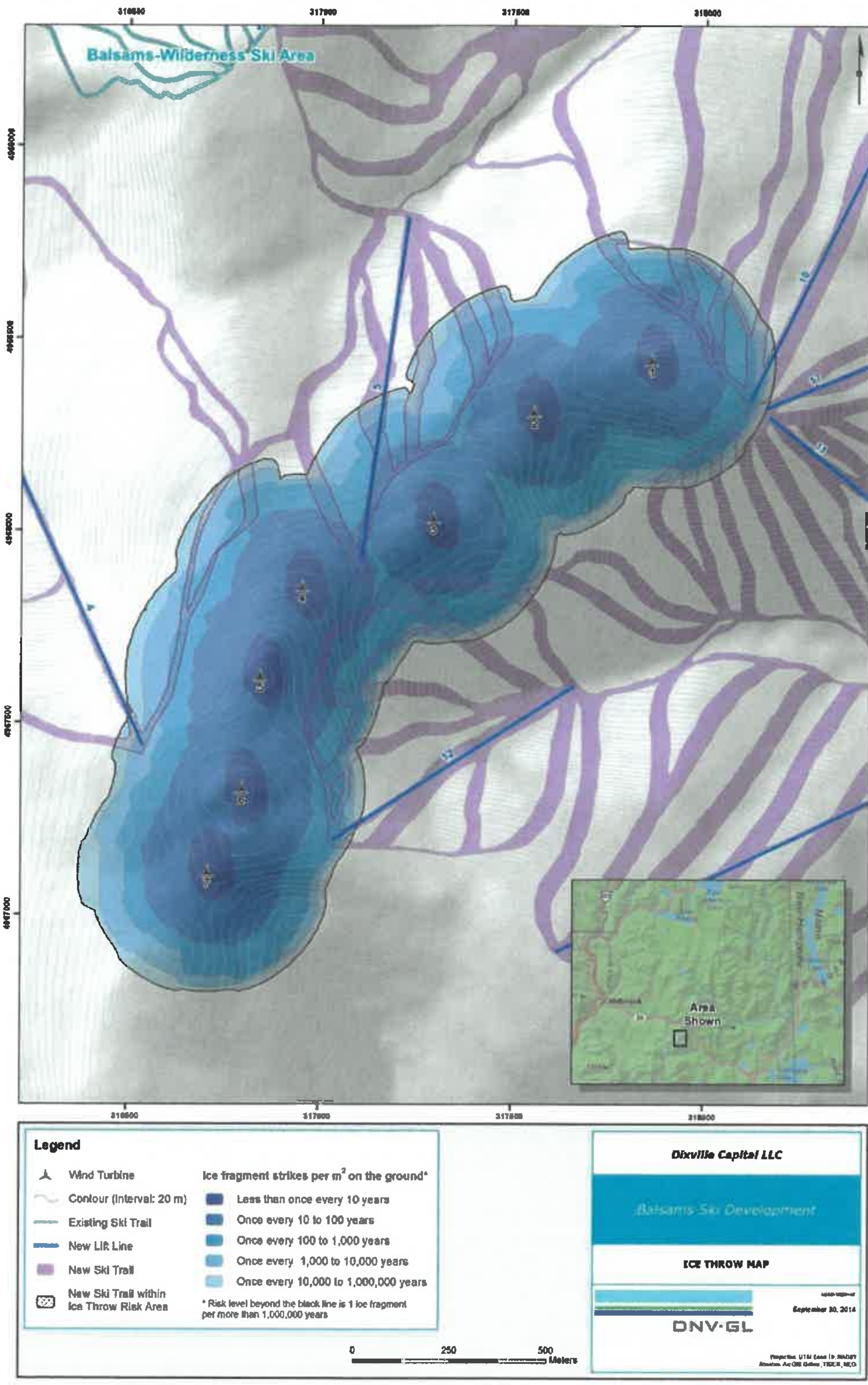

Figure 2-3: Risk of ice fragment strikes on the ground.

2.2 Risk of ice fragment hit

As previously discussed, Figure 2-3 above does not represent the probability of ice throw hits on skiers. Instead, it presents the probability (per $1m^2$ unit area) for a static object on the ground which would remain motionless at its location during the entire period of time between October and April. In order to assess the risk of ice fragment hits to individuals (probability of hit), DNV GL further considered the probability of skier present as described below. Finally, individual risks for skiers must be summed up to assess the risk of ice fragment hit at Balsams.

Two cases were distinguished, namely skiers on trails and skiers on ski lifts. The reason for this distinction is that on average, the number of skiers per unit area is higher on the lifts than on the trails. Additionally, the lifts are on average 25 ft above ground level, which could potentially represent different levels of probability of ice hit when compared to those at ground level depicted in Figure 2-3.

The following Sections presents results of the DNV GL analysis of ice fragment hit to skiers prior to the application of any mitigation measure such as a risk-based operating protocol.

2.2.1 Skiers on ski trails

2.2.1.1 Probability of ice throw and skier presence

To estimate the probability of simultaneous presence of skier and ice throw strike on ski trails; DNV GL calculated the ratio of the total area occupied by all skiers over the total skiable area available. This resulted in a constant probability presented in Table 2-2, which is considered constant in time, or by location on the ski trails.

Table 2-2: Ski trails assumptions.

Item	Assumption used	Source
Total ski trail area	2,100 acres	Dixville
Number of skiers on ski trails	3,300 skiers per day on average; assuming a 33% average utilization rate over the season and 10,000 skiers on peak days.	Dixville
Average number of skiers on ski trails	3,300 skiers, 100% of the time	DNV GL
Typical skier footprint	1 m^2	DNV GL
Probability of skier presence	**4.6×10^{-4}**	**DNV GL**

DNV GL recognizes that this is a simplifying assumption as the skier density per unit area may vary with location (higher close to ski lift arrivals) and time (e.g. weekends, or peak days). While more precise assumptions could be made; the following simplified assumptions are used:

- Constant probability in time: Instead of assuming a constant 33% utilization rate 100% of the time, other distributions could be used. However, no further information was available to tailor a specific distribution. Additionally, a constant probability in time is consistent with the constant probability in time for ice throw.
- Constant probability in space: While the probability of skier presence is higher around ski lift arrivals, those areas are also closer to wind turbines where the probability of ice throw is higher too. As a result, it is expected (and supported in this analysis) that risk levels are already above acceptable threshold in those areas even with this simplifying assumption. Away from those areas, the assumption is probably conservative as the density of skiers is expected to be lower than the assumed value.

The probability of hit, in this report, is defined as the simultaneous probability of skier presence on ski trail and ice throw strike is defined as the product of the probability of ice throw and the probability of skier presence.

Figure 2-4 depicts the probability of hit per unit area (1 m^2) on ski trails. Green and yellow-shaded areas represent probabilities not exceeding 1 hit in 500,000 years. DNV GL considers that at these low levels of probability, no risk mitigation is required.

Areas shaded in orange or red present significant risks (above 1 hit in 500,000 years) and require mitigation means such as trail closure.

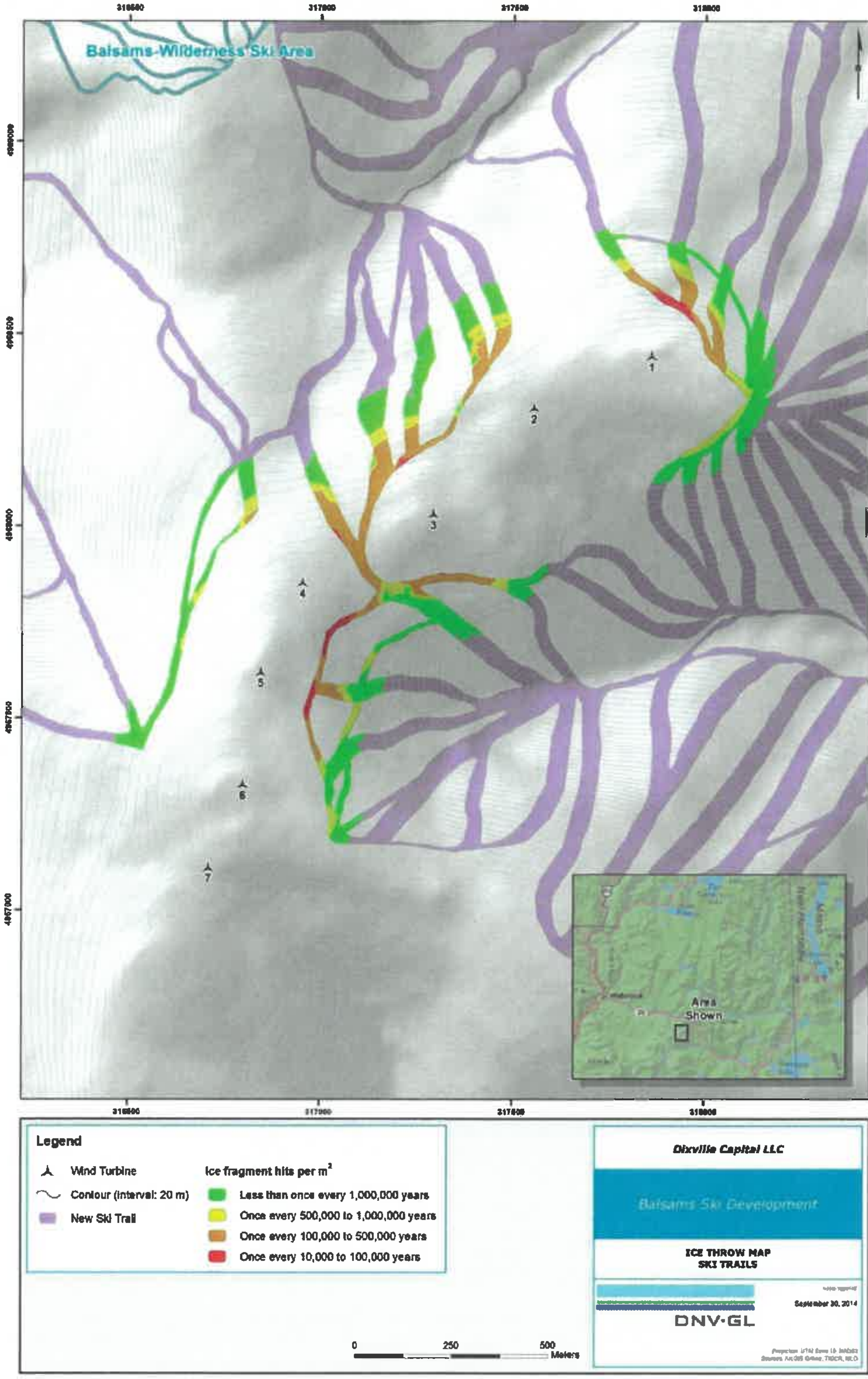

Figure 2-4: Risk of ice hit to skiers on the ground.

2.2.1.2 Risk of ice fragment hit on ski trails

The overall probability of hit in Balsams (risk of hit) for skiers on ski trails in presented in Table 2-3, as a function of the area that would remain open to skiers during ice throw events. This table presents the summation of all probabilities for all skiers present on ski trails.

Table 2-3: Overall ice fragmemt hit risk on ski trails.

Area that remain open	Cumulative Risk for the Resort
Purple + Green	1 hit in 28-29 years
Purple + Green + Yellow	1 hit in 13-14 years
Orange / Red	Not reported as the risk is deemed very high

This table helps establish setbacks for a risk-based operating protocol. For instance, according to Table 2-3, by limiting skiers' access to purple and green areas during ice throw risk periods, one ice fragment hit is expected in 28-29 years, over the whole facility. By relaxing the limited area to the purple, green and yellow areas, the risk increases to one hit in 13-14 years.

2.2.2 Skiers on ski lifts

2.2.2.1 Probability of ice throw and skier presence

To estimate the probability of simultaneous presence of skier and ice throw strike on ski lifts; DNV GL used a similar approach discussed above for ski trails. The main assumptions are summarized in Table 2-4.

Table 2-4: Ski lifts assumptions.

Item	Assumption used	Source
Chair separation	60 ft	Dixville
Chair width	5 ft	Dixville
Number of lifts	6	Dixville
Average ski lift height	25 ft	Dixville
Chair capacity	4 skiers	DNV GL; based on information from Dixville
Lift speed	500 ft/min	Dixville
Lift utilization rate	30% of full capacity	DNV GL; based on 8 runs per skier per day for a total of 3,300 skiers per day using the 6 lifts
Probability of skier presence	**4.3×10^{-2}**	**DNV GL**

The following remarks provide the rationale behind the assumptions presented in Table 2-4:

- Chair capacity: According to Balsams, amongst the 6 ski lifts considered, 4 have 4-skier chairs, one has 3-skier chairs and one has 2-skier chairs; which translates to a mean value of 3.5 skiers per chair. The value used by DNV GL is considered to a reasonable assumption providing slightly conservative results.
- Lift utilization risk: By assuming, conservatively, that all 3,300 skiers will continuously and exclusively use the 6 ski lifts considered, DNV GL estimates that each skier would achieve more than 25 ski runs during the day. By considering a more realistic value of 7-8 runs per skier per day, an average utilization rate of 30% is obtained.
- Average ski lift height: It is expected that at a given distance from a wind turbine, the probability of ice throw strike at 25 ft above the ground is lower than its probability of hitting the ground. As such, the probability levels per unit area estimated in Section 2.1.5 (see Figure 2-3) might be slightly conservative. A rough estimate shows that by using a more precise calculation, the end results may change by some 5 to 10 meters, i.e. the risk lines shown in the figures would move 5 to 10 meters towards the wind turbines. However, DNV GL estimates that such lengths are within the model uncertainty. Additionally, DNV GL notes that the skiers are at ground level at ski lift arrivals. Therefore, the ice throw probability per unit area used was the same as the one calculated at ground level and no modifications were used to account for the varying ski lift heights. DNV GL estimates this assumption to be conservative.

The probability of hit, defined as the simultaneous probability of skier presence on ski lift and ice throw strike is defined as the product of the probability of ice throw and the probability of skier presence; assuming the two events are independent.

Figure 2-5 depicts the probability of hit per unit area (1 m^2) on ski lifts. Areas shaded in orange, red or dark red present significant risks (above 1 hit in 500,000) and require mitigation means such as lift closure. It is noted that these areas lie outside the generic setback distance (doted yellow line) which was historically used when no modeling tool was available. Green and yellow-shaded areas represent probabilities not exceeding 1 hit in 500,000 years. As previously mentioned, DNV GL usually considers that at these low levels of probability, no risk mitigation may be required. However, this statement must be considered along with the overall risk as discussed below.

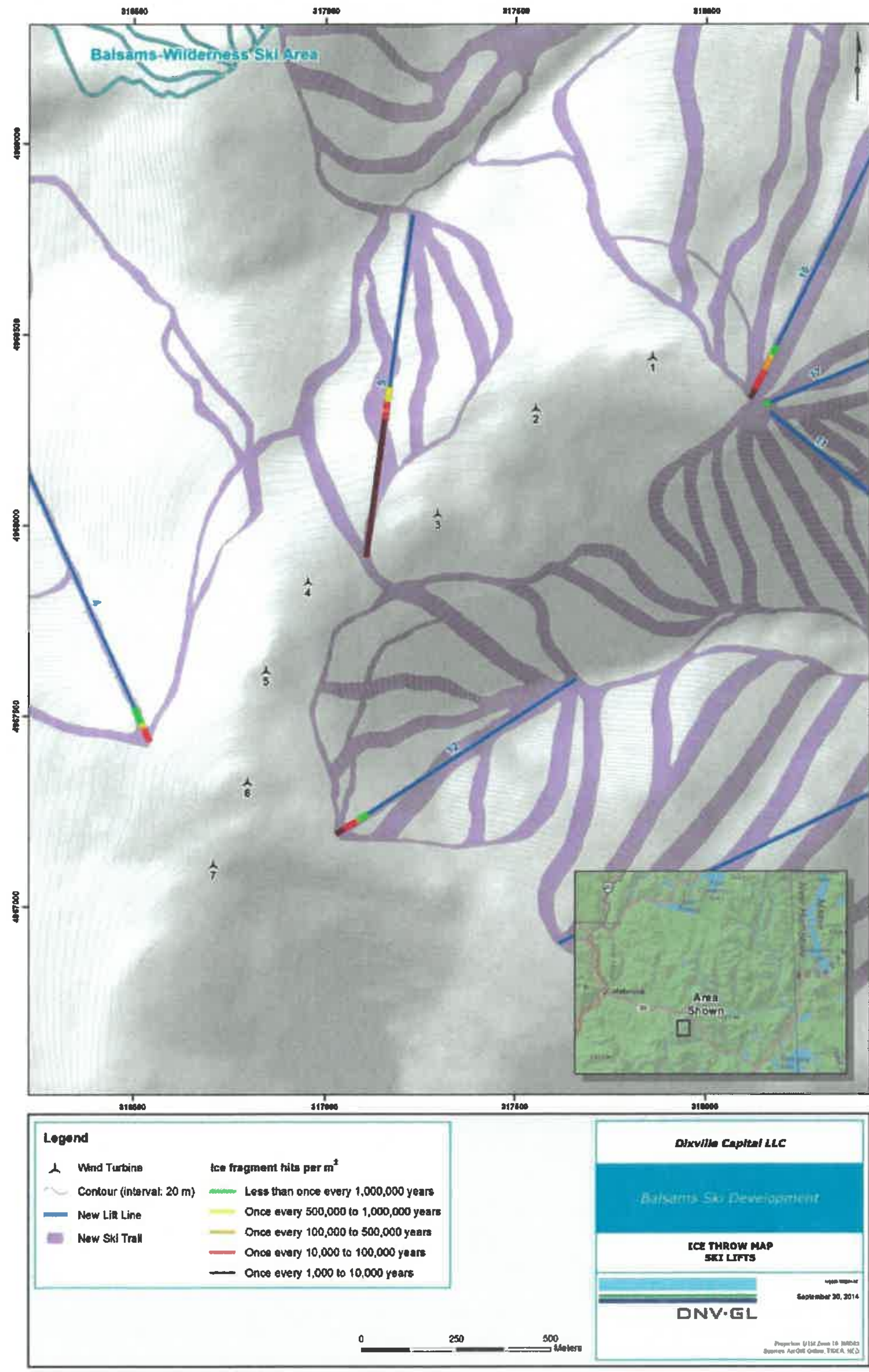

Figure 2-5: Risk of ice hit to skiers on ski lifts.

2.2.2.2 Risk of ice fragment hit on ski lifts

The overall probability of hit in Balsams (risk of hit) for skiers on ski lifts in presented in Table 2-5, as a function of the area that would remain open to skiers on ski lifts during ice throw events. This table summarizes the summation of all probabilities for all skiers present on ski lifts.

Table 2-5: Overall ice fragmemt hit risk on ski lifts.

Area that remains open	Cumulative Risk for the Resort
Blue + Green	1 hit in 31,000+ years
Blue + Green + Yellow	1 hit in 8,400+ years
Blue + Green + Yellow + Orange	1 hit in 1,200+ years
Blue + Green + Yellow + Orange + Red	1 hit in 115+ years
All	1 hit in 4-5 years

This table helps establish setbacks for a risk-based operating protocol. For instance, according to Table 2-5, the level of risk, should all lifts be operational even during ice-throw-risk periods, is one hit every 4-5 years, for the whole facility. By ensuring that no skier is present in dark red regions (green, yellow, orange and red allowed), the risk of ice fragment hit is reduced to one in 115 years. This may be done by changing the current siting of the ski lift location or by enforcing ski lift shut-downs during which blade ice throw risk is present.

2.3 Overall risk assessment

The overall risk of ice fragment at Balsams is the sum of risk on ski trails and ski lifts. Based on the results presented above, the ski trails have lower levels of risk but potentially affect a larger number of skiers while ski lifts have higher risk levels but fewer skiers are at risk.

The overall risk of ice hit, primarily driven by the ski trail risk, ranges from 1 hit in 4-5 years down to 1 hit in 28-29 years based on a specific scenario of trail and lift operational protocol and potential setbacks to be established by such a protocol. These are further discussed in Section 3.

When analysing these results, it should be noted that a number of simplifying assumptions as described in Sections 2.2.1.1 and 2.2.2.1 were used. Additionally, as mentioned in Section 2.1.4, in the absence of sufficient onsite data, a number of conservative assumptions were used in the ice throw Monte Carlo simulations.

It shall also be noted that the above represents an ice throw hit, and not necessarily an injury resulting from the hit.

3 INDUSTRY PRACTICE

Dixville plans to implement a risk-based operational protocol, namely Balsams Operating Protocol, to mitigate such risks. DNV GL selectively reviewed industry practice and national ski activity and societal risks to substantiate its comments and recommendations presented in Sections 4 and 5 below. This section summarizes the results of DNV GL's review.

3.1 Brief industry survey

In order to sense the current industry practice, DNV GL tried to contact ski resorts which *coexist* alongside operational wind turbines. Unfortunately, DNV GL was not able to identify an ideal case study due to a number of challenges, and notably the limited number of similar cases. Two facilities, one in Quebec and one in Sweden, were eventually identified and contacted. It is noted that unlike Balsams, the ski resorts were developed well before the wind turbines were installed in their vicinity.

3.1.1 Ski resort in Quebec

DNV GL contacted representative of a ski resort [14] located in Quebec, Canada presenting similarities with Balsams development. Downhill ski trails are located on the western face of a ridge which reaches some 850 m amsl. Seven 80 m hub height turbines are installed on the ridge at approximately 350 m from the ski resort according to the contacted representative; although DNV GL notes from publically available aerial imagery[3] that a few turbines appear to be less than 200 m away from some ski trails. Access roads to the turbines are signalled but remain open at all times.

After more than 5 years of operation, the ski resort has not reported any ice throws to date; although it recognizes detecting ice fragments on the ground is very challenging and one cannot definitely exclude the possibility of ice fragments having landed on the ski resort property since the wind farm was commissioned.

According to the ski resort representative, a very limited level of communication exists with the wind farm operator. DNV GL understands that no specific protocol is in place to coordinate ski resort and wind farm operations.

Finally, the ski resort representative mentioned a nacelle fire during which resulted in blade fragments being thrown as far as 150 m away from the turbine tower. The ski resort closed the nearest ski trail proactively. Several fiberglass fragments were observed on ski resort property following this incident but no injuries were reported.

3.1.2 Ski resort in Sweden

DNV GL contacted a Swedish company [15] who operates 3 wind turbines sited close to ski slopes in eastern Sweden. According to the contacted representative, one of the turbines was commissioned as early as 1996 at top of a ski slope. Routine daily inspections are performed to assess blade icing risk; and the turbine is shut off as soon as ice build-up is observed. The representative mentions that during some winter seasons the turbine may remain shut for several weeks as the operator is fully responsible for the safety of the skiers.

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[3] Googlemap.

The ski representative reports that 2 more recent turbines were commissioned in 2012 at approximately 500 – 600 m from the ski slopes. Despite this setback distance, because the area is considered as a recreational zone, turbine blades are equipped with heating systems and visual inspections are routinely performed to detect potential ice build-up. Additionally, specific signage around the turbines warns against risk of ice and/or snow fall.

3.1.3 Industry practice conclusions

A brief review of the two case studies above shows that:

- Lack of communication, clear definition of roles and responsibilities, and mutually agreed operational protocols between the wind farm and the ski resort may result in an increased level of hazard;
- Access to wind farm roads and turbines must be restricted and sufficient signalling should be used to warn the public against the hazards;
- Routine and regular daily visual inspections are performed to detect ice build-up on blades; and
- Blade heating and ice detection may largely mitigate the risk of ice throw; although visual inspection remains necessary.

DNV GL notes that amongst the above, routine and regular visual inspection of turbine blades, performed under strict safety rules, is of paramount importance in any risk-based operating protocol.

3.2 US ski resorts and societal risks

In order to grasp the meaning of the risks quantified in Section 2 for Balsams, it is useful to set meaningful risk levels for comparison. The following two paragraphs present such risk levels to help understand the severity of quantified risks and set the thresholds of acceptable risks to be achieved by risk control and mitigation measures at Balsams.

3.2.1 Fatality and injury risks related to skiing activity

According to the National Ski Areas Association (NSAA) [7], on average during the past 10 years, skiers/snowboarders have suffered 49 serious injuries per season; which translated to 0.86 serious injuries per million skier visits. Given that Dixville plans about half a million visitors per season, one (1) serious injury is expected every 2-3 years. With respect to fatal injuries, NSAA reports 0.44 incidents per million visits in 2012/2013 [7], which was significantly lower than the 1.06 incidents per million visits in 2011/2012 [9]. For Balsams, using the 2011/2012 national statistics which is generally in line with the average long-term statistics as per Dixville, one fatality could be expected every 2 years.

With respect to ski lifts [8], based on statistics from the State of Colorado, NSAA reports 227 falls from lifts between 2001/2002 and 2011/2012 in CO (or 22.7 falls per year). NSAA reports that only 4 instances were due to mechanical/operator error; while 19 were due to unknown causes. 4 falls due to operator/mechanical errors over a period of 10 years translates to one such incidence every 2.5 years.

Based on the above statistics reported by NSAA, by adding fatal and serious injury statistics, one fatal or serious injury could be expected during each season due to the inherent risk of the activity.

3.2.2 Societal risks

In addition to the specific risks of skiing, DNV GL also considered the societal risks defined as risks commonly experienced in society.

A number of such risks are reported below:

Risk Type	Probability
Fatal rail travel accidents (annual risk – commuter) [10] *2 daily journeys, 45 weeks per year* [10]	1 in 95,000+ years
Fatal aircraft Accident (annual risk – vacationer) *2 flights per annum* [10]	1 in 62.5 million years
Odds of being struck by lightning in a given year *Based on US averages for 2004-2013* [12]	1 in 960,000 years
5,700 pedestrians killed in the US *Injury Facts, 2013 edition reported by NSAA* [8]	1 in 52,600+ years (a US population of 300 million is assumed by DNV GL)

One societal risk commonly used in the industry is the risk of lightning strike, considered as a typical risk for outdoor activities. According to NOAA [11], the national statistics of lightning fatalities by state during the 2003-2012 period range from 0 to 0.77 per million per year. NOAA estimates that the national risk of death or injury is 1 in 960,000 years [12].

NOAA reports that during the 2003-2012 period, no lightning strike-related fatalities have been reported in New Hampshire. This can be explained by the fact that lightning strike frequencies are indeed very low in New Hampshire. They range from 0.5 flashes per km^2 per year in the north to 2 flashes per km^2 per year in the south of the state [13]. For Balsams, a strike rate of 0.5-1 flash per km^2 per year is reported; resulting in a rate of 1 strike per m^2 in 1-2 million years. Assuming a footprint of 1 m^2 for a person, this is a risk of 1 strike in 1-2 million years, which is indeed almost twice as low as the national average.

3.2.3 Suggested risk levels

Based on the previous review of risks, DNV GL suggests using the following thresholds for Balsams guests, based on the third-party information presented above:

- Balsams overall risk – Overall risk of ice fragment hit: 1 hit in 50-100 years; and
- Societal risk – Probability of ice fragment hit per unit area: 1 in 500,000 years or less.

These risks, while not zero, are deemed significantly low compared to ski-specific and societal risks at the national level. However, DNV GL makes no conclusion on an acceptable risk. These are further discussed below.

4 REVIEW OF BALSAMS OPERATING PROTOCOL

As demonstrated in Section 2, the overall risk of ice fragment hit to Balsams' guests requires specific risk mitigation means. DNV GL reviewed Balsams Operating Protocol prepared by Dixville [16] defining a risk-based approach where ski trails and lifts are closed upon detection of blade ice throw hazard and re-opened when the conditions are considered as safe.

This section presents the results of DNV GL analyses and review.

4.1 Balsams Operating Protocol

The protocol defines three exclusion zones around wind turbines:

1. Operations Setback #1: An area 50 meters (165 feet) in radius from a turbine base creating an exclusion zone to Balsams personnel and equipment;
2. Resort Operational Setback #2: An area 135 meters (445 feet) in radius from a turbine base creating a Balsams guest exclusion zone; and
3. Special Event Setback #3 – An area 255 meters (837 feet) in radius from a turbine base creating a Balsams guest exclusion zone put in place during periods prone to blade ice throw risk.

Setback #1 radius is based on the blade length of the wind turbine (approximately 40 m), plus an additional 10 m.

Setback #2 radius is based on the total height (tip height) of the wind turbine (approximately 125 m), plus an additional 10 m.

Setback #3 is based on an historic generic formula[4], when no site specific modeling tool was available.

In Figure 4-1, the constant 135 m radius Setback #2 and 255 m radius Setback #3 are presented as yellow and green dotted line.

[4] Hub height + rotor diameter, multiplied by 1.5. As per [4]

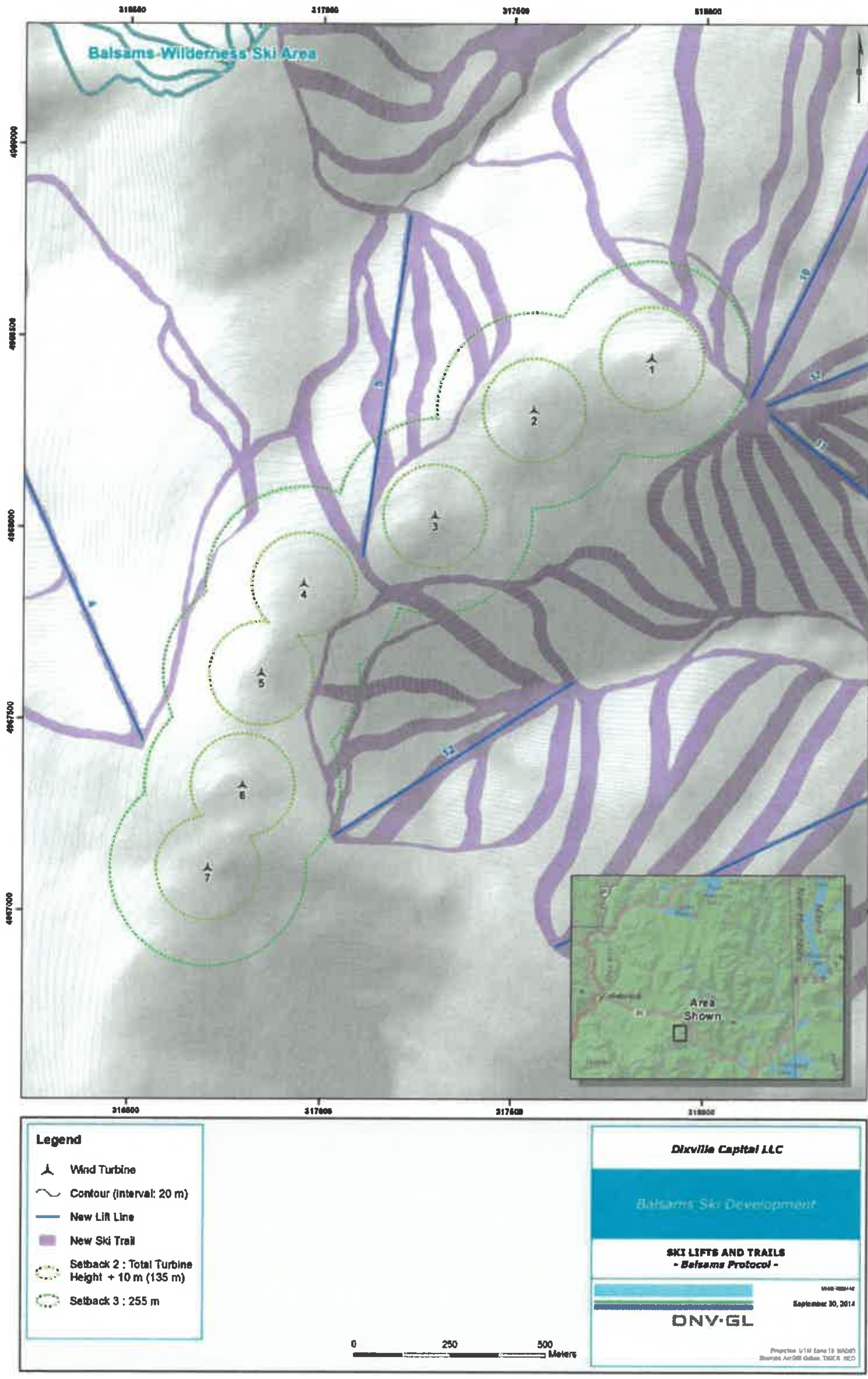

Figure 4-1: Proposed Balsams Operarting Protocol Setbacks.

The protocol is indeed based on a risk management approach where, instead of completely avoiding the risk of ice throw by closing the resort, some level of residual risk is accepted by closing specific trails and lifts only. Setbacks #2 and #3, depicted in Figure 4-1, show that by applying the proposed operating protocol, ski trails included in Setback #3 along with ski lift #5 will be closed should blade ice throw risk be identified by Balsams personnel. Such an approach may be valid provided the residual risk is acceptable to Dixville and Balsams and the protocol is robust.

The following paragraphs provide a high-level review of the proposed protocol by focusing on:

- Residual operating risks – assuming the protocol is thoroughly applied; and
- Protocol robustness – analysing potential items which may hinder the full application of the protocol.

4.2 Residual risks of the protocol

The residual risks of applying the proposed Setbacks #1, #2 and #3 were reviewed with a focus on ice fragment hit residual risks. For Setback #3, DNV GL performed a more detailed and quantitative analysis. More precisely, based on DNV GL's understanding of the proposed operating protocol, Balsams' guests will be evacuated from the areas delimited by Setback#3 if ice fragment hit risk is present. As a result, the risk of ice fragment hit to guests is limited to the areas lying outside of this perimeter.

Figure 4-2 presents the proposed Balsam's operating protocol setbacks superimposed to ice fragment hit risk levels estimated by DNV GL. The estimated risk of ice fragment hit for the resort and for individual guests using the modelling results of Section 2 are summarized in Table 4-1 and discussed in Table 4-2.

Table 4-1 Residual risks of currently proposed Operating Protocol.

Risk source	Resort risk	Skier risk
A. Ski Trails	1 hit in 27-28 years	1 hit in 500,000+ years
B. Ski Lifts	1 hit in 72-73 years	As high as 1 hit in 1,000-10,000 years
Total (A+B)	1 hit in 19-20 years	As high as 1 hit in 1,000-10,000 years

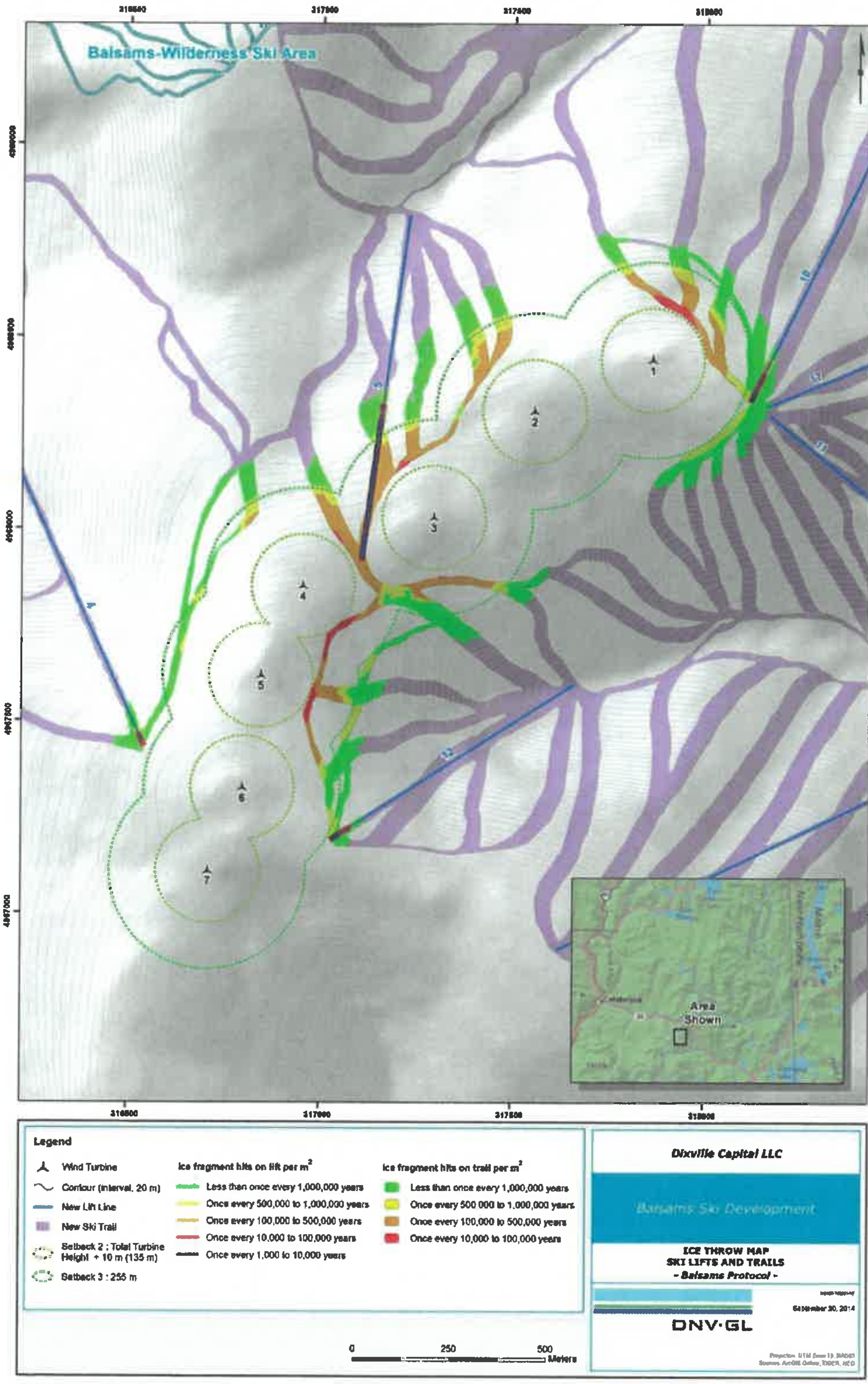

Figure 4-2: Proposed Balsams Operarting Protocol Setbacks vs. Ice fragment hit risk.

Table 4-2: Review of operating protocol residual risks.

Setback	Purpose	Description	DNV GL Comments and Conclusion
Operations Setback #1	Avoid falling objects	Applies at all times and at all Balsams personnel and equipment. In conjunction with Setback #2, also applies to Balsams guests.	In line with best practice; residual risk is deemed to be negligible. Area should be clearly signaled and exclusion enforced.
Resort Operational Setback #2	Avoid tip-over and minor icing events	Applies at all times to Balsams guests. Balsams staff may penetrate if no ice is detected on blades.	In line with best practice; residual risk is deemed to be negligible. Balsams personnel penetrating the area should be aware of potential ice throw risks when penetrating this zone. Zone entry should be prohibited and be exceptionally granted to Balsams personnel (presence of two recommended) only when required.
Special Event Setback #3	Mitigate risk of ice fragment hit	Applies to Balsams guests when ice throw risk is identified.	Overall resort risk: Residual risk for the resort is about 1 hit in 19-20 years, which is lower than expected rate of fatality or serious injury due to skiing activity (1 per year); but well above the suggested threshold (1 in 50-100 years, see section 3.2.3). Individual skier risk (societal risk): Residual ski trail risks comply with suggested threshold (less than 1 in 500,000 years, see Figure 2-4). Ski lifts 4, 10 & 12 exceed the suggested threshold as they represent risks levels as high as 1 hit in 1,000 – 10,000 years. It is noted that Balsams' operating protocol implies the closure of ski lift 5, which also exceeds the threshold.

DNV GL concludes that the residual risk of ice fragment hit (Setback #3), provided the operating protocol is thoroughly applied without hindrance, is not compliant with suggested thresholds described in Section 3.2.3.

DNV GL recognizes that a number of conservative assumptions have been embedded in the risk modeling (see Section 2.1.4) which might temper the above statements and conclusions. However, it is still recommended to:

- Modify Setback #3 from a fixed distance in all directions from a given wind turbine, to a setback tailored to specific ski trails; and
- Modify the location of ski lift 4, 10 & 12 arrivals to achieve lower risk levels.

Such scenarios are proposed in Section 6 for Dixville's consideration.

4.3 Robustness of the protocol

As previously noted, the risk-based approach is based on the acceptance of a non-zero but low-enough residual risk level if the operating protocol is fully enforced. The previous residual risk assessments are not valid if the protocol is not applied in a full and timely manner. The following table presents a number of critical items identified and discussed by DNV GL.

Table 4-3 Review of the robustness of the proposed protocol.

Item	DNV GL comments
Enforcement of Setback #2	It is recommended that guests be *physically* prevented from penetrating the zone delimited by Setback #2 at all times. Sufficient signage should be provided to inform them on risks of trespassing.
Ice Detection	Blade ice detection using binoculars may be hindered by atmospheric conditions. Balsams personnel should have a clear understanding of how to complete their inspection tasks under such circumstances. Balsams' personnel training, preparation and equipment should comply with the risk of ice fragment throws even in areas where the risk is deemed low. It is notably recommended, though not required, that they work in pairs when inspecting the turbines for the presence of blade ice. The criteria triggering the enforcement of Setback #3 should be defined and implemented in the procedures. It is suggested that observation of blade ice on any one turbine trigger enforcement of Setback #3 at neighbouring, if not all, turbines. Further inspection of those turbines should be performed before relaxing the Setback at any location. It is recommended that ice detection hardware (camera, vibration-based detector, etc.) be implemented on wind turbine blades to improve the efficiency

Item	DNV GL comments
	of ice detection.
Enforcement of Setback #3	If blade ice is detected after the resort is opened to guests, the time elapsed before the ski trails and lifts are cleared and Setback #3 is enforced should be minimized. Balsams personnel should follow a clear procedure which deals with all potential situations. For instance, they should know how to handle those skiers who are already on a ski lift. Setback #3 should be clearly visible and ideally physically prevent guests from penetrating the exclusion areas, with appropriate signage. High level of diligence should be kept to monitor the absence of guests on ski trails and lifts until the blade ice throw risk is cleared. A turbine-specific chart should clearly specify which ski lifts and trails are deemed affected when blade ice is detected on any given turbine.
Communication	Communication between Balsams and GR is especially important when re-opening decision is made based on turbine shut down by GR. Communication between Balsams personnel is critical, notably when establishing or clearing Setback #3. Collaboration between Balsams and GR is essential in identifying icing events and improving the protocol. The risk of ice throw should be communicated to Balsams guests, on days with potential ice throw, before they embark on a ski lift leading to Dixville Peak.
Decision to re-open	The chart of decision authorities and responsibilities should be clearly established. This chart should not rely on 3rd parties such as GR personnel as Balsams is deemed responsible for its guests.

DNV GL expects that experience will be gained as Balsams personnel will use the operating protocol. It is also recommended that ice fragments observed on Balsams grounds be reported if/when observed. This feedback along with those from GR personnel and Balsams guests should be used to update and improve the operating protocol continuously.

5 SUGGESTED MODIFICATIONS TO REDUCE RESIDUAL RISKS OF THE PROTOCOL

Based on the estimates of the residual risks of Balsams Operating Protocol presented in Section 4, and given the national risk levels presented for US ski resorts and societal risks, DNV GL suggests some modifications to the proposed protocol. More precisely, DNV GL suggests replacing the fixed-radius Setback #3 to selective trail closures; and modifying a number of ski lifts as described in this Section.

5.1 Ski trails

DNV GL and Dixville attempted to define a location-specific exclusion zone designed to replace the generic and constant 255 meter (837 feet) radius areas around turbine bases (Setback #3) by applying the following guidelines:

- Maximize the number of trails which could remain open;
- Lower the overall resort risk to the extent possible; and
- Comply with the societal risk threshold of 1 hit in 500,000+ years.

The results of this exercise are depicted in Figure 5-1 and are referred to as Scenario 1. In this Figure, it is proposed to replace Setback #3 by the grey-shaded exclusion area – Ski Trails Closed (Scenario 1). In this scenario, DNV GL has assumed that no skiers would be present on grey-shaded trail areas or downhill of trails closed uphill, and that no skier would attempt climbing uphill. By enforcing this exclusion zone during periods of time blade ice throw is expected, the overall risk for the resort is 1 hit in 33-34 years; this is still marginally higher than the threshold suggested in Section 3.2.3, but lower than the risk associated with the currently proposed setback (green dashed line in Figure 5-1). With respect to individual skier risk (societal risk), all ski trails outside of the proposed exclusion area lie in zones where the risk of ice fragment hit is less than 1 in 500,000 years (green and yellow areas in), which complies with the threshold suggested in Section 3.2.3.

Table 5-1 Residual risk of suggested scenarios for ski trail closure.

Ski trails options	Resort risk	Skier risk
Original operational protocol (255 m fixed setback #3)	1 hit in 28-29 years	1 hit in 500,000+ years
Scenario 1 (Selective trail closure)	1 hit in 33-34 years	1 hit in 500,000+ years

The suggested scenario, while not fully complying with thresholds suggested in Section3.2.3, presents a lower level of risk than the originally proposed Setback #3 and, potentially allows keeping some additional ski trails open.

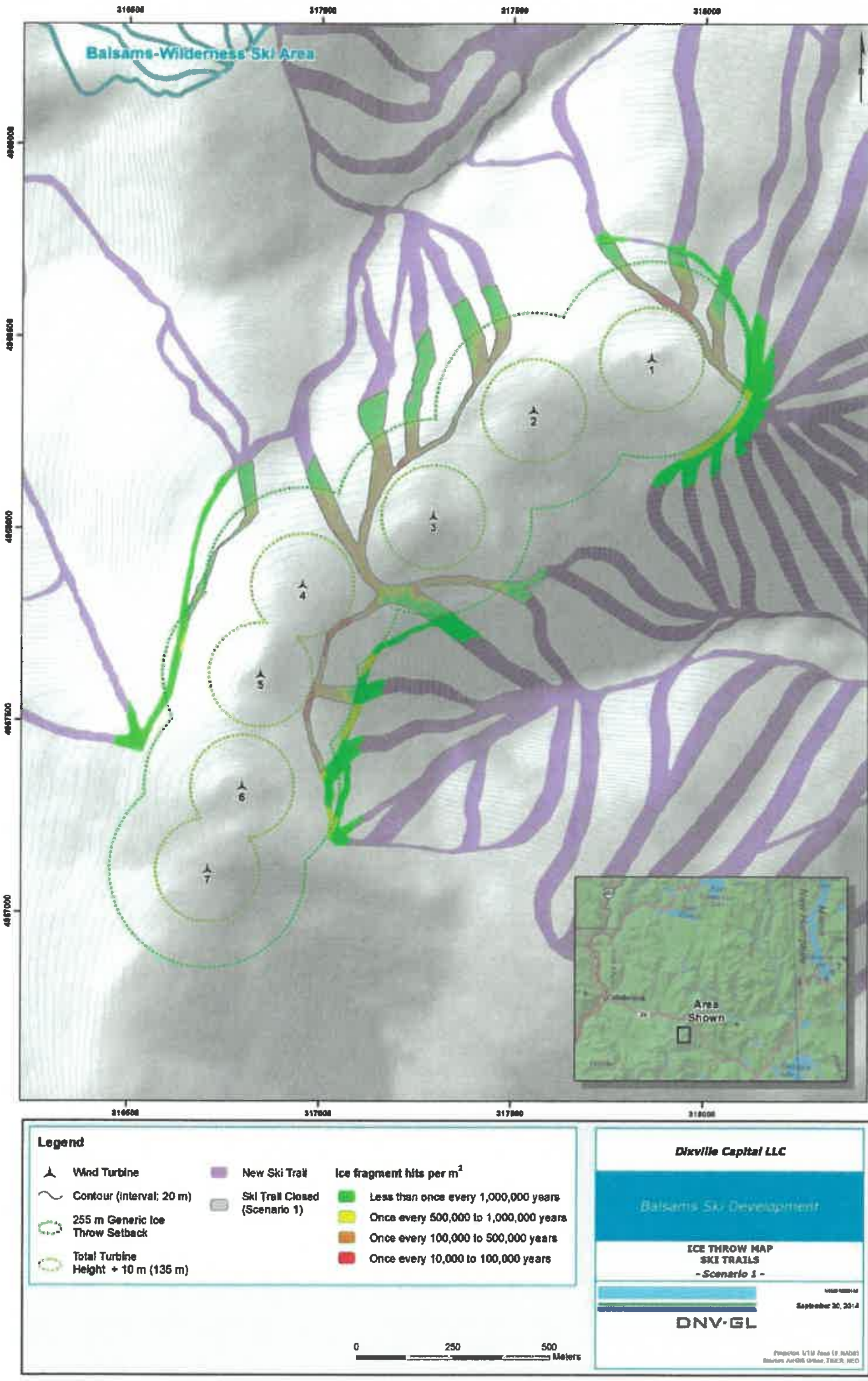

Figure 5-1: Suggested ski trail exclusion area (Setback #3).

5.2 Ski lifts

Concerning the ski lifts, DNV GL notes that ski lift #5 is to be closed during icing events, if suggested risks levels are to be achievable.

Ski lift #10 and #12 present risks of the order of 1 hit in 1,000 to 10,000 years around their respective arrival points (see Figure 2-5). Ski lift #4 presents somewhat lower risk levels of the order of 1 hit in 10,000 – 100,000 years. DNV GL suggests these lifts be modified in such a way that their respective risk levels drops to at least 1 hit in 100,000+ years or less. Two such configurations or options are presented in Figure 5-2 where ski lifts #4, #10 and #12 are relocated (Options 1 & 2) and shown along with their original tracks. The suggestion modifications to these ski lifts are summarized in Table 5-2.

Table 5-2 Suggested modifications to ski lifts*.

Ski lift #	Option 1	Option 2
4	Arrival point to be moved approximately 15 m southwest of current position	Arrival point to be moved approximately 30 m southwest of current position
10	Arrival point to be moved approximately 25 m southeast of current position	Arrival point to be moved approximately 55 m southeast of current position
12	Arrival point to be moved approximately 30 m southeast of current position	Arrival point to be moved approximately 45 m southeast of current position

*: Ski lift #5 is assumed closed in all cases.

Table 5-3 presents the risk levels of the original and modified ski lifts.

Table 5-3 Residual risk of suggested options for ski lift modifications*.

Ski lift options	Resort risk	Skier risk
Original operating protocol	1 hit in 72-73 years	As high as 1 hit in 1,000 to 10,000 years
Option 1	1 hit in 750+ years	1 hit in 10,000+ years
Option 2	1 hit in 3,400+ years	1 hit in 500,000+ years

*: Ski lift #5 is assumed closed in all cases.

Option 2 complies with thresholds suggested in Section 3.2.3 while option 1 would require the closure of ski lifts #4 and #10 (in addition to #5) to fully comply with suggested risks levels when blade ice throw risk is observed at site.

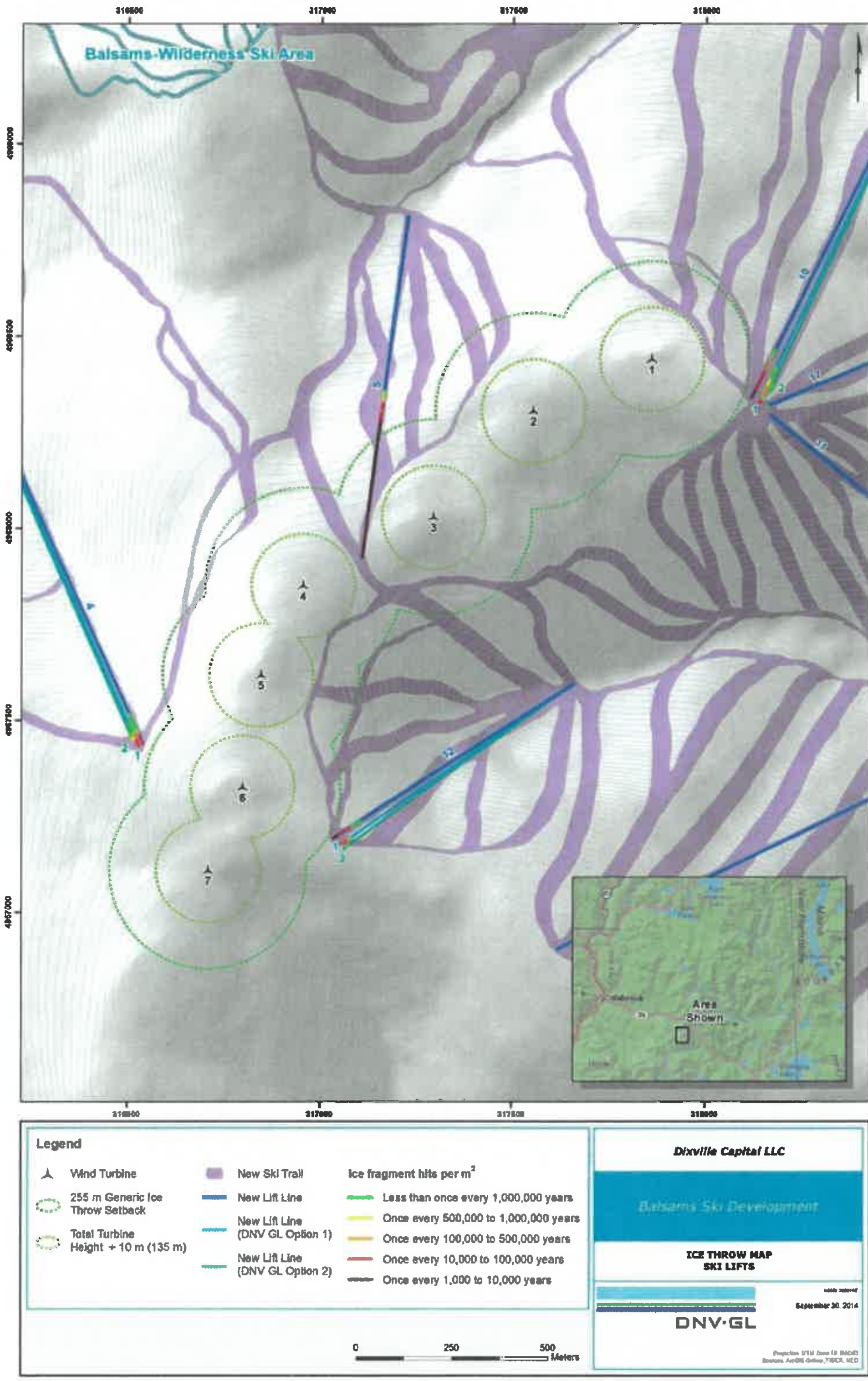

Figure 5-2: Suggested Ski Lift Modifications.

5.3 Overall residual risks

Figure 5-3 presents the ski trail Scenario 1 and ski lift Options 1 & 2 discussed above. Table 5-4 below summarizes the residual risks assuming various operating protocols as described in the first column.

Table 5-4 Overall residual risk of suggested scenarios and options.

Scenario/Option	Resort risk	Skier risk
Original operational protocol (ski lift and trails)	1 hit in 19-20 years	As high as 1 hit in 1,000-10,000 years
Ski trail Scenario 1 (Selective closure) Ski lift #5 closed during icing events	1 hit in 22-23 years	As high as 1 hit in 1,000-10,000 years
Ski trail Scenario 1 (Selective closure)		
Ski lift Option 1	1 hit in 31-32 years	1 hit in 10,000+ years
Ski lift Option 2	**1 hit in 33-34 years**	**1 hit in 500,000+ years**

DNV GL notes that Scenario 1/Option 2 pair (bold face in Table 5-4) presents the lowest level of risk and the closest configuration to suggested thresholds. If this scenario were adopted, during periods of time where blade ice throw is expected, the grey-shaded ski trails – Ski Trail Closed (Scenario 1) in Figure 5-3 – would need to be closed and guests be evacuated by Balsams personnel. Concurrently, ski lift #5 should also be closed and guests be evacuated by the personnel.

It should be noted that the above relates to risk of ice throw hit to skiers. The risk of ice impacting the ground[5] is higher and fragments are expected to land in areas within the purple-shaded areas, depicted in Figure 5-1. Skiers may see ice throws or encounter ice fragments on the ground at higher rates than estimated above.

[5] Skiers are not continuously present at any given location 24/7 during the whole winter season.

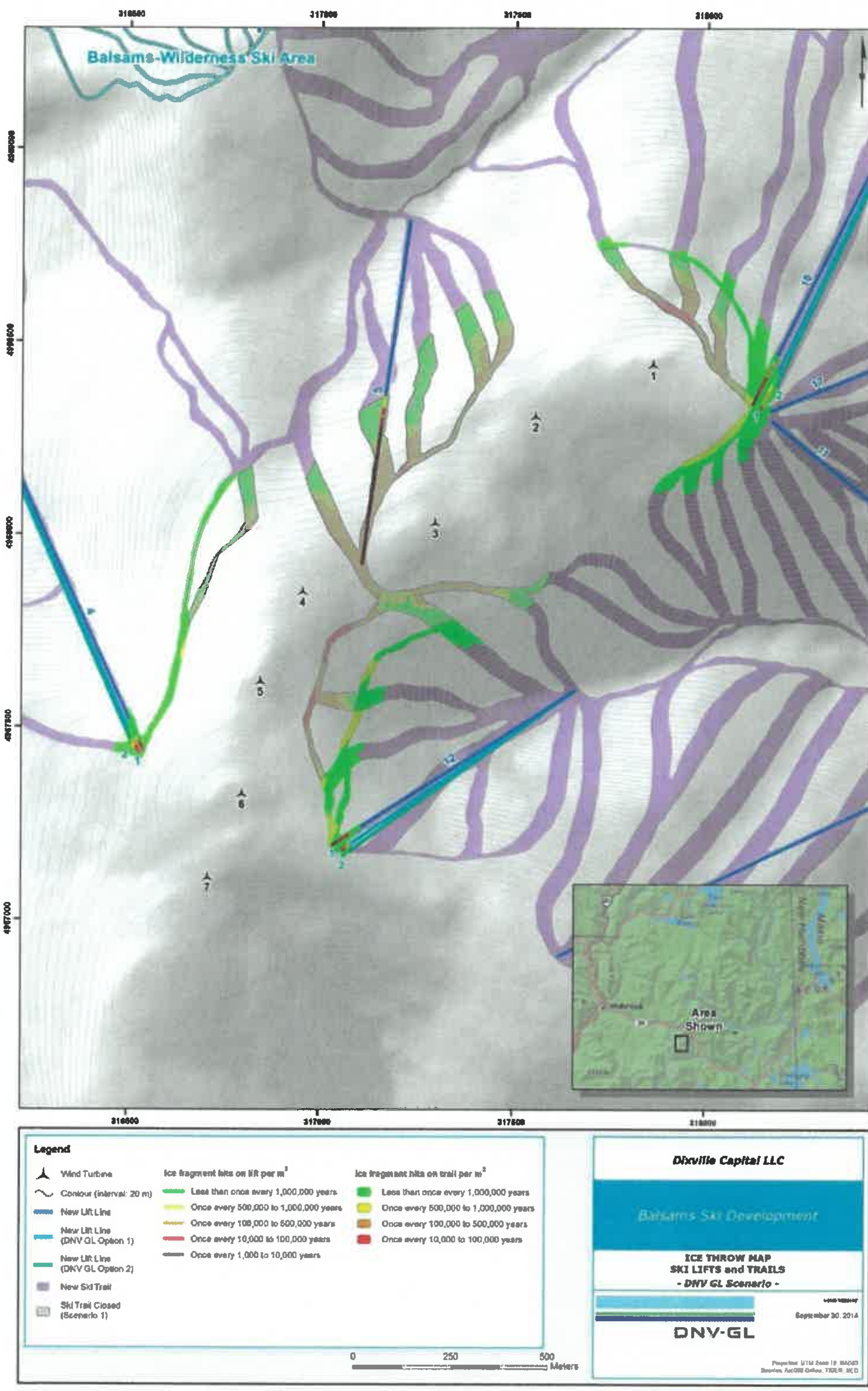

Figure 5-3: Suggested ski trail scenario and ski lift options.

6 CONCLUSIONS

DNV GL reviewed the operating protocol prepared by Dixville, and designed to mitigate the risk of ice throw by the GR wind farm turbine blades to future guests of Balsams Development Project at Dixville Peak, New Hampshire. The operating protocol is part of a risk-based approach where a limited level of residual risk is deemed acceptable.

DNV GL assessed the residual risk of ice throw to the ski resort guests assuming the thorough and full implementation of the protocol. The assessment was based on available onsite data, information obtained from GR and from Dixville, and DNV GL experience and proprietary probabilistic modeling tools.

The residual risk was compared to national statistics of fatal or serious injuries at US ski resorts; and to societal risks such as lightning strike. This exercise was aimed at suggesting a residual risk, which is an additional risk due to the presence of turbine blade ice throw, which would be low compared to the level of risk expected at an average US ski resort; or a societal risk. DNV GL makes no conclusion on an acceptable risk.

DNV GL concluded that the setbacks in the proposed operating protocol and the siting of ski lift arrivals could be modified according to scenarios and options presented in section 5 to lower the residual risk of ice fragment hit to Balsams guests. By implementing the suggested modifications, the residual risks could be as low as the numbers presented below.

Table 6-1 Overall residual risk of suggested scenarios and options vs. national statistics.

	Residual ice fragment hit risk (Original Balsams protocol)	Residual ice fragment hit risk (DNV GL Scenario 1/Option 2)	Reference US Statistics
Overall Resort Risk			Fatal or serious injury at a ski resorts
Risk Level	1 hit in 19-20 years	1 hit in 33+ years	1 per year (source: [8])
Risk to individual guests (societal risk)			Odds of being struck by lightning
Risk Level	1 hit in 1,000+ years	1 hit in 500,000+ years	1 in 960,000 years (Source: [11])

DNV GL notes that the above estimates or residual ice throw risks are to be considered in the context of a number of inherently conservative assumptions made due to the lack of more precise information or data. DNV GL notably highlights the following:

- Blade ice fragment hits do not necessarily result in fatal or serious injuries;
- The total number of annual ice fragments to be thrown is based on conservative assumptions;
- The ballistics of ice fragment throw were based on conservative fragment mass and density;
- All ice fragments were assumed to be thrown during operating hours of the ski resort.

DNV GL also reviewed the critical elements of the operating protocol and provided limited comments to enhance its robustness. The comments notably concern the turbine blade ice detection means, practical issues in enforcing the required setbacks, communication protocols and decision making chain of authority.

DNV GL notes that reducing the risk of ice throw by employing wind turbine ice detection hardware and/or wind turbine icing event operation protocols (such as pre-emptive shut downs, de-icing, start-up with no ice present on blades, etc.), provide enhanced risk mitigation.

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