North Atlantic

Appendix L: Ice Throw Hazard Analysis

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Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviations and Acronyms

Abbreviation	Definition
°C	Degrees Celsius
CanREA	Canadian Renewable Energy Association
IEA	International Energy Association
kg	kilogram
kV	kilovolt
LOHC	Liquid organic hydrogen carrier
M	Meters
m/s	Meters per second
MW	megawatt
NL	Newfoundland and Labrador
PPE	Personal protective equipment

1.0 Introduction

North Atlantic Refining Corp. (North Atlantic) is proposing to undertake the development of a wind to hydrogen project (the Project) on the Isthmus of Avalon Region in Newfoundland and Labrador (NL). This Project will entail development, construction, operation and eventual decommissioning of a 324 megawatt (MW) Wind Farm consisting of 45 wind turbines on an undeveloped peninsula situated between Sunnyside and Deer Harbour. The Wind Farm will provide renewable electricity via a 138 kilovolt (kV) transmission line to a newly developed Hydrogen Generation Plant (HGP), from where generated hydrogen will be transported to a Hydrogenation Plant (HP) for transformation into a Liquid Organic Hydrogen Carrier (LOHC), which will be shipped from North Atlantic's port facilities to domestic and international markets for use in various decarbonization technologies.

GHD Limited (GHD) was retained by North Atlantic to conduct an ice throw hazard analysis as part of the Registration for the planned wind turbines as part of the Project. The ice throw hazard analysis was completed using the 55 proposed wind turbine locations, wind data provided by North Atlantic, and the Vestas V162 wind turbine model, with a hub height of 119 meters (m) and rotor diameter of 162 m, which was assumed as a basis for wind turbine design. Note that the ice throw risk assessment is based on these key wind turbine model parameters (hub height and rotor diameter) – should these parameters change, the ice throw risk assessment presented in this report is no longer valid and should be reconducted.

The risk of ice fall or throw is a notable hazard for wind turbine operations in cold climates. Although there have been limited ice throw events leading to public property damage globally, and no known recorded events to date of a person being struck by a falling or thrown ice fragment, the consequences associated can be significant – potentially leading to serious injury or fatality – and therefore should be mitigated as much as reasonably achievable.

2.0 Wind Turbine Ice Hazards Background

2.1 Ice Hazard Context

Cold climate conditions present distinct operational challenges for wind turbines. Wind turbine blades and associated components are vulnerable to in-fog icing and freezing rain events, causing the accumulation of ice mass. This buildup can interfere with data collection systems, introduce vibrations due to blade imbalance, and impact aerodynamic performance of the blades, reducing power conversion efficiency. Accumulated ice may dislodge from the blades or structure either by melting or mechanical breakage, resulting in ice throw or ice fall. These ice throw or ice fall events can pose significant safety risks to people, animals, and property.

The Canadian Renewable Energy Association (CanREA) has published a series of *Best Practices for Wind Farm Icing and Cold Climate Health & Safety* guidelines, the latest of which was updated with a 2020 publication, which is utilized as the methodology basis for this Wind Farm ice throw assessment (CanREA, 2020).

Accumulated ice on wind turbines can shed from wind turbines through two primary mechanisms:

- **Ice Throw** refers to ice fragments detaching from the rotating wind turbine blades during operation, where the ice fragments can be projected significant distances from the wind turbine. The maximum potential throw distance has been determined empirically to depend primarily on the hub height and blade length of the wind turbine.
- **Ice Fall** refers to ice fragments detaching from the wind turbine when the wind turbine rotor is stationary, resulting in ice falling within a smaller radius of the wind turbine. The maximum potential fall distance has been determined empirically to depend on the wind turbine hub height, blade length, and potential wind speeds. The majority of ice will typically fall within the footprint of the wind turbine itself, although some fragments may be carried a greater distance from the wind turbine by strong gusts of wind.

In either case of ice fall or ice throw, the ice fragments can present a significant hazard to people, animals, and property that lie within the maximum ice fall or throw zone. A 0.2-kilogram (kg) ice fragment falling from a height of just 30 to 50 metres (m) carries enough force to potentially land a fatal blow to an unprotected human head (CanREA, 2020). The risk of ice fall or throw is most likely to occur when temperatures rise or are around 0 degrees Celsius (°C), or when a wind turbine resumes operation after being paused during an icing event. General risk mitigation measures following icing events are discussed in Section 2.3.

2.2 Ice Classification & Risk of Icing Occurrence

Ice accretion occurs during periods of meteorological icing, which is defined as the periods during which atmospheric conditions are favorable for ice build-up on structures, including wind turbines. The total duration that ice is present on structures is defined as the instrumental icing period, as ice can remain on structures for hours or even days after a meteorological icing event has occurred.

The International Energy Association (IEA) and CanREA further define *rotor icing* as the period during which ice is present on the rotor blades of a wind turbine. Rotor icing is not equivalent to instrumental icing due to the geometry of the blades, rotational speed, and resultant relative velocity of the wind acting upon the blades. Rotor ice can accrete faster on rotor blades than on static structures when the rotor is in operation. The ablation phase of rotor icing, during which ice remains on the blades, is generally shorter than the period of instrumental icing, particularly when blade heating or other ice mitigation technologies are used. According to publications from the IEA Task 19 workforce on wind turbine icing and commentary from DNV (IEA Wind TCP Task 19 Wind Enery in Cold Climates, 2022), (Kinstom, 2014), rotor blade icing periods may correspond to half the period of instrumental icing, depending on the operating conditions and any blade de-icing technologies employed.

There are different methods for determining the risk of icing occurrence at a site, from direct site measurement campaigns to meso-scale modelling. CanREA refers to the wind power icing atlas, called WIceAtlas, created and managed by the VTT Technical Research Centre of Finland, which provides probability levels of in-cloud icing risk worldwide based on meso-scale modelling (VTT Technical Research Centre of Finland, 2023), for assessing the risk of icing occurrence. The WIceAtlas follows the IEA's Ice Class Definitions, which define the risk of meteorological and instrumental icing by IEA Ice Class 1 through 5 as described in Table L-2.2-1 below.

Table L-2.2-1 IEA ice class definitions (IEA Wind, 2017).

IEA Ice Class	Meteorological Icing (% of the year)	Instrumental Icing Risk (% of the year)
1	0 – 0.5	0 – 1.5
2	0.5 – 3	1 – 9
3	3 – 5	6 – 15
4	5 – 10	10 – 30
5	>10	>20

2.3 Best Practices & Risk Mitigation

The general hazards presented by ice throw/fall include:

- Serious injury or fatality to an unprotected worker or member of the public within the vicinity of the maximum ice throw zone during periods of rotor icing.
- Serious injury or fatality to cattle or wildlife within the vicinity of the maximum ice throw zone during periods of rotor icing[1].
- Damage to property and infrastructure within the maximum ice throw zone during periods of rotor icing, including damage to vehicles, equipment, electrical or other infrastructure, and buildings.

While the potential consequence of ice throw impacting a person is rated as high, due to the possibility of serious injury or fatality, it is worth noting that, to date, in the history of Wind Farm operations in cold climates, there has never been a recorded incident of injury or fatality from a human being struck by falling or thrown ice. The risk occurrence or likelihood is very low at the outer areas of the maximum ice throw zone and considered null outside of the maximum ice throw zone. Directly under the wind turbine, or any iced structure, CanREA recommends the risk should be considered as medium during periods of rotor icing (CanREA, 2020), as this is the zone in which most ice will shed from the structure.

There are several mitigation measures that can be employed by Wind Farm operators in cold climates to mitigate the hazards presented by ice fall or throw. These include the following:

- **Shutdown the wind turbines during rotor icing periods:** Generally, the ice throw zone is notably larger than the ice fall zone. During periods of rotor icing, which can be detected through a variety of direct and indirect methods (IEA has a detailed report on the technologies/methods available (IEA Wind TCP Task 19, 2021)), wind turbine operators have the ability to pause wind turbine operations. This measure significantly reduces the risk of ice throw by limiting potential ice detachment to ice fall closer to the wind turbine base, effectively reducing the

Figure L-2.3-1 Permanent ice protection device installed at wind turbine base (CanREA, 2020).

[1] Note that there are no active farming / ranching operations within the study area, so this risk is not addressed. The risk of wildlife being struck by an ice fragment is always present for any Wind Farm in cold climates but cannot be effectively mitigated by signage or otherwise.

hazard zone to the ice fall zone. Pausing the wind turbine also mitigates vibrational impacts from blade imbalance due to uneven ice accretion, and results in less ice accumulation due to the lowered relative velocity of wind to the blades.

- **Ice protection devices:** In the case that workers must attend to wind turbines during or after periods of rotor icing (for example, for maintenance when residual ice may still be present on the structure), appropriate ice protection devices should be installed at the wind turbine base such that workers can step directly from their vehicle into a covered walkway that leads to the base access. An example of a permanent ice protection device is shown in Figure L-2.3-1.
- **Restrain site access:** Public access to Wind Farms can be restricted, for example with fences and/or private property signage. The maximum ice throw zone could be used to determine the limits of site access restrictions.
- **Public Danger Warning Signs:** Operators should add signage to warn the public of the risk of ice fall around the maximum ice throw zones to emphasize the importance of not entering the area during and following periods of icing events. Public danger warning signs should be visible and placed strategically, keeping in mind potential recreational activities in the area (such as hiking and snowmobiling trails). Additionally, danger warning signs can be equipped with flashing lights to indicate ongoing icing events, which can be tied to the operator's ice detection system. Educational signs can be added to any parking lots, trail heads, etc. to provide more detailed information. On public recreational trails, signs can be located at the points where the trail intersects with the maximum ice throw boundary, warning the public to remain clear of the area during potential icing events.
- **Anti- and De-Icing Technologies:** Wind farm project developers can opt for ice prevention technologies as part of the wind turbine package, which can include blade heating technology that actively reduces the rotor icing period by mitigating ice accretion and speeding up the ablation of ice from the blades.
- **Follow the best practices detailed by CanREA** (CanREA, 2020)**:** These include employing occupational health and safety systems and requirements including adequate personal protection equipment (PPE) for all workers, education on the hazard and right to refuse unsafe work, regular inspections of protective equipment such as ice protection devices, among other recommendations.

3.0 Ice Throw Hazard Analysis Methodology

3.1 Approach & Methodology

The ice throw analysis presented is based on the high-level, conservative approach recommended by CanREA in the 2020 *Best Practices for Wind Farm Icing and Cold Climate Health and Safety* document (CanREA, 2020). This methodology is widely accepted as being conservative (as ice throw risk outside of the determined zone is considered null), however it does not result in probability distribution of an ice throw impact within the maximum ice throw zone. Should a statistical ice throw risk assessment be required within the ice throw zone, a more detailed analysis based on statistical computer models will be needed, which can allow for resizing (shrinking) the ice fall risk zone with a more precise and less conservative methodology. This type of analysis can provide quantitative evaluation of the expected probability of an ice fragment hitting the ground, measured as the number of strikes anticipated per square meter per year. The IEA Wind TCP Task 19 has published detailed guidance on such statistical ice throw risk assessment (IEA Wind TCP Task 19 Wind Enery in Cold Climates, 2022). The remainder of this section describes the CanREA methodology employed in the current study.

The risk of icing occurrence is determined utilizing the WIceAtlas icing map for the wind turbine locations (VTT Technical Research Centre of Finland, 2023) and IEA Ice Class definitions (IEA Wind, 2017).

The maximum ice throw zone is evaluated with the following equation, as recommended by CanREA (CanREA, 2020) and determined empirically by Seifert *et al.* (Seifert, Westerhellweg, & Kroning, 2003):

$$d_t = 1.5 * (D + H)$$

Where:

- d_t is the maximum ice throw distance (m)
- D is the wind turbine rotor diameter (m)
- H is the wind turbine hub height (m)

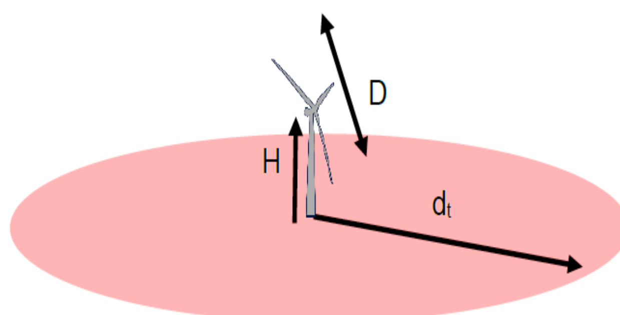


Figure L-3.1-1 Maximum ice throw distance area (CanREA, 2020).

The maximum ice fall distance, on the other hand, is a result of the hub height, rotor diameter, and the wind speeds acting on the falling ice fragment. Ice fall should therefore be evaluated for a range of typical wind speeds, and actual wind speeds should be evaluated during rotor icing events to assess the safety of workers being near and around the wind turbines. Periods of higher wind speeds represent greater risk of ice falling beyond the direct footprint of the wind turbine.

The equation for maximum ice fall distance as recommended by CanREA and similarly determined empirically by Seifert *et al.* is as follows:

$$d_f = \frac{\frac{D}{2} + H}{15} * V$$

Where:

- d_f is the maximum ice fall distance (m).
- D is the wind turbine rotor diameter (m).
- H is the wind turbine hub height (m).
- V is the wind speed at hub height (m/s).

The maximum ice fall zones are determined for a range of wind speeds considering historical wind speed data supplied by met mast data collected by North Atlantic. Note that site-specific wind speed at hub height data was not available for this study; rather met mast data from a height of 60 m was provided and is compared against modelled data provided by Hatch for the Wind Farm at 100 m height.

The study assesses the maximum ice throw zone and ice fall zones for the wind turbine model evaluated and then identifies and assesses risks within the maximum ice throw zone for each wind turbine via geospatial data. Notable hazards are identified, and potential mitigation measures are recommended.

3.2 Key Assumptions

The following key assumptions have been used for the ice throw analysis:

- Evaluation is based on the Vestas V162 wind turbine model, with a hub height of 119 m and rotor diameter of 162 m. At this stage, the wind turbine manufacturer is assumed, however, the final wind turbine selection is expected to be similar in specifications and performance to the Vestas model referenced.
- The latest planned wind turbine locations were provided via shape file on February 7, 2025. Should the planned locations be modified, it is recommended to perform an updated ice throw

assessment on the additional locations. Shape files were also provided with the Collector Lines and transmission infrastructure.

- Wind speed data was provided by North Atlantic per data collected at the met mast located within the planned Wind Farm footprint for the period from January 18, 2024, to September 30, 2024, located at latitude 47°49'37.52"N, longitude 53°47'26.38"W. This data is compared to wind speed meso-scale modelling assessed by Hatch that were purchased from Vortex Data.

4.0 Project & Site Details

4.1 Wind Turbine Characteristics & Locations

The Project will consist of up to 55 wind turbines located on an undeveloped peninsula between Sunnyside and Deer Harbour in the Isthmus of Avalon region adjacent to the Avalon Peninsula, NL. The Wind Farm will provide renewable electricity via a 138 kV transmission line to produce green hydrogen through electrolysis. The produced hydrogen will undergo hydrogenation to be converted into methylcyclohexane, an LOHC, for shipment to domestic and international markets for use in various decarbonization technologies.

The ice throw analysis was completed using the Vestas V162 wind turbine model, with a hub height of 119 m and rotor diameter of 162 m. The wind turbines have an installed rated power of 7.2 MW and come with pitch and variable speed control. It is GHD's understanding that North Atlantic is intending to utilize anti- and/or de-icing technology.

Figure L-4.1-1 shows the proposed locations of the potential 55 wind turbine locations that were assessed in this ice throw hazard analysis. Note that GHD understands that North Atlantic intends to proceed with 45 wind turbines, but all 55 wind turbine locations are assessed in this ice throw hazard analysis.

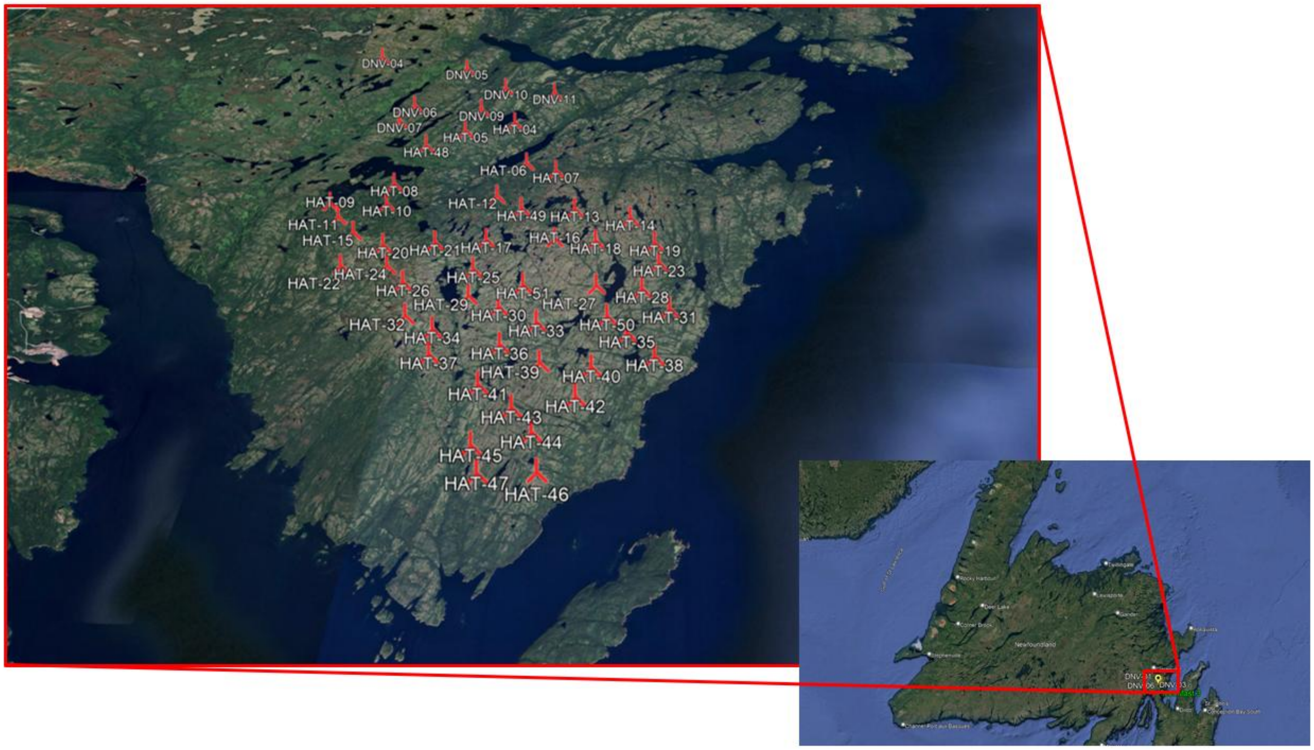
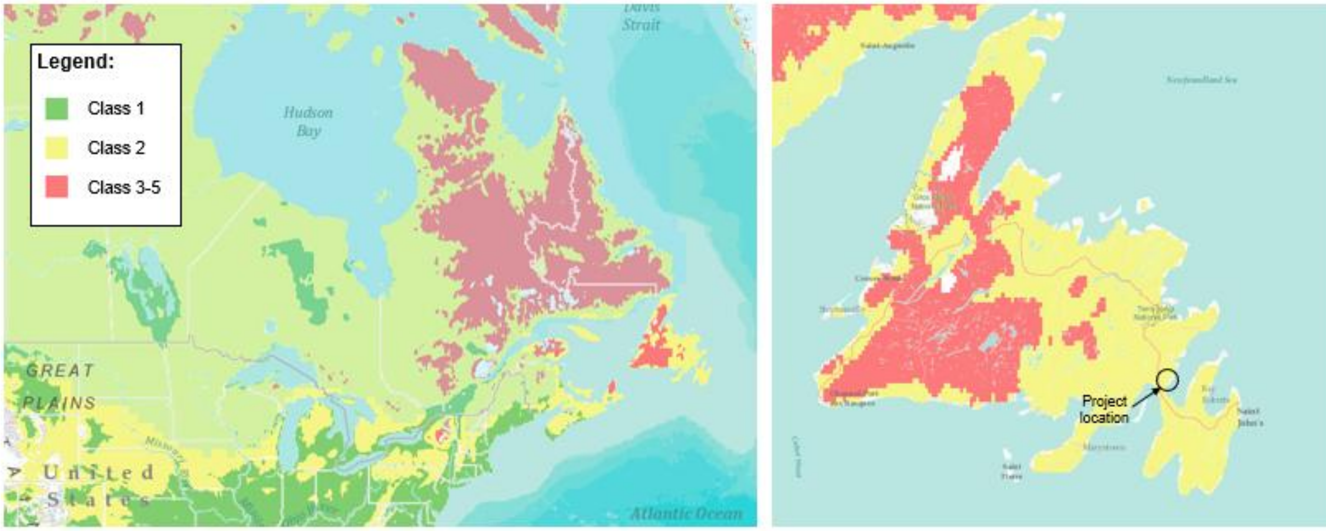


Figure L-4.1-1 Planned locations of the wind turbines.

4.2 Site Conditions

The potential for instrumental icing and for ice throw or fall is influenced by site specific meteorological conditions. The IEA Ice Classification for the region is utilized to assess the potential for instrumental and rotor icing.

Figure L-4.2-1 presents the WIceAtlas IEA Ice Classifications for Eastern Canada (a) and zoomed in on the Island of Newfoundland with the Project location identified (b).



(a) WIceAtlas snapshot for Eastern Canada

(b) WIceAtlas snapshot for Newfoundland with Project location identified

Figure L-4.2-1 WIceAtlas IEA ice classification for Eastern Canada and the Project location (VTT Technical Research Centre of Finland, 2023).

As indicated by WIceAtlas in the figure above, the IEA Ice Class for the Project location is Class 2. This classification corresponds to anticipated:

- Meteorological icing occurrence 0.5 to 3% of the year (average of 1.8 to 11.0 days per year).
- Instrumental icing occurrence 1 to 9% of the year (average of 3.7 to 32.9 days per year).

The rotor icing period, during which ice is present on the wind turbine blades, is not equivalent to instrumental icing and is typically shorter as ice tends to shed more readily from wind turbine blades than static structures due to movement, vibrations, and heating from de- and anti-icing systems. The duration of rotor icing varies significantly for a wind turbine at stand-still versus in operation, and for wind turbines with ice mitigation technologies such as integrated blade heating. A factor of 50% for rotor icing compared to instrumental icing has been assumed in other studies (IEA Wind TCP Task 19 Wind Enery in Cold Climates, 2022), (Kinstom, 2014), which would correspond to an expected rotor icing occurrence of between 2 and 17 days per year for this Project. A conservative evaluation of rotor icing likelihood would equate rotor icing duration with instrumental icing duration, for a maximum expected rotor icing occurrence of up to 33 days per year for this Project.

It is GHD's understanding that North Atlantic intends to use anti- or de-icing technology in the procured wind turbines. These systems can significantly reduce the period of rotor icing by mitigating the build-up of ice on blades and accelerating the process of melting / detaching ice from the blades. This reduces the likelihood of rotor icing occurrence, mitigating risks of ice throw and fall.

Wind speed data for the Project location was provided by North Atlantic from met mast measurements taken at a height of 60 m recorded from January 18, 2024, to September 30, 2024. Using the upper end of recorded wind gusts provides for a conservative assessment of ice fall zone as the likelihood of an ice fragment breaking off at the exact moment that the maximum wind gust is realized is very low (Seifert, Westerhellweg, & Kroning, 2003).

The frequency of recorded wind speeds from the provided met mast data is visualized below. Data analysis shows that recorded wind speed was less than 15 metres per second (m/s) 97.5% of the time. Only 2.5% of recorded wind speeds exceeded 15 m/s, and only 0.35% of recorded wind speeds exceeded 20 m/s. No recorded wind speeds exceed 25 m/s.

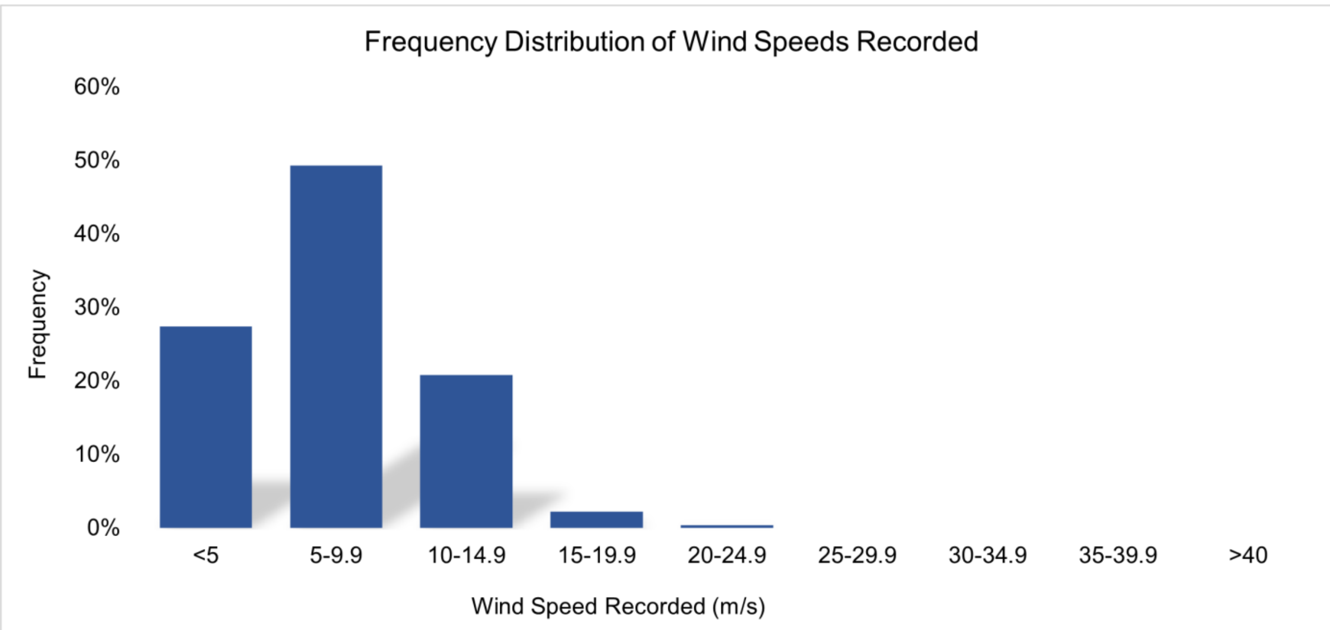


Figure L-4.2-2 Frequency distribution of wind speeds from met mast data.

The Hatch Pre-FEED Report dated 2024, provided by North Atlantic, contained a wind speed frequency distribution graph using an alternate data source (mesoscale modelling) at a hub height of 100 m, over a 10-year period from January 1, 2013, to December 31, 2022. This data is represented in the figure below and reaffirms that wind speeds greater than 20 m/s occur rarely and wind speeds in excess of 25 m/s are not expected.

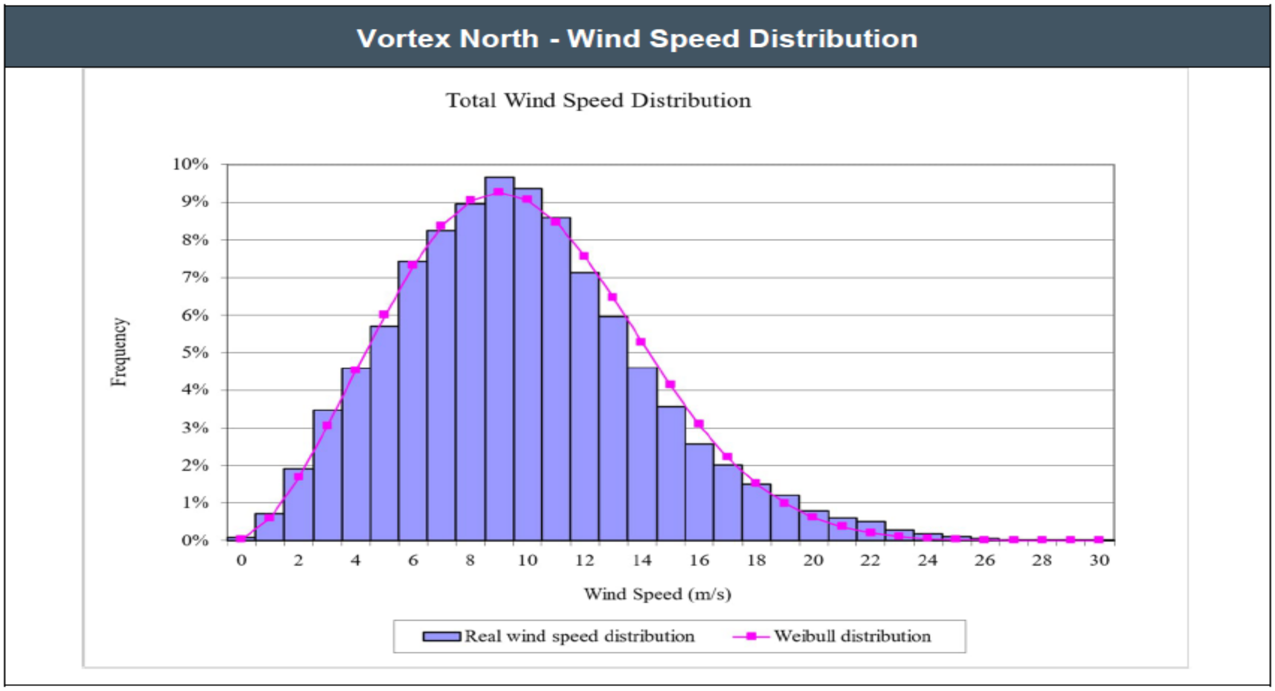


Figure L-4.2-3 Frequency distribution of wind speeds from mesoscale data.

5.0 Evaluation Results & Discussion

5.1 Ice Throw & Fall Results

5.1.1 Maximum Ice Throw

Following the methodology described in Section 3.0, with a hub height of 119 m and rotor diameter of 162 m, **the maximum ice throw distance for the planned wind turbines is 421.5 m**.

Appendix L-1 presents the assessment of the maximum ice throw radius for each of the 55 proposed wind turbine sites using Google Earth to identify potential hazards within the ice throw zone. Risks identified and recommended mitigation measures are discussed in Section 5.2.

5.1.2 Ice Fall

The maximum ice fall distance, when the wind turbines are paused, depends on both the wind turbine characteristics (hub height and rotor diameter) and wind speeds. Following the methodology described in Section 3.0, the maximum ice fall distance from the wind turbines for various wind speeds is provided in Table L-5.1-1.

Table L-5.1-1 Maximum ice fall distance by wind speed.

Wind speed (m/s)	Max ice fall distance (m)
0	0
5	67
10	133
15	200
20	267
25	333

The likelihood of ice falling a distance greater than 333 m (the maximum ice fall distance) when the wind turbines are paused is considered extremely low to null. This is due to the very low probability of an ice fragment detaching at the same time as a wind gust exceeding 25 m/s. The met mast data presented in Section 4.2 recorded zero instances of wind speed exceeding 25 m/s. Therefore, assessing the risks within the maximum ice throw zone of 421.5 m reasonably accounts for the risks of ice fall.

5.2 Risk Identification & Mitigation

5.2.1 General Risks & Mitigations for All Wind Turbines

Public engagement conducted by North Atlantic found that there was potential for privately-owned cabin areas within the Wind Farm area, specifically near wind turbines HAT-09 and HAT-48. These cabin areas are not visible in Google Earth; however approximate locations were provided in shape files for consideration in this analysis. Further public engagement and field monitoring confirmed that there is no intent to build at these locations, as discussed under section 5.2.2.1 below.

Apart from the two potential cabin areas near HAT-09 and HAT-48, there are no established hiking trails, public-access lands, or private properties located within the maximum ice throw zones for all other wind turbines. Hiking trails were investigated using All Trails and regional trail maps in Newfoundland, with no hiking trails identified in the Wind Farm area.

The primary risks for all wind turbines are associated with worker access and Project-related infrastructure (Collector Lines, transmission lines, substations, access roads). General risks applicable to all planned wind turbine locations include the following:

a. Workers accessing the wind turbines for maintenance / operations purposes during periods of rotor icing may be struck by a falling or thrown ice fragment.
b. Worker vehicles may be struck by falling or thrown ice fragments during periods of rotor icing, which can lead to further incidents or injury.
c. Damage to wind turbine structure or associated aboveground electrical and ancillary infrastructure.

The risks associated with item (a) above include possible serious injury and/or death if workers are within the ice throw zone without ice protection and adequate PPE. Ideally, this risk is best mitigated by avoiding maintenance activities during periods of rotor icing, such that workers do not enter the maximum ice throw zone when ice is detected to be present on the structure or blades. If workers must access the wind turbine during possible rotor icing periods, the following risk mitigation measures should be employed:

- **Use ice protection devices:** Ice protection devices can be mobile units deployed as needed or permanent installations at each wind turbine base. These devices should provide an entryway for workers to exit their vehicles and enter the wind turbine base while remaining fully protected from any falling ice fragments, such as the structure shown previously in Figure L-2.3-1.

- **PPE and training in accordance with CanREA Best Practices recommendations:** Workers should be aware of the risks, should be aware of active rotor icing events, and should have adequate PPE such as hard hats, steel toed boots, and cold weather protective gear.

The risks associated with item (b) above include damage to property which could lead to unexpected costs and potential for a vehicle in motion to crash due to an ice fragment impact disrupting the driver. The key mitigation measure is for workers to drive cautiously in the ice throw zone, which should be addressed through adequate training for operation and maintenance personnel. Vehicles should be equipped with cold weather protection for workers (blankets, heater, water, etc.) in the case of a vehicle breakdown.

The risks associated with item (c) above include damage to property which could lead to unexpected costs. Aboveground equipment sensitive to potential impacts from ice fragments can be protected with caging or housing. Following rotor icing events, operators should inspect equipment within the ice throw zones for any damage and plan repairs to ice protection devices as needed.

Across all the wind turbines and identified hazards, a key factor influencing the associated risks is the likelihood of rotor icing occurrence. Rotor icing periods can be reduced with both active and passive ice mitigation techniques. These may include, for example, hydrophobic coatings on the blades that provide passive mitigation of ice accretion, or active blade heating systems that target the sections of the blades most susceptible to icing, thereby mitigating ice buildup and accelerating the rate of ice ablation. Vestas offers anti- and de-icing technologies that could be considered for this Project that would effectively reduce the expected periods of rotor icing.

Finally, a general risk mitigation measure across all the wind turbine sites can be to pause the wind turbines during active rotor icing events to reduce the likelihood of ice falling at greater distances.

5.2.2 Specific Risks Identified for the Planned Wind Turbine Locations

Attachment 1 provides a visual identification of features within the maximum ice throw zone for each of the 55 proposed wind turbine locations that present hazards from ice throw or fall. The features identified include the following.

5.2.2.1 Cabin Areas near Wind Turbines HAT-09 and HAT-48

Public engagement conducted by North Atlantic identified two potential private cabin areas within the proposed Wind Farm footprint, including the two cabins (pink dots) and cabin areas (yellow circles) shown in Figure L-5.2-1. One cabin area is within the maximum ice throw zone for wind turbine HAT-48 and the other is near the maximum ice throw zone for wind turbine HAT-09. Note that there are no existing cabins or other property currently in these areas, as confirmed through field assessment conducted by North Atlantic.

However, further engagement from North Atlantic confirmed that for the potential cabin area near HAT-09, there is no license to occupy or crown land claim. There is a license to occupy for the cabin area near HAT-48, however North Atlantic has verbal confirmation that the owner does not intend to build in this location.

As such, the wind turbine locations that overlap with these potential cabin areas do not present risk for the foreseeable future.

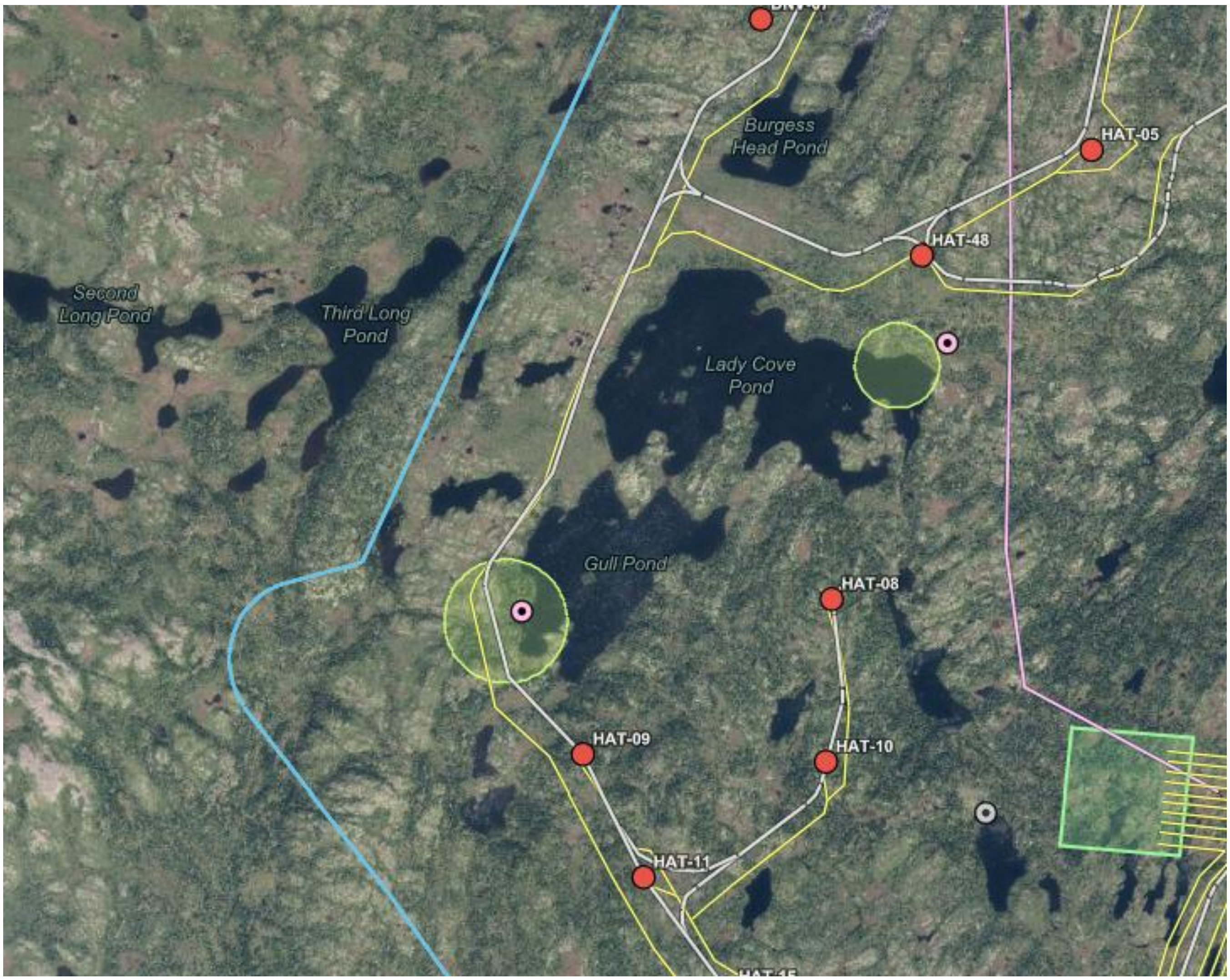


Figure L-5.2-1 Potential cabin areas identified by North Atlantic near wind turbines HAT 09 and HAT 48.

5.2.2.2 Project Roads

Project roads planned to be constructed for operation and maintenance access were within the maximum ice throw zones of all 55 proposed wind turbines. Ice fall or throw may strike workers driving and working within the ice throw zones, potentially causing serious injury and/or fatality, or vehicle and property damage.

Potential risk mitigation measures include the following:

- Operators should be informed of the risks of ice fall and throw and appropriate mitigation measures should be employed. These may include worker training and education, use of adequate PPE, installation of signage indicating the hazardous area and potentially indicating active rotor icing periods, and work stand down during periods of active rotor icing within ice throw zones unless absolutely necessary. For added mitigation, the Project could consider an active notification system whereby operations staff are notified of the start and finish of every rotor icing event.

5.2.2.3 Transmission Lines

Planned transmission lines associated with the Project are within the maximum ice throw zones of Wind Turbines HAT-05, DNV-04, and DNV-05. Ice throw may strike power lines or associated infrastructure and cause damages that could potentially lead to power outage resulting in economic losses. There are minimal potential mitigation measures unique to this risk. As with all other wind turbines, pausing the wind turbines during periods of active rotor icing will reduce the likelihood of ice fragments falling beyond the immediate area of the wind turbine itself.

5.2.2.4 Collector Lines & Substations

Collector Lines will transmit energy produced from each of the wind turbines to a collector substation. Aboveground electrical infrastructure may be struck by thrown or falling ice fragments, potentially resulting in damages, loss of power and associated economic losses.

Collector Lines are located in all wind turbine maximum ice throw zones. Proposed substations are located within the maximum ice throw zone of Wind Turbine HAT-12. There are minimal potential mitigation measures unique to this risk. As with all other wind turbines, pausing the wind turbines during periods of active rotor icing will reduce the likelihood of ice fragments falling beyond the immediate area of the wind turbine itself. Protective casing can be installed around key equipment at the substations.

6.0 Conclusions & Recommendations

The risk of ice fall or throw is a notable hazard for wind turbine operations in cold climates. Although there have been limited ice throw events leading to public property damage globally, and no known recorded events to date of a person being struck by a falling or thrown ice fragment, the consequences associated can be significant – potentially leading to injury or fatality – and therefore should be mitigated to the extent that is reasonably achievable.

The main risks identified in this ice throw analysis are summarized below along with recommended mitigation measures. Across all risk items identified and wind turbine locations, two potential mitigation measures can be applied: (a) pausing the wind turbines to reduce the likelihood that ice fragments are thrown beyond the wind turbine footprint, and (b) investing in anti- and de-icing technologies from the wind turbine manufacturer to minimize the duration of rotor icing periods.

Table L-6.0-1 Summary of key risks and mitigation measures.

Risk Description	Relevant Wind Turbines	Recommended Mitigation Measures
Cabin areas near wind turbines HAT-09 and HAT-48.	HAT-09 HAT-48	Cabin areas are noted however as North Atlantic confirmed that there is currently no property at these locations, no license to occupy at the cabin area near HAT-09, and no intent to build by the owner of the cabin area near HAT-48, there are no recommended mitigation measures as these areas do not present risk for the foreseeable future.
Wind farm operation and maintenance workers accessing wind turbines may be struck by thrown/falling ice resulting in serious injury and/or fatality.	All wind turbines	Invest in ice protection devices at all wind turbines to provide safe worker access. Temporary ice protection devices can be used if site traffic by operation and maintenance personnel is anticipated to be minimal. Educate and train employees in the potential risks and safety measures in accordance with the CanREA Best Practices. Ensure adequate PPE for all workers, and that vehicles are equipped with cold climate protection for workers in the event of emergency (blankets, heater, water, first aid kit, etc.).

Risk Description	Relevant Wind Turbines	Recommended Mitigation Measures
Service roads within maximum ice throw zones, where Project workers in vehicles may be struck by a thrown or falling ice fragments. Such incidents could result in serious injury or death in addition to property damage and economic loss.	All wind turbines	Operations should be educated on the risk of ice fall and throw, and mitigation measures should be employed, such as worker training and education, adequate PPE, signage indicating the hazardous area and potentially indicating active rotor icing periods, and work stand down during periods of active rotor icing within ice throw zones. For added mitigation, the Project could consider an active notification system whereby operations staff are notified of the start and finish of every rotor icing event. Workers driving in the maximum ice throw zones should be trained for winter driving conditions and to drive cautiously to mitigate consequence risk in the event that their vehicle is struck by an ice fragment. Ensure adequate PPE for all workers, and that vehicles are equipped with cold climate protection for workers in the event of emergency (blankets, heater, water, first aid kit, etc.).
Substation infrastructure can be struck by ice throw.	HAT-12	Critical equipment at the substation can be protected with casing or caging to mitigating consequence of ice throw. Alternatively, as there is only a small portion of the substation area that crosses into the maximum ice throw distance for HAT-12, the design team can eliminate this risk item by ensuring no infrastructure is installed in this corner area. See the HAT-12 figure in Attachment 1.
General risk of ice throw.	All wind turbines	Invest in anti- or de-icing technologies to reduce the anticipated rotor icing periods and thereby mitigate the likelihood of ice fall and throw. Pause wind turbines during periods of detected active rotor icing events to mitigate the risk of ice throw.

7.0 References

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Appendix L-1: Maximum Ice Throw Distance Figures

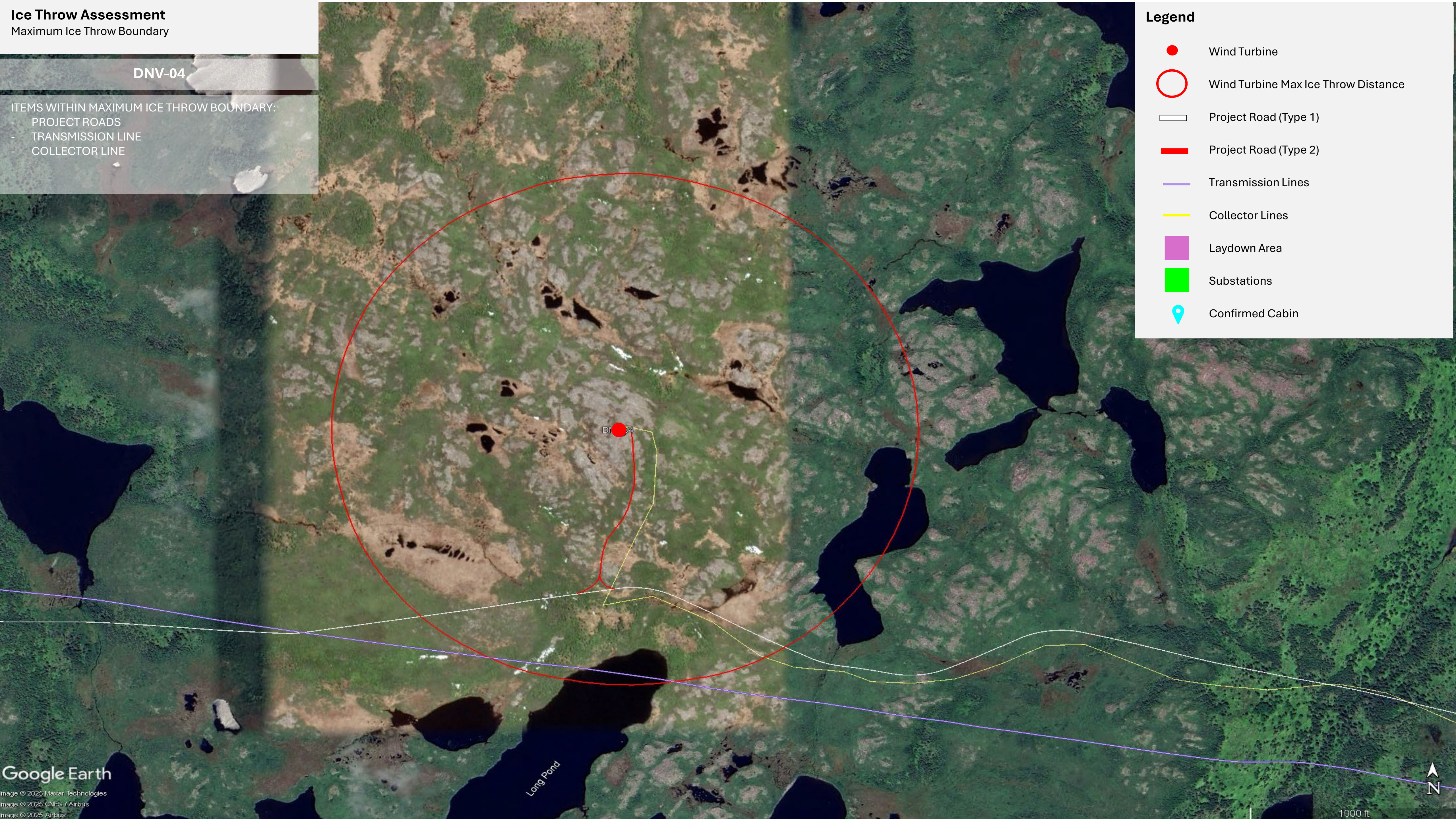
Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-04

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- TRANSMISSION LINE
- COLLECTOR LINE



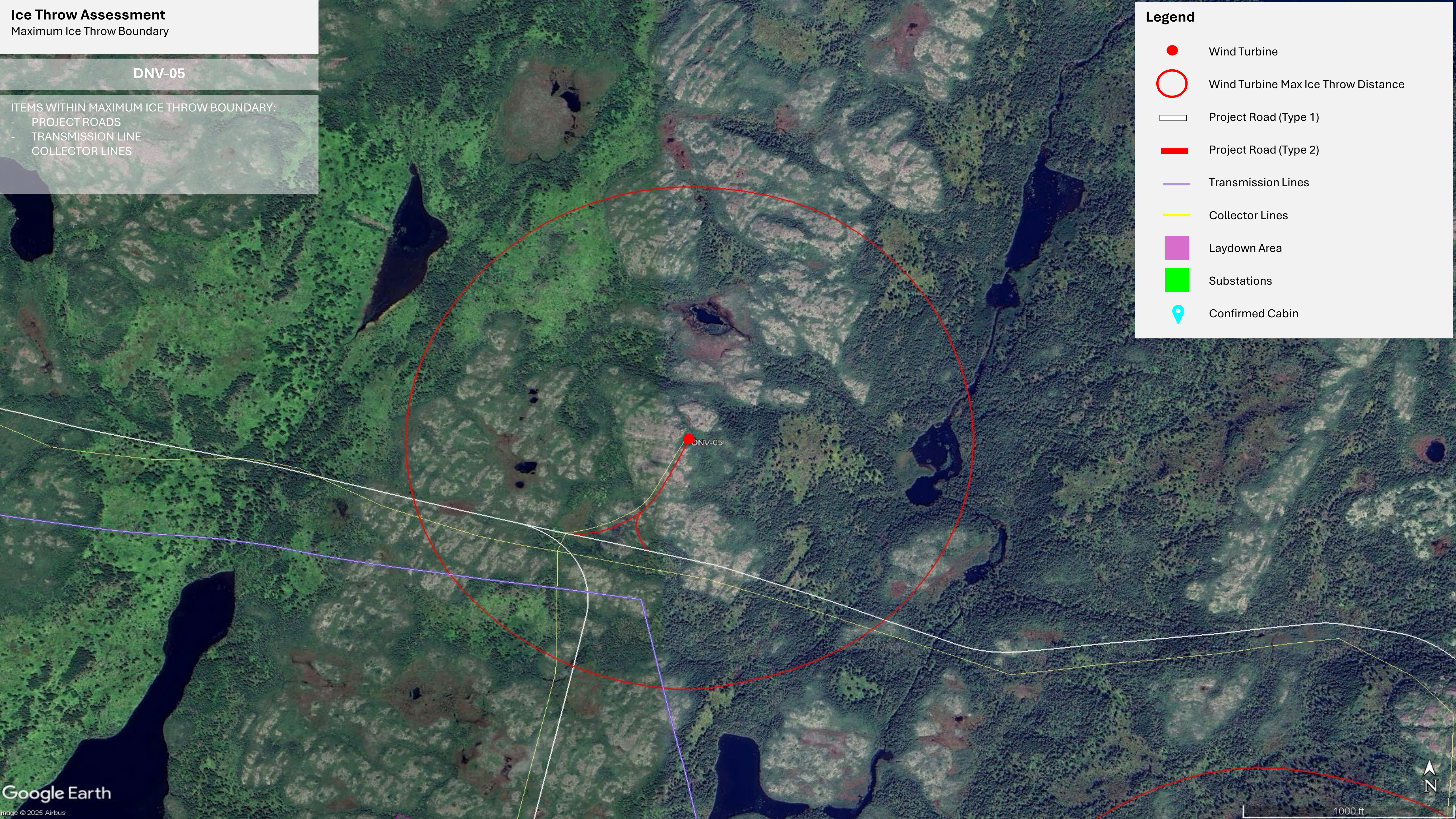
Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-05

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- TRANSMISSION LINE
- COLLECTOR LINES



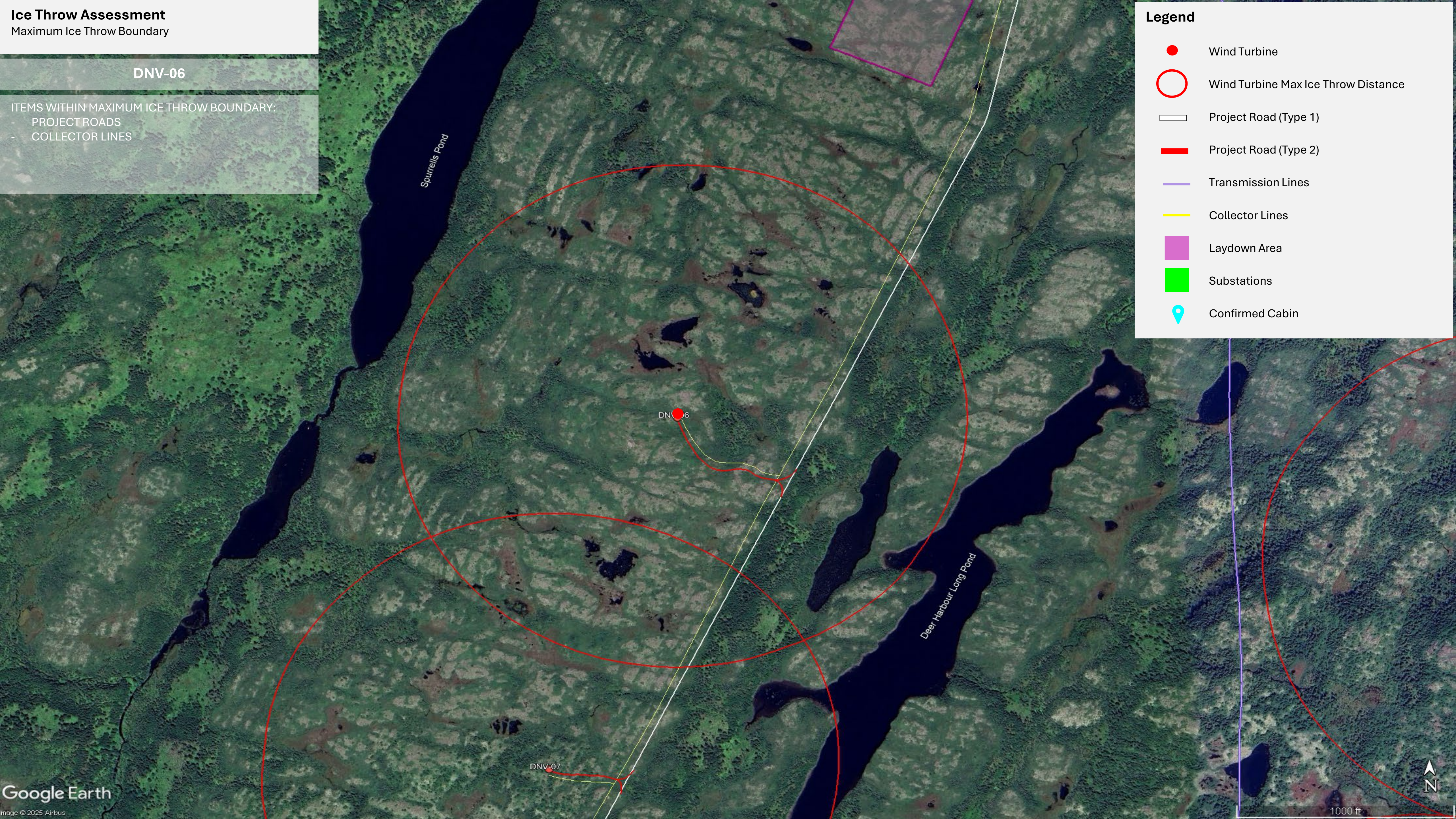
Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-06

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES

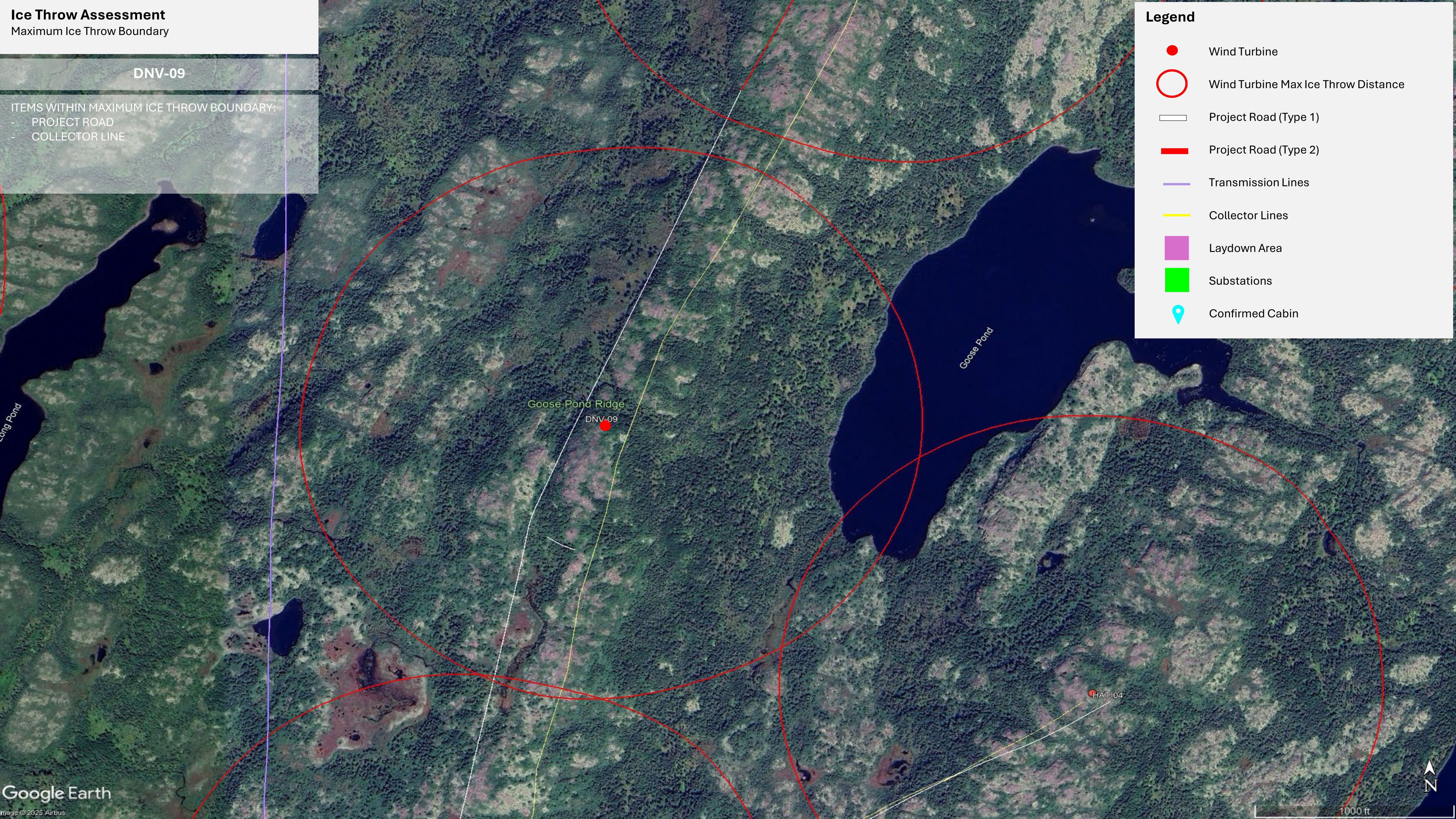


Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-07

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES



Ice Throw Assessment
Maximum Ice Throw Boundary
DNV-09
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
Goose Pond Ridge
DNV-09
Goose Pond
Long Pond
HAT-04
N
1000 ft
Google Earth
Image © 2025 Airbus

Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-10

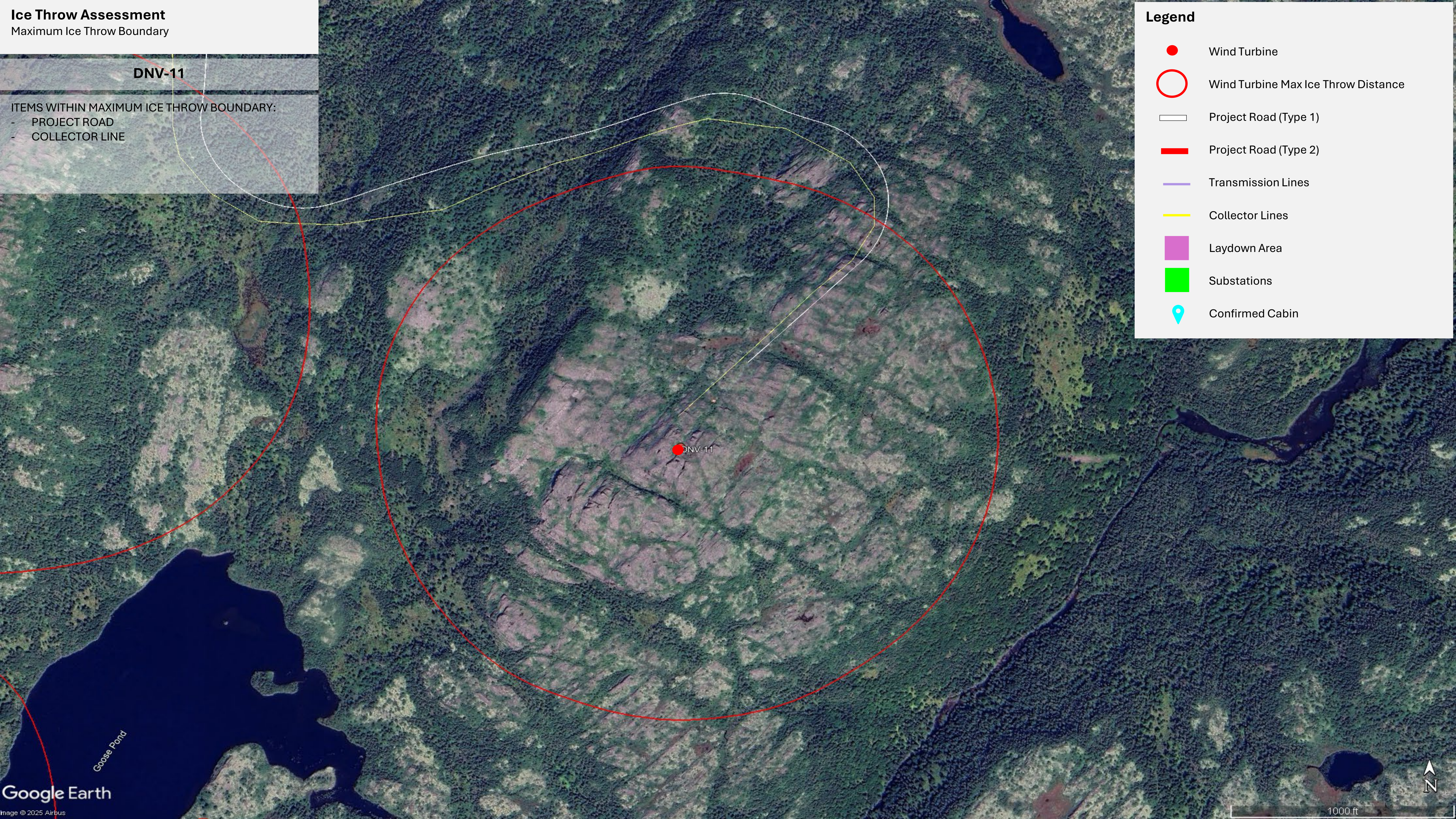
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE

Ice Throw Assessment

Maximum Ice Throw Boundary

DNV-11

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE



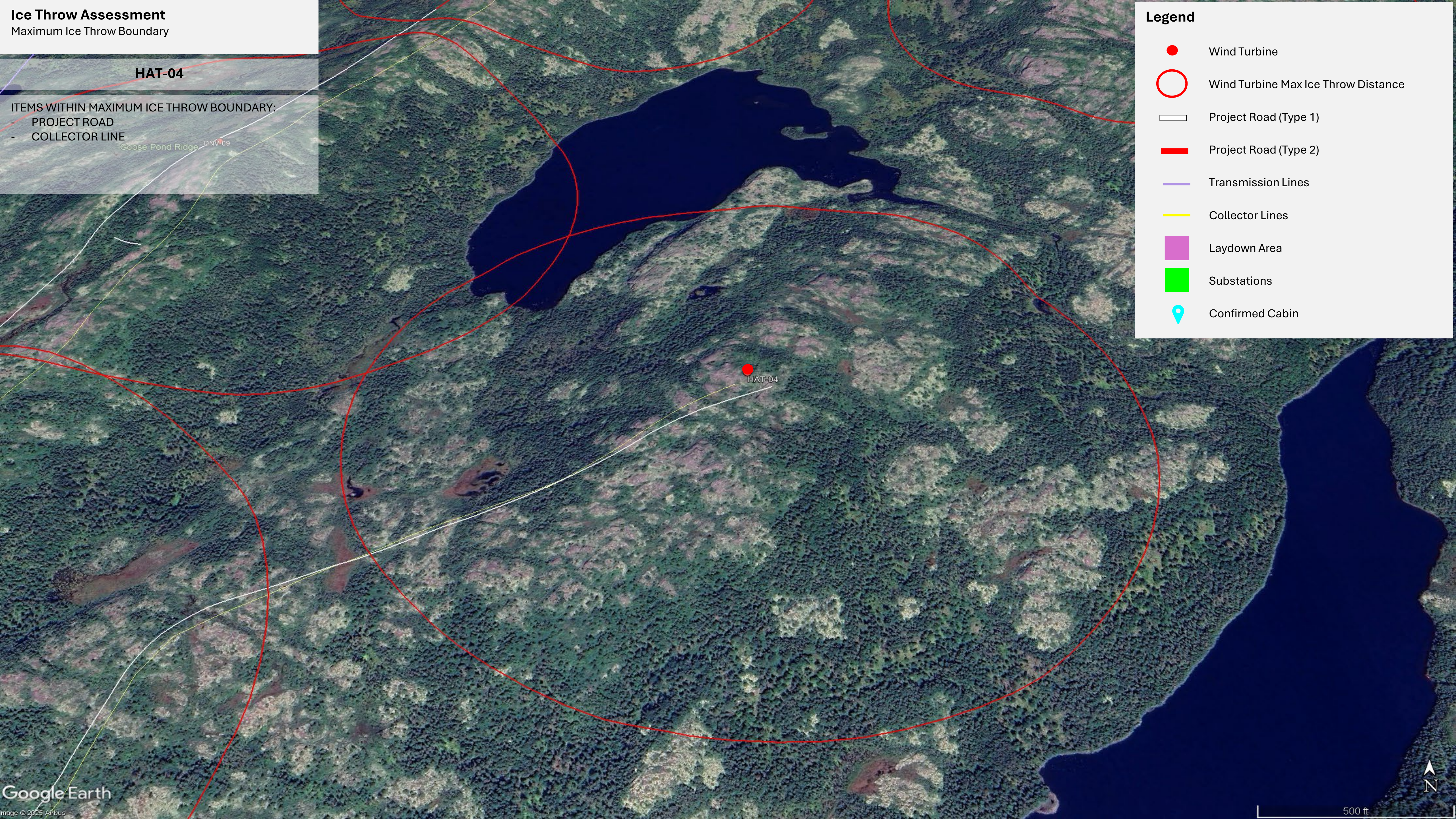
Ice Throw Assessment

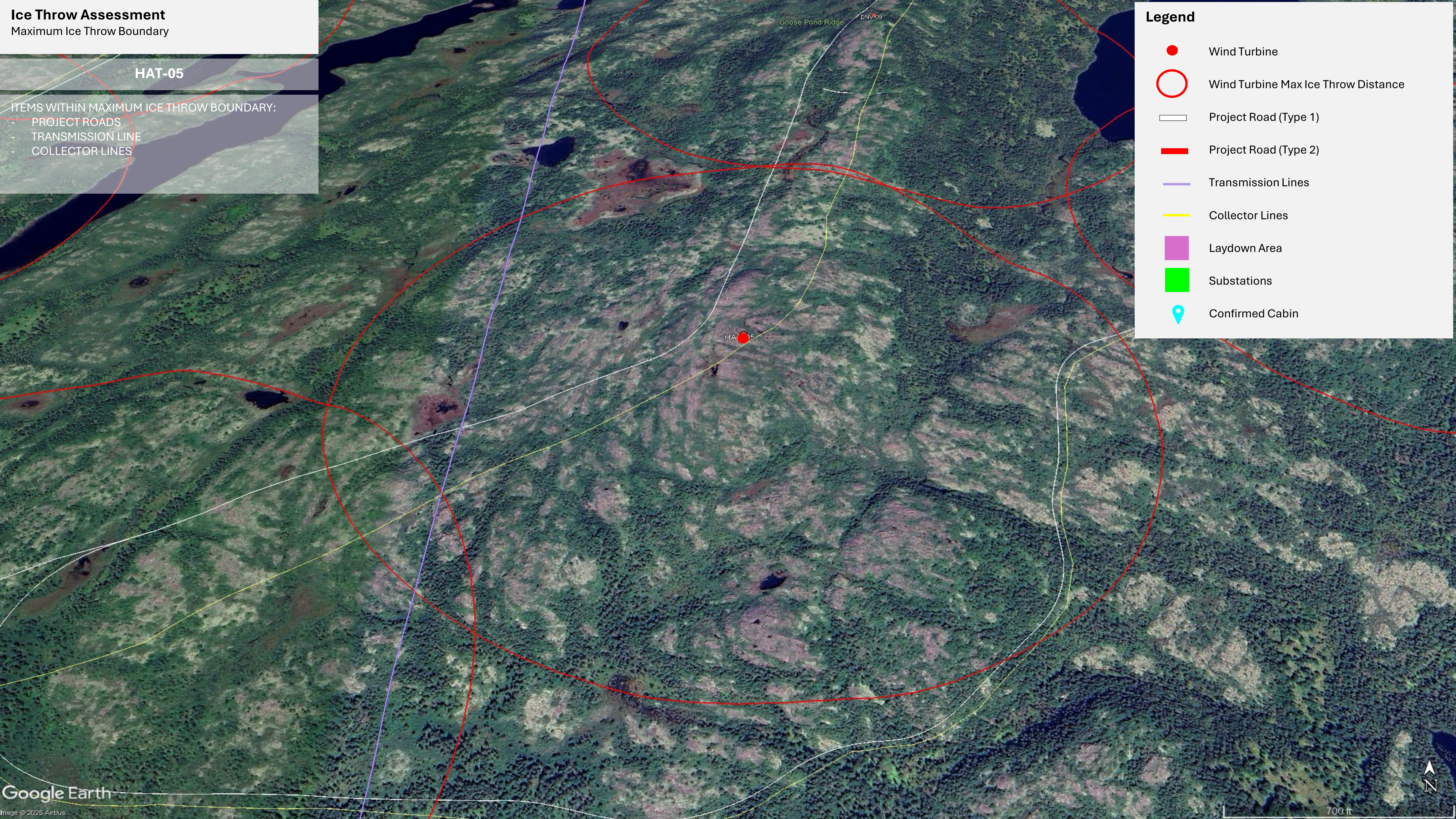
Maximum Ice Throw Boundary

HAT-04

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE





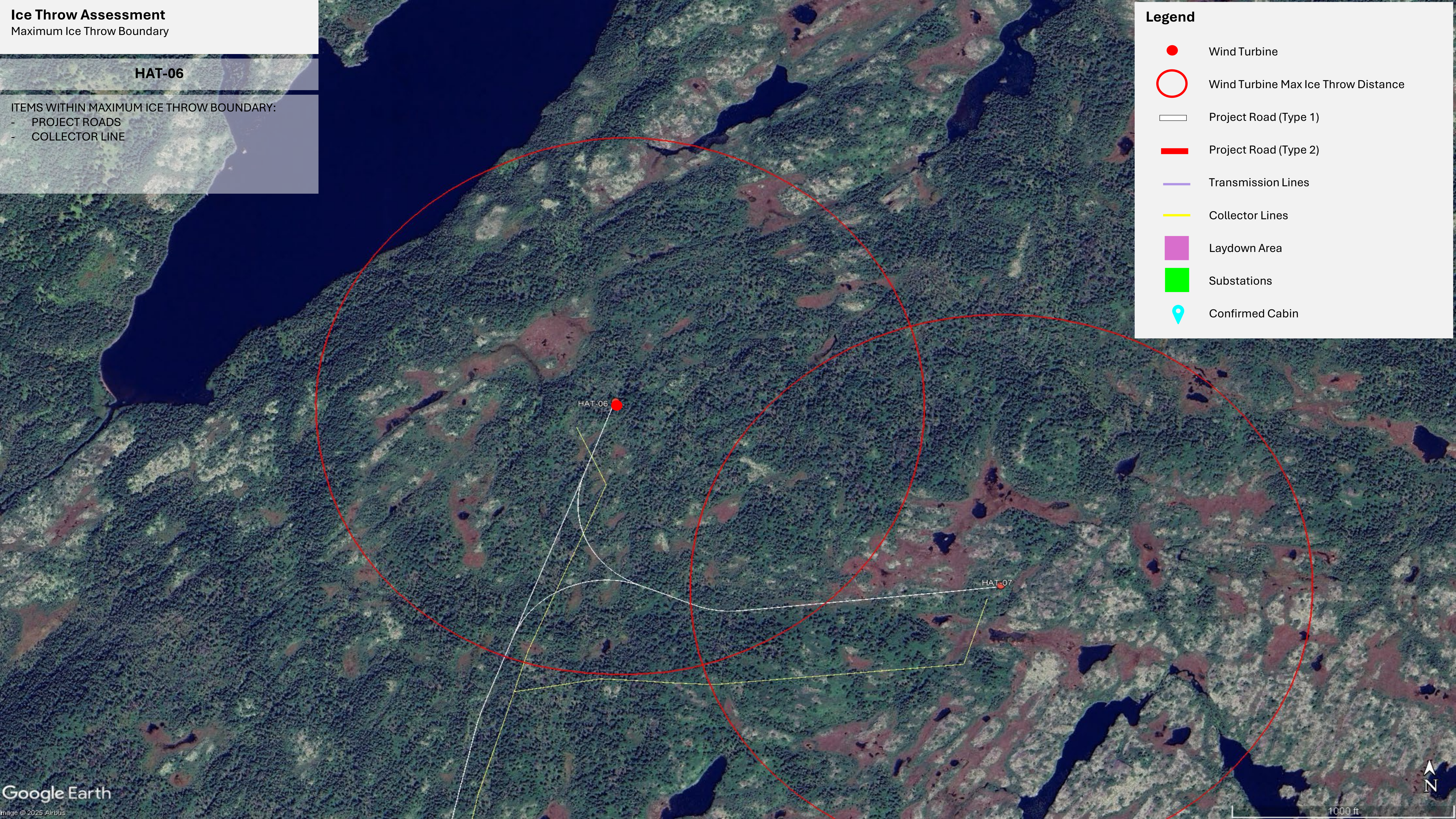
Ice Throw Assessment
Maximum Ice Throw Boundary
HAT-05
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- TRANSMISSION LINE
- COLLECTOR LINES
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
Goose Pond Ridge
Google Earth
Image © 2025 Airbus
700 ft
N

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-06

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE

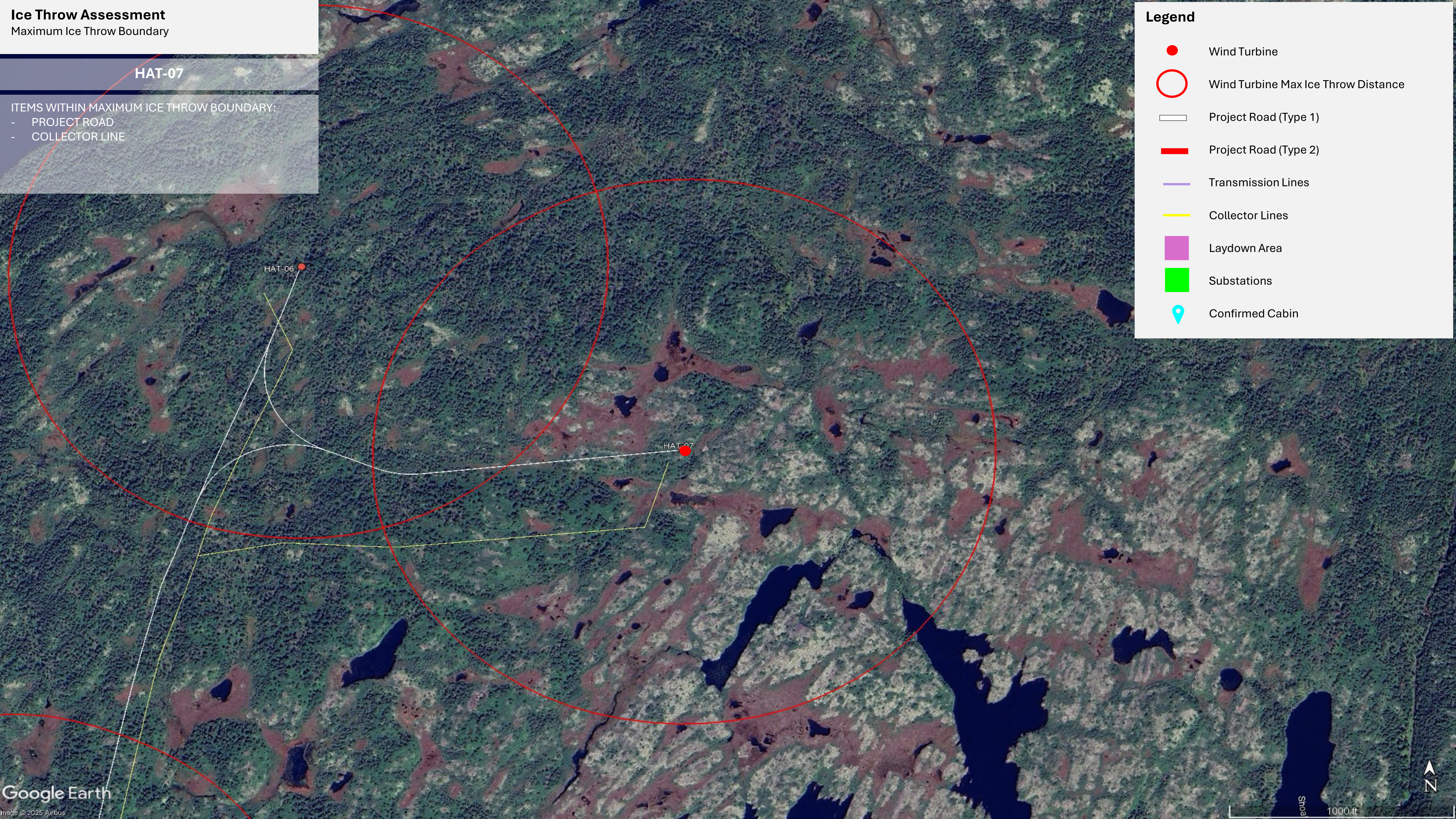


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-07

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-08

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE

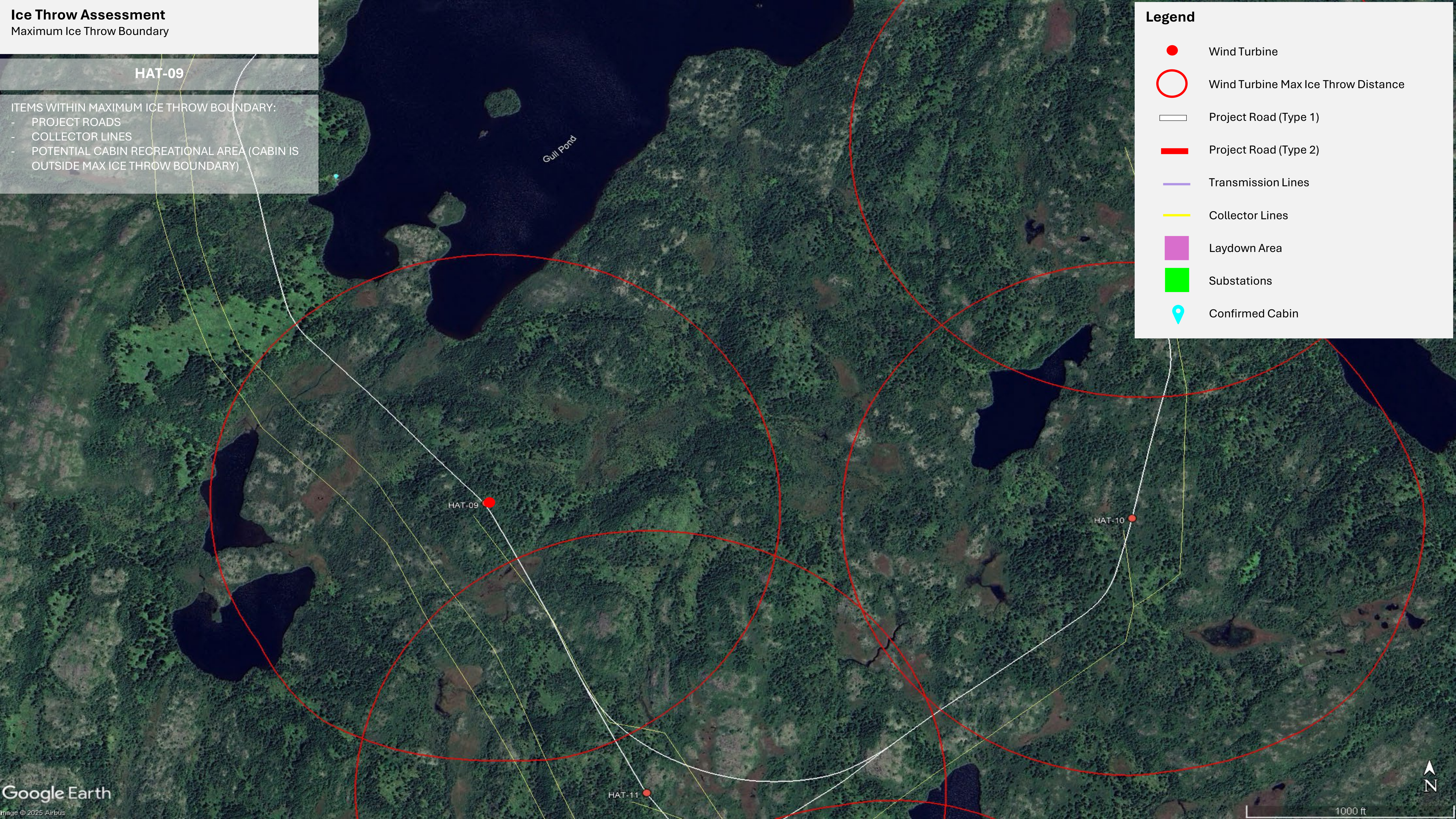
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-09

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES
- POTENTIAL CABIN RECREATIONAL AREA (CABIN IS OUTSIDE MAX ICE THROW BOUNDARY)



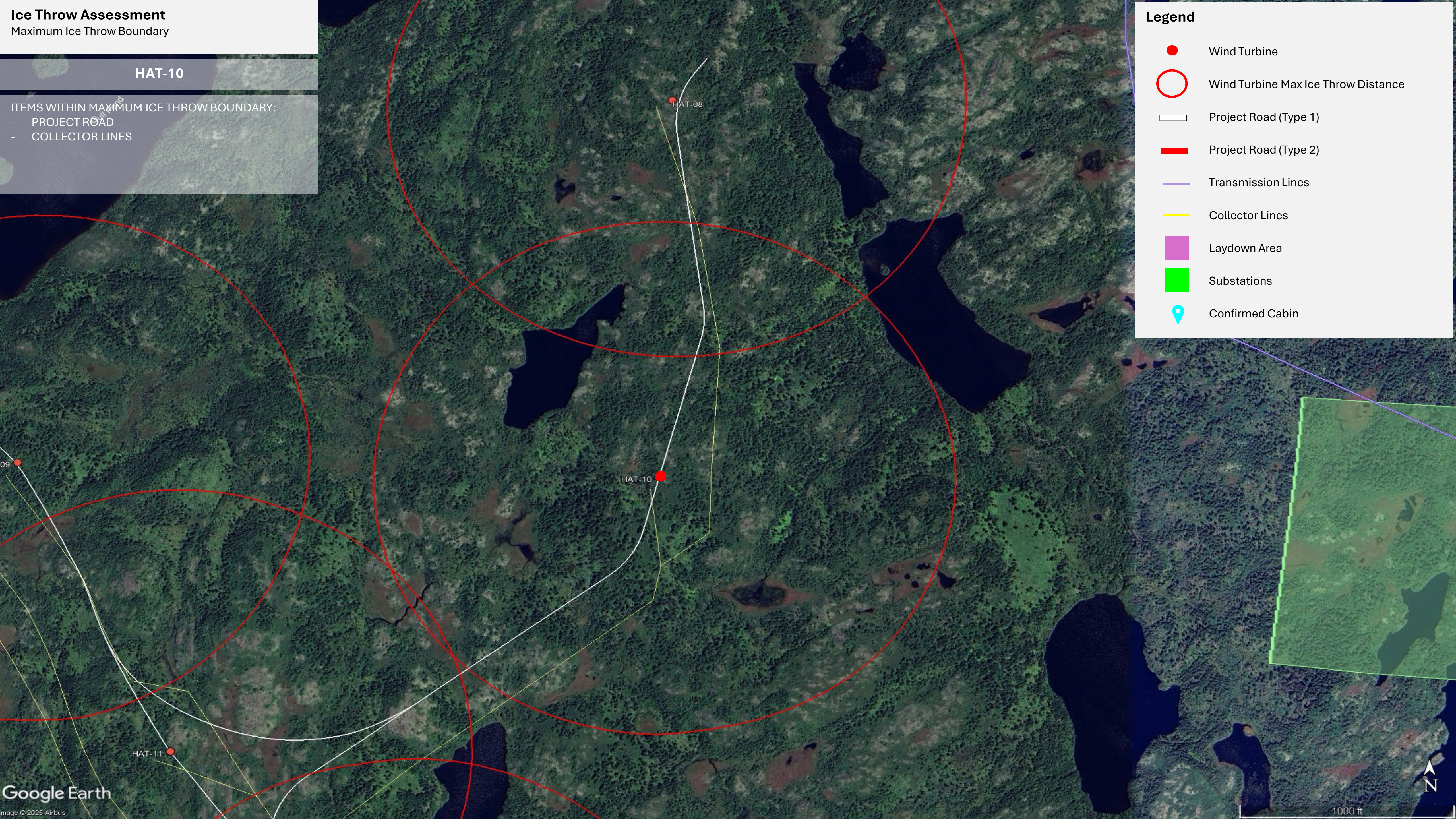
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-10

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINES



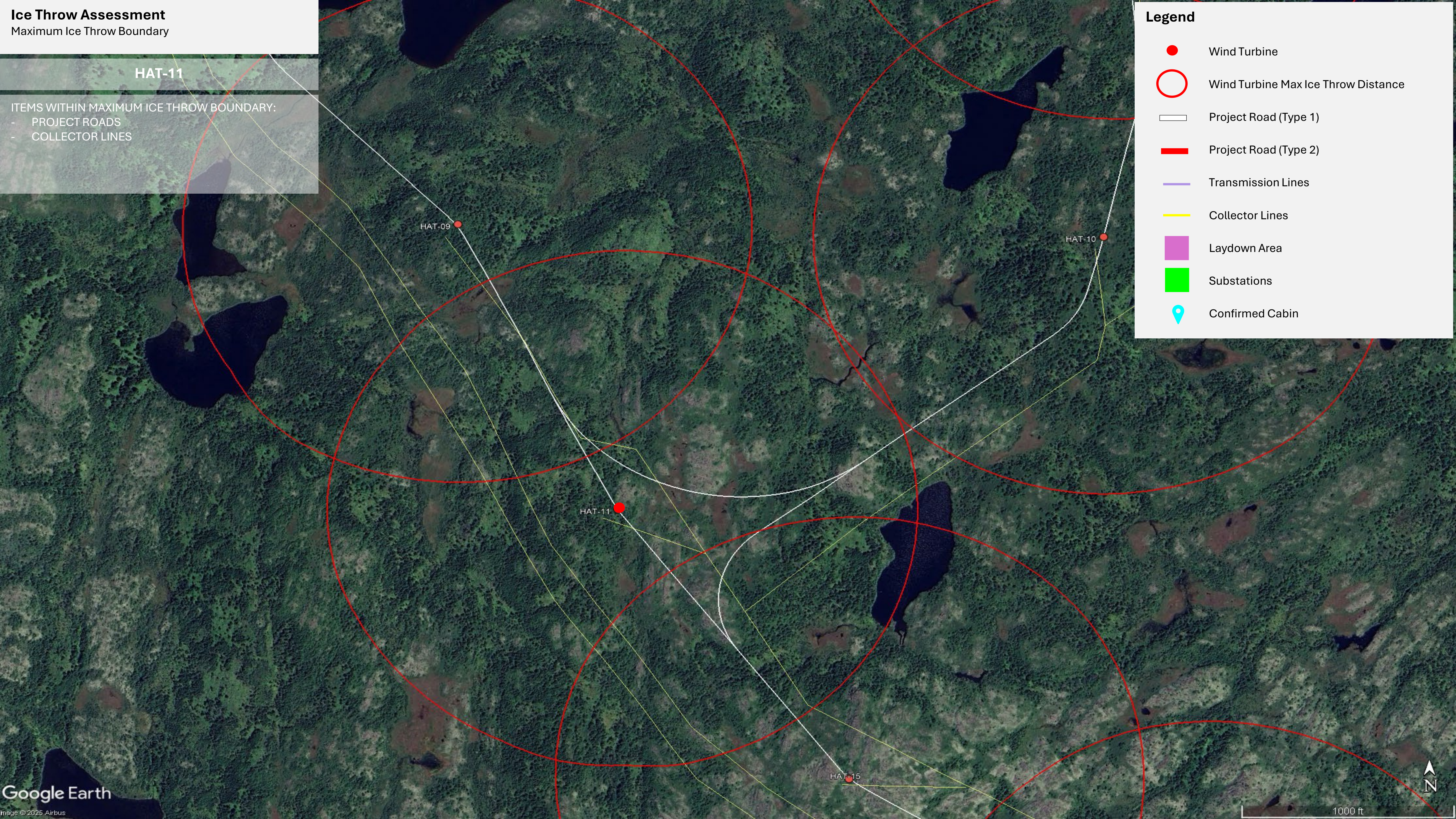
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-11

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES

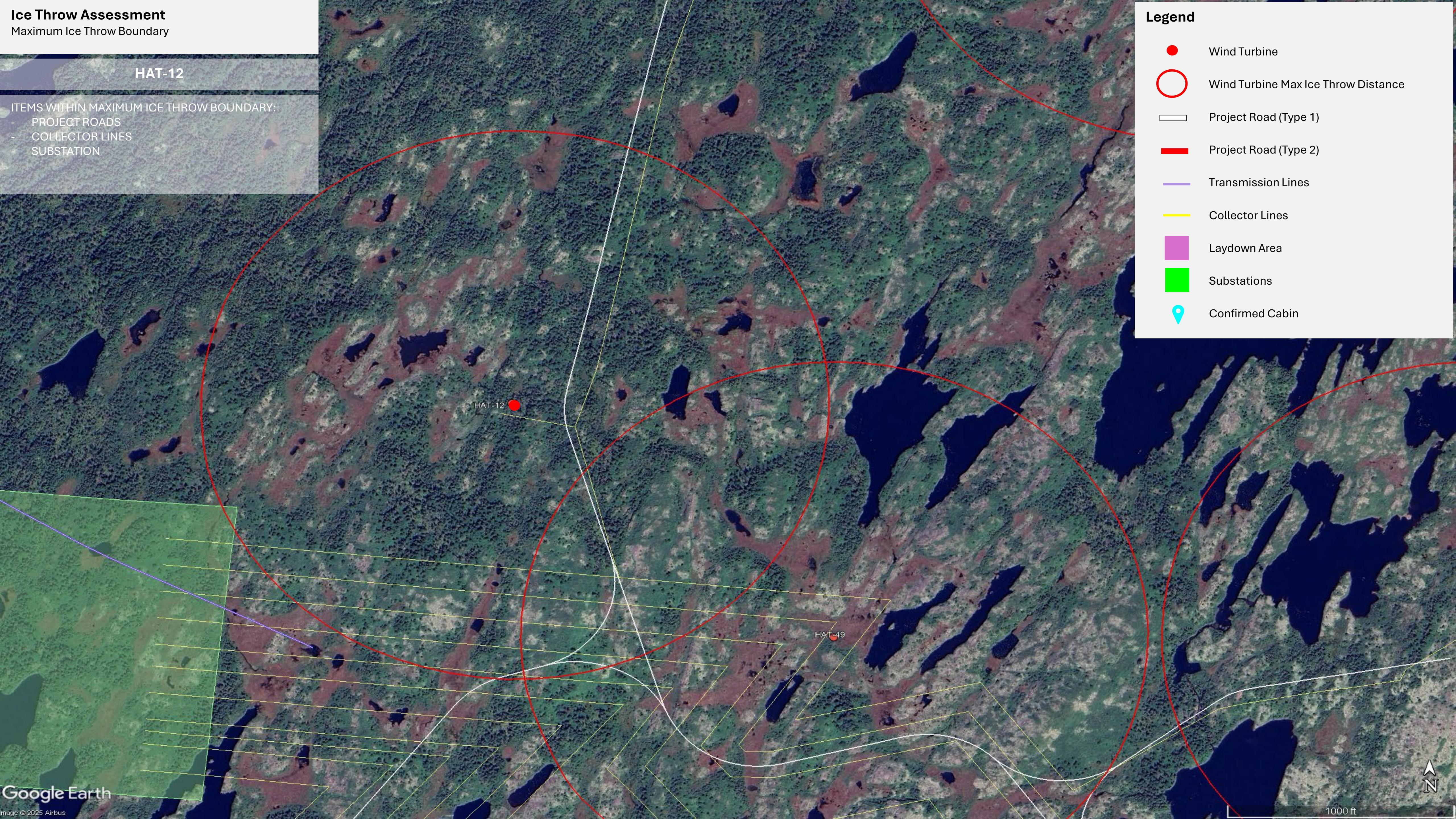


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-12

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES
- SUBSTATION



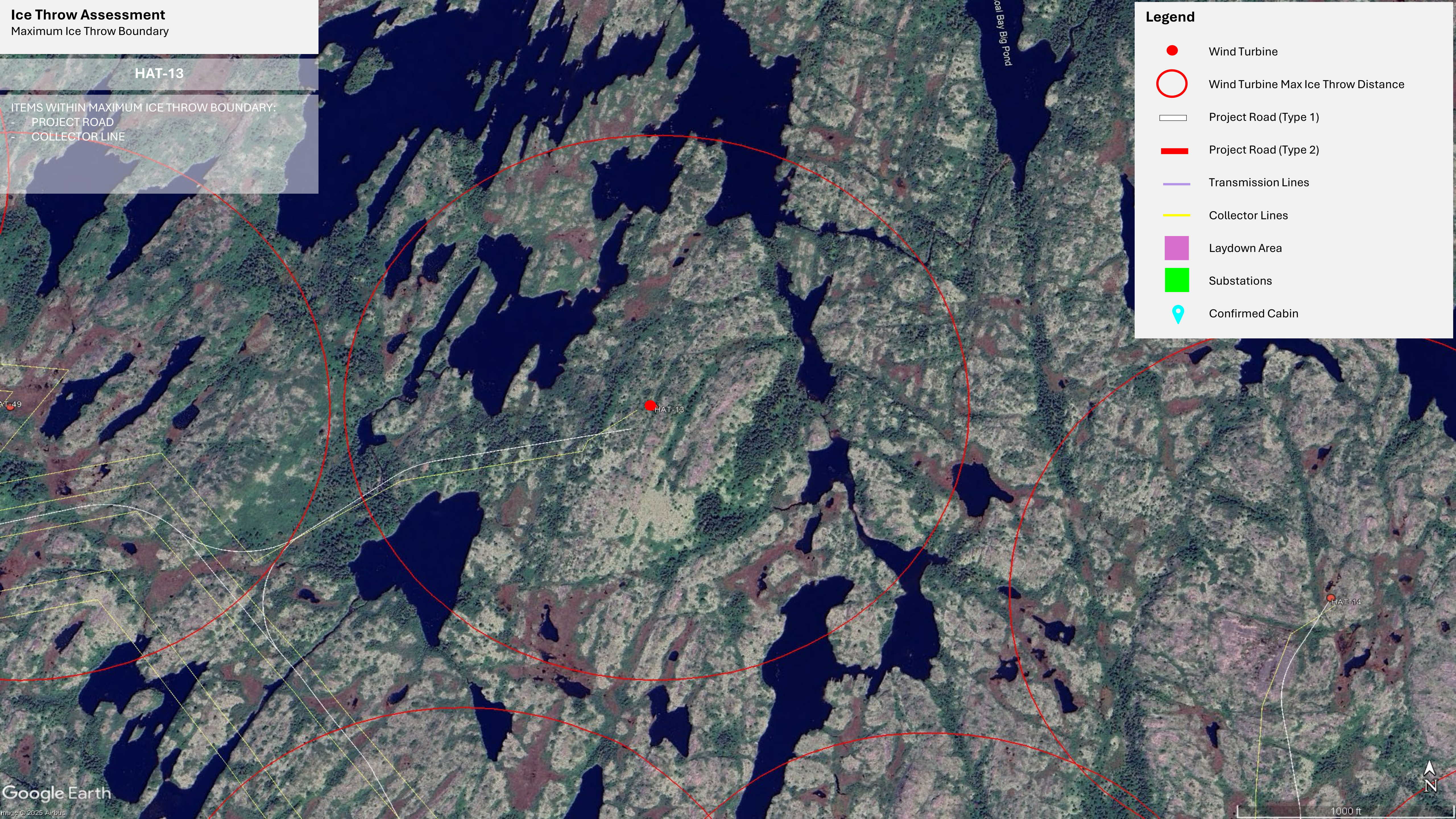
Ice Throw Assessment

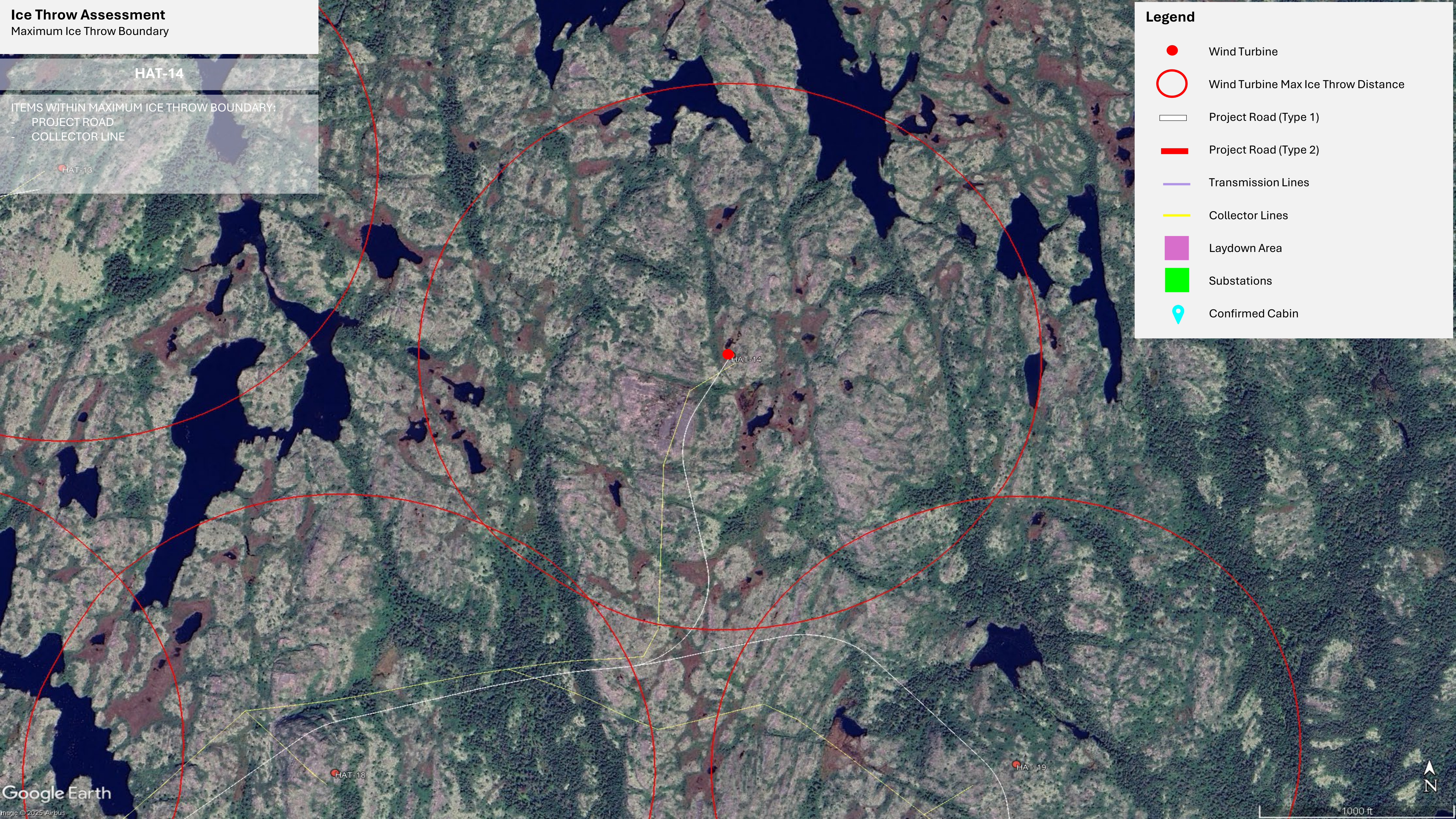
Maximum Ice Throw Boundary

HAT-13

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE




Ice Throw Assessment
Maximum Ice Throw Boundary
HAT-14
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE
HAT-13
HAT-14
HAT-18
HAT-19
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
Google Earth
Image © 2025 Airbus
1000 ft
N

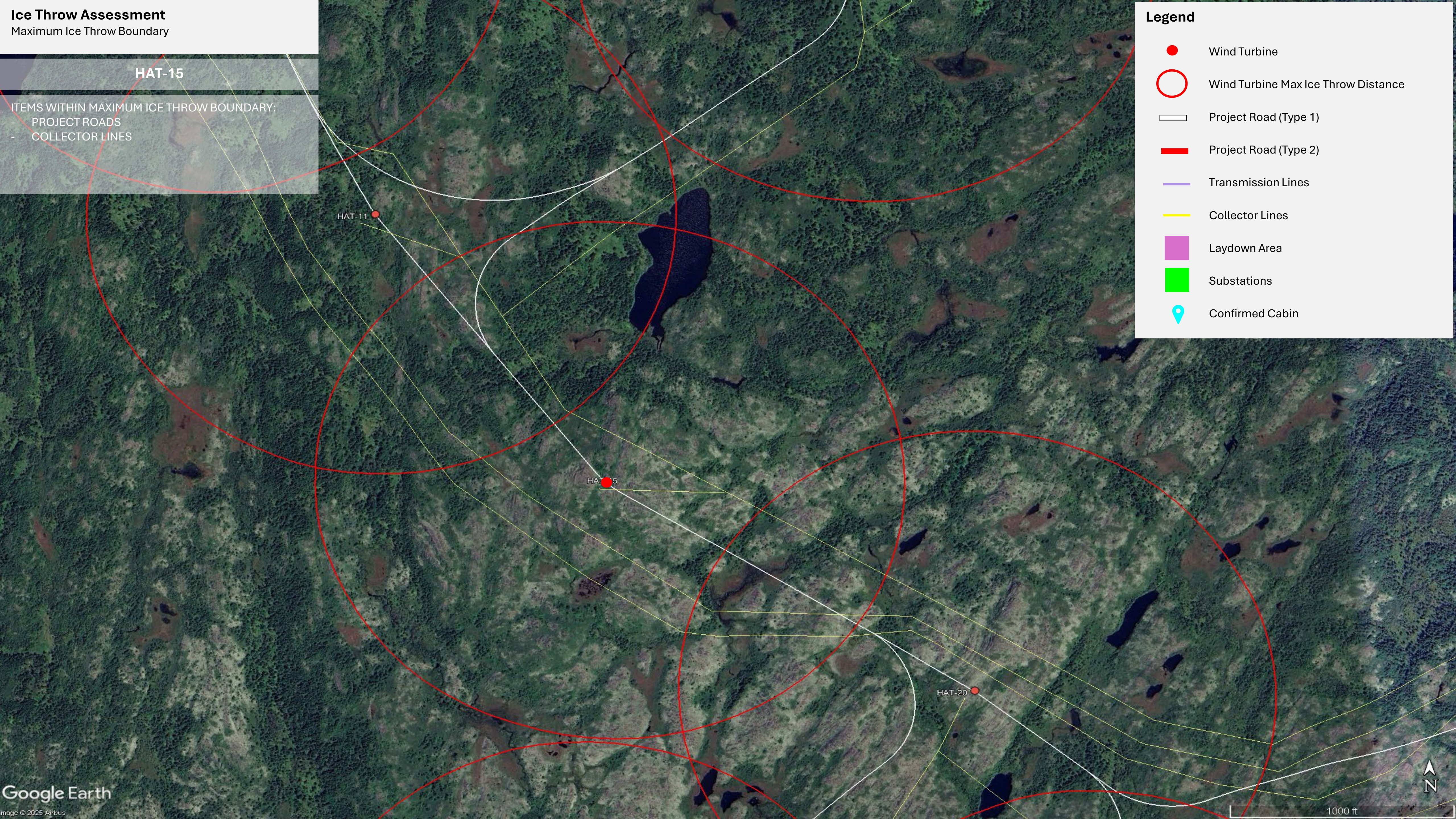
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-15

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES

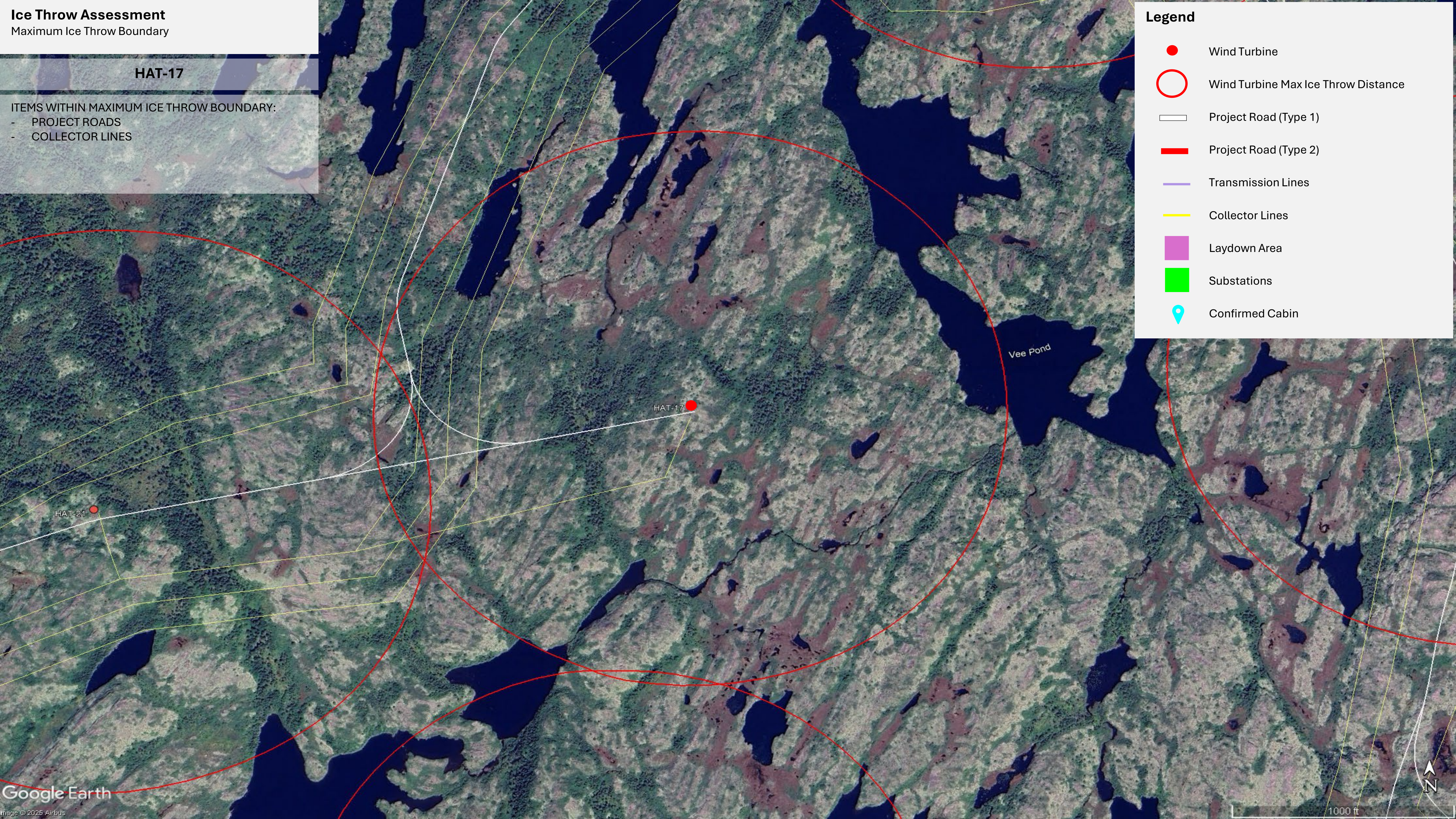



Ice Throw Assessment
Maximum Ice Throw Boundary
HAT-16
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
Vee Pond
HAT-18
N
1000 ft
Google Earth
Image © 2025 Airbus

Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-17

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

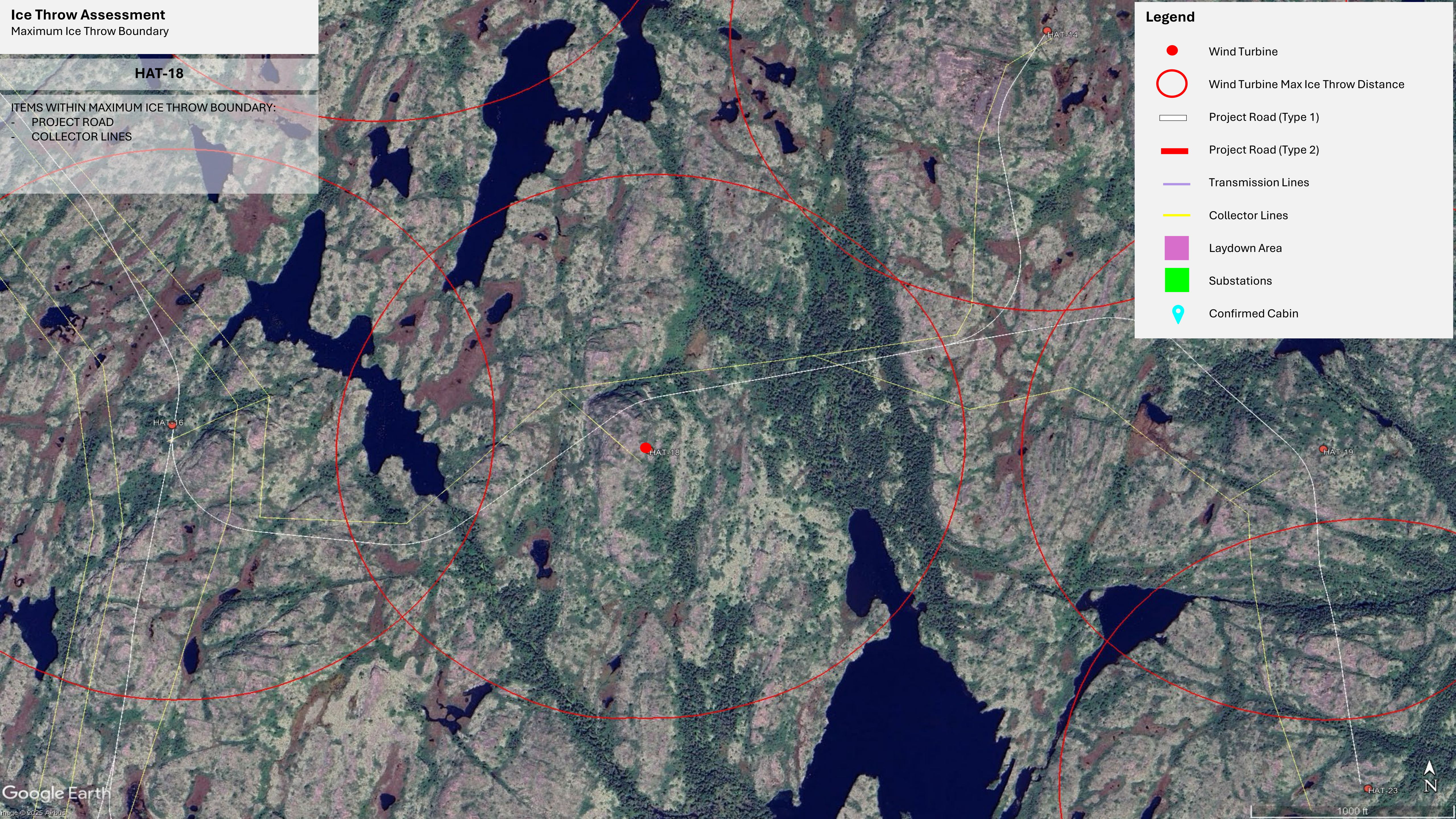


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-18

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINES

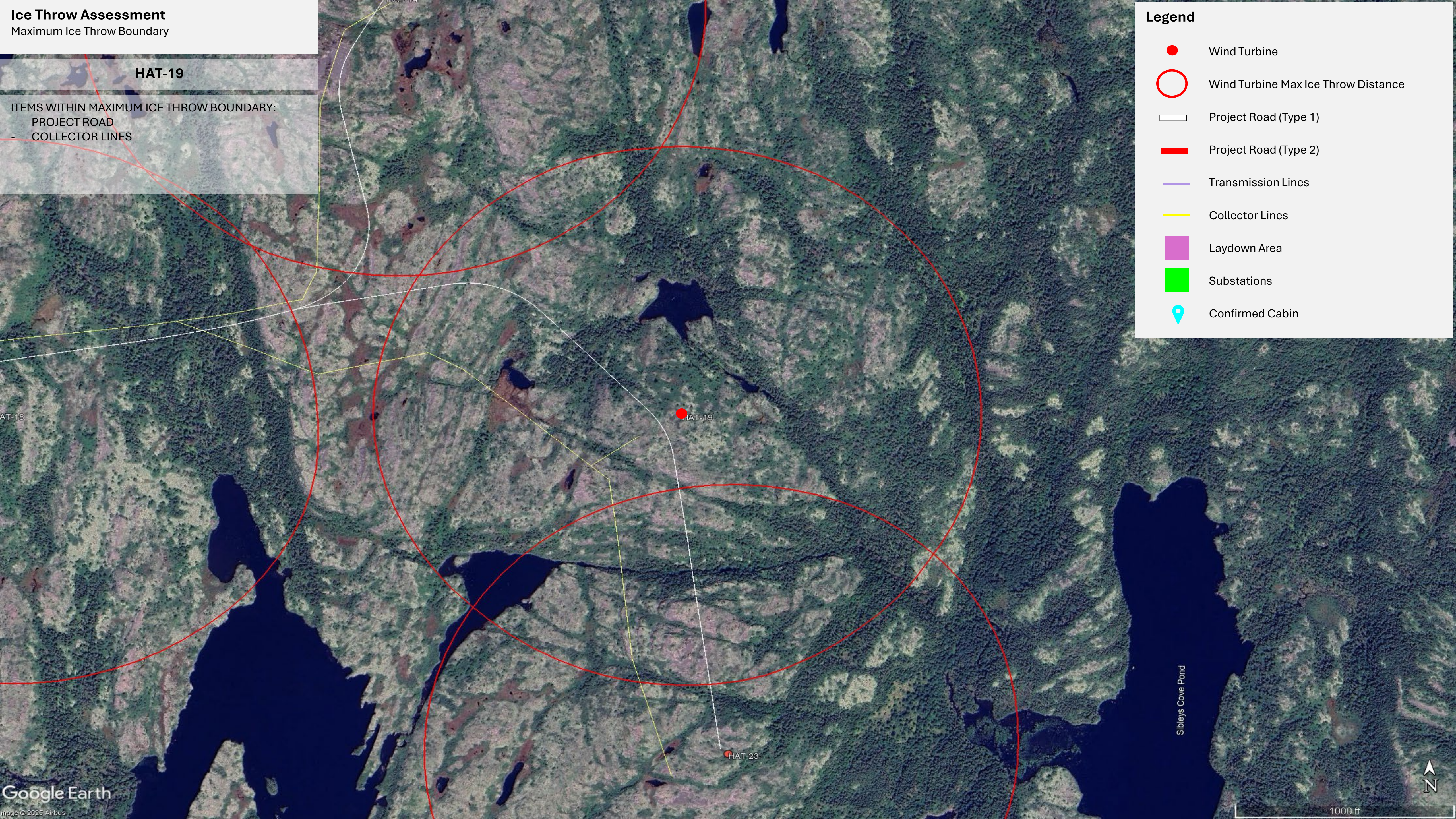


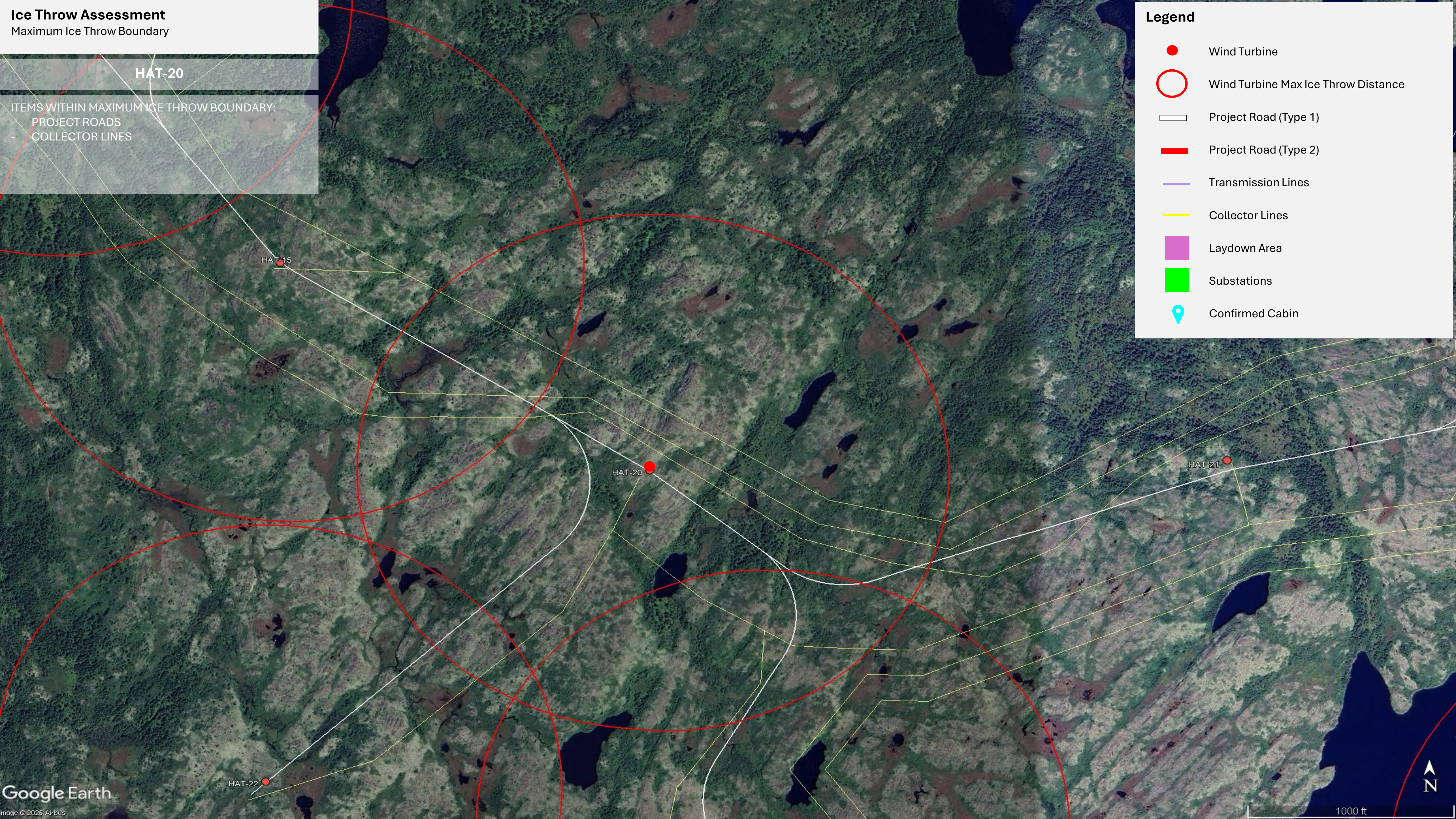
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-19

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINES



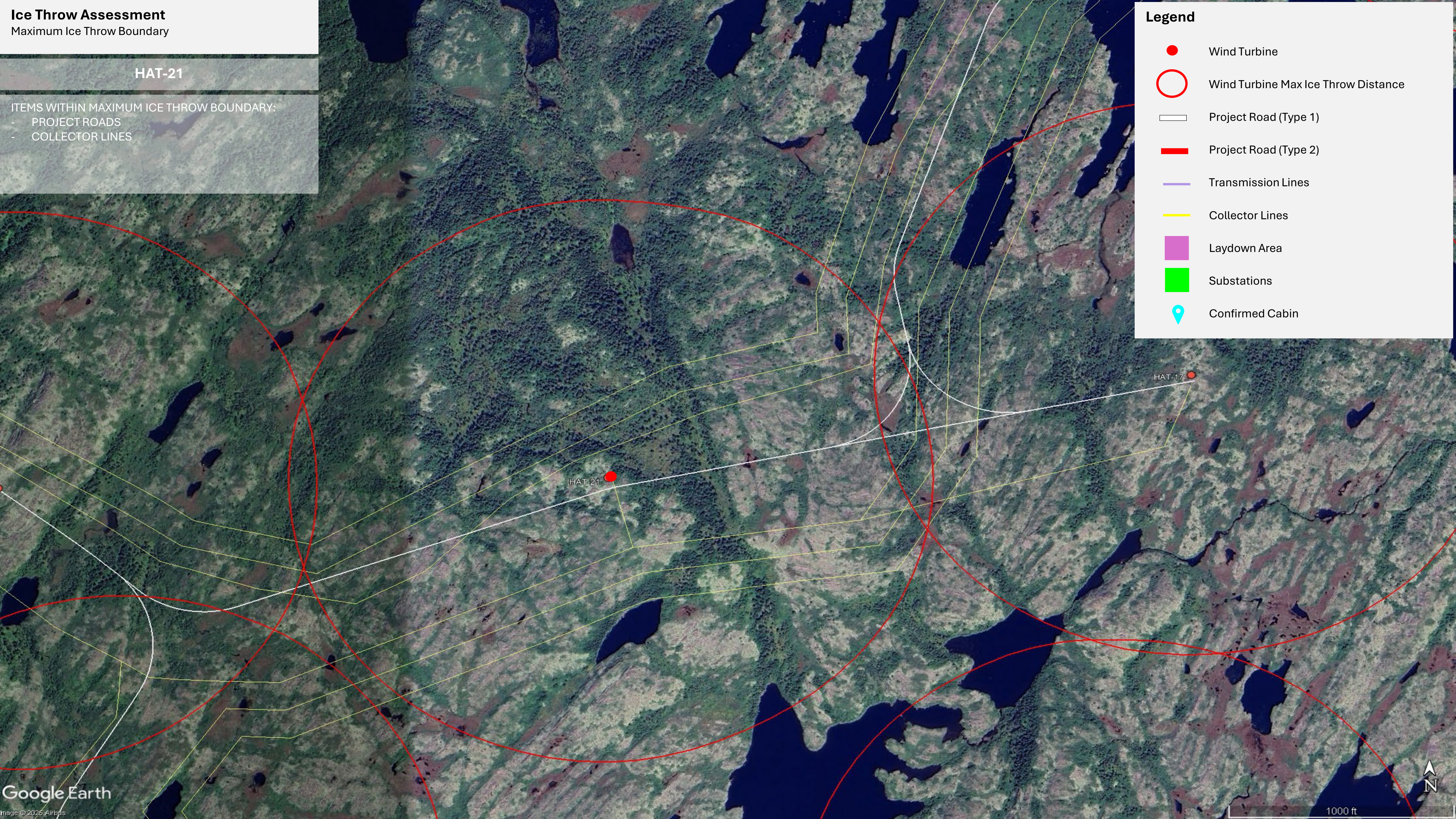

Ice Throw Assessment
Maximum Ice Throw Boundary
HAT-20
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
HAT-15
HAT-20
HAT-21
HAT-22
Google Earth
Image © 2025 Airbus
1000 ft
N

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-21

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

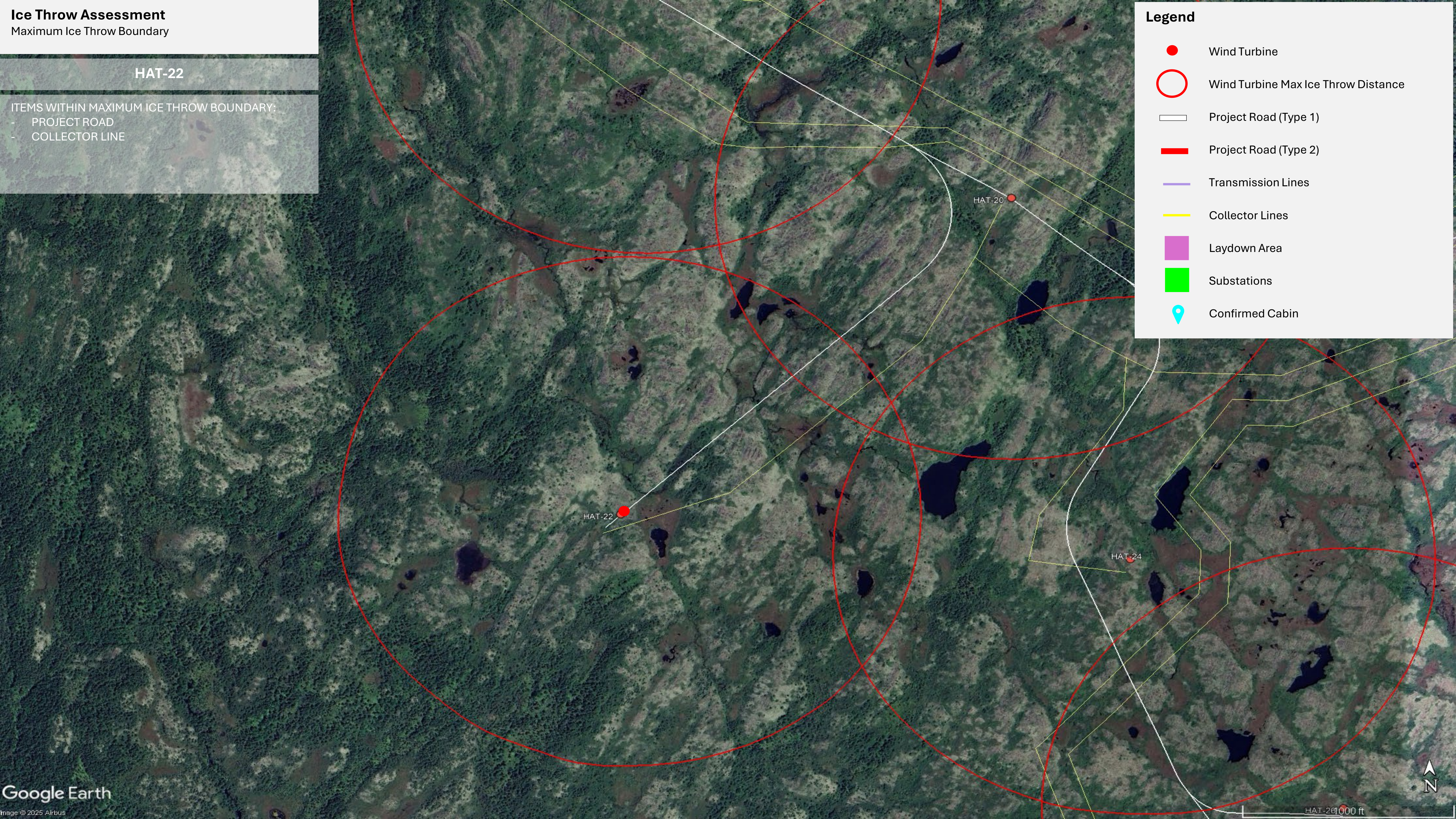


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-22

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE



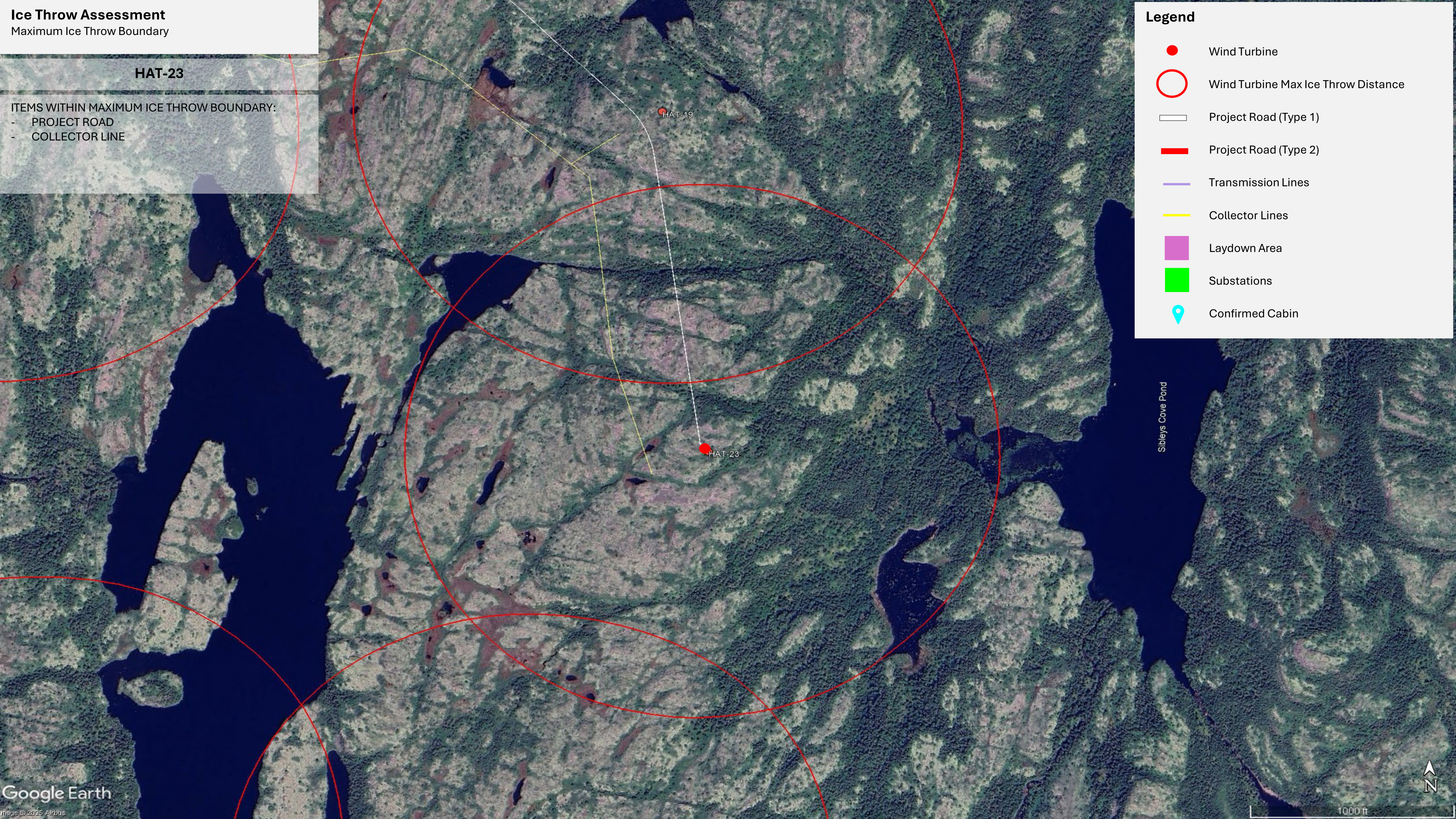
Ice Throw Assessment

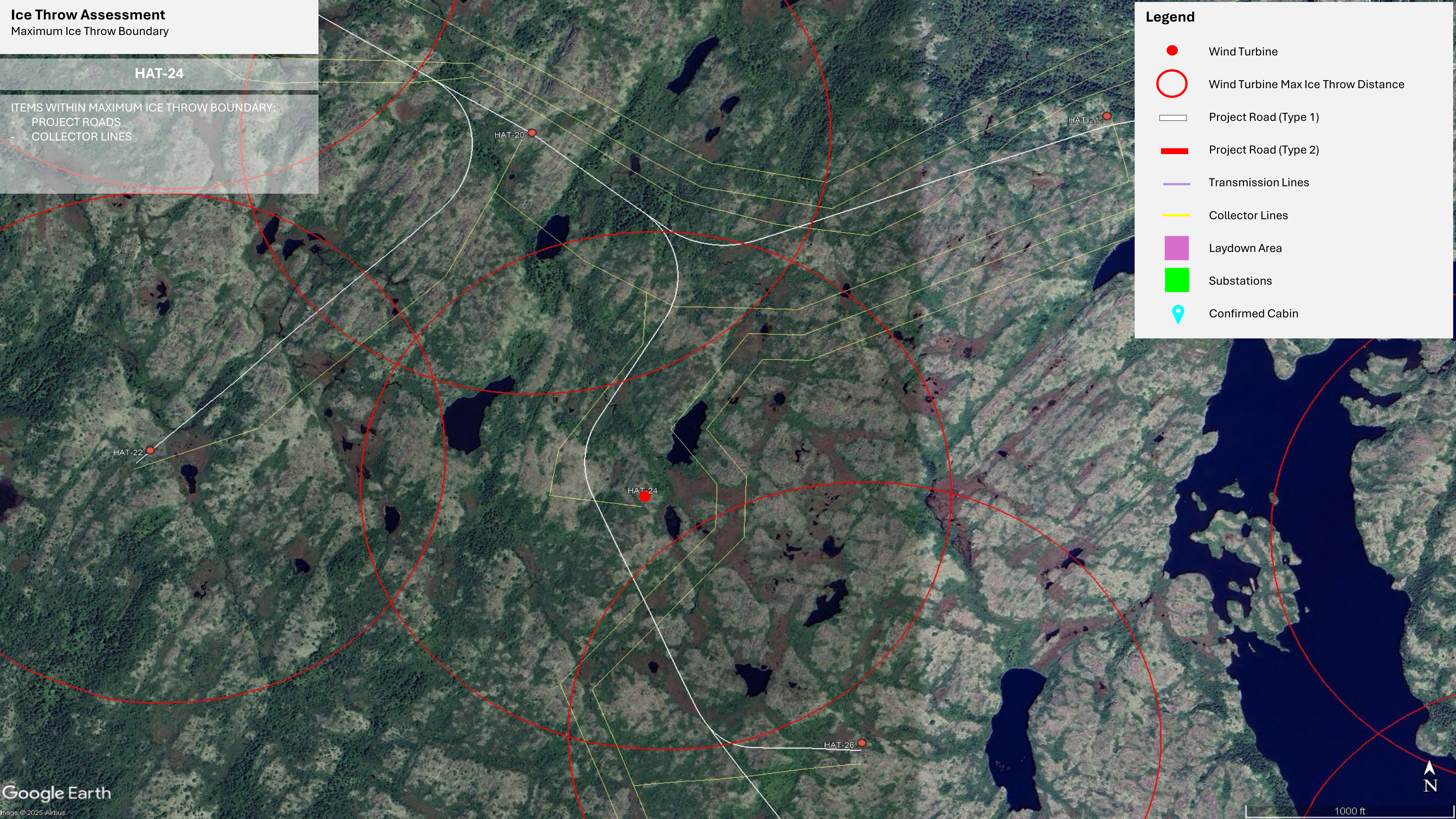
Maximum Ice Throw Boundary

HAT-23

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE





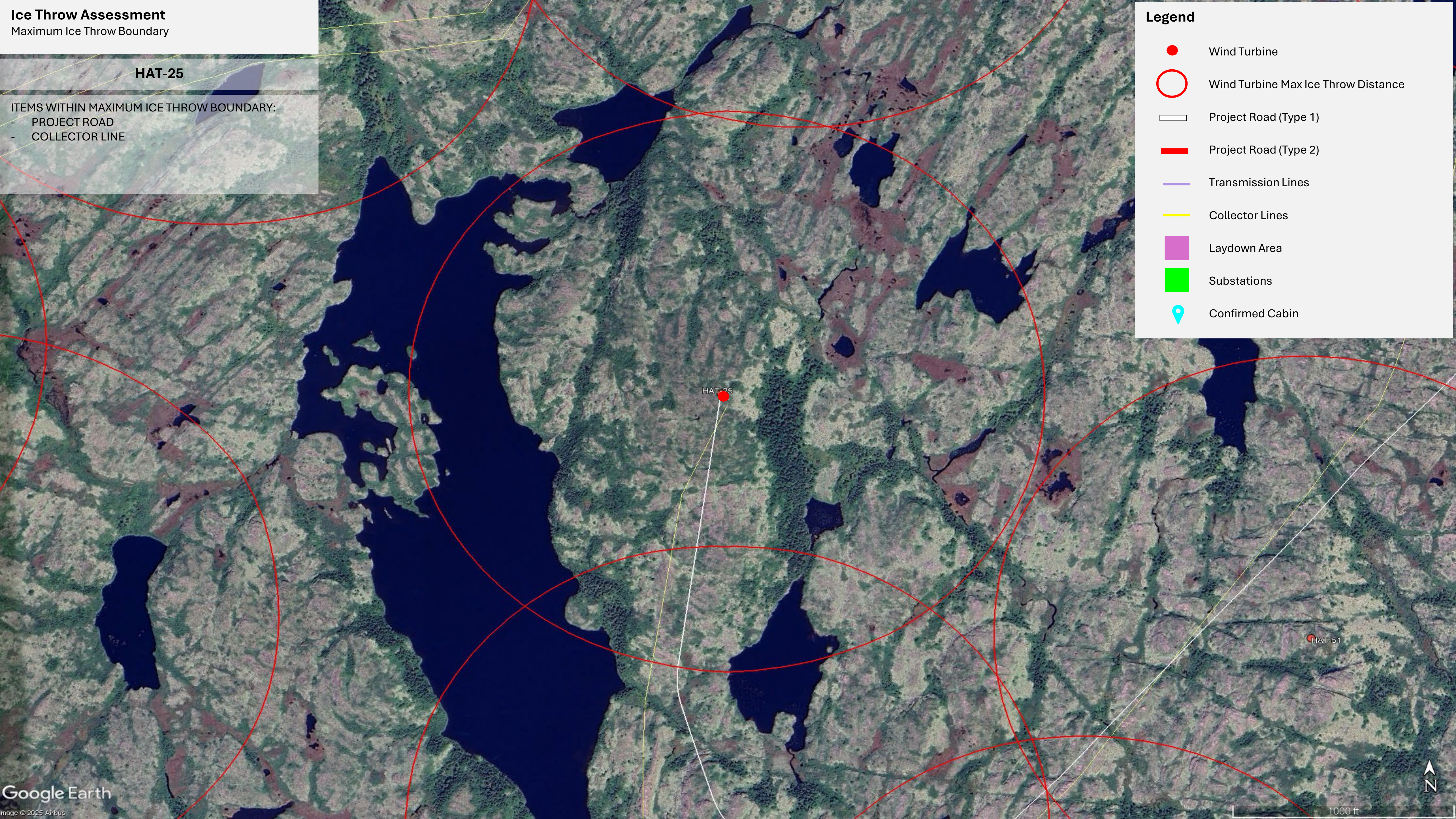
Ice Throw Assessment
Maximum Ice Throw Boundary
HAT-24
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES
Legend
Wind Turbine
Wind Turbine Max Ice Throw Distance
Project Road (Type 1)
Project Road (Type 2)
Transmission Lines
Collector Lines
Laydown Area
Substations
Confirmed Cabin
HAT-20
HAT-21
HAT-22
HAT-24
HAT-26
N
1000 ft
Google Earth
Image © 2025 Airbus

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-25

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE

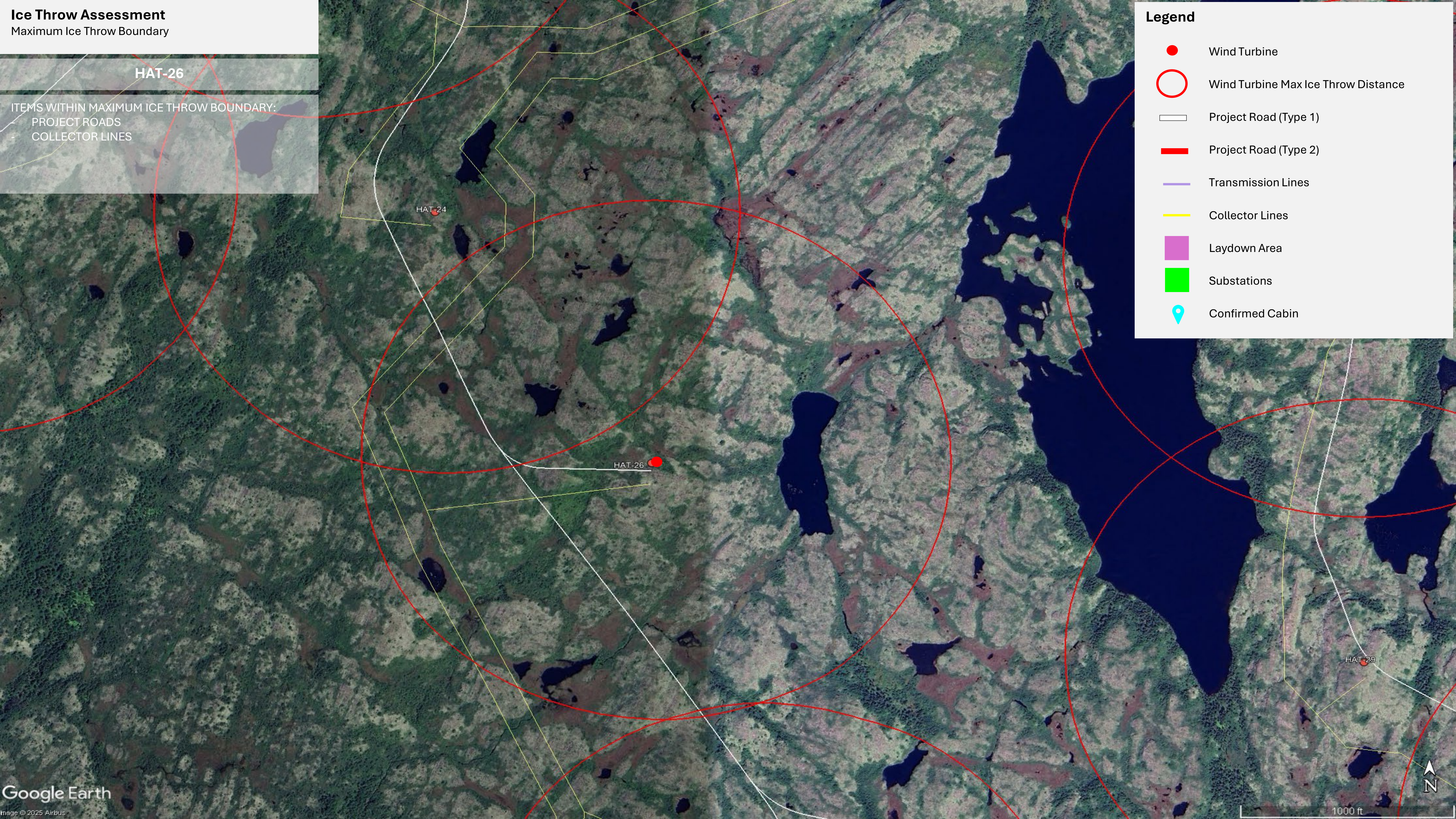


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-26

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

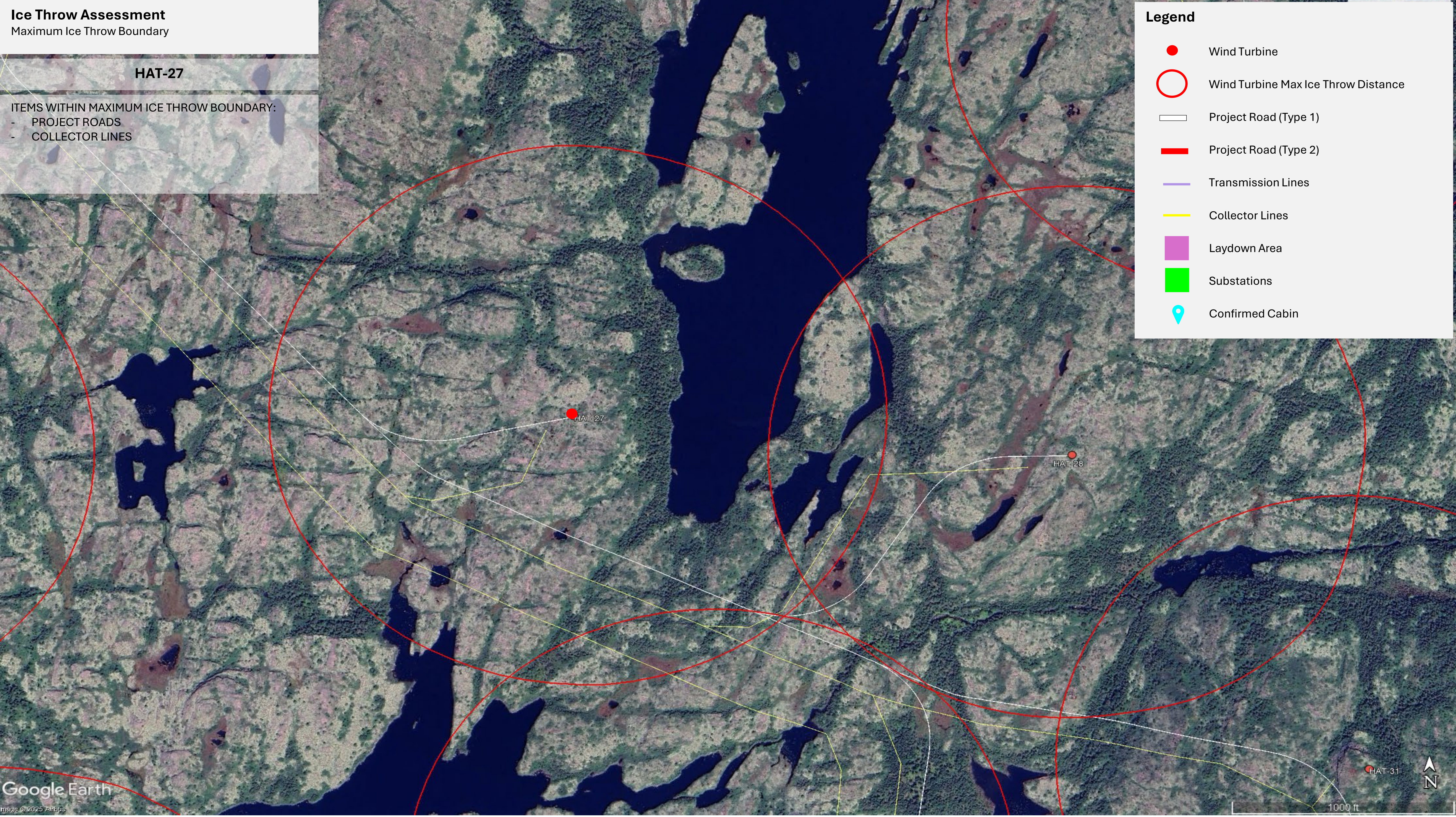


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-27

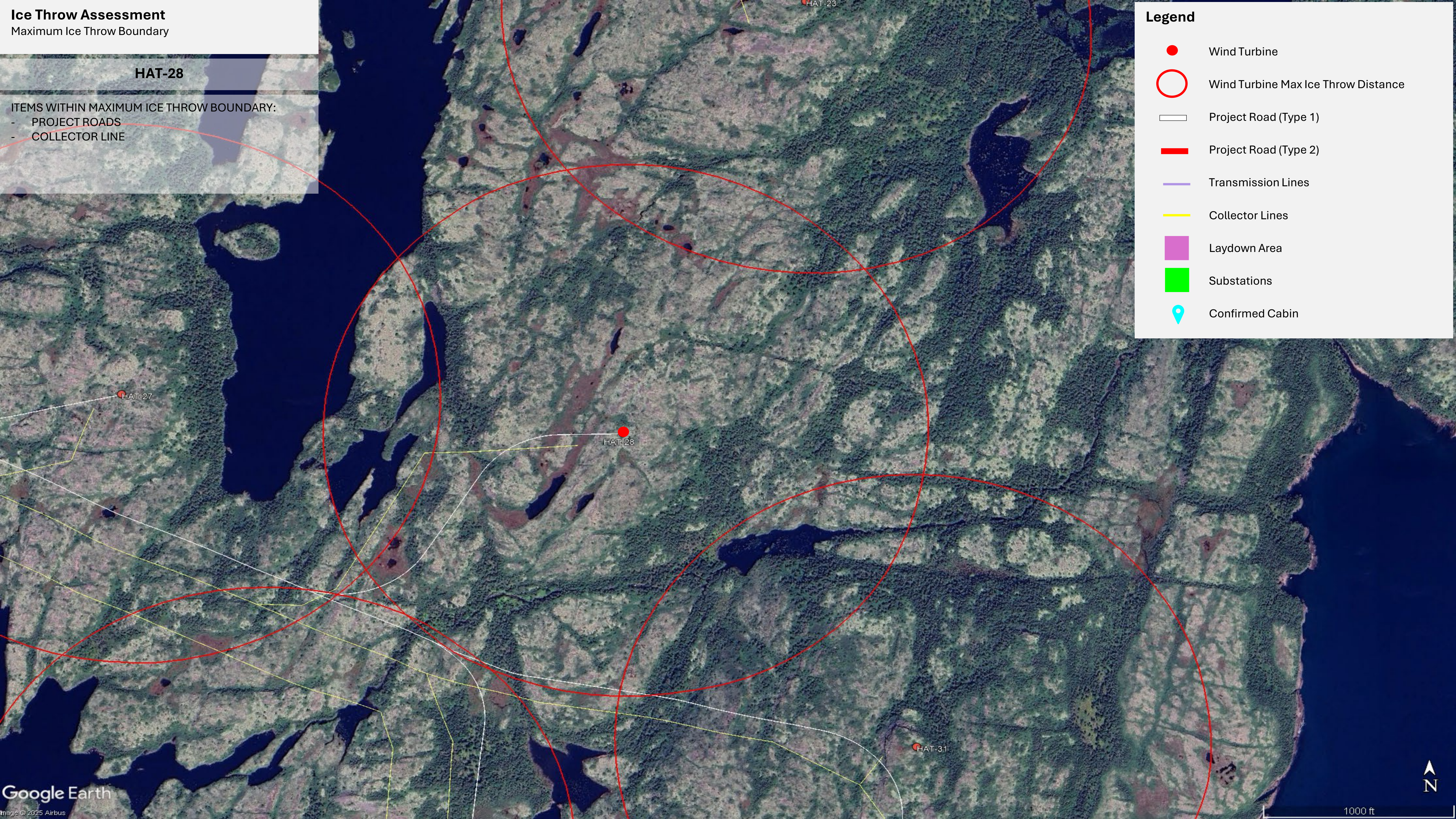
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES



Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-28

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-29

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-30

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-31

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINES

Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-32

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

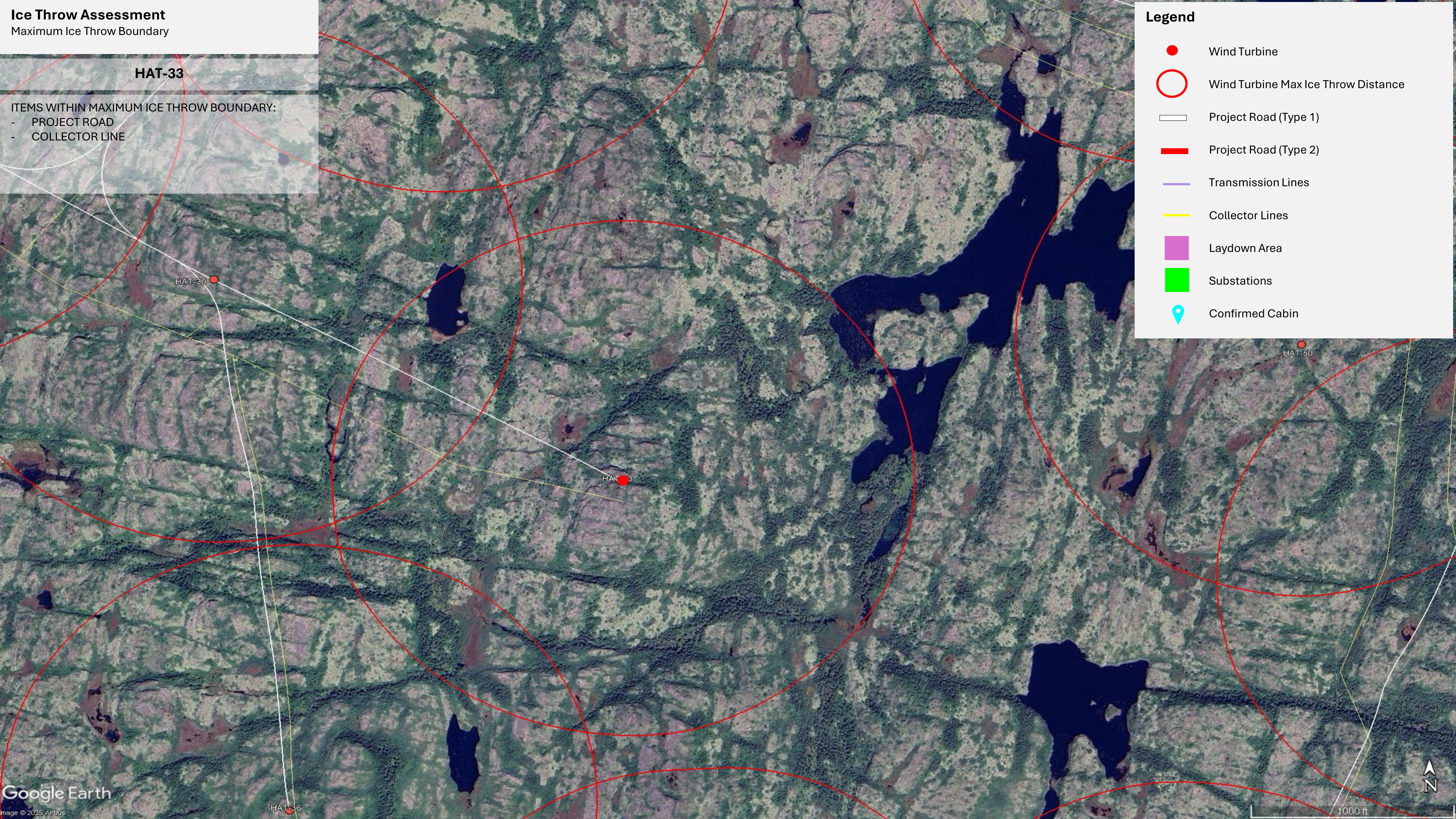
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-33

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE

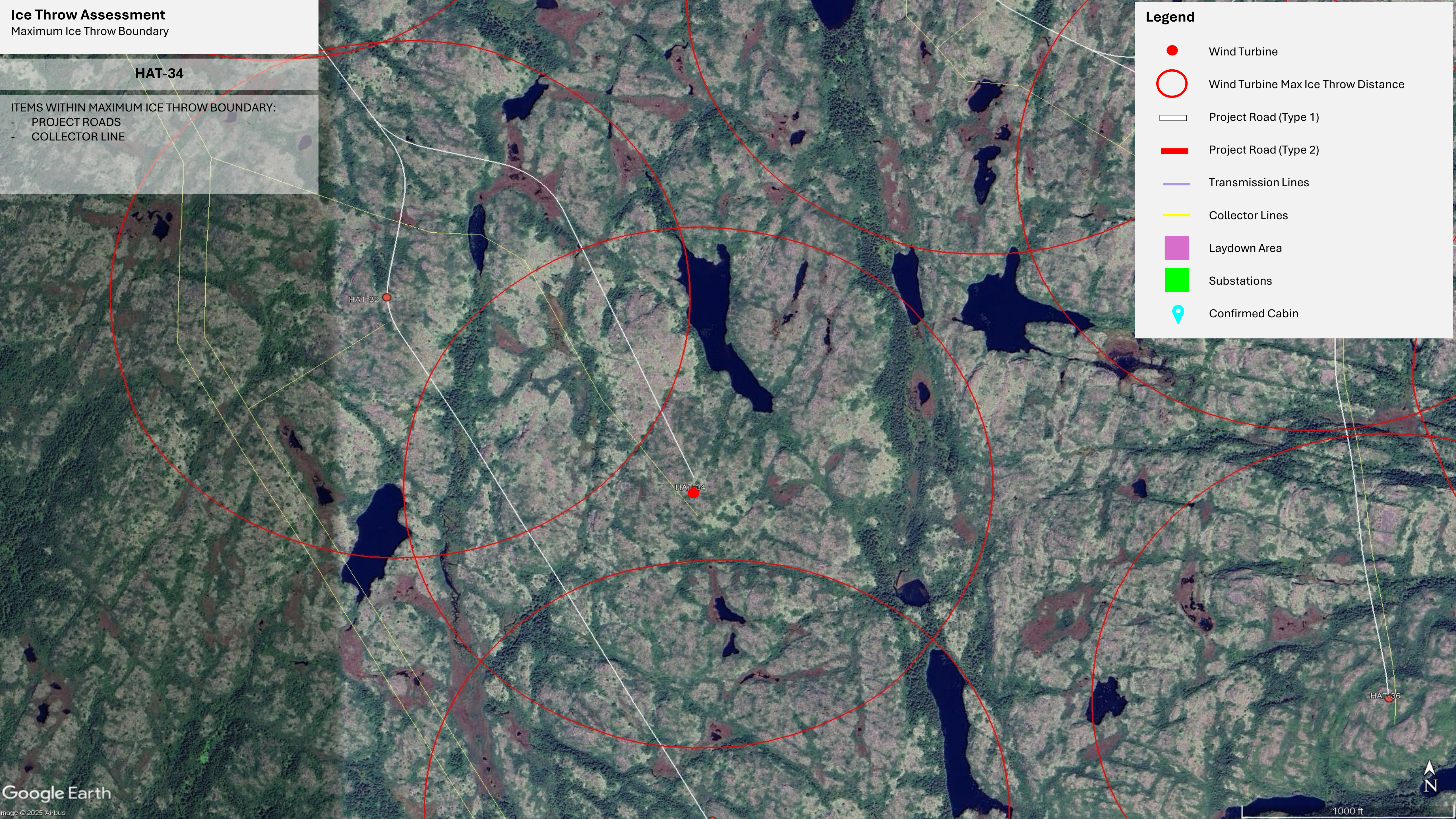


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-34

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE

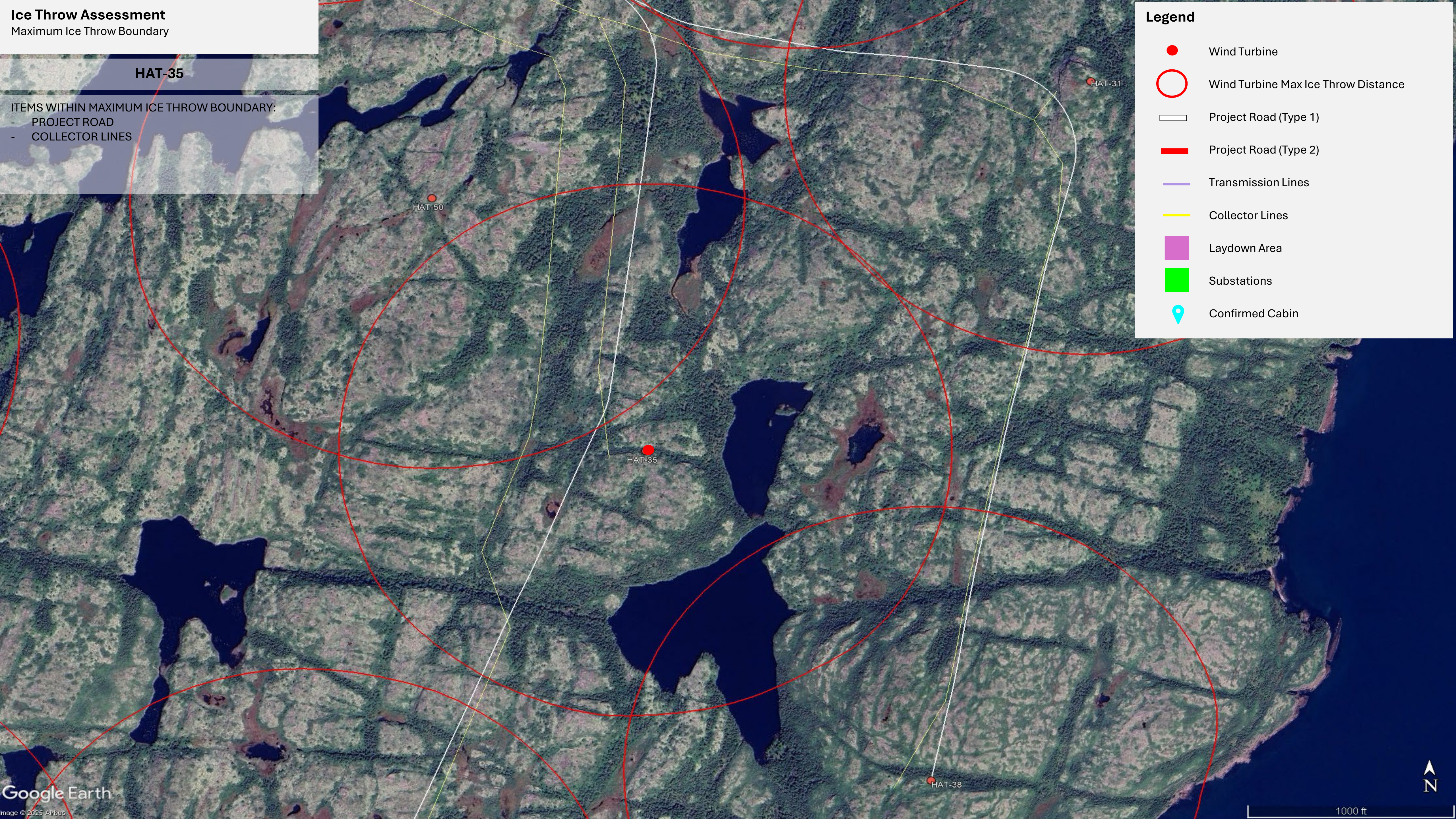


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-35

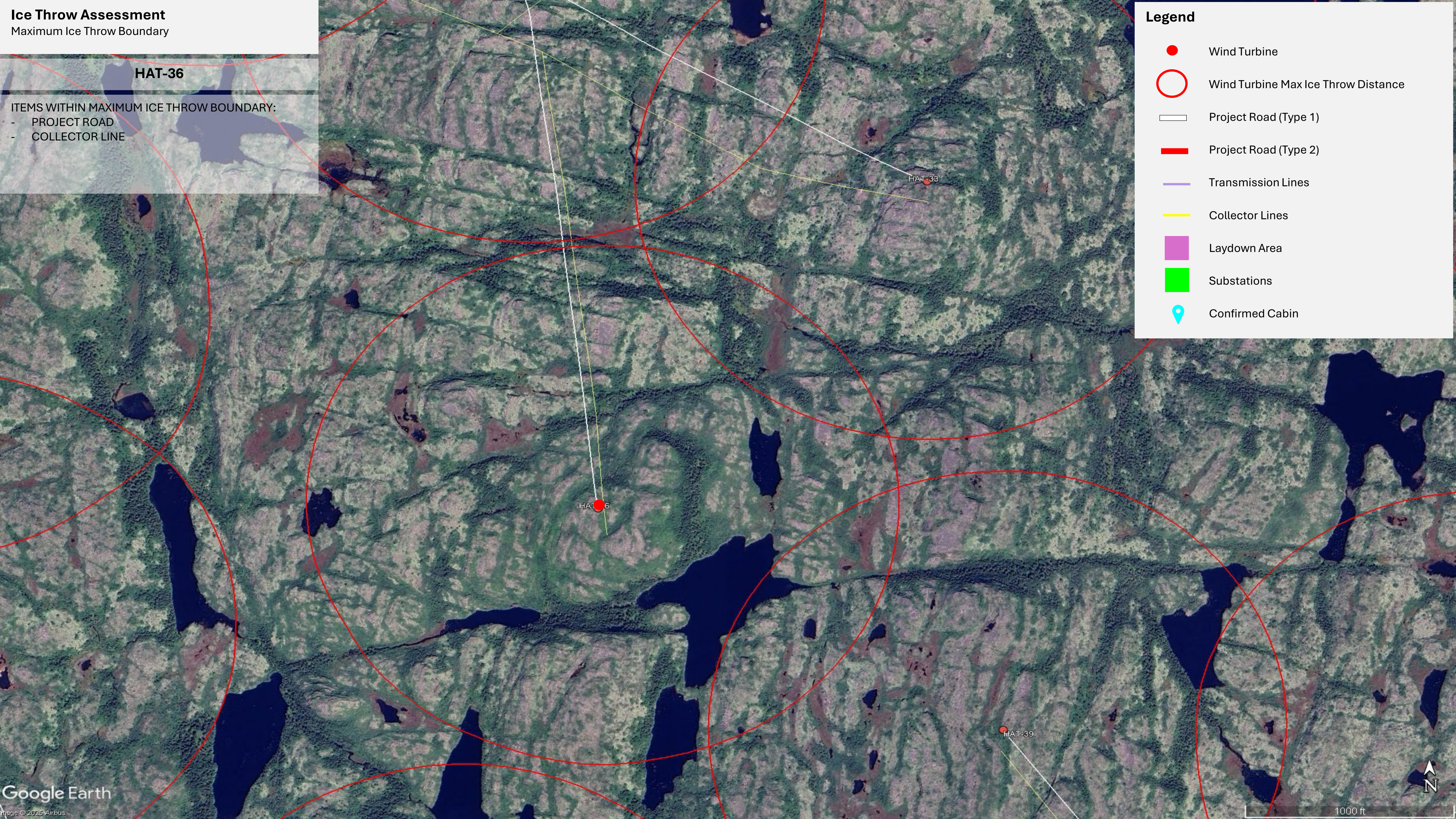
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINES



Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-36

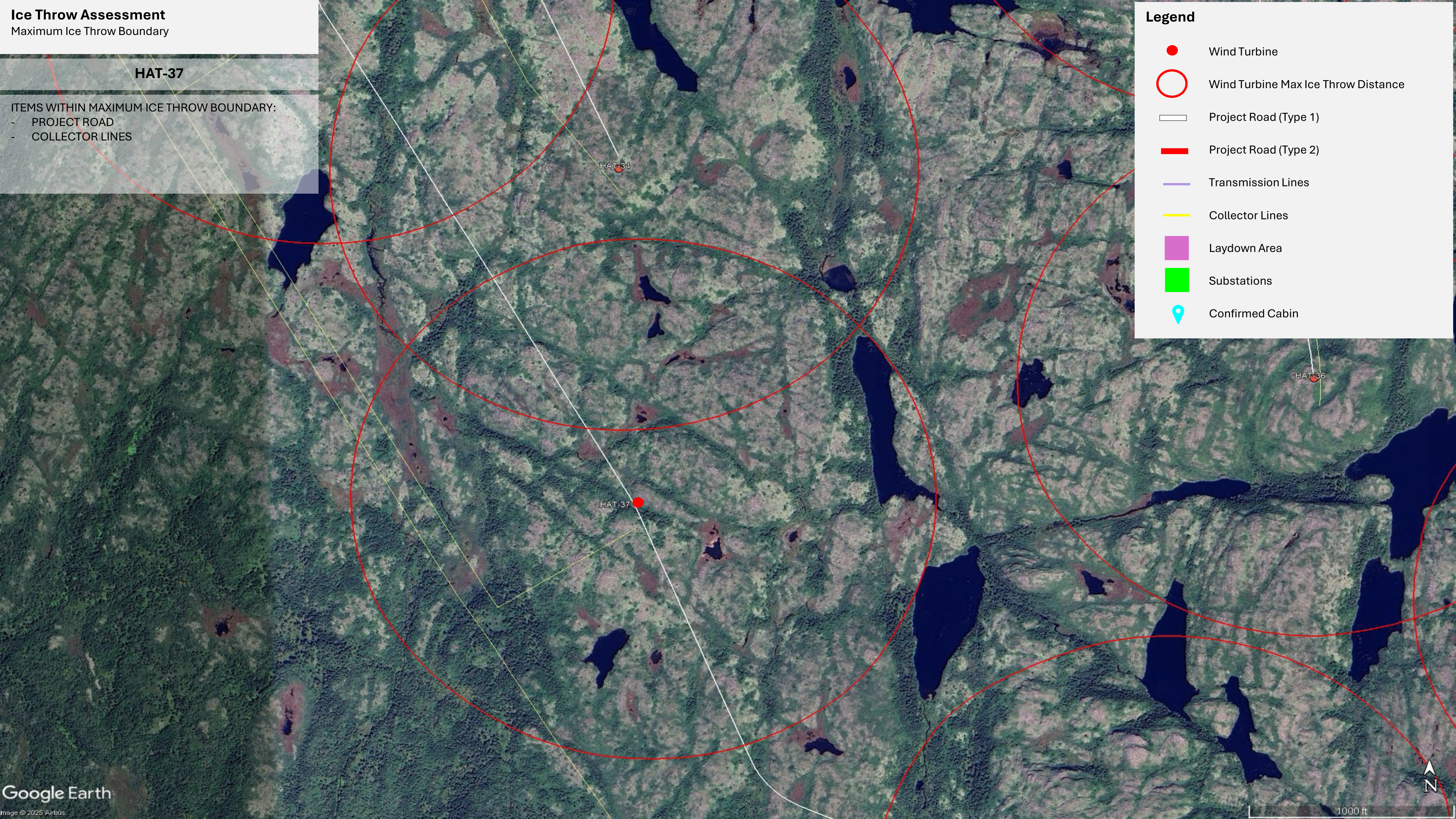
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINE



Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-37

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINES



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-38

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE

Legend

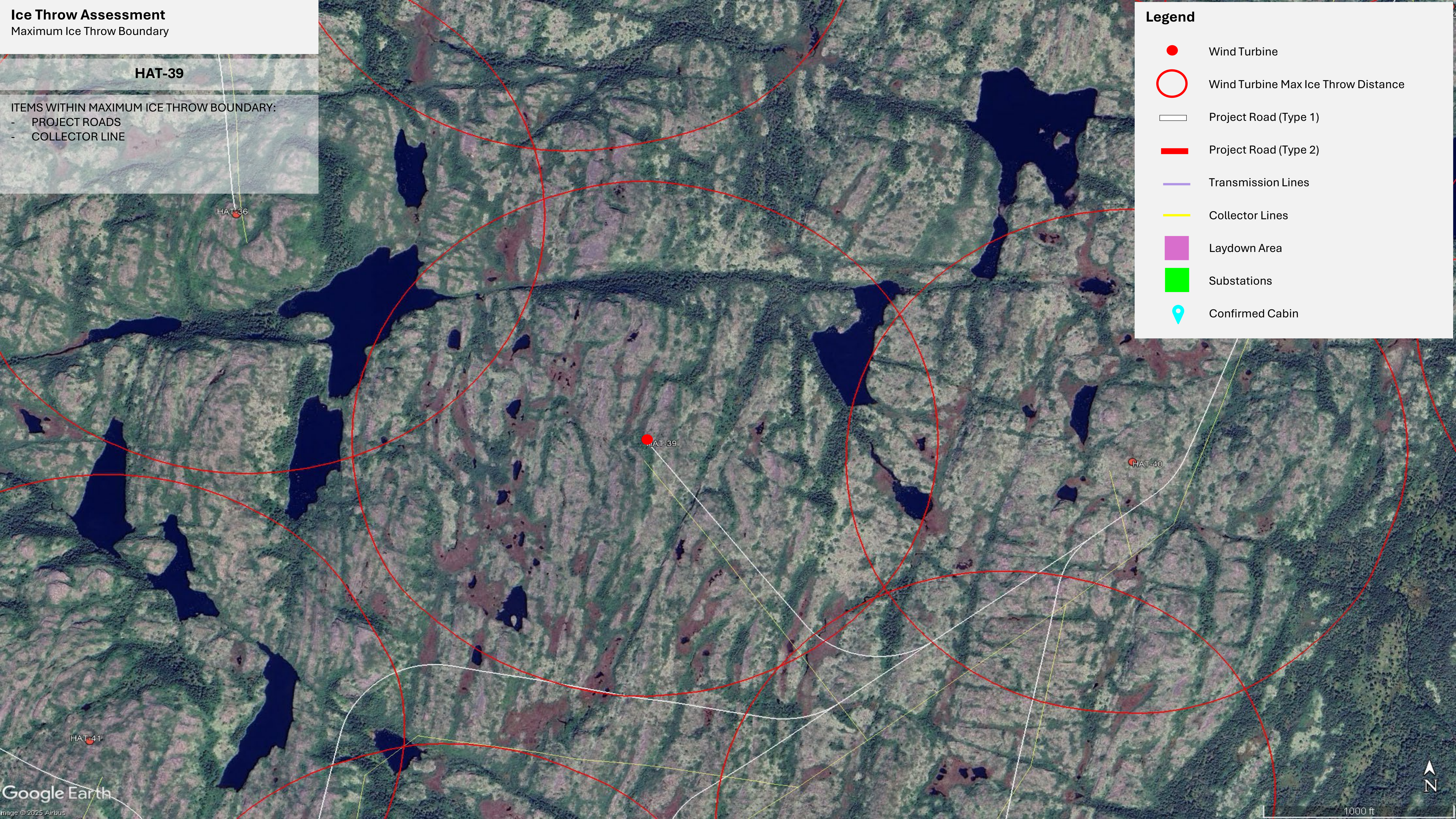
- Wind Turbine
- Wind Turbine Max Ice Throw Distance
- Project Road (Type 1)
- Project Road (Type 2)
- Transmission Lines
- Collector Lines
- Laydown Area
- Substations
- Confirmed Cabin

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-39

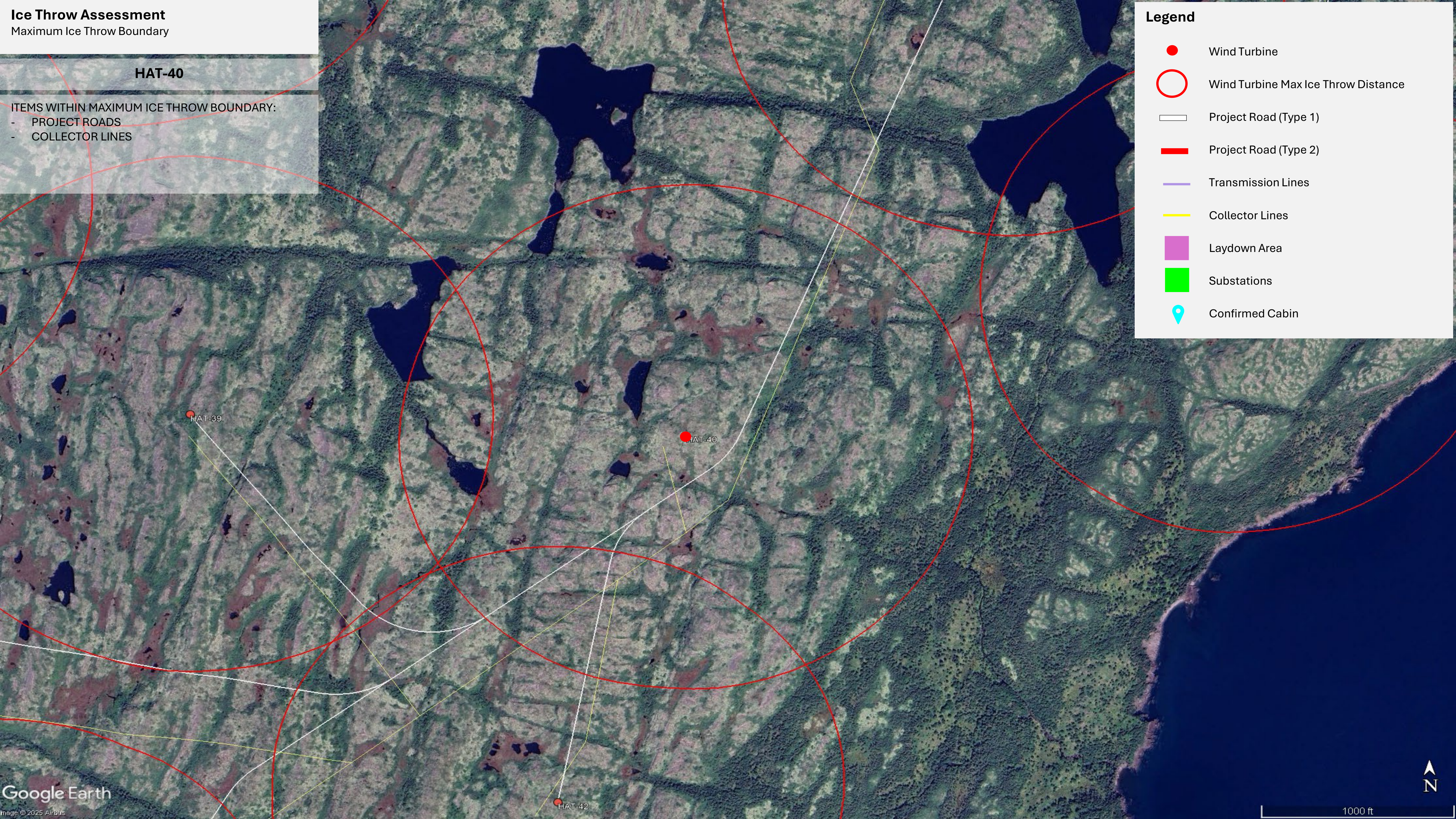
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE



Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-40

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES



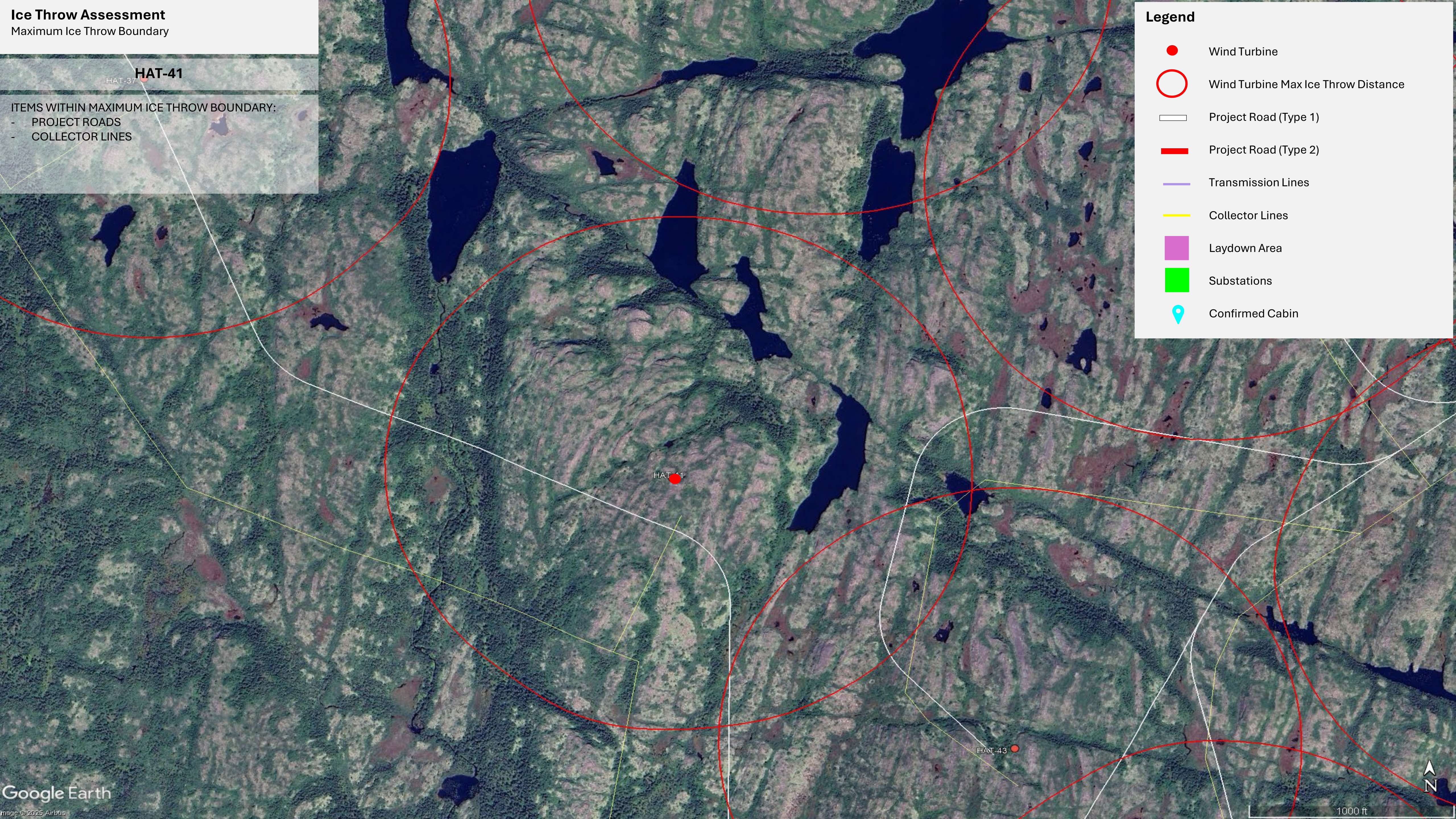
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-41

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES

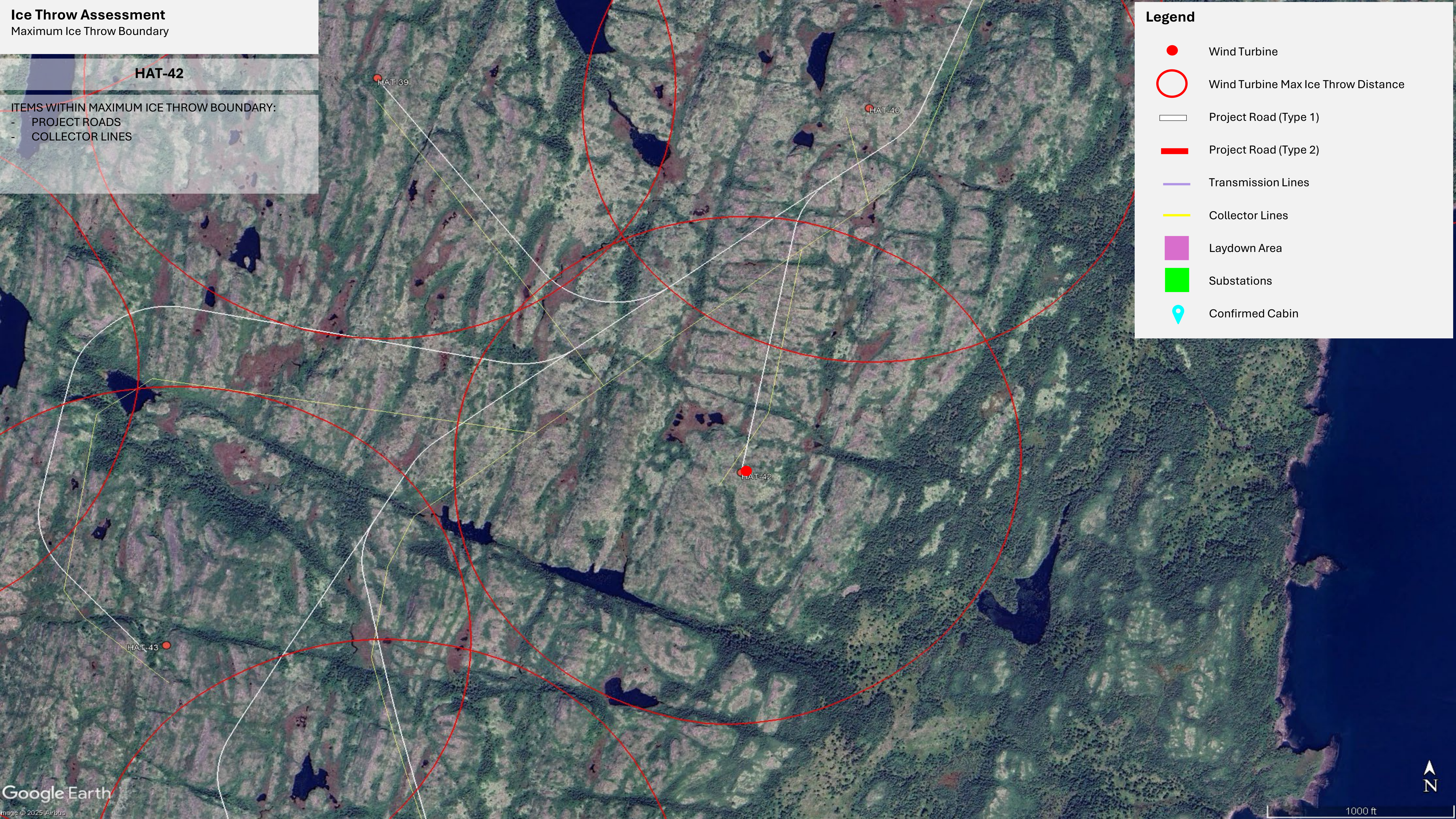


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-42

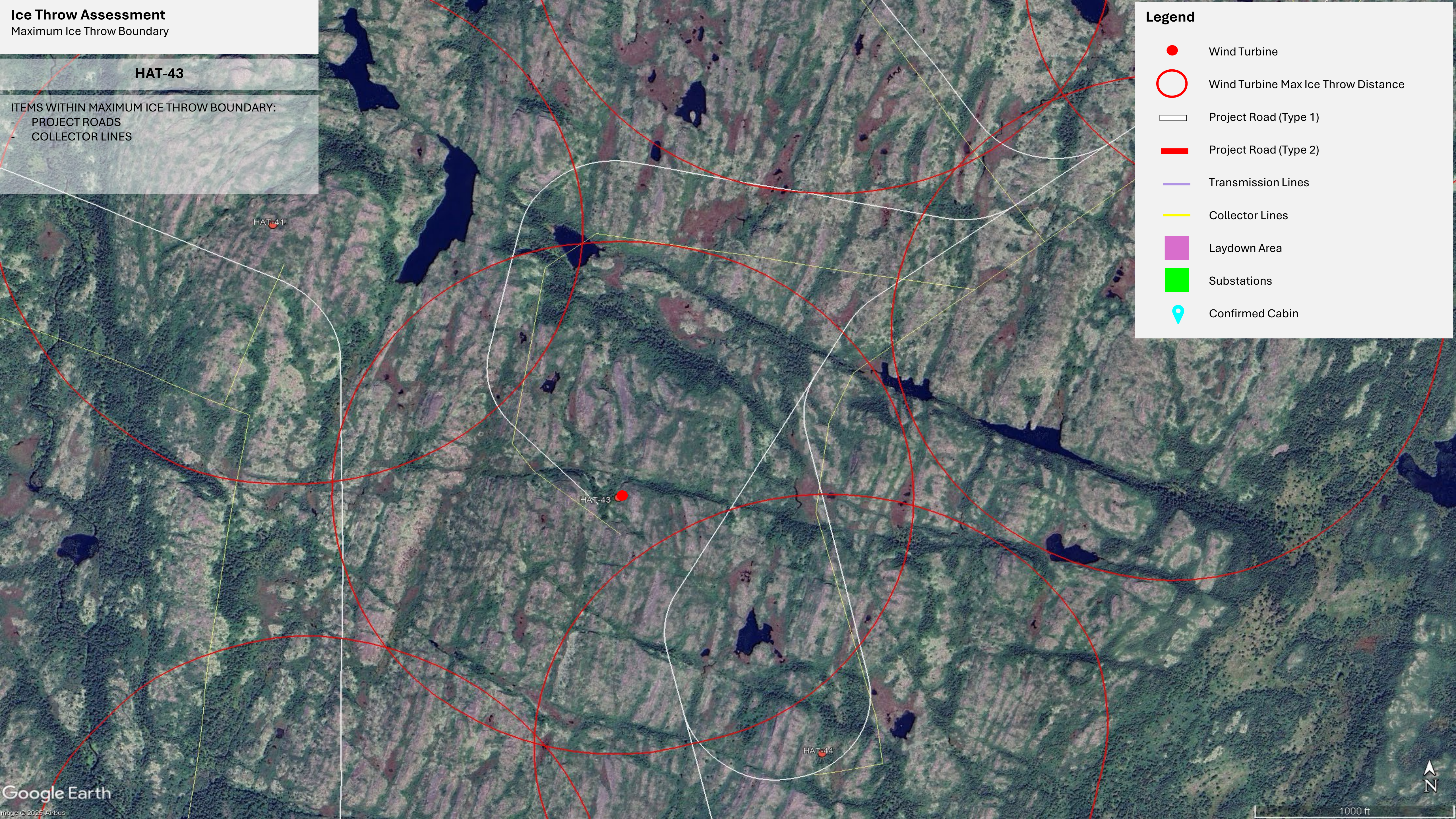
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES



Ice Throw Assessment
Maximum Ice Throw Boundary

HAT-43

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES

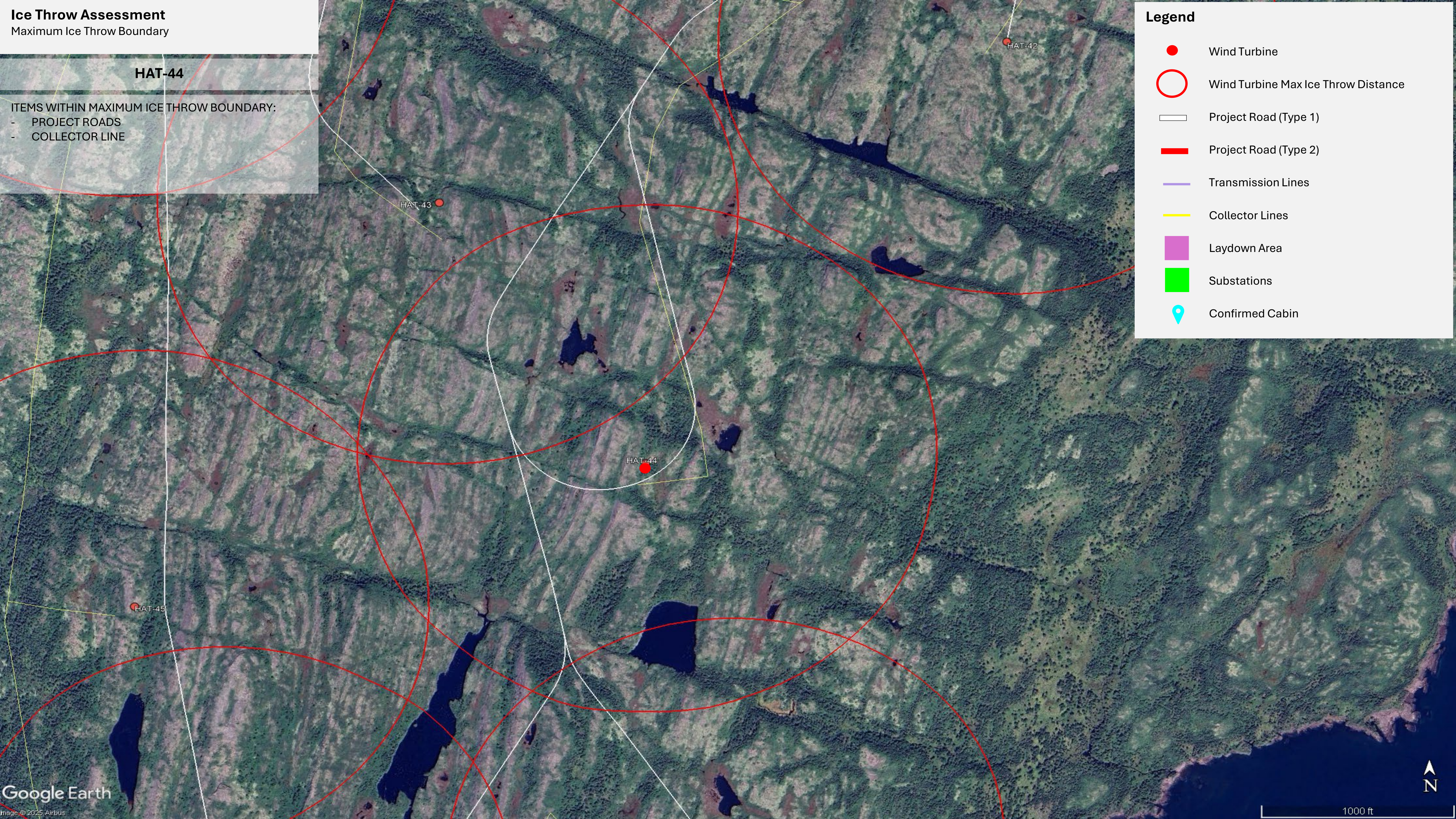


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-44

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE

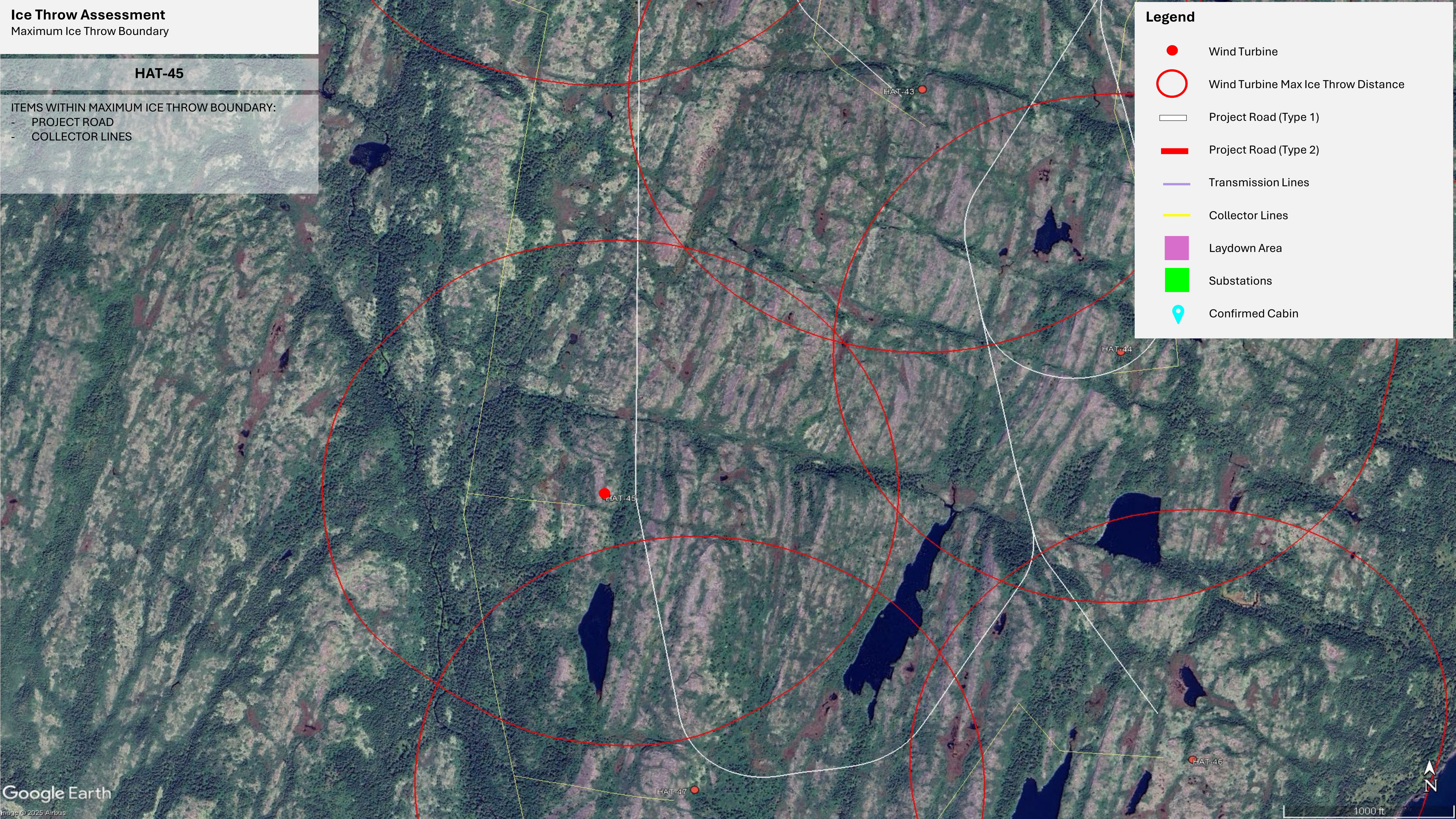


Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-45

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROAD
- COLLECTOR LINES



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-46

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINE

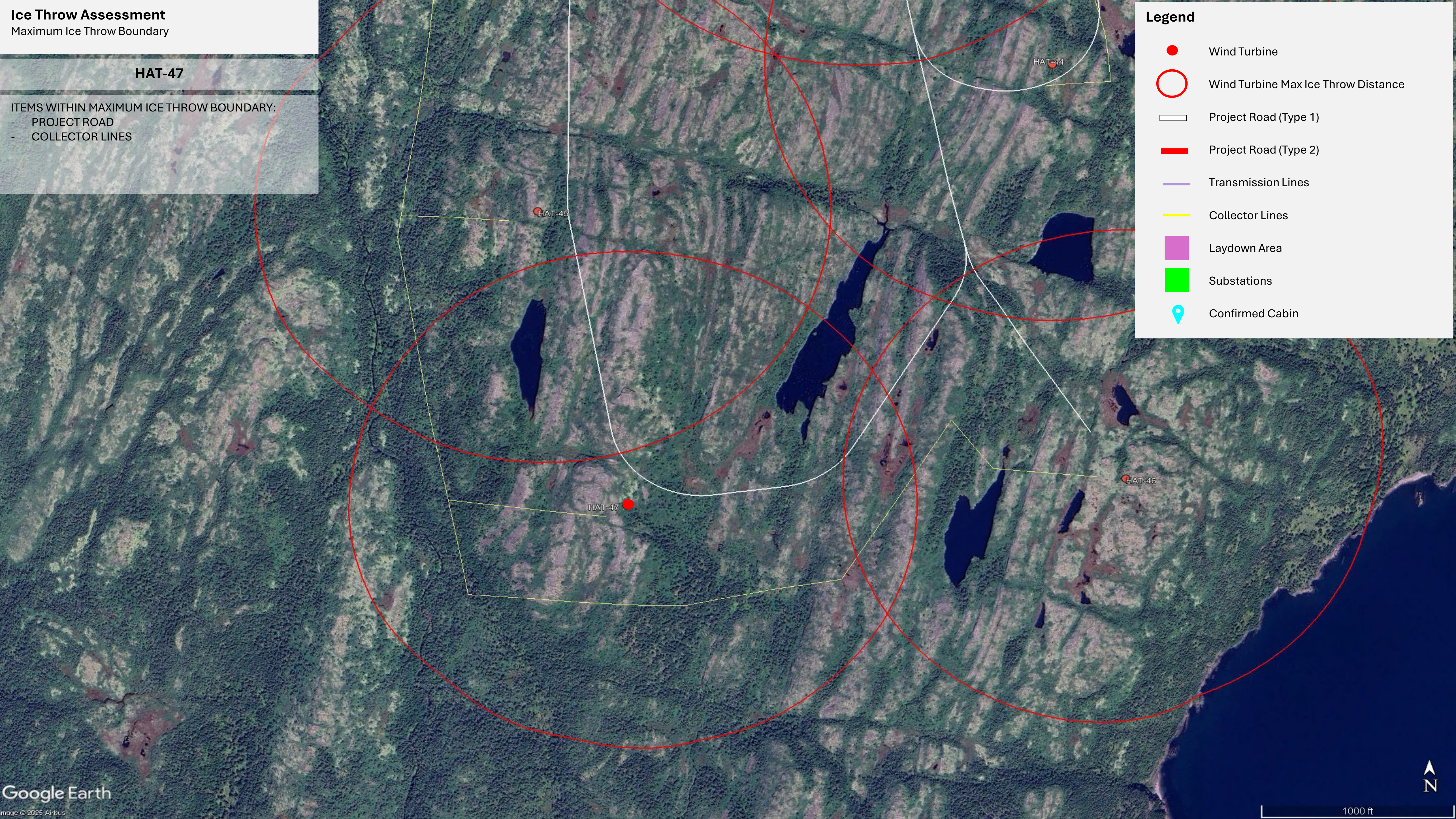
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-47

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINES



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-48

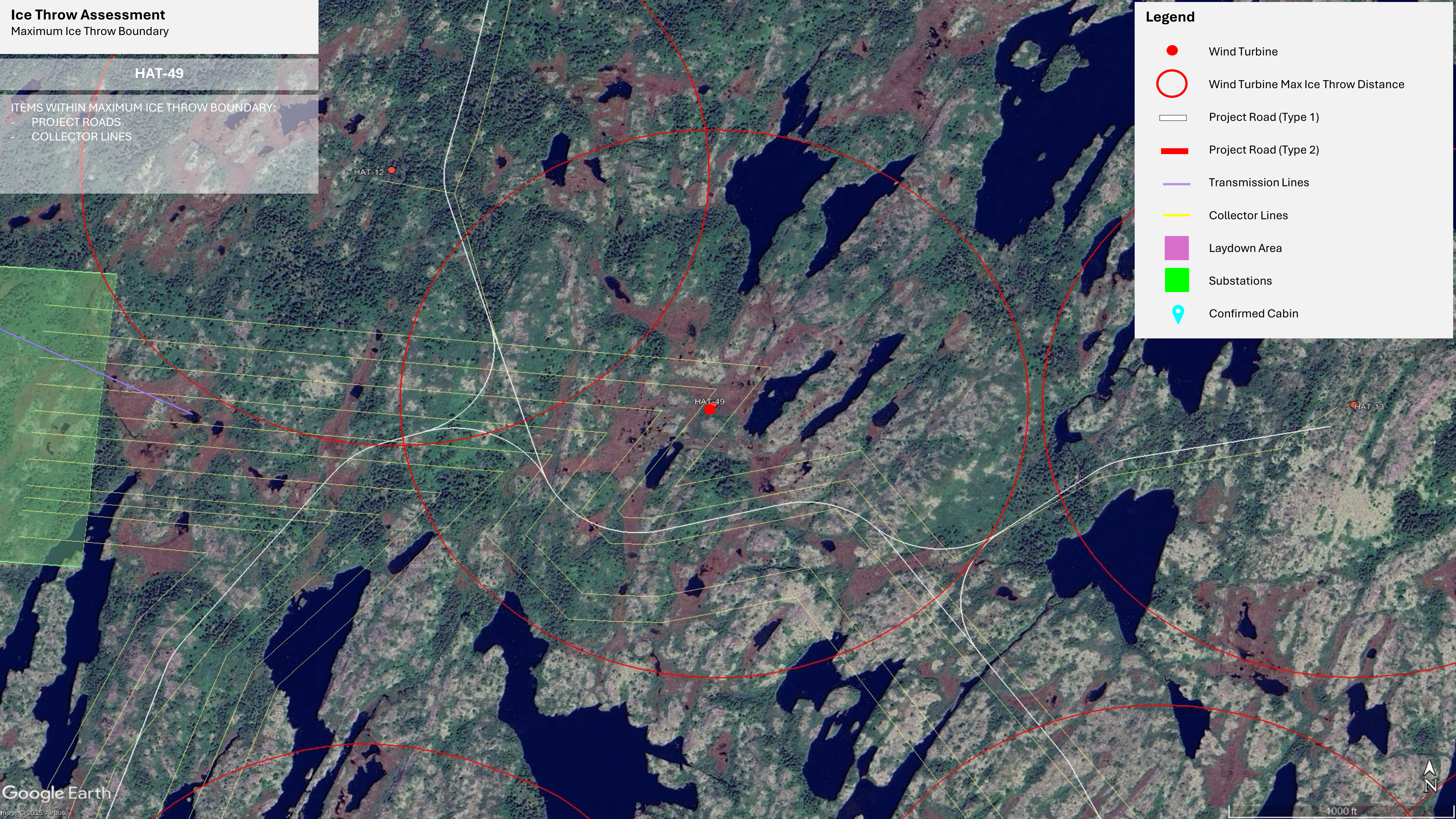
ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES
- CONFIRMED CABIN & CABIN AREA

Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-49

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:
- PROJECT ROADS
- COLLECTOR LINES



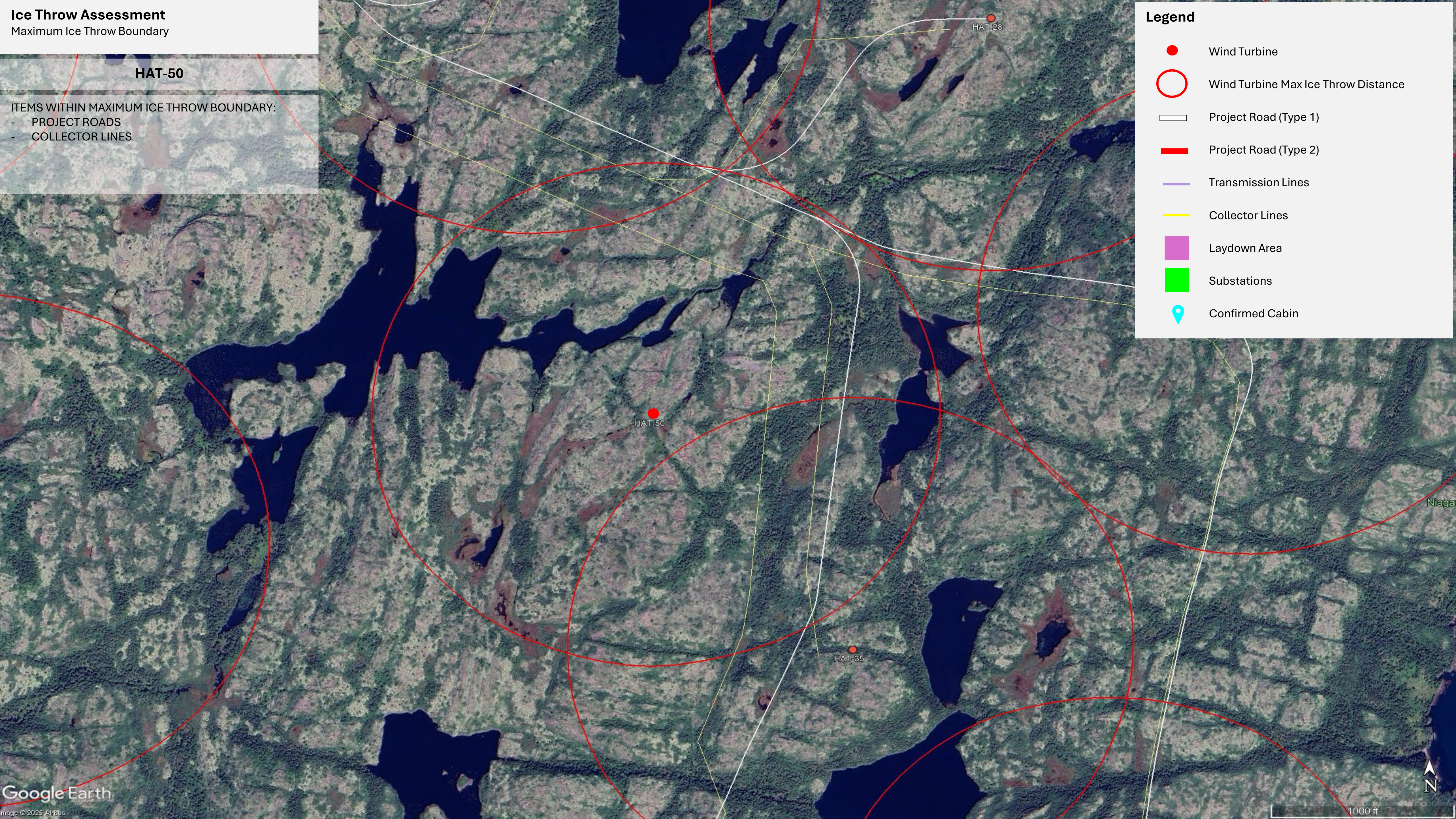
Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-50

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROADS
- COLLECTOR LINES



Ice Throw Assessment

Maximum Ice Throw Boundary

HAT-51

ITEMS WITHIN MAXIMUM ICE THROW BOUNDARY:

- PROJECT ROAD
- COLLECTOR LINE