STATE OF NEW HAMPSHIRE
BEFORE THE ENERGY FACILITY SITE EVALUATION COMMITTEE

Docket No. SEC 2014-03

Motion of Granite Reliable Power, LLC (“GRP”)
to Amend the Certificate of Site and Facility

SUPPLEMENTAL TESTIMONY OF KENNETH D. KIMBALL ON BEHALF OF APPALACHIAN MOUNTAIN CLUB

October 23, 2014

Q. Questions of professional expertise and opinions in the area of restoration have been suggested in this proceeding. Do you have experience in ecological restoration work?

A. Yes. I was the principle in researching and designing the wetland restoration project of the ecologically important (migratory waterfowl from Russia and fish breeding/nursery for Caspian Sea fishery) 39 square mile Anzali (Pahlavi) Mordab wetland in the Caspian Sea basin, Iran while working in the Smithsonian/Peace Crops Environmental program. My restoration design plans were recently acknowledged in the just published book "*Limnological methods for environmental rehabilitation – The fine art of restoring aquatic ecosystems*" by Sven Bjork, which covers case studies of environmental rehabilitation projects from around the world[1].

I was the principle investigator in overseeing AMC's development and implementation of the recovery plan[2] for the federally listed alpine plant *Potentilla robbinsiana* for the US Fish and Wildlife Service and White Mountain National Forest, one of the rarest alpine plants in the world. This New Hampshire alpine plant was removed from the federally listed endangered species list in 2002 due to successful implementation of a recovery plan. This was only the 11th species and second plant species to ever be removed from the federally endangered species list due to successful recovery at that time. The Appalachian Mountain Club was awarded the US Fish and Wildlife Service's Regional Director's Award for this effort. There were lessons learned from testing different rearing and transplant techniques[3]. In particular and relevant to this proceeding, in that project we similarly experienced minimal bare root transplant success due to

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[1] Bjork, S. 2014. Limnological methods for environmental rehabilitation – the fine art of restoring aquatic ecosystems. Section II.2.g. The Pahlavi Mordab Wetland, Iran. Pp 260-293. Schweizerbart Science publishers. Stuttgart, Germoany.

[2]J. Doucette and Kimball, K.D. 1991 . Robbin's cinquefoil (Potentilla robbinsiana) Recovery Plan,. US Fish and Wildlife Service, NE Region 23 pp.

[3]Brumback,W., D.Weihrauch and Kimball,K.D.2004. Propagation and Transplanting of an endangered Alpine Species, Robbins Cinquefoil, Potentilla robbinsiana. *Native Plants J*.5:91-97.

a variety of factors and that using potted or plugs typically have much higher success rates. Therefore failure with bare root tree transplants, as was tried in this HER, does not necessarily imply that other components of the HER restoration tree replanting effort where bare root transplant trees were used are problematic.

Q. Do you have experience in the resistance and resiliency of northeastern subalpine and alpine ecosystems to stress factors?

A. Yes. I have been involved in numerous studies on the resistance and recovery of these ecosystems. These include but are not limited to analyses on the rates of recovery from hiker trampling and the ecological recovery following removal of the extensive military aircraft ice testing buildings and living facilities in both the subalpine forest and alpine zone on Mount Washington, NH. More recently I was the principal investigator of a multi-year NOAA grant, which included collaborators from the Mount Washington Observatory, University of New Hampshire and Plymouth State University on "Climate and air pollutant trends and their influence on the biota of New England's subalpine and alpine ecosystems". A number of peer reviewed publications have been coming forth from that research[4]. Dr. Robert Caper and I co-

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[4]K. D. Kimball, M. L. Davis, D. M. Weihrauch, G. Murray, and K. Rancourt. 2014. Limited alpine climatic warming and modeled phenology advancement for three alpine species in the Northeast United States. *American J. of Botany*. 101:1437-1446

-- Murray, Georgia LD, Kimball, K.D. et al. "Long-Term Trends in Cloud and Rain Chemistry on Mount Washington, New Hampshire." *Water, Air, & Soil Pollution* 224.9 (2013): 1-14.

--Seidel, T.M., Weihrauch, D., Kimball, K.D., Pszenny, A., Soboleskil, R., Crete, E. and G. Murray. 2009. Evidence of climate change declines with elevation based on `temperature and snow records from 1930s to 2006 on Mount Washington, New Hampshire, USA. *Arctic, Antarctic, and Alpine Res.* 41:361-372.

-- Murray, G., Kimball, K**.,** Hill, L.B., et al. 2009. A comparison of fine particle and aerosol strong acidity at the interface zone (1540 m) and within (452 m) the planetary boundary layer of the Great Gulf and Presidential-Dry River Class I Wildernesses on the Presidential Range, New Hampshire US. *Atmos. Environ.*43:3605-3613.

organized and AMC hosted the National Science Foundation northeastern alpine state-of-the-science workshop[5] in 2011.

Q. Do you have experience with invasive plant species?

A. Yes. My PhD thesis research at the University of New Hampshire was on milfoil (*Myriophyllum heterophyllum*) a problematic aquatic invasive species. Concurrently I had a National Science Foundation Science for Citizens fellowship with the Lakes Region Planning Commission to develop a NH State strategy to address this invasive species. My research and recommendations provided the underlying framework still used by NH in the management of this invasive species. This provided me with first-hand experience on controlling non-native species; the best strategy is to prevent or impede their introduction early on as control can be difficult and expensive and at times impossible afterwards.

Q. Do you have research experience with northeastern high elevation forest?

A. Yes. I have[6] as has Dr. David Publicover, AMC's senior staff scientist and forest ecologist. AMC has mapped all of the high elevation forest above 2700 feet elevation in NE and NY, including the post 1975 logging history based on best available remote sensing imagery. The results were summarized[7] and can be accessed on Google Earth for any particular mountain area

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[5]Caper, R.S. ,Kimball, K.D.et al. 2013. Establishing alpine research priorities in Northeastern North America. *Northeastern Naturalist* 20:559-577.

[6]Kimball, K.D. and M. Keifer. 1988. Climatic comparisons with tree-ring data from montane forests: are the climatic data appropriate? *Canad. J. Forest Res.*18:385-390.

-- Kimball, K.D. 1988. Relationship of air pollutants and climate with red spruce vigor on Mt. Washington, NH**.** *Envir. Monitor. and Assessment*12:289

[7]Publicover, D. and Kimball, K.D. 2012. High-elevation spruce-fir forest in the Northern Forest: an assessment of ecological value and conservation priorities. Submitted for Proceedings of the Eastern Canada and US Forest

>2700 feet elevation area, including Mount Kelsey at http://www.outdoors.org/conservation/wherewework/northeast-high-elevation-areas.cfm.

Q. Do you concur with Dr. Kilpatrick's testimony description relative to this project's impacts to pine martin, Bicknell thrush and other species and how road corridors and fragmentation in this montane spruce-fir forest can become new avenues for increased predator travel?

A. Yes. AMC's testimony in both this and other similar previous cases AMC had participated in presented similar information on anticipated ecological impacts. AMC supported the NHFG request for post construction impact studies on pine martin and Bicknell's thrush to gain site-specific knowledge on these impacts. This project's post-construction study results confirmed the validity of some of AMC's concerns on habitat fragmentation effects in these high elevation spruce-fir ecosystems. I do note some factual inaccuracies in Dr. Kilpatrick's testimony, possibly because he has never been on site and appears to have relied on input from his graduate student plus roadside pictures. He cites a report that no forest harvesting above 2700 feet elevation on Mount Kelsey site has occurred. Our analysis (Appendix 1) shows that not to be the case; since 1975 ca. five percent had been harvested and further timber harvesting on Mount Kelsey to 3,000 feet elevation had been permitted, which never happened due to the transfer of lands above 2700 feet elevation, minus the wind farm project footprint, into NHFG ownership as part of the negotiated mitigation plan. Also at elevations from 2700 to 3472 feet asl at this site over 82% of this habitat is spruce-fir forest (Publicover at

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Science Conference, Durham, NH. and at http://www.outdoors.org/conservation/wind/upload/Publicover-and-Kimball-ECANUSA-proceedings.pdf http://www.outdoors.org/conservation/wherewework/northeast-high-elevation-areas.cfm.) and the northern hardwood component (particularly sugar maple) Dr. Kilpatrick describes is expected to be minimal at this elevation range on this mountain.

AMC understood some of the likely impacts Dr. Kilpatrick describes could not be fully resolved on-site through minimization or avoidance. It is the reason off-site mitigation to protect other large high-elevation spruce-fir habitat blocks in the immediate area from future threats of wind farm development and timber harvesting was essential and was accomplished (see Appendix 2). These off-site mitigation parcels were selected because they were under threat, had modeled Bicknell's habitat and contain many of the habitat elements associated with high elevation spruce-fir pine martin habitat. The land protection fund from this agreement also contributed to additional lands protected as part of the 31,000 acre buffer established around the nearby Umbagog National Wildlife Refuge - specifically quality spruce-fir pine martin habitat (934 acre Greenough Pond fee purchase to NHFG ownership in 2013).

Q. Could you clarify the purpose of the HER and proposed Amended plan and AMC's role as there appears to be confusion.

A. Understanding that the impacts of the road and turbines could not be fully resolved on-site, in addition to the off-site mitigation, the HER is intended to temporally and spatially reduce the on-site habitat fragmentation. The NHFG was the lead in designing and implementing the HER plan as described in the certificate issued. Lessons learned from the post-construction studies, in particular enhanced predation on pine martin by canine who are using the packed winter roads for access, raised the question of whether the HER vegetation restoration plan may also contribute to a similar effect during the growing season by providing linear corridors of non-native grass and possible prey habitat that could potentially increase or encourage canine or other predator presence. Grassy roadside corridor habitat could possibly host desirable prey species, e.g. rodents, insects, birds (including turkey) and seeds or fruits not typically found in this zone. Dr. Kilpatrick's literature review testimony appears to confirm and repeat AMC's concern. When the request came from Brookfield to AMC to modify the road width from 12 to 16 feet, as required based on the settlement agreement, AMC, after consultation with and additional recommendations to NHFG (Will Staats), concurred. AMC's recommendations were based in part on available post-construction study results that were not available when the original HER was developed and lessons learned by Brookfield and NHFG, e.g. poor success rate of bare root tree transplants. AMC recommended no further uses of grass and hay (species or seed sources that are non-native for this elevation) for erosion control, supported NHFG's approach to further reduce the non-forested , "open space" at the turbine pads and to target the transplanted spruce-fir trees to both the newly defined turbine pad restoration areas and where applicable along the linear road corridor. Understory in general is naturally limited in these high elevation forest ecosystems and grasses are very atypical (See NH Natural Heritage Bureau description of the High-elevation spruce-fir systems (S4) and high elevation balsam fir forest (S3S4) habitats at Appendix 3.)

Q. Does Dr. Kilpatrick misrepresent elements of both your discussions with him and your testimony?

A. Yes. He states "*Dr. Kimball considers that the grasses that were planted and introduced from the hay mulch as part of the original restoration plan, are the primary cause of the increased numbers of rodents which are attracting carnivores to the edge habitat along the* *road*." My objective was to reduce the possibility of a non-native grass strip providing the very type of habitat corridor that would attract predators, a possibility that is not negated by Dr. Kilpatrick's literature citations. I never suggested that there was direct evidence that a grassy corridor was a "*primary cause of an increased number of rodents attracting carnivores*" only that it was logical to reduce this **possible** hazard from becoming an additional growing season impact due to HER erosion control methods. As a correction to Dr. Kilpatrick's statement, AMC's concurrence with amendments to the HER and Kimball's earlier filed testimony simply states "*WHEREAS based on the post construction pine martin study there is evidence of winter mortality by canine predators that are gaining access by way of the road, predation that* ***potentially*** *could be enhanced due to high elevation roadside grass seeding and resultant creation of attractant prey population habitat impact*" and "*As the Windpark currently stands and operates this Amendment and it's HER Plan* ***possibly may better ameliorate to some degree*** *threats to the pine martin population. It is my professional judgment based on consultation with Dr. Publicover and NH Fish and Game Department that this may be preferable to repeatedly disrupting roadside vegetation and reseeding with erosion control grass to form linear prey rodent habitat corridors, which in return could attract additional predators into this once intact old growth sub-alpine forest ecosystem on Mt. Kelsey*." Mine are reasonable professional judgment conclusions based on best available scientific information.

Q. Do you concur with Dr. Kilpatrick's statement "The mitigation agreement does nothing to address most of the factors that have adversely impacted the populations of these two threatened species"?

A. No. Dr. Kilpatrick appears to blend the HER and mitigation agreement as one and the same and then omits major elements of the mitigation plan. The road width element was but one of multiple elements in the overall mitigation agreement and development and implementation of the HER was appropriately assigned to the NHFG when the certificate was issued. Dr. Kilpatrick appears to not fully understand the off-site mitigation that created larger blocks of protected high elevation habitat that were also under threat. These habitats likely have high value for these two threatened populations.

Furthermore the reference I provided Dr. Kilpatrick at his request on predator-prey attraction relationships using roadside buffer corridors, of which to my knowledge there are no studies based on northeastern high elevation roads, was based on *Microtus pennsylvanicus,* the meadow vole. In his testimony he states "*However, in New Hampshire there is only a single rodent species, the meadow vole (Microtus pennsylvanicus), that occurs predominantly in grasslands and the increased rodent abundance is in response to the edge habitat (Johnson et al. 1977; Adams and Geis 1983; Tattarsall et al. 2002.) rather than the presence of grass*." It is unclear what his point is. However *Microtus pennsylvanicus* has been found even in the alpine zone of Mount Washington[8]. Other mammal species normally associated with mid or lower elevation habitats are also found in northeastern alpine habitat including the woodchuck, red fox,

[8] Slack, N.G. and A.W. Bell. 2013. Field guide to the New England Alpine summits – mountaintop flora and fauna in Maine, New Hampshire, and Vermont. 3rd edition. Applachian Mountain Club Books. At page 155.

-- M. Jones and L. Wiley. Editors. 2013. Eastern Alpine Guide: Natural History and Conservation of Mountain Tundra East of the Rockies. University of Massachusetts Amherst / Beyond Ktaadn, i.e. at Chapter 6 Fauna. *"While most of the larger mammals retreat to below treeline for winter, a few small mammalshave distributions that extend far north into arctic tundra, and can persist quite well both above and below treeline in the mountains year-round, as evidenced by their presence at our winter cameras stations, and the numerous trails left under the snow in meadows and bogs. This list includes ermine (Mustelaerminea), red-backed vole (Clethrionomysgapperi), and masked shrew (Sorexcinereus). In Garrit Miller's (1893) wanderings on the PresidentialRange of New Hampshire, from which he first described rock voles and a regional subspecies of the red-backed vole (Clethrionomysgapperiochraceus), he also encountered* ***meadow voles (Microtuspennsylvanicus)*** *and starnosedmoles (Condyluracristata) inhabiting the Alpine Garden on the eastern cone of Mount Washington."*

moose and bear. They may use the artificial, non-forested vegetation corridors along both the Mount Washington Cog Railroad and private Mount Washington Auto Road to increase their access to these higher elevation habitats and similar would not be unexpected on Mount Kelsey with the newly constructed road. Possibly to be attracted to the road corridor of concern in this proceeding in greater abundance as a prey species would be the generalist and quite adaptable white footed deer mouse, *Peromyscus maniculatus*. It is a problem species for food storage at AMC's high elevation huts. Furthermore I and others have observed foxes hunting and even turkey along the non-native grass road buffers abutting Route 16 at my office at 2,000 feet elevation in Pinkham Notch, NH and even along the private Mount Washington Auto Road buffers to the summit of the mountain, where I travel.

Q. Do you agree with Dr. Kilpatrick's statement "*these restoration plans either have or may have unintended affects of introducing species that may not be desirable*"?

A. I recommended no further use of non-native grasses but instead the use of on-site organic mulch for erosion control so his statement is confusing. Furthermore high elevation spruce–fir forest soils contain a top organic layer comprised of leaf litter, branches and tree boles that break down slowly due to the acidic and poor nutrient nature of the plant material, impeded drainage and cool, damp environment enhanced by frequent orographic cloud formation (see Appendix 3). It is the reason using native organic mulch material instead of non-native grasses for erosion control and to start re-establishing a more natural-like top soil organic layer that would normally be present in this ecosystem is more desirable. To my knowledge no such readily available top soil source exists above 2700 feet elevation to mine, and if mined would result in a transferred impact to other high elevation areas when trying to mine it. Therefore using on-site ground up tree materials is not an unreasonable strategy to mimic as best as possible the surface organic layer at these elevations in this forest type. Mining forest soils from lower elevations potentially carries a higher risk of introducing species that may not be desirable.

Q. **Do you agree with Dr. Kirkpatrick that "in his opinion that the proposed changes to the plan will do nothing to improve the efficacy of the plan and may actually make things worse" and he goes onto say "In addition, the high elevation restoration plan associated with this mitigation seems to suffer from lack of planning, poor implementation, development of protocols that are based on beliefs rather than knowledge."?**

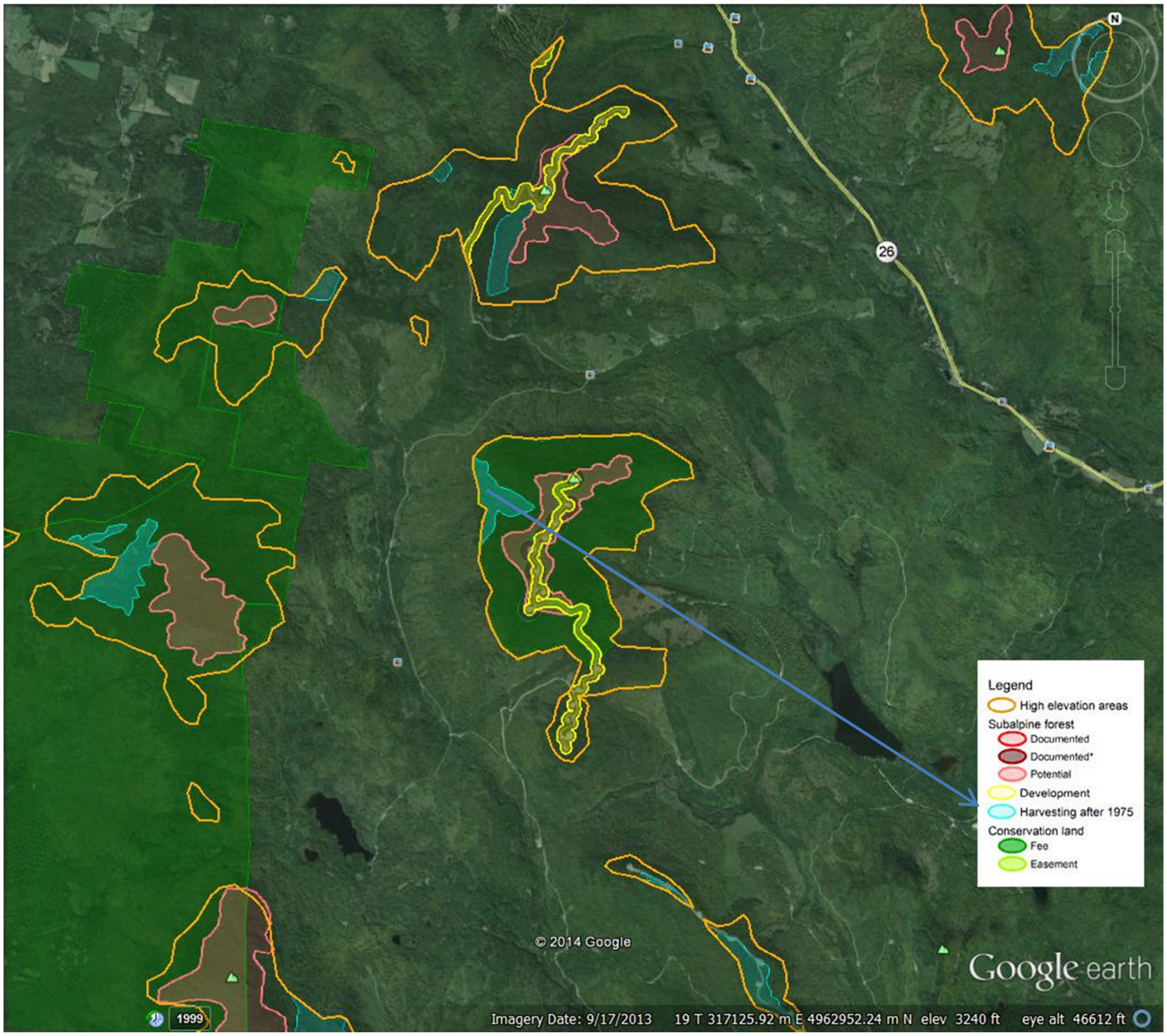
A. I do not concur with his conclusion that it "*will do nothing and may actually make things worse*". He provides no evidence to his claim of how the amended HER could make things worse. His literature citations appear to support AMC's concerns that roads and non-native vegetative buffers could attract additional predators during the growing season. In the NH Natural Heritage Bureau's descriptions of this forest type at Appendix 3, grasses are not listed. The amended HER plan, with the objective to increase the rate of reforestation in the impacted zone, was developed and implemented by NHFG staff who have considerable experience in this habitat and was not based on "*beliefs rather than knowledge*". The fact that lessons were learned and applied, e.g. greater presence of effective canine predators invading the area of concern from post construction studies, poor success rate using bare root tree transplants, etc. Dr. Kilpatrick confuses as "*lack of planning, poor implementation and development of protocols that are based on beliefs rather than knowledge*". NHFG and AMC's proposed changes to the amended HER are a reasonable form of what is commonly known as adaptive management in restoration work.

At the technical session, Dr. Kilpatrick admitted he has never conducted an ecological restoration project.

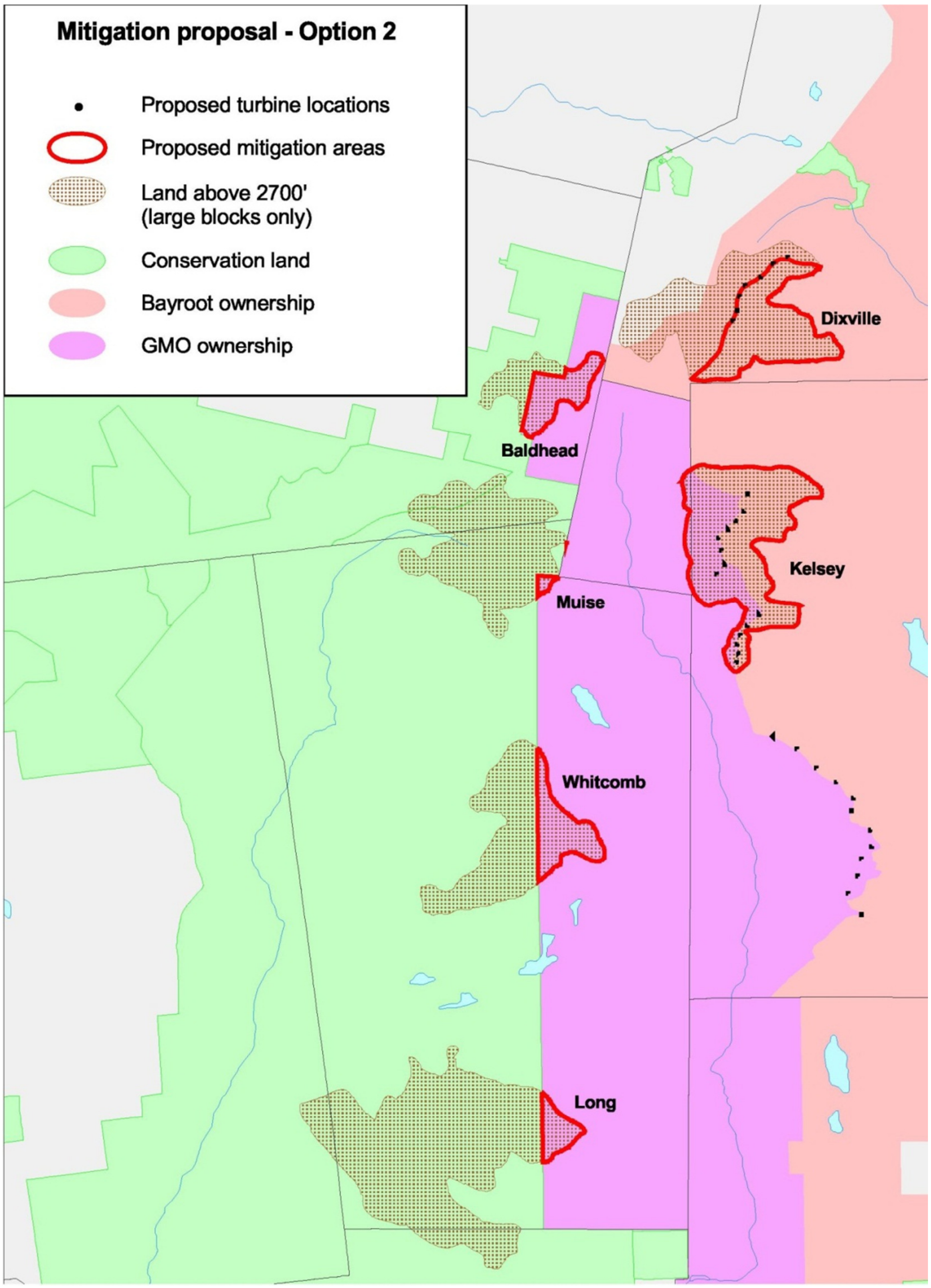
In summary AMC never assumed that the HER would be a panacea for some on-site impacts, but the HER is based on reasonable assumptions by experienced professionals familiar with the site and has a reasonable chance of accelerating the reforestation rate to tone down some habitat fragmentation impacts faster. Dr. Kilpatrick's literature citations echo many of AMC's listed objections to development on this high elevation ecosystem, which is the reason a combination of on-site and major off-site mitigation were essential to address in part the very serious impacts of this project in this important ecosystem.

Dr. Kenneth D. Kimball
Director of Research
Appalachian Mountain Club

Appendix 1. Mt Kelsey, NH. Over 5% of the above 2700 foot elevation forest was harvested post 1975 based on available remote sensing imagery.



Appendix 2. High elevation spruce fir forest off-site mitigation. These proposed mitigation parcels were protected from all future forest harvesting (excluding Dixville and Whitcomb) or wind development (excluding Whitcomb) and abut existing protected blocks to create larger protected blocks sought by Bicknell thrush and pine martin.



Appendix 3. NH Natural heritage Bureau

DIVISION OF FORESTS AND LANDS

High-elevation balsam fir forest (S3S4)

New Hampshire's ***high-elevation balsam fir forests*** typically occur on upper mountain slopes between 3,500 and 4,500 ft. in elevation throughout the White Mountains, though the range varies considerably with topography and exposure. They are sometimes found as low as 3,500 ft. on exposed ridges and summits, and as high as 5,200 ft. in more protected valleys or cirques. Most peaks above 3,500 ft. have decent examples.

Balsam fir (*Abies balsamea*) dominates, and there is a corresponding absence or lower abundance of both red spruce (*Picea rubens*) and heartleaf birch (*Betula papyrifera*). The canopy height in this community is typically in the 2-10 m range, a reduction from the taller stature of trees at lower elevations (which grow to 20-25 m height). At higher elevations near treeline, these short trees ultimately diminish to krummholz stature (<2 m). They frequently transition to black spruce - balsam fir krummholz, red spruce - heath - cinquefoil rocky ridge, alpine/subalpine communities, or heath - krummholz communities above, and *high-elevation spruce - fir forest* below.

Wind is a primary disturbance factor in these forests. Blowdowns are common, often taking the form of patches of wind-induced mortality known as fir-waves. Fir-waves are linear patches of blowdown or standing dead trees oriented perpendicular to the prevailing wind, and arranged in a progression of adjacent lines of different-aged regeneration. These waves can be seen as gray undulations across mountainsides. A common theory suggests that the trees primarily die from the death of needles and roots due to chronic wind stress.

Certainly some (or many) examples of this natural community in the White Mountains are "virgin" old-growth in a strict sense, although their age structure and dynamics are poorly understood and studied. Balsam fir typically declines and dies after 70 years, often as a result of fir-wave phenomena. Tree cores of "scrub" fir indicate higher maximum ages, with some trees attaining 90-140 or more years.

Soils are similar to those found in *high-elevation spruce - fir forests*: nutrient-poor, acidic Inceptisols or Spodosols with a deep, slowly decomposing humus layer and the variable presence of a grey, leached E (elluviated) horizon. Drainage varies from well to moderately-well drained. Condensation from cloud-intercept contributes a significant amount of moisture to this forest community. Colder temperatures and deep, late-melting snowpacks at high elevations also contribute to high moisture levels, low soil temperatures, a shortened growing season, and accumulation of soil humus.

CHARACTERISTIC VEGETATION: The canopy is dominated solely by balsam fir (*Abies balsamea*), with red spruce (*Picea rubens*) and birches (*Betula* spp.) also present but less abundant. Black spruce (*Picea mariana*) is occasional at higher elevations. The shrub layer may be sparse, but is usually characterized by some combination ofshowy mountain ash (*Sorbusdecora*), mountain holly (*Nemopanthusmucronatus*), velvet-leaf blueberry (*Vacciniummyrtilloides*), creeping snowberry (*Gaultheriahispidula*), and twinflower (*Linnaeaborealis*). A low diversity of herbs is also characteristic, but species present may include mountain wood fern (*Dryopteriscampyloptera*), rosey twisted stalk (*Streptopus roseus*), goldthread (*Coptistrifolia*), naked miterwort (*Mitellanuda*), northern wood sorrel (*Oxalismontana*), starflower (*Trientalisborealis*), bluebead lily (*Clintoniaborealis*), andCanada mayflower (*Maianthemumcanadense*).

Moss and liverwort cover can be quite high (as much as 80-100%), forming a deep, spongy carpet over thick (9-20+ cm) organic humus. Dominant bryophyte species include *Bazzania trilobata*, *Mylia taylori*, *Hypnum imponens*, and *Dicranum scoparium*. *Cladonia* spp. and otherlichens are present on ground surfaces, tree roots, stems, lower branches and decaying logs. These moist moss carpets sometimes form a natural habitat for the rare heart-leaved twayblade (*Listera cordata*).

Other species may be encountered in sheltered openings of this community, including stiff clubmoss (*Lycopodiumannotinum*), wild-currants (*Ribes lacustre* and *R. glandulosum*), sheep laurel (*Kalmia angustifolia*), Labrador tea (*Ledum groenlandicum*), rhodora (*Rhododendron canadense*), alpine bilberry (*Vaccinium uliginosum*), dwarf bilberry (*V.cespitosum*), lowbush blueberry (*V. angustifolium*), mountain cranberry (*V. vitis-idaea*), and large-leaved goldenrod (*Solidagomacrophylla*).

Good examples of this community can be seen just below treeline on many of the state's higher mountain peaks, such as those of the Presidential Range.

High-elevation balsam fir forests often occur as part of a larger **high-elevation spruce - fir forest systems**.

High-elevation balsam fir forest on Mt. Bond (photo by Ben Kimball)

Fir wave in a ***high-elevation balsam fir forest*** (photo by Ben Kimball)

high-elevation balsam fir forest on North Twin Mtn. (photo by Ben Kimball)

High-elevation spruce - fir forest (S4)

High-elevation spruce - fir forests occur on upper mountain slopes and ridges in New Hampshire. The composition of these forests is significantly influenced by disturbance history, and to a lesser extent by variations in soil and elevation. Species composition also varies along a moisture gradient. In drier conditions, the community has more heath shrubs and other dry-site species, and can be transitional on shallow-to-bedrock sites to the*red spruce - heath - cinquefoil rocky ridge* community. In moister conditions, it has greater bryophyte cover. Red spruce and balsam fir are typical canopy dominants. The importance of heartleaf birch and paper birch may increase after disturbance. Some post-disturbance patches may be strongly birch-dominated, and in some examples these "birch glades" persist for decades after disturbance. This community is generally found in the mountains, from 2,500–4,000 ft. in elevation, but it also occurs locally on shallow, rocky soils of lower ridges and other infertile sites (e.g. talus slopes), and higher on relatively protected sites (e.g., ravines).

Soils are generally very nutrient-poor, acidic Inceptisols or Spodosols with a deep, slowly-decomposing humus layer and the variable presence of a grey, leached E (elluviated) horizon. Drainage varies from well to moderately-well drained (somewhat poorly to poorly drained soils are more typical of *lowland spruce - fir forest* and spruce swamps). The needle litter of conifers is low in nutrients, and due to its acidity it decomposes slowly and contributes to organic matter accumulation. Condensation from cloud-intercept contributes a significant amount of moisture to this forest community. Colder temperatures and deep, late-melting snowpacks at high elevations also contribute to high moisture levels, low soil temperatures, a shortened growing season, and accumulation of soil humus.

CHARACTERISTIC VEGETATION: The canopy consists of various combinations of Red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), and heartleaf birch (*Betula cordifolia*), paper birch (*Betula papyrifera*), and yellow birch (*Betula alleghaniensis*). Common understory plants that are more restricted to or more abundant in this community than lower elevation forests include bunchberry (*Cornus canadensis*), twinflower (*Linnaea borealis*), Bartram's serviceberry (*Amelanchier bartramiana*), goldthread (*Coptis trifolia*), mountain ashes (*Sorbus decora* and *S. americana*), black spruce (*Picea mariana*), mountain holly (*Nemopanthus mucronatus*), velvet-leaf blueberry (*Vaccinium myrtilloides*), and creeping snowberry (*Gaultheria hispidula*).

Understory plants shared with northern hardwood forests include intermediate wood fern (*Dryopterisintermedia*), spinulose wood fern (*D. campyloptera*), northern wood sorrel (*Oxalis acetosella*), shining clubmoss (*Huperzialucidula*), starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), bluebead lily (*Clintonia borealis*), and long beech fern (*Phegopterisconnectilis*). The woody understory is usually sparse. Mosses and liverworts are often abundant and commonly include *Bazzania trilobata, Dicranumscoparium, Hypnumcurvifolium, Pleuroziumschreberi*, and *Ptilium crista-castrensis*. Others bryophytes include *Brotherellarecurvans, Bazzaniadenudata, Scapanianemoria, Drepanocladusuncinatus, Pohlianutans,Sphagnum russowii,S. girgenshonii,* and others. Lichens often cover trees and boulders.

A very similar, related community is the *high-elevation balsam fir forest*.

Good examples of ***high-elevation spruce - fir forest*** communities can be seen at Nancy Brook RNA, The Bowl RNA, and on the upper slopes of nearly any peak in the state that rises above 3,000 ft. elevation.

These forests often occur as part of a larger **high-elevation spruce - fir forest system**.

Old-growth ***high-elevation spruce - fir forest*** at Nancy Brook (photos by Ben Kimball)

High-elevation spruce - fir forest (foreground) on Ridge of the Caps (photo by Ben Kimball)

Coarse woody debris in a ***high-elevation spruce - fir forest*** in the White Mountains (photo by Ben Kimball)

High-elevation spruce-fir forest on Cannon Mtn. (photo by Ben Kimball)

High-elevation spruce-fir forest on Franconia Ridge in the White Mountains. View of Mt. Flume and Mt. Liberty from Little Haystack (photo by Ben Kimball)