The UMBS Adaptive Aspen Management Experiment (AAME) [updated 2/12/18]

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Summary: This document describes forest manipulations on the interlobate moraine, known locally as the Pellston Hill, to be implemented in spring 2019. Goals of the manipulations are many and complementary. First, make UMBS forests less vulnerable to climate change (ongoing and future) by implementing the Northern Institute of Applied Climate Science (NIACS) Climate Change Response Framework (CCRF). The CCRF is based upon forest adaptation concepts of *resistance, resilience,* and *transition* (Figure 10 in Swanston et al. 2016). Testing these concepts with experimental manipulations, while maintaining untreated *reference* areas, will make UMBS a formal demonstration site in the NIACS network, showcasing alternatives for aspen management in the face of climate change. The second goal is to generate science products pertaining to harvest impacts on hydrology and biogeochemistry using revenue gained from timber sales. Third, create research opportunities for classes, students, and investigators, and fourth, build relationships with partners in the forestry industry and forest-climate science and outreach institutions that will serve UMBS interests and advance climate-adaptive forest management. Below, I move from general to specific in describing the areas, objectives, and research questions associated with the treatments.

Management Area: Figure 1 shows the location of the aspen-dominated 183 ha management area, subdivided into 18 units ranging in size from ~2 – 73 ha each. Unit shapes and sizes are constrained by existing stand ages, research sites, and questions. Seven units are young stands regenerated after clearcuts in the early 1970s (18, 19) or early 1980s (units 2, 4, 6, 8, 10, 12). The young units total ~25 ha and provide a second structure / age class in the current landscape mosaic, which is dominated by mature aspen dating to the 1908-1919 period (Art Cooper plot data). Of these areas of old aspen, presently totaling ~157 ha in the management area, ~30 ha will be harvested during this set of manipulations. Units to be harvested are colored in pink (3, 7, 9, 13), while units that are to remain in reference condition are dark green (1, 5, 11, 14, 15, 16, 17). Areas are allocated into cut (pink) vs. reference (dark green) units according to several criteria. First, ensure that research locations, such as long-term plots (orange and purple points including Landscape Ecosystems, 50 Year and Art Cooper

Plots) and study areas (e.g., Honeysuckle Creek headwaters and Burt Barnes' aspen clones in units 14 and 15, respectively) are not affected by manipulations. Second, protect unique hydrologic features, such as Surprise Pond (in unit 11) and a swamp / ephemeral stream between units 6 and 7. Third, allocate treatments across space in such a way that the distinct forest adaptation *concepts* (resistance, resilience, transition, reference) can be tested at the landscape level, by implementing specific *strategies* and *approaches* at the unit level, while allowing for stand-level (within-unit) flexibility in *tactics* (again see Swanston et al. 2016). This experimental framework allows *strategies* and *approaches* to be evaluated across a range of ecosystem conditions within each unit (e.g., tree composition, soils, hydrology), while affording *tactical* flexibility for the consulting forester and logging operators to respond to on-the-ground constraints. Fourth, allocate sufficient overall area to treatments as to make the necessary timber sale economically attractive to the operators who will bid on and perform the work. The details below describe a management plan that optimizes across the above four criteria.

Treatments: The overall long-term goal of harvesting is to modify the existing, aspen-dominated forest of the management area into a matrix of conditions better positioned to maintain their ecological functions as climate continues to change. The more immediate goal of harvesting is to provide locations and funds for studying forest management impacts on carbon forms, turnover, and mobility in soils and groundwater. Treatments will produce immediate changes in forest composition, structure, hydrology, and biogeochemistry that then play out over longer time frames, as the units undergo succession. The treatments will remove standing biomass (mostly aspen) in order to either: 1) regenerate young, homogenous-structure aspen/birch cover types (*resistance*); 2) regenerate aspen-dominated cover, but with greater structural and compositional diversity (*resilience*); 3) encourage succession to more structurally and compositionally diverse cover types (*transition*). Specific treatments vary according to the current cover types, soils, and hydrology present on the units, which are represented quite well by the landscape-level ecosystem types (Figure 2) in the management area. For a thorough description of ecosystem types, refer to Pearsall (1995); for consideration of their soils and hydrology (Hofmeister et al. 2018a), and groundwater chemistry (Hofmeister et al. in review); for their application to forest growth rates Nave et al. (2017). Briefly, key ecosystem factors in the management area include: 1) landform, including parent material, slope and aspect; 2) hydrology; 3) soil texture. These three factors affect current vegetation cover, and will continue to do so into the future regardless of treatment. Regarding landform, the key difference in the management area is between moraine vs. outwash, dune, and beach ridge landforms. Moraine ecosystems (types 109, 113, 116, 118 in Figure 2) have nutrient-rich, fine-textured glacial till near the surface; these are level to gently sloping and because slopes are generally N- and E-facing, the topoclimate is cooler and moister. The presence of a seasonal (109, 113) to permanent (116, 118) water table ≤2 m of the surface is closely tied to the depth to till, which in some places is present as a fragipan or otherwise dense enough to exclude deep rooting. Bigtooth aspen is very productive on these ecosystems, and accessory species range from mesic northern hardwoods (beech, maples, red oak, basswood) to riparian and wetland species (trembling aspen, green and black ash, balsam fir). Outwash (36, 39, 47, 59, 60), dune (74), and beach ridge (75, 76) ecosystems have their differences, but share a common difference from moraine ecosystems in that they all have deep, sandy parent materials. Outwash landforms are mostly nearly level; dunes and beach ridges have locally steep slopes of any aspect; overall all of these ecosystems are considerably drier and lower in fertility than moraine ecosystems and typically support lower-stature and lower-density cover types dominated by bigtooth aspen, red maple and oak, and white and red pines. A seasonal (spring melt) water table exists in these ecosystems only in sporadic locations directly adjacent to (topographically below) moraine ecosystems. Following this brief overview of ecosystem types, some short definitions of the forest adaptation concepts that motivate the more detailed, unit-level management treatments are in order:

Resistance actions improve the defenses of an ecosystem against expected changes, in order to maintain relatively unchanged conditions. In this context, *resistance* means to resist climate-driven changes in forest composition by regenerating a vulnerable cover type in a protected location.

Resilience actions allow some change, but help an ecosystem return to its prior state after a disturbance, either naturally or through management. In this context, *resilience* means to maintain aspen-dominated stands as such, but to increase their structural and compositional diversity so their functions (e.g., C uptake, hydrology) can better recover from future climate change impacts and other disturbances.

Transition actions actively facilitate change, in order to help ecosystems adapt to changing conditions. In this context, *transition* means to convert aspen-dominated stands more diverse cover types that will have a higher probability of maintaining ecosystem functions despite future climate and disturbances.

Reference describes a state of no intervention, in which ecosystems undergo climate change and other disturbances and their responses to those drivers are monitored.

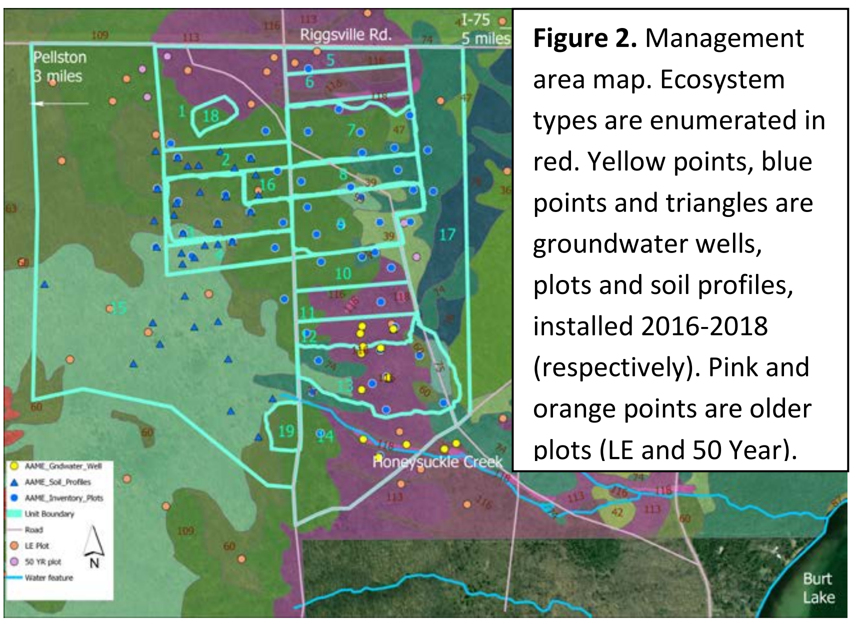

Figure 2. Management area map. Ecosystem types are enumerated in red. Yellow points, blue points and triangles are groundwater wells, plots and soil profiles, installed 2016-2018 (respectively). Pink and orange points are older plots (LE and 50 Year).

<u>Unit 3</u> Concept: *Resilience*. This 6 ha unit is the least diverse, in terms of ecosystem types (3) and current forest cover, which is overwhelmingly dominated by very tall, large-diameter bigtooth aspen. Red oak, beech, and white birch are present as scattered codominants, and understory (pole and sapling) species primarily include red maple, beech, and striped maple. Most of the unit is level to gently sloping, with a general E-facing aspect, but with some locally very steep (>25%) slopes in the northern portion of the unit. All portions are on the moraine. The ecosystem types present (59, 60, and 109) are excessively- to well-drained, and except in the ravine in the northern portion (and then only in spring) there is likely no

water table present. Thus, given the relative lack of species and structural diversity, and the relatively dry soil/ecosystem types present, this unit is particularly vulnerable to climate change. The goal then is to remove most of the over-mature aspens, which are increasingly being blown over due to their height and the restrictive subsoil (a fragipan is present in some areas of this unit), resulting in a more spatially complex forest structure and species composition that will be better positioned to recover from climate change-induced disturbances (now and in the future). The treatment will: 1) remove all diseased beech and 2) ~75% of the aspen on the overall unit. Aspen removals will be most intensive at the western edge of the unit, and leave an increasing density of residual large aspens as one moves eastward through the unit. This feathering effect (eastward-increasing residual aspen density) will create a more diffuse boundary on the unit's eastern edge than if all aspen were removed from the entire unit, in order to increase boundary layer resistance and make the units located to the east (16 and 9) less vulnerable to strong winds. Overall aspen retention will be ~19 trees per hectare. On unit 3, stems of all other co-dominant and understory species will be retained to the degree possible; these include primarily red oak and red maple, but also some non-diseased beech (~15 per ha). After the removals are conducted, future work may involve the planting of southern genotypes of species already present at UMBS (e.g., red oak, white pine, bigtooth aspen, sugar maple), and introductions of species that reach range limits near to the south (e.g., white oak, Hill's oak, shagbark hickory) or farther afield. Planted trees will need to be protected from browse; this may be accomplished by planting within 10-12 slash piles (each 15m diameter and 1 m tall) that will be created across the unit during harvesting.

<u>Unit 9</u> Concept: *Resilience*. This 7 ha unit has slightly higher diversity of ecosystem (4) and cover types than Unit 3. It occupies level to gently sloping, mostly N/E facing lower flanks of the moraine. There are some local areas of S-facing slopes and outwash channels in the northeastern portion of the unit, where the edge of the moraine meets outwash and dune ecosystems. Bigtooth aspen dominates throughout. Aspen is very tall and large-diameter on the moraine (ecosystem 109), where red oak and beech are codominant, and red maple, beech, and striped maple form the understory. On the drier outwash (39), dune (74), and deep outwash over till ecosystems (59), aspen density, height, and diameter is lower; codominant and understory taxa are red maple, red oak, white pine, and white birch. Given the slightly higher level of ecosystem and cover type diversity here, it is likely more resilient (at the unit level) to climate change and its impacts than Unit 3, but still vulnerable due to the dominance of bigtooth aspen throughout. Further, its topographic variability (both N- and S-facing slopes) may afford opportunities to test the performance of different planted species. Similar to Unit 3, treatment of this unit is intended to increase spatial, compositional, and structural diversity, though the harvest prescription differs somewhat. The prescription is to: 1) remove ~95% of aspen, with a more or less uniform distribution of retained aspen (~5 per ha). 2) Remove all diseased beech [retaining ~12 non-diseased beech per ha]. 3) In drier eastern portions of the unit, remove ~20% of pole-sized red and white pine in densely stocked areas totaling 1-3 ha, in order to release residual pines and oaks from shading; also remove ~15 red oaks from this area to provide firewood for the UMBS campus and a small quantity of high-value sawlogs.

<u>Unit 7</u> Concept: *Transition*. This 7 ha unit has the second-highest level of within-unit ecosystem diversity, with diverse cover types and locally complex topography. The majority of the unit is on level to gently sloping N/E facing lower moraine slopes (ecosystem 109), where very tall, large-diameter bigtooth

aspen dominate but with a notable presence of sapling, pole, and even co-dominant stems of red oak, red maple, yellow and paper birch, ironwood, striped maple, basswood, and hemlock. An eastward-running meltwater channel that is adjacent to (but outside) the unit's northern edge holds nearly perennially saturated soils, and supports a cover of trembling aspen, balsam fir, ash (green and black), red maple, white pine, hemlock, and white cedar. The eastern 1/3 of the unit includes gentle E, S, and W-facing slopes that flank a low-lying, northward-running (dry) outwash channel, bounded along its S and E sides by old dunes. In these areas of sandier parent materials the stem density and canopy cover is lower, and dominated by bigtooth aspen. The aspen is of lower stature and in some areas is codominant with red pine and even a few jack pines (apparently plantation), while red oak, white pine, red maple and balsam fir are accessory taxa. Given the diversity of existing cover types, topographic and hydrologic positions, and the presence of considerable accessory species diversity, this unit lends itself to management intended to transition away from dominance by bigtooth aspen, towards more diverse cover types. In order to achieve this transition, removals on this unit will be done with great care, and will exclusively target aspen (all of it over-mature and some of it beginning to break up or fall over) and diseased beech. All other stems of all species, from co-dominant to understory sizes, will be retained to the degree possible, except in the northeastern portion of the unit, where some localized areas of red pine (<2 ha) will be lightly thinned to release over-crowded residual stems from light competition. In this part of the unit, care has been taken to leave a dense overstory of red and white pines in locations that shade the cool, wet hydric ecosystems between this unit and Unit 6.

<u>Unit 13</u> Concept: *Resistance*. This 10 ha unit has the highest level of within-unit ecosystem diversity (9 ecosystem types), and accordingly, much within-unit variety in soils, hydrology, and vegetation. It also has a favorable physiographic position (NE-facing aspect with locally steep slopes and high water tables), making it well suited to attempts to resist climate change-driven drought and heat. Further, the unit is within part of the Honeysuckle Creek Watershed (HCW) where we have sampled soils and groundwater since 2016. It is isolated from the HC headwaters by a moraine/dune ridge to its south, creating a physically separate sub-basin where the impacts of clearcutting on hydrology, soil C turnover and mobilization can be studied in real time, and compared to adjacent stands (reference and 1980s clearcut) on ecosystem types that extend into adjacent units. In this case, all of these factors align well with a "business-as-usual," resistance-oriented management strategy. In other words, nearly all merchantable stems will be cut and removed from this unit, with the intent of regenerating a mixed aspen-birch cover type. This cover type is generally viewed as a climate change loser in northern Lower Michigan (Handler et al. 2014). We will test that prediction with a uniform prescription, applied across the range of ecosystems presented in the unit (including drier outwash and dune ecosystems on the unit's E edge), intending to learn whether a "typical" approach to aspen-birch management can sustain it despite ongoing climate change. The prescription for this unit is to remove all merchantable stems except 3 mature white birch per ha, 1-2 mature red oak per ha, and some healthy beech (~7 per ha). Mature white birch in this unit are now in the latter stages of decline, but those retained will act as a seed source for the post-harvest period. Retained beech show little to no sign of bark disease and may represent resistant genotypes. Retained red oak are intended as a seed source, especially important in light of the loss of most beech to bark disease.

Units 1, 5, 11, 14, 15, 16, 17 Concept: *Over-mature Reference*. These units include the full range of ecosystem and cover types, landforms, soil and hydrologic conditions present on the units to be treated, and afford the opportunity to continue monitoring aspects of these ecosystems as they continue to advance through succession, which will increasingly involve the blowdown and breakup of over-mature aspen. Future management activities could be conducted in areas of units 15 or 17, but if so, that management should be restricted to areas that have no long-term monitoring locations (e.g., plots).

Units 2, 4, 6, 8, 10, 12, 14, 18, 19 Concept: *Young Reference*. These units include the full range of ecosystem types, landforms, soil and hydrologic conditions present on the units to be treated, and afford the opportunity to continue monitoring aspects of these ecosystems as they begin to enter mid-successional stage. Because these are younger stands (cut in the 1970s and 1980s), they may be useful as a "time machine" of sorts, either in comparison to the over-mature reference units, or to the treatment units harvested in 2019. Given the good growth rates of aspen currently dominating these units, it is conceivable that merchantable biomass could be harvested from them within the next 10 years, especially if included in a larger timber sale involving other units.

Overall, this set of proposed treatments will provide immediate opportunities to study management impacts on hydrology, biogeochemistry, and organismal behavior in forest ecosystems. During the years following treatments, additional treatments may be considered for portions of the management area not presently proposed for manipulation. If realizing the significant revenue currently held in the mature aspen is a management goal, additional harvesting should be conducted soon, since these stands are beginning to break up and the large trees are susceptible to windthrow. Regardless whether additional revenue is desired, the landscape mosaic of stands in the overall management area will create more heterogeneous forest conditions, to the benefit of the landscape and its researchers. Below is an overview research questions and activities that are top priorities for the 2018 and 2019 field seasons.

Research questions: These treatments integrate with ongoing and create new opportunities for research projects. The project team will continue publishing papers on soil and ecosystem hydrology and biogeochemistry. Management treatments will address objectives of the original McIntire-Stennis grant (Drevnick, Kerkez, Nave) that funded the initiation of the HCW study, pertaining to the effects of harvesting on the hydrologic movement of C and Hg. Key projects completed or ongoing in 2018, and proposed for the 2019 field seasons are:

1. Forest inventory: The 2018 AAME team (Olivia Brinks, John Den Uyl, Elizabeth Feliciano, Edie Juno, Katy Hofmeister, Luke Nave, and Adam Schubel) marked and GPS'd 53 permanent plots (10 m radius each) distributed across the management units (blue points in Fig. 2). Data recorded includes: 1) for every standing tree >8 cm dbh: species, dbh, status (live or dead), azimuth from plot center, approximate distance, whether marked for retention during harvest, and if beech, the density of scale infestation [3 categories]; 2) for every tree <8 cm dbh but reaching dbh, the species and size class (0-2, 2-4, 4-6, or 6-8 cm dbh). These data were the basis for Elizabeth Feliciano's Frontiers project at UMBS, and provide a complete forest inventory baseline before management treatments occur. Data are available upon request by any researcher.

2. Soil sampling for post-hoc experiment: The 2018 AAME team sampled 25 soil profiles (to E'Bt horizon or 2 m depth, whichever is shallower) from Units 2, 3, 4, 15, and 16. Combined with 11 profiles sampled from unit 15 in 2015 (REU Carl Thompson) by the same methods and archived for future analyses, this sample set will be used to test for impacts of past harvesting on the storage and stability of C in multiple soil C pools. Laboratory processing has been completed and extractions and analyses are in progress. Analyses for this study will likely run well into 2019; most will be performed in the UMBS Analytical Lab, and some will occur through NIACS' Carbon, Water, and Soils Lab. This will eventually yield a novel paper on multiple mechanisms of soil C stabilization in Spodosols and accompanying analysis of management effects on soil C stability.
3. Groundwater, porewater, and soil sampling for real-time experiment: Den Uyl, Hofmeister, and Nave augmented existing monitoring locations in Units 12 (1980s harvest), 13 (2019 harvest), and 14 (reference) for a study of the real-time effects of management on water table dynamics, soil C stability and transport in pore- and groundwater. As of this writing, 13 water table wells are installed to the restrictive layer (till) or to 2m (whichever is shallower); 12 possess water level loggers. Soils have been collected, processed and archived for all of these locations. Some soils were collected with the TCI Sustainability Class in August 2018. Tension lysimeters were deployed to the B1 horizon (~30 cm) at 12 of the locations in fall 2018 by Den Uyl.
4. 2019 Groundwater and porewater sampling: Biweekly collections of groundwater and porewater (from wells and lysimeters) are planned to begin with spring melt 2019, continue throughout 2019, and run 1-2 years after harvesting. These water samples, along with the soils from the water sampling locations, will be analyzed for C forms and fluxes for a paper documenting the real-time changes in C hydrobiogeochemistry following harvest.
5. 2019 Coarse woody debris: Collecting woody debris data is a priority for 2019; this could be done by class projects using the new permanent sample plots where trees have been inventoried.

References and additional resources:

NIACS' Forest Adaptation Workbook (https://adaptationworkbook.org/). The Adaptation Workbook is a web-based process for incorporating climate change adaptation into forest planning. I have used the Adaptation Workbook as I have developed this management plan (with special help from Stephen Handler, Maria Janowiak, Dean Reid and Adam Schubel) and will share it / walk through it with anyone interested.

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