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Use of Windbreaks for Hurricane Protection of Critical Facilities

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Abstract

The infrastructure of the Langley Research Center is under potential risk in the future because of more intense hurricanes with higher speed winds and flooding. A potential method of protecting the Center's facilities is the placement of a windbreak barrier composed of indigenous trees. The "New Town" program that is now in progress creates a more condensed area of focus for protection. A potential design for an efficient tree windbreak barrier for Langley Research Center is proposed.

Introduction

NASA Langley Research Center is a facility that impacts countless people throughout the country and across the world. Since its federal opening in 1917, the center has contributed to the advancement of aeronautics and science by working towards NASA's goals. On an economic scale, the center had a 2.1 billion dollar impact nationally in the past year [1]. The research programs taking place at the facility deal with aeronautics, space exploration, and global climate. These projects are handled and managed by the 1900 civil servants and 1800 contractors employed at the center proving that Langley is a value to the nation.

The center's location on the coast of the Chesapeake Bay creates risks to the infrastructure due to storms that the area encounters, the most dangerous being hurricanes. Damage to the infrastructure due to these conditions would affect not only thousands of jobs, but the progress of many NASA projects. Langley is in a process of new construction called the "New Town" Program which will consolidate the majority of Langley's buildings into a smaller infrastructure footprint while many outlying buildings will be demolished. This process of rebuilding which began in 2009 is focused on modernizing the center's facilities. Figure 1 shows a map of the New Town area and the year when each renovation will be complete. The bulk of Langley's campus will be located in this area by the time of the program's completion in 2018, making it the focus for disaster protection.

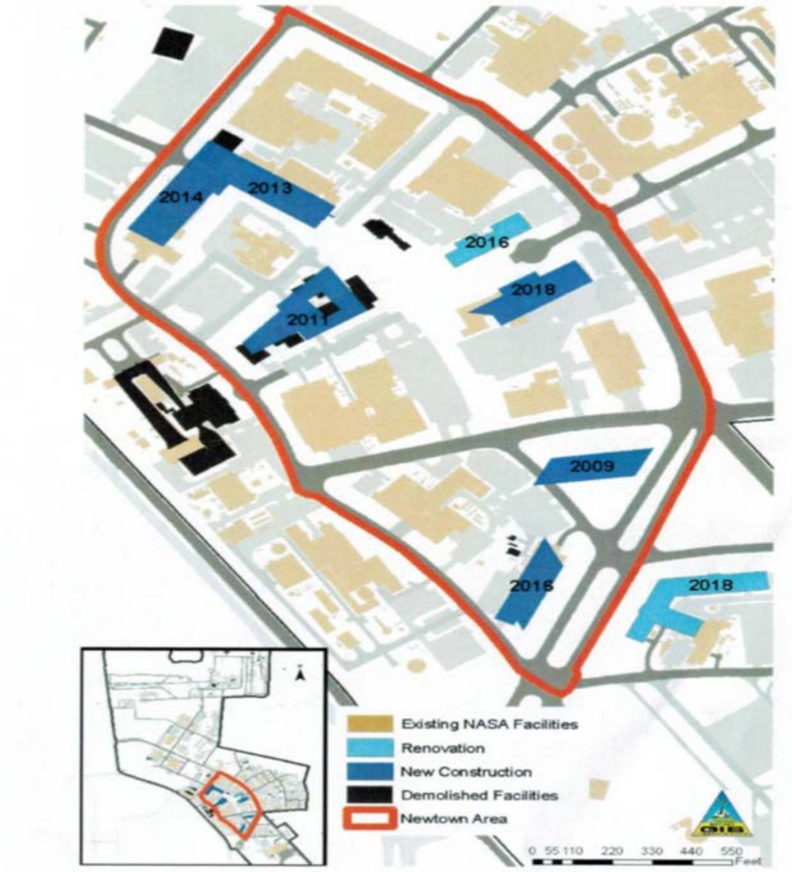

Figure 1. Layout of "New Town" Program Area.

2. Hurricane Risk

Hurricanes are common in the Chesapeake Bay area, with five major storms hitting the area within the century. Figure 2 shows a map of the hurricanes whose paths have gone through the Chesapeake Bay Area between 1851 and 2009[2]. It is evident from the figure that the most frequent passes were of tropical storms and hurricanes of category 1 and 2, and rarely a category 3. These types of storms have winds ranging from 30mph to 130mph with storm surges ranging from 4 to 12 feet. Although the most frequent storms that have passed through were category 3 and below, there are studies that show there will be a shift in this pattern due to global climate change [3]. Models of future hurricane projection show a decrease in lower category (1-3) hurricanes and an increase of higher category (4 and 5) expected to hit land in the future. Figure 3 shows a graph of the projected hurricane changes in the Atlantic over the 21st century. [4].

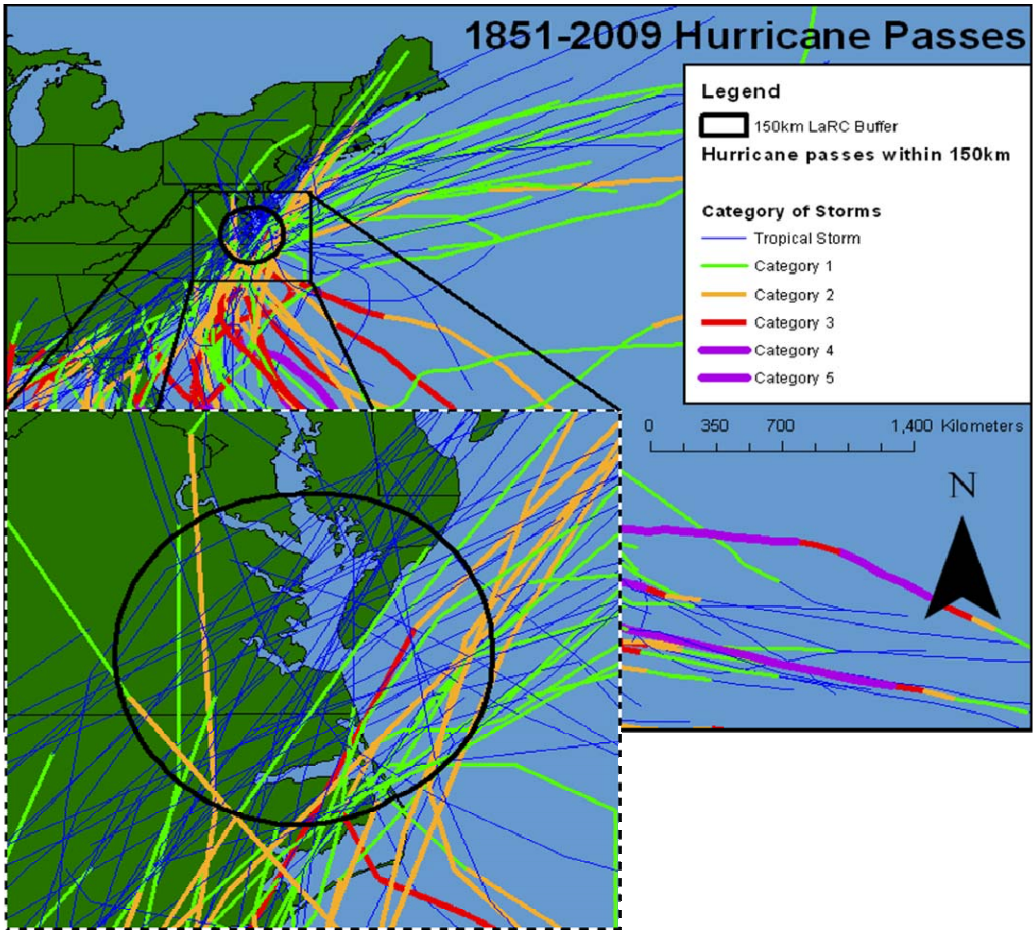

Figure 2. Map of storm and hurricane paths through the Chesapeake Bay area between 1851 and 2009.

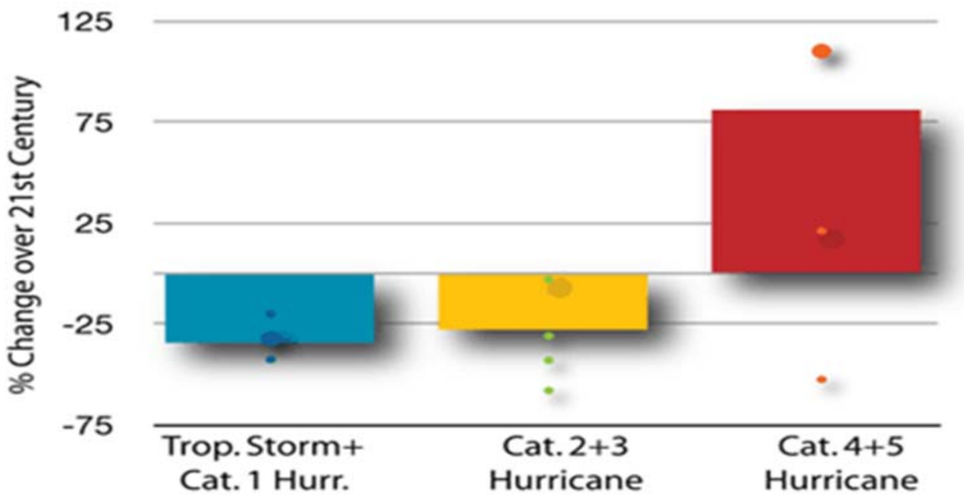

Figure 3. Graph of the projected hurricane changes over the 21st century.

These types of storms prove to be a great threat to Langley's facilities. The high winds and flooding can cause drastic damage to the infrastructure of the center. Therefore, the need for a method of protecting the center is essential in the coming years, especially if the trends of Figure 3 are realized.

3. Physics of Protective Windbreaks

Windbreaks can be defined as protective structures built to decrease wind flow to a specific area. There are different materials that are used to build these structures, but the most beneficial protection of Langley's facilities would be a tree windbreak. Tree windbreaks are composed of tree rows of different heights, densities, and properties that are arranged and positioned in a specific way to decrease winds. Figure 4 shows the schematic of how wind breaks work. The air hits the windbreak and some is slowed down by the barrier and passes through, and some is pushed over the top of the windbreak, leaving an area behind the windbreak of much lower wind speed.

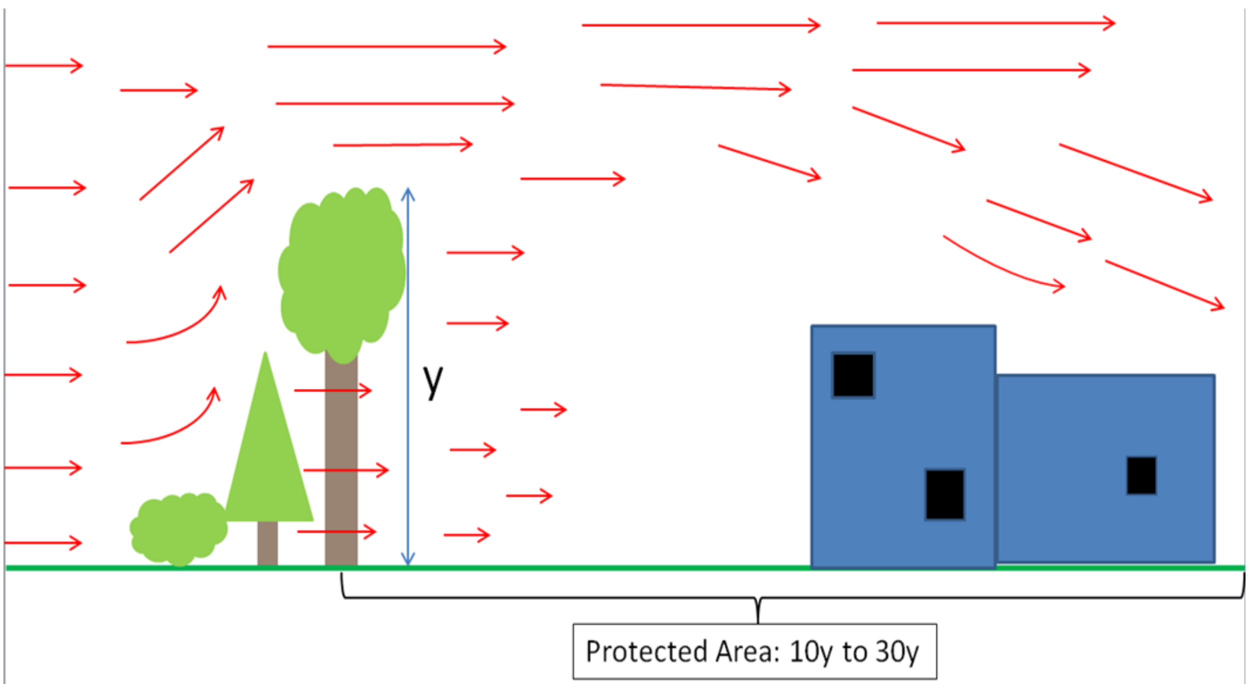

Figure 4. Windbreak Schematic

The keys to a successful tree windbreak are height and porosity. The length of protection that a wind break provides is a factor of the height of the tallest tree row ranging from 5 times the height on the windward side of the windbreak out to 30 times the height on the leeward side. The maximum wind reduction of a windbreak usually extends out to 10 times the height of the tallest tree row, but some reduction can extend out to 30 times the height. Figure 5 shows the relationship between windbreak tree height, x, the length of protection, and the amount of wind speed reduction [5].

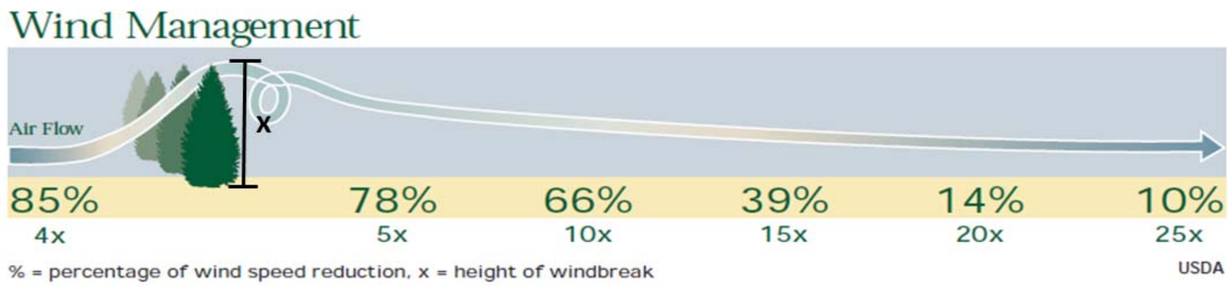

Figure 5. Wind management schematic that shows the relationship between wind speed reduction and height of windbreak. [5]

The density of the windbreak is important because of turbulence. If the structure is too dense, there is low porosity, forcing the wind over the trees and turbulently down the other side. The schematic in Figure 6 shows how the air flow changes with the density of the trees in a windbreak. When winds become turbulent they tend to create gusts of wind in different directions. When dealing with high speed winds, these gusts can become damaging to the infrastructure that the windbreak is meant to protect.

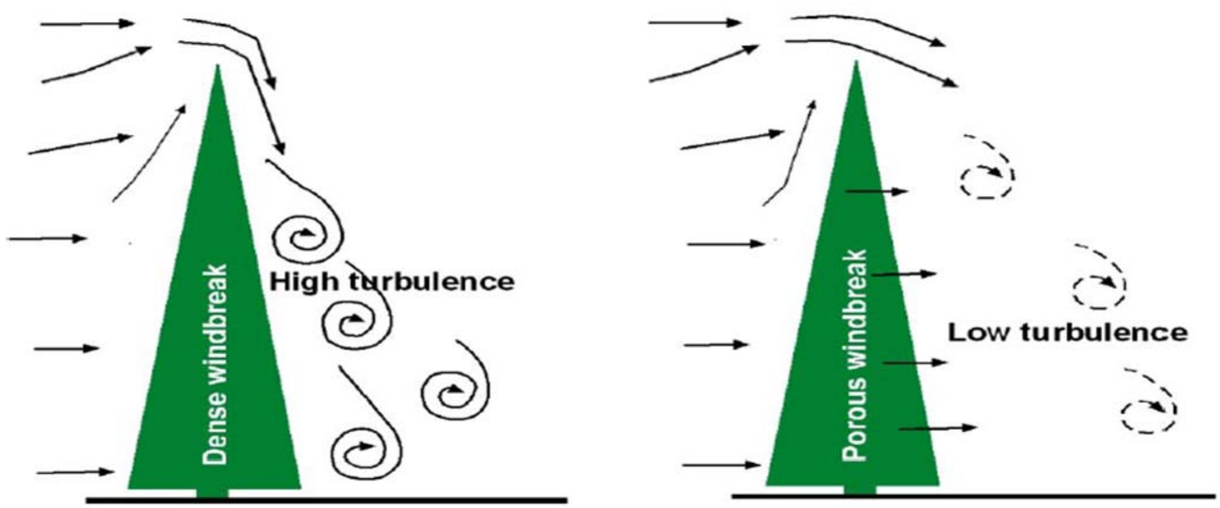

Figure 6. Diagram showing the turbulence caused by windbreaks that are too dense.

Wind breaks are most efficient when they have no openings, but if there are needs for breaks in the barrier for access points, they should be built in a specific way. In order to avoid wind tunnel effects within the windbreak, gaps should be angled so that the windbreak can still have an effect. Figure 7 below shows an example of appropriate angled gaps in a windbreak and an inappropriate straight cut gap.

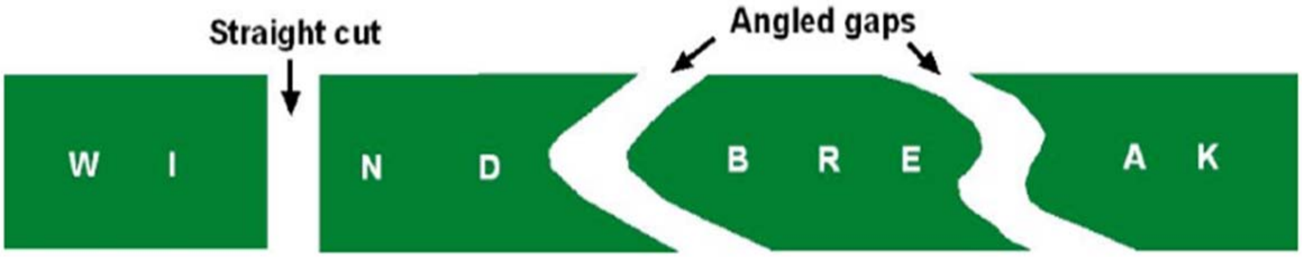

Figure 7. Diagram of the appropriate gaps for effective windbreaks.

The use of tree windbreaks to protect fields and infrastructure is not a new idea. There are many successful windbreaks being used to protect homes, farms, and crops across the country. Windbreaks can be used not only for a barrier against wind, but also for privacy and a shield from snow. Pictured in Figure 8, is a half mile long windbreak in Iowa that has been successfully protecting a crop field for 15 years. This windbreak design is composed of five rows [6].

Figure 8. Iowa Windbreak composed of red cedar, white pine, Norway and White spruce, along with 7 kinds of oaks [7].

Another successful wind break is pictured in Figure 9 protecting a farmstead. The angled trees create an area of protection for the infrastructures from wind and snow. This windbreak has been successfully used for 10 years [7].

Figure 9. Ten year old windbreak composed of white pine and honeysuckle. [7]

4. Preliminary Design of "New Town" Protective Windbreak

In order to efficiently protect Langley's "New Town" area from high winds, a windbreak design must have the following characteristics: Tall trees for maximum protection distance, sufficient porosity, fast growing trees that can sustain the Hampton Roads climate and adapt to Langley's soil. The placement of the windbreak should be determined by the wind direction of potential hurricane winds. Data from NOAA on past wind speeds and directions in the Chesapeake Bay area show that most high winds from storms over the last 20 years were from the northeast [8]. Figure 10 shows a wind rose of this data for the New Town area. The wind rose diagram pictured in Figure 10 shows the wind speed, direction, and frequency. The numbers along the x-axis of the diagram are assigned to a circle and represent the scale of how frequent each wind speed occurred in each direction over the past years.

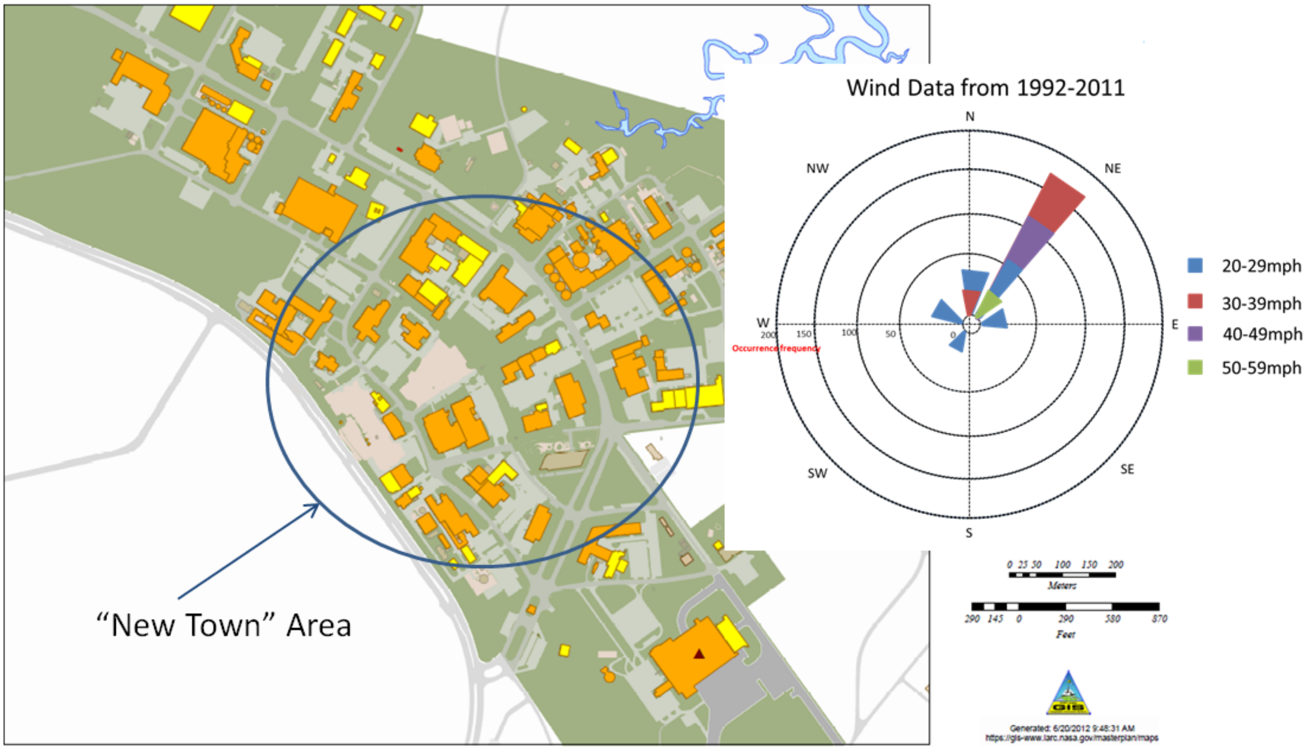

Figure 10. The Langley New Town area with respect to the directions of past high winds.

According to this wind data, the path for high winds is from the northeast. This means that the placement of the windbreak should be along the northeastern side of the facility. This works well with the “New Town” program because this is where the majority of the current infrastructure will be demolished for the renovation. A placement design for the wind break is shown on the map in Figure 11 along with the protection distances.

Falling trees must be considered when determining the placement of the windbreak. Winds from storms shown in figures 2 and 3 do not pose the threat of creating tree projectiles that could cause damage to infrastructure during a storm. A NOAA website describes the types of damage done to infrastructure and tree projectiles are only a threat with winds over 90 mph [9]. Therefore, Langley’s windbreak must be placed far enough away from infrastructure that it cannot cause damage because of falling trees.

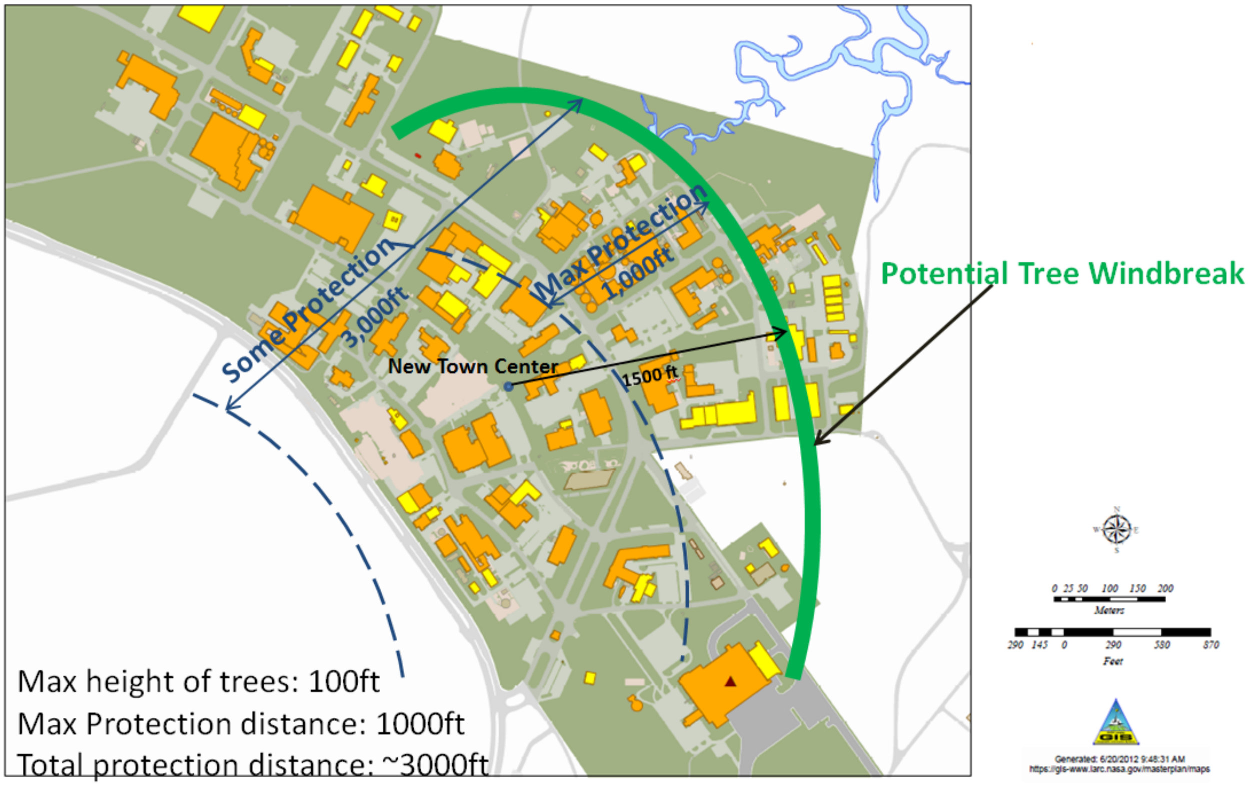

Figure 11. Possible placement of Langley windbreak providing protection of New Town area.

In order for this windbreak placement to be effective, the tallest tree row would be at least 100 feet, creating an overall protective length up to 3,000 feet. The other rows of trees will be used only to create the right density. The proposed design consists of four rows minimum of a mixture of dense conifers and tall broad leaf trees. Figure 12 shows the set-up of the rows within this windbreak design. The first two rows at the windward side (to the left) contain the shorter trees in the design, small to medium conifer rows that are spaced closer together. The next two rows are on the leeward side and consist of taller trees, and medium to tall broadleaf trees that are spaced a bit farther apart. This design is composed of dense and broad trees to create a good amount of porosity and the right height to protect the area needed. Adding double rows of the middle trees to thicken the windbreak can add to the effectiveness of the design.

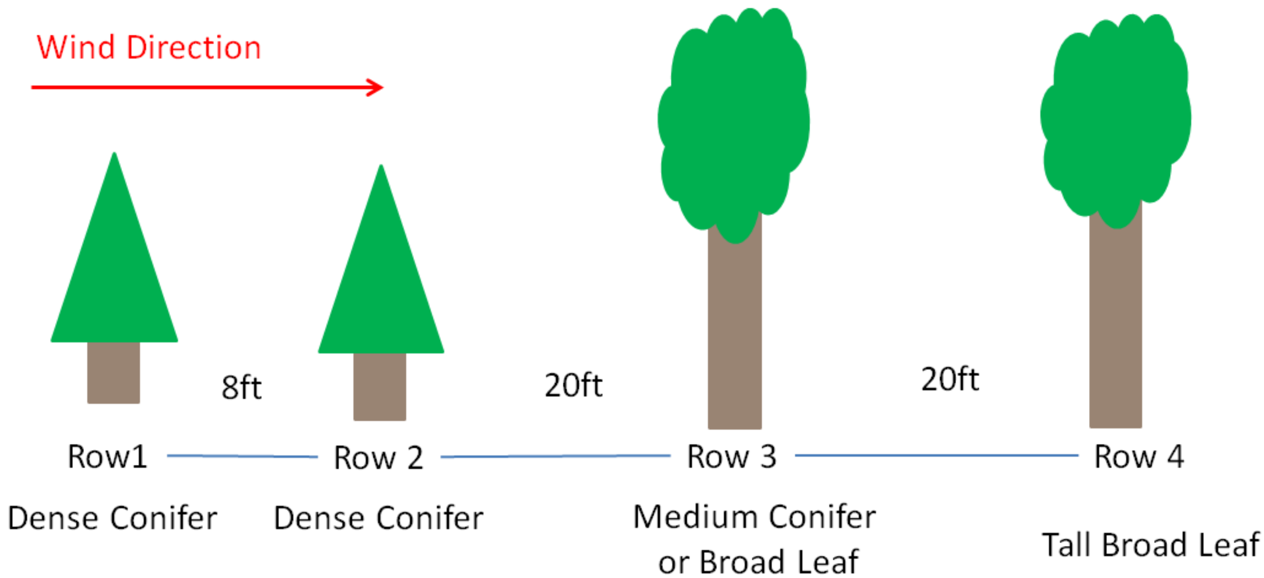

Figure 12. Langley Windbreak Potential 4-row Design.

The types of trees used for the windbreak must be carefully chosen in order to be effective. The trees must be indigenous or able to grow in the Virginia climate and medium to poorly drained soils because of the heavy flooding caused by hurricanes. They must be fast growing so that the windbreak can become effective as soon as possible. The trees must be durable enough to withstand the high winds that they will experience with the minimal amount of breaking. The trees proposed for this windbreak are as follows: Arborvitae, green ash, and black alder for the first two rows, and bald cypress, Norway spruce and American Sycamore for the last two rows. Table 1 below lists these selections along with the characteristics that make them qualify along with the cost ranges of the trees. Overall, the cost estimate of the trees in the windbreak can range from 13 to 19 thousand dollars according to arborday.org, fastgrowingtrees.com, windbreaktrees.com and tnnursery.net.

Row	1 Dense Conifer	2 Dense Conifer	3 Medium Conifer or Broad Leaf	4 Tall Broad Leaf
Tree(s)	Arborvitae	Green Ash or Black Alder	Bald Cypress or Norway Spruce	American Sycamore
Characteristics	50ft or less Fast growing Dense Poor-medium drained soils	50ft or more Fast growing Dense Poor-medium drained soils	80ft or more Fast growing Not as dense Poor-medium drained soils	100ft or more Fast growing Not as dense Poor-medium drained soils
Cost Range per tree	$3.00- $72.00	$0.55-$30.00	$4.00-$9.00	$50.00-$65.00
Estimated # of trees	355	355	236	236
Total cost range estimate	$887-$1,768	$196-$267	$944-$2,006	$11,672-$14,858
TOTAL ESTIMATE	**$13,000 to $19,000**			

Table 1. Recommended trees for the Langley windbreak that are indigenous to Virginia and have the required characteristics.

5. Conclusion

Langley Research Center is a value to not only the science community but the nation as a whole. The intense hurricanes projected for the future of Hampton Roads pose a threat to the center's infrastructure and research projects. The "New Town" Program plans to create an area of renovated and new buildings that are more condensed, creating an area of focus for protection in the center. The windbreak proposed is focused on protecting this new area, and should be able to be effective not long after the time of its completion. In addition to being a barrier for protecting Langley from wind, the tree windbreak can produce a few other benefits. It can help soak up water from flooding, beatify the campus and provide nature for walking trails, and create habitats for the wildlife on the center. The use of a well-designed tree windbreak barrier is a cost effective, environmentally friendly way to protect the center from inclement weather high winds of the future.

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14. ABSTRACT
The protection of NASA Langley Research Center from future hurricanes is important in order to allow the center to fulfill its mission. The impact of the center is not only great within NASA but the economy as well. The infrastructure of the Center is under potential risk in the future because of more intense hurricanes with higher speed winds and flooding. A potential method of protecting the Center's facilities is the placement of a windbreak barrier composed of indigenous trees. The "New Town" program that is now in progress creates a more condensed area of focus for protection. A potential design for an efficient tree windbreak barrier for Langley Research center is proposed.

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