10-Year Tree Maintenance and Planting Plan

Prepared for:

Virginia Tech

Prepared by:

Bartlett Consulting

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10-Year Tree Maintenance and Planting Plan
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Introduction

In January 2023, Jamie King, Urban Forest Manager and University Arborist for Virginia Tech, contacted Bartlett Tree Experts about developing 10-year maintenance and planting plans for the Virginia Tech campus urban forest. Bartlett was asked to build a roadmap for proactive tree care and increasing tree canopy cover to 25% by 2050.

The specific goal was to review campus resources including the existing campus tree inventory, urban tree canopy assessment, Geographic Information Systems (GIS) data layers, Urban Forest Master Plan and Campus Master Plan and further analyze the existing tree canopy. Findings from the analysis, along with industry standards, campus operational goals, and input from Virginia Tech about future needs would guide the recommendations in the maintenance and planting plans.

Assignment

Our assignment was to:

- Summarize the existing campus tree inventory
- Develop a routine tree maintenance plan focused on day-to-day tree care
  - Identify and create prioritized maintenance zones that consider proximity to grey infrastructure, occupancy, use, and tree population.
  - Identify tree population susceptibilities to biotic and abiotic pests/stresses and develop preservation plans for vulnerable tree specimens and stands
  - Develop detailed inspection and pruning cycles by maintenance zones
  - Develop and illustrate work plan expense projections for routine maintenance operations
- Develop a tree planting plan
  - Use the existing tree inventory to assess species diversity and tree population's vulnerability to the changing climate, biotic, and abiotic pests/stresses
  - Develop diversity thresholds for future planting to improve population resiliency
  - Analyze available planting spaces and develop a prioritized work plan with canopy expansion projections
  - Identify and illustrate opportunities for canopy expansion inside and beyond the highly urbanized campus considering known and future development plans such as the Campus Master Plan and utilizing insight from Virginia Tech about the feasibility of the individual projects
  - Develop a work plan with expense projections for planting initiatives towards a goal of increasing tree canopy cover by just over 10% by 2050. Include three options: ideal, moderate, and minimal planting intensities
  - Design an installation and establishment program for tree planting with three scalable options for the ideal, moderate, and minimal planting initiatives.
  - Illustrate the added maintenance burden of the defined canopy expansion planting programs.

Limits of the Assignment

These plans rely on data provided by Virginia Tech. As a result, it is limited to and by analysis of health and structure data, with reliance on data provided without professional verification by Bartlett Consulting.

This assignment was not a Tree Risk Assessment as defined by industry standards. The owner/client should not infer that any information contained in, or absent from, the inspection, report, or deliverable material is meant to declare a tree or group of trees to be “safe” or the risk of failure mitigated in any way.

Bartlett Consulting used several means and methods to provide tree locations on maps, sketches, or drawings, and the use of tree locations on maps, sketches, diagrams, and/or in pictures are intended to aid the Client in understanding the deliverables provided, and may not be to scale and should not be considered precise locations, engineering surveys, or architectural drawings.

Bartlett Consulting used one or more software, or other programs, developed by other companies or government agencies, which are designed to help provide estimates on the environmental benefits of trees, shrubs, or other plant materials. The Client understands that any such method, software, type, year, or version used is meant to provide a sound, scientific method to help the Client understand the environmental benefits of the collected data.

Acknowledgements

Key team members involved in the development of this report are listed below:

- Darya Barar, Managing Consulting Urban Forester, HortScience | Bartlett Consulting
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- Jamie King, Urban Forest Manager & University Arborist, Virginia Tech
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- Adam Braaten, Local Manager, Bartlett Tree Experts
- Dr. Chris Riley, Research Scientist & Technical Support Specialist, Bartlett Tree Research Laboratories

Summary of Existing Campus Tree Inventory

The existing campus tree inventory at Virginia Tech has been developed over several years, primarily with inputs from students and interns. Data is often captured during the summer break and updates are focused on areas of new plantings or new development.

For this analysis, the inventory was limited to trees located within the districts outlined in the Campus Master Plan, plus the area to the west of Lane Stadium known as Stadium Woods. There were a total of 10,786 trees within these boundaries. Overall, the tree population on campus was inventoried in good health (63% of the population) and immature in age (67% of the population). The following sections summarize the information collected in the tree inventory.

Tree Species Breakdown

The inventory revealed 263 tree species with sugar maple (*Acer saccharum*) being the most populous (Table 1). In general, and when feasible, it is recommended that a site not have more than 10% of its trees represented by a specific tree species and not more than 20% represented by a single genus. Diversity in tree species assists with the longevity and sustainability of the tree population on a site. When replanting on the site occurs, we recommend referencing this table and selecting tree species that are not already amongst the most populous to increase diversity.

TABLE 1: TREE SPECIES BREAKDOWN

Species	Count	% Distribution Total
Abies	**13**	**0.1%**
(fir)	1	0.0%
concolor (white fir)	8	0.1%
fraseri (Fraser fir)	4	0.0%
Acer	**1337**	**12.4%**
(maple)	8	0.1%
buergerianum (trident maple)	28	0.3%
campestre (hedge maple)	42	0.4%
ginnala (Amur maple)	20	0.2%
griseum (paperbark maple)	19	0.2%
henryi (Henry maple)	1	0.0%
miyabei (maple)	4	0.0%
negundo (boxelder)	54	0.5%
nigrum (black maple)	44	0.4%
palmatum (Japanese maple)	81	0.8%
pensylvanicum (striped maple)	2	0.0%
platanoides (Norway maple)	116	1.1%
pseudoplatanus (sycamore maple)	1	0.0%
rubrum (red maple)	399	3.7%
saccharinum (silver maple)	12	0.1%
saccharum (sugar maple)	496	4.6%

Species	Count	% Distribution Total
x freemanii (Freeman maple)	9	0.1%
tataricum (Tatar maple)	1	0.0%
Aesculus	**35**	**0.3%**
(buckeye)	13	0.1%
flava (yellow buckeye)	3	0.0%
hippocastanum (horsechestnut)	3	0.0%
parviflora (bottlebrush buckeye)	10	0.1%
x carnea (red horsechestnut)	5	0.0%
x woerlitzensis (buckeye)	1	0.0%
Alnus	**12**	**0.1%**
(alder)	12	0.1%
Amelanchier	**286**	**2.7%**
(serviceberry)	241	2.2%
arborea (downy serviceberry)	24	0.2%
canadensis (serviceberry)	3	0.0%
laevis (serviceberry)	1	0.0%
x grandiflora (serviceberry)	17	0.2%
Asimina	**3**	**0.0%**
triloba (pawpaw)	3	0.0%
Betula	**197**	**1.8%**
(birch)	9	0.1%
alleghaniensis (yellow birch)	2	0.0%
lenta (black birch)	14	0.1%
nigra (river birch)	148	1.4%
papyrifera (paper birch)	15	0.1%
populifolia (gray birch)	8	0.1%
utilis (Asian white birch)	1	0.0%
Buxus	**2**	**0.0%**
(boxwood)	2	0.0%
Callitropsis	**7**	**0.1%**
nootkatensis (Alaska cedar)	7	0.1%
Calocedrus	**1**	**0.0%**
decurrens (incense cedar)	1	0.0%
Camellia	**1**	**0.0%**
japonica (camellia)	1	0.0%
Carpinus	**89**	**0.8%**
betulus (European hornbeam)	30	0.3%
caroliniana (American hornbeam)	57	0.5%
japonica (Japanese hornbeam)	2	0.0%
Carya	**76**	**0.7%**
(hickory)	12	0.1%
cordiformis (bitternut hickory)	10	0.1%

Species	Count	% Distribution Total
glabra (pignut hickory)	22	0.2%
laciniosa (shellbark hickory)	3	0.0%
ovata (shagbark hickory)	11	0.1%
tomentosa (mockernut hickory)	18	0.2%
Castanea	**9**	**0.1%**
dentata (American chestnut)	4	0.0%
mollissima (Chinese chestnut)	5	0.0%
Catalpa	**28**	**0.3%**
(catalpa)	2	0.0%
bignonioides (southern catalpa)	16	0.1%
speciosa (northern catalpa)	10	0.1%
Cedrus	**13**	**0.1%**
atlantica (atlas cedar)	9	0.1%
deodara (deodar cedar)	4	0.0%
Celtis	**50**	**0.5%**
laevigata (sugarberry)	1	0.0%
occidentalis (hackberry)	49	0.5%
Cephalotaxus	**1**	**0.0%**
harringtonia (plum yew)	1	0.0%
Cercidiphyllum	**16**	**0.1%**
japonicum (katsura tree)	16	0.1%
Cercis	**127**	**1.2%**
canadensis (eastern redbud)	126	1.2%
chinensis (Chinese redbud)	1	0.0%
Chamaecyparis	**26**	**0.2%**
obtusa (hinoki cypress)	5	0.0%
obtusa 'Tempelhof' (Tempelhof hinoki cypress)	2	0.0%
pisifera (sawara false cypress)	19	0.2%
Chionanthus	**32**	**0.3%**
retusus (Chinese fringe tree)	2	0.0%
virginicus (fringe tree)	30	0.3%
Cladrastis	**83**	**0.8%**
kentukea (yellowwood)	83	0.8%
Cornus	**329**	**3.1%**
(dogwood)	10	0.1%
× rutgersensis (hybrid dogwood)	5	0.0%
alternifolia (alternateleaf dogwood)	5	0.0%
florida (flowering dogwood)	193	1.8%
kousa (kousa dogwood)	102	0.9%
mas (Cornelian cherry)	10	0.1%
x (dogwood)	1	0.0%
x elwinortonii Venus® (Venus dogwood)	3	0.0%

Species	Count	% Distribution Total
Cotinus	**2**	**0.0%**
coggygria (smoke tree)	2	0.0%
Crataegus	**110**	**1.0%**
(hawthorn)	59	0.5%
mollis (downy hawthorn)	1	0.0%
phaenopyrum (Washington hawthorn)	1	0.0%
viridis (green hawthorn)	48	0.4%
x lavallei (carriere hawthorn)	1	0.0%
Cryptomeria	**22**	**0.2%**
japonica (Japanese red cedar)	22	0.2%
Cunninghamia	**1**	**0.0%**
lanceolata (unlisted tree)	1	0.0%
Cupressus	**106**	**1.0%**
arizonica (Arizona cypress)	105	1.0%
sempervirens (leyland cypress)	1	0.0%
Diospyros	**4**	**0.0%**
virginiana (common persimmon)	4	0.0%
Elaeagnus	**2**	**0.0%**
umbellata (autumn olive)	2	0.0%
Eucommia	**4**	**0.0%**
ulmoides (hardy rubber tree)	4	0.0%
Fagus	**133**	**1.2%**
grandifolia (American beech)	96	0.9%
sylvatica (European beech)	37	0.3%
Firmiana	**1**	**0.0%**
simplex (Chinese parasoltree)	1	0.0%
Fraxinus	**132**	**1.2%**
(ash)	3	0.0%
americana (white ash)	90	0.8%
excelsior (European ash)	7	0.1%
pennsylvanica (green ash)	32	0.3%
Ginkgo	**61**	**0.6%**
biloba (ginkgo)	61	0.6%
Gleditsia	**48**	**0.4%**
triacanthos (honeylocust)	48	0.4%
Gymnocladus	**43**	**0.4%**
dioicus (Kentucky coffeetree)	43	0.4%
Halesia	**13**	**0.1%**
carolina (snowdrop tree)	7	0.1%
tetraptera (mountain silverbell)	6	0.1%
Hamamelis	**26**	**0.2%**
virginiana (witch hazel)	18	0.2%

Species	Count	% Distribution Total
x intermedia (witch hazel)	7	0.1%
x intermedia 'Angelly' (witch hazel)	1	0.0%
Hydrangea	**6**	**0.1%**
paniculata (panicle hydrangea)	3	0.0%
paniculata 'Grandiflora' (panicle hydrangea)	3	0.0%
Ilex	**122**	**1.1%**
(American holly)	2	0.0%
(holly)	7	0.1%
aquifolium (English holly)	1	0.0%
cornuta (Chinese holly)	3	0.0%
opaca (American holly)	83	0.8%
vomitoria (yaupon)	2	0.0%
x attenuata (topal holly)	24	0.2%
Juglans	**313**	**2.9%**
cinerea (butternut)	2	0.0%
nigra (black walnut)	311	2.9%
Juniperus	**206**	**1.9%**
(juniper)	2	0.0%
virginiana (eastern red cedar)	204	1.9%
Koelreuteria	**13**	**0.1%**
paniculata (goldenrain tree)	13	0.1%
Laburnum	**12**	**0.1%**
anagyroides (golden chain tree)	12	0.1%
Lagerstroemia	**99**	**0.9%**
(crapemyrtle)	15	0.1%
indica (crapemyrtle)	84	0.8%
Larix	**22**	**0.2%**
decidua (European larch)	22	0.2%
Ligustrum	**2**	**0.0%**
sinense (Chinese privet)	2	0.0%
Liquidambar	**105**	**1.0%**
styraciflua (sweetgum)	105	1.0%
Liriodendron	**139**	**1.3%**
tulipifera (tulip tree)	139	1.3%
Lonicera	**1**	**0.0%**
(honeysuckle)	1	0.0%
Maackia	**8**	**0.1%**
amurensis (Amur maackia)	8	0.1%
Maclura	**3**	**0.0%**
pomifera (Osage orange)	3	0.0%
Magnolia	**164**	**1.5%**
(magnolia)	52	0.5%

Species	Count	% Distribution Total
acuminata (cucumber tree)	5	0.0%
grandiflora (southern magnolia)	68	0.6%
stellata (star magnolia)	1	0.0%
tripetala (umbrella magnolia)	1	0.0%
virginiana (sweetbay)	17	0.2%
x soulangeana (saucer magnolia)	19	0.2%
(mag)	1	0.0%
Magnoliopsida	**19**	**0.2%**
(tree hardwood)	19	0.2%
Malus	**196**	**1.8%**
(apple)	22	0.2%
(crabapple)	168	1.6%
angustifolia (southern crabapple)	4	0.0%
pumila (apple)	2	0.0%
Metasequoia	**53**	**0.5%**
glyptostroboides (dawn redwood)	53	0.5%
Morus	**24**	**0.2%**
(mulberry)	1	0.0%
alba (white mulberry)	1	0.0%
rubra (red mulberry)	22	0.2%
Nyssa	**125**	**1.2%**
biflora (swamp tupelo)	1	0.0%
sinensis (Chinese tupelo)	5	0.0%
sylvatica (black tupelo)	119	1.1%
Ostrya	**34**	**0.3%**
virginiana (eastern hophornbeam)	34	0.3%
Parrotia	**20**	**0.2%**
persica (Persian ironwood)	20	0.2%
Paulownia	**1**	**0.0%**
tomentosa (royal paulownia)	1	0.0%
Phellodendron	**24**	**0.2%**
amurense (Amur corktree)	24	0.2%
Photinia	**1**	**0.0%**
villosa (christmas berry)	1	0.0%
Physocarpus	**6**	**0.1%**
opulifolius (diabolo ninebark)	6	0.1%
Picea	**328**	**3.0%**
(spruce)	2	0.0%
abies (Norway spruce)	195	1.8%
glauca (white spruce)	10	0.1%
pungens (blue spruce)	120	1.1%
rubens (red spruce)	1	0.0%

Species	Count	% Distribution Total
Pinopsida	**5**	**0.0%**
(tree softwood)	5	0.0%
Pinus	**560**	**5.2%**
(pine)	13	0.1%
echinata (shortleaf pine)	1	0.0%
flexilis (limber pine)	2	0.0%
mugo (pine)	1	0.0%
nigra (Austrian pine)	42	0.4%
palustris (longleaf pine)	8	0.1%
parviflora (Japanese white pine)	7	0.1%
pungens (table mountain pine)	4	0.0%
resinosa (red pine)	4	0.0%
rigida (pitch pine)	1	0.0%
strobus (eastern white pine)	399	3.7%
sylvestris (scotch pine)	25	0.2%
taeda (loblolly pine)	6	0.1%
thunbergii (Japanese black pine)	26	0.2%
virginiana (Virginia pine)	21	0.2%
Pistacia	**3**	**0.0%**
chinensis (Chinese pistache)	3	0.0%
Platanus	**266**	**2.5%**
occidentalis (American sycamore)	37	0.3%
x hispanica (London plane)	229	2.1%
Platycladus	**3**	**0.0%**
orientalis (Oriental arborvitae)	1	0.0%
orientalis 'Aurea Nana' (Oriental arborvitae)	2	0.0%
Poncirus	**1**	**0.0%**
trifoliata (trifoliate orange)	1	0.0%
Populus	**3**	**0.0%**
deltoides (eastern cottonwood)	1	0.0%
grandidentata (bigtooth aspen)	1	0.0%
(poplar)	1	0.0%
Prunus	**997**	**9.2%**
(ornamental cherry)	207	1.9%
(plum)	2	0.0%
avium (sweet cherry)	428	4.0%
cerasifera (flowering plum)	1	0.0%
serotina (black cherry)	313	2.9%
serrulata (kwanzan cherry)	34	0.3%
subhirtella (higan cherry)	4	0.0%
x yedoensis (yoshino flowering cherry)	8	0.1%
Pseudolarix	**2**	**0.0%**

Species	Count	% Distribution Total
amabilis (golden larch)	2	0.0%
Pseudotsuga	**13**	**0.1%**
menziesii (douglas fir)	13	0.1%
Pyrus	**65**	**0.6%**
(pear)	7	0.1%
calleryana (callery pear)	58	0.5%
Quercus	**1801**	**16.7%**
(oak)	9	0.1%
acutissima (sawtooth oak)	63	0.6%
alba (white oak)	429	4.0%
bicolor (swamp white oak)	169	1.6%
coccinea (scarlet oak)	82	0.8%
ellipsoidalis (northern pin oak)	2	0.0%
falcata (southern red oak)	3	0.0%
hemisphaerica (Darlington oak)	3	0.0%
imbricaria (shingle oak)	4	0.0%
lyrata (overcup oak)	34	0.3%
macrocarpa (bur oak)	59	0.5%
michauxii (swamp chestnut oak)	83	0.8%
montana (chestnut oak)	5	0.0%
nigra (water oak)	10	0.1%
palustris (pin oak)	96	0.9%
phellos (willow oak)	166	1.5%
robur (English oak)	2	0.0%
rubra (northern red oak)	297	2.8%
shumardii (shumard oak)	9	0.1%
texana (nuttall oak)	23	0.2%
velutina (black oak)	252	2.3%
x saulii (Saul's oak)	1	0.0%
Rhus	**1**	**0.0%**
(sumac)	1	0.0%
Robinia	**245**	**2.3%**
pseudoacacia (black locust)	245	2.3%
Salix	**17**	**0.2%**
(willow)	11	0.1%
babylonica (Wisconsin weeping willow)	3	0.0%
nigra (black willow)	3	0.0%
Sambucus	**1**	**0.0%**
nigra ssp. canadensis (common elderberry)	1	0.0%
Sassafras	**55**	**0.5%**
albidum (sassafras)	55	0.5%
Stewartia	**4**	**0.0%**

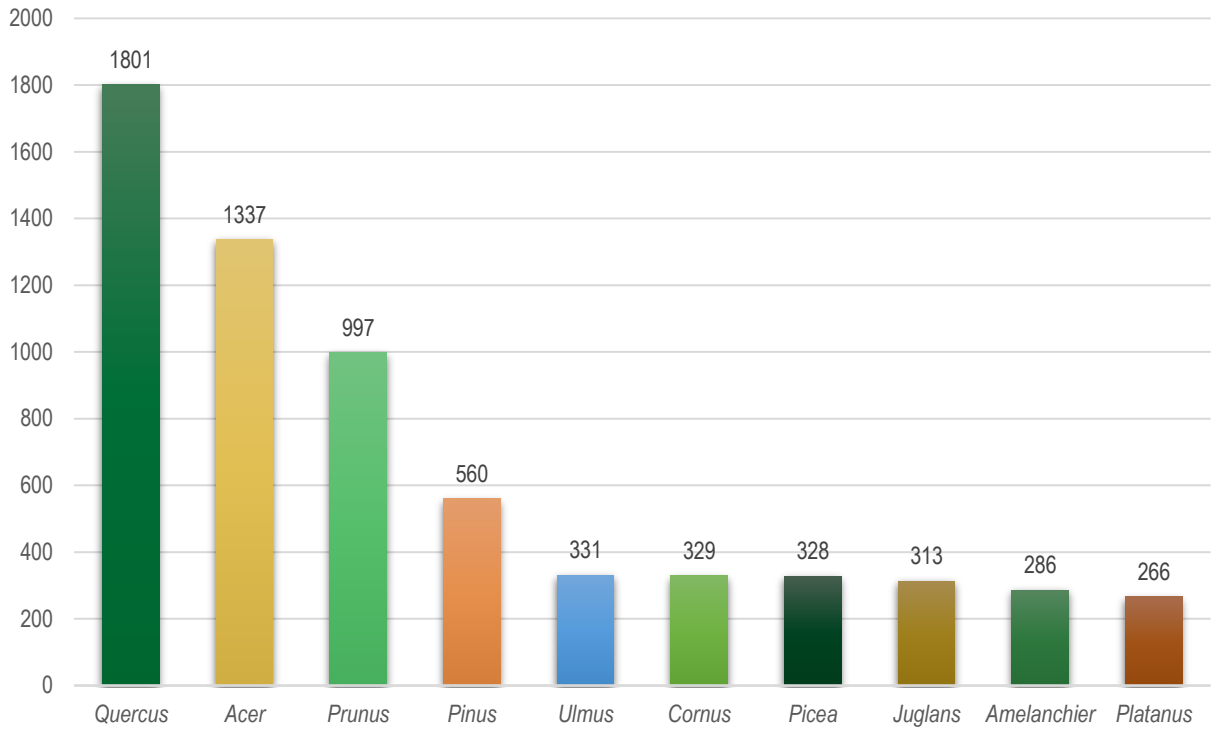
Species	Count	% Distribution Total
monadelpha (tall stewartia)	1	0.0%
pseudocamellia (Japanese stewartia)	3	0.0%
Styphnolobium	**9**	**0.1%**
japonicum (Japanese pagoda tree)	9	0.1%
Styrax	**14**	**0.1%**
japonicus (Japanese snowbell)	13	0.1%
obassia (fragrant snowbell)	1	0.0%
Syringa	**8**	**0.1%**
(Japanese tree lilac)	2	0.0%
(lilac)	1	0.0%
reticulata (Japanese tree lilac)	5	0.0%
Taxodium	**178**	**1.7%**
distichum (baldcypress)	178	1.7%
Taxus	**16**	**0.1%**
(yew)	16	0.1%
Tetradium	**3**	**0.0%**
daniellii (Korean evodia)	3	0.0%
Thuja	**239**	**2.2%**
(arborvitae)	13	0.1%
occidentalis (northern white cedar)	223	2.1%
plicata (western red cedar)	2	0.0%
(Atlanitc white cedar)	1	0.0%
Thujopsis	**1**	**0.0%**
dolobrata 'Koreanum' (hiba)	1	0.0%
Tilia	**185**	**1.7%**
americana (American basswood)	20	0.2%
cordata (littleleaf linden)	148	1.4%
petiolaris (silver linden)	14	0.1%
x euchlora (Crimean linden)	3	0.0%
Tsuga	**74**	**0.7%**
canadensis (eastern hemlock)	70	0.6%
chinensis (Chinese hemlock)	1	0.0%
sieboldii (southern japanese hemlock)	3	0.0%
Ulmus	**331**	**3.1%**
(elm)	2	0.0%
alata (winged elm)	1	0.0%
americana (American elm)	138	1.3%
glabra 'Camperdownii' (camperdown elm)	1	0.0%
parvifolia (Chinese elm)	140	1.3%
procera (English elm)	6	0.1%
pumila (Siberian elm)	6	0.1%
rubra (slippery elm)	10	0.1%

Species	Count	% Distribution Total
thomasii (rock elm)	1	0.0%
x 'Cathedral' (cathedral elm)	25	0.2%
x hollandica (Dutch elm)	1	0.0%
Viburnum	**6**	**0.1%**
(viburnum)	1	0.0%
prunifolium (black haw)	5	0.0%
Zelkova	**70**	**0.6%**
serrata (Japanese zelkova)	70	0.6%
Ziziphus	**1**	**0.0%**
jujuba (indian jujube)	1	0.0%
x Hesperotropsis	**82**	**0.8%**
leylandii (leyland cypress)	82	0.8%
Grand Total	**10786**	**100.0%**

Top Ten Genera

The following chart summarizes the top ten genera within the inventory. *Quercus, Acer, Prunus,* and *Pinus* combine for nearly half (44%) of the entire inventory population.

GRAPH 1: TOP TEN GENERA



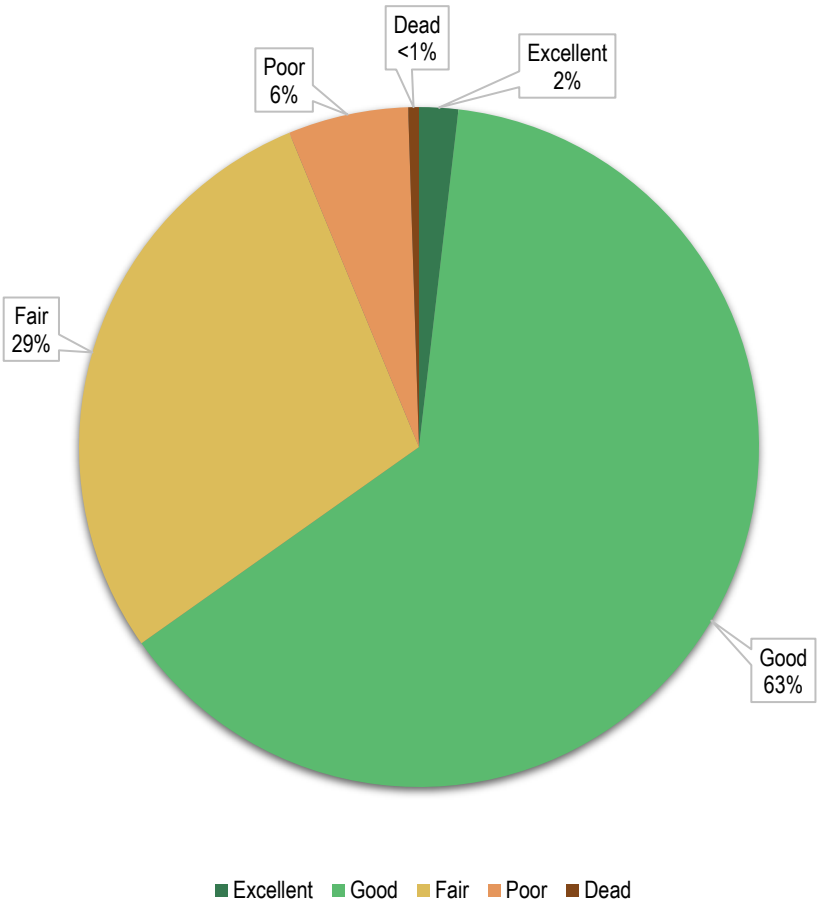
Health Class

Sixty-five percent (65%) of the tree population was assigned either an excellent or good health class rating (Table 2 and Graph 2). Trees in fair health made up 29% of the population. In general, trees in good health are better suited to live longer and require less maintenance over time. Trees in fair health can generally increase to good with proper maintenance. Even with proper maintenance, it may not be possible to elevate a tree in poor condition to one in good.

TABLE 2: HEALTH CLASS DISTRIBUTION

Health Class	Quantity	% of Population
Excellent	200	2%
Good	6833	63%
Fair	3081	29%
Poor	617	6%
Dead	55	<1%

GRAPH 2: HEALTH CLASS DISTRIBUTION GRAPH



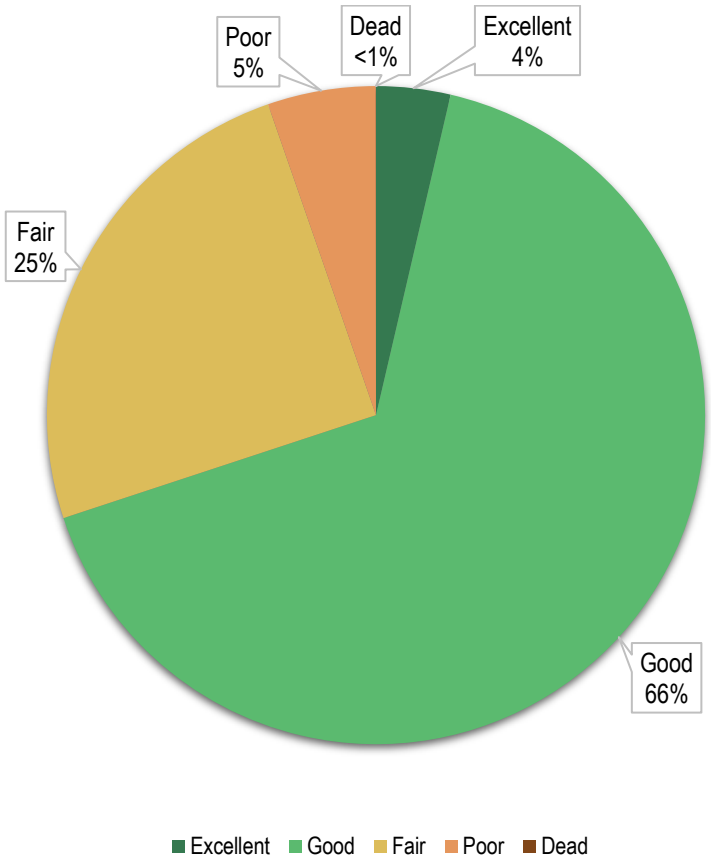
Structure Class

Seventy percent (70%) of the tree population was assigned either an excellent or good structural condition rating (Table 3 and Graph 3). Trees with fair structure made up 25% of the population. In general, trees in fair structural condition can be mitigated with proper pruning practices, but trees in poor structural condition will likely need to be removed.

TABLE 3: STRUCTURE CLASS DISTRIBUTION

Structure Class	Quantity	% of Population
Excellent	200	4%
Good	6833	66%
Fair	3081	25%
Poor	617	5%
Dead	55	<1%

GRAPH 3: STRUCTURE CLASS DISTRIBUTION GRAPH



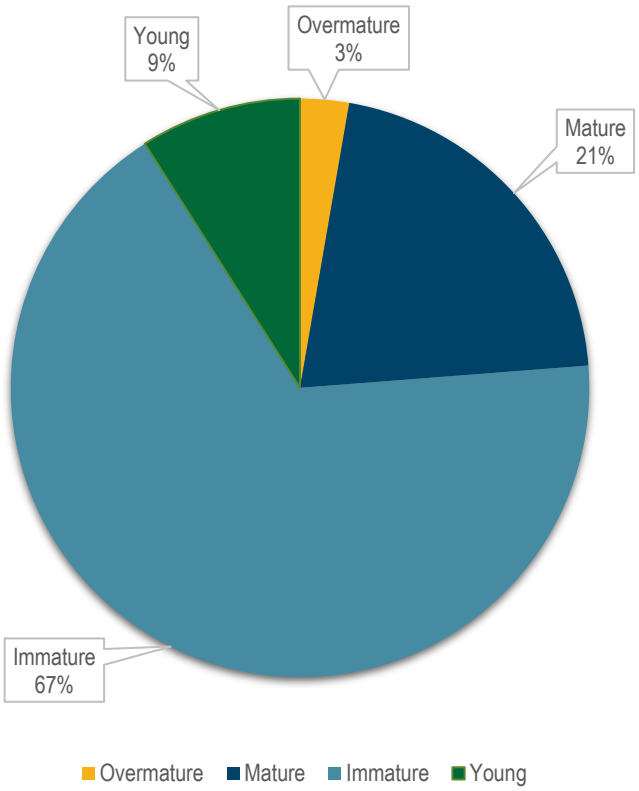
Age Class

Along with monitoring the condition of trees on campus, it is important to understand the age class or stage of development. Seventy six percent (76%) of the population was classified as immature or young in age while only 3% were classified as overmature (Table 4 and Graph 4). Typically, to have a sustainable tree population, the age class distribution should have the majority of trees in the young categories followed by immature then mature. The fewest trees should fall in the overmature category. This distribution assists managers with planning for the future knowing that not all trees planted will make it to maturity due to challenging growing conditions in the urban environment and other external limitations.

TABLE 4: AGE CLASS DISTRIBUTION

Age Class	Quantity	% of Population
Overmature	294	3%
Mature	2270	21%
Immature	7250	67%
Young	972	9%

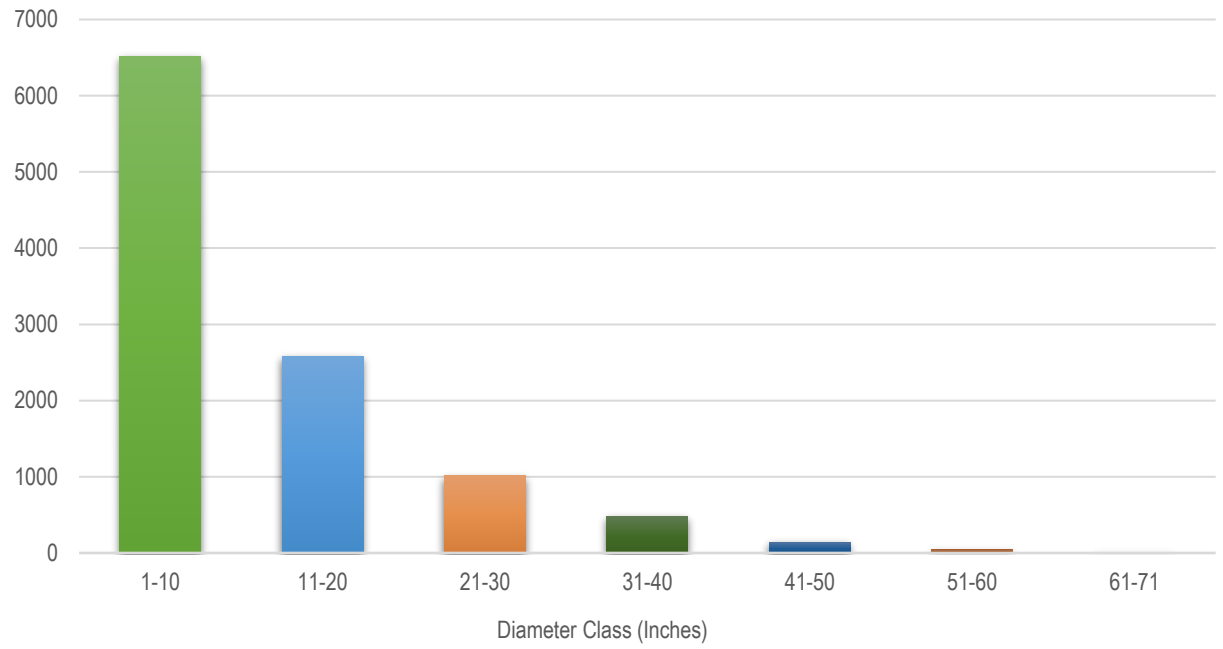
GRAPH 4: AGE CLASS DISTRIBUTION GRAPH



Trunk Diameter

As with health and age class, knowing tree trunk diameters provides important information about trees. Sixty percent (60%) of the tree population had a trunk diameter of 10 inches or less (Graph 5) Smaller trunk diameters generally equate to younger trees. Similar to age class, it is recommended that there be plenty of smaller trees on a site to provide a greater chance of maintaining the overall population as trees develop, die or are removed.

GRAPH 5: TREE DIAMETER DISTRIBUTION GRAPH



Environmental Benefits

The i-Tree Eco Version 6 application was used to analyze the environmental benefits provided by the trees in the Virginia Tech campus tree inventory. The results of that analysis are summarized in the following table:

TABLE 5: I-TREE ECO ENVIRONMENTAL ANALYSIS RESULTS

Environmental Benefit	Amount	Value
Total Pollution Removal	1.868 tons/year	$5.26 thousand/year
Carbon Storage	6.06 thousand tons	$1.03 million
Carbon Sequestration	70.82 tons/year	$12.1 thousand/year
Oxygen Production	188.8 tons/year	…
Avoided Runoff	2.088 million gallons/year	$18.7 thousand/year

Maintenance Plan

As a global leader in urban forestry education, Virginia Tech is well-informed on the benefits of urban trees and the costs associated with mismanagement or neglectful management.

Purposeful, directed, and proactive maintenance of trees in the built environment is essential to ensuring that Virginia Tech's campus trees remain healthy and structurally sound, and to avoid potential conflicts within the built campus environment. An appropriately directed and funded maintenance plan ensures that the campus urban forest can retain and increase its asset value over time. A well-maintained campus urban forest is one that is supported to succeed. We believe that a successful campus urban forest is one that is capable of providing well-understood socio-ecological, environmental, and economic benefits to the university; its students, staff, and faculty; and other communities throughout the town of Blacksburg and Montgomery County.

Virginia Tech urban forestry staff retained Bartlett Consulting to produce a 10-year (2024 to 2034) campus-wide maintenance plan for the campus urban forest. The focus of maintenance planning is on management priorities, including both reactive and proactive arboricultural and urban forestry works. Included in this plan are projections of realistic costs for maintenance. This plan includes considerations for the following criteria:

- Maintenance zones, with zones prioritized considering infrastructure, occupancy, and use.
- Integrated pest management, considering tree health and tree population vulnerability, and developing preservation plans for vulnerable tree specimens and stands.
- Pruning cycles, providing detailed pruning cycles within maintenance zones.
- Work planning, providing cost projections for routine maintenance operations.

This plan includes twenty-four (24) university districts within the urban forest management area on campus. Of the twenty-four districts, twenty-two (22) contain trees that were inventoried and included in the Department of Forest Resources & Environmental Conservation's 2018 Inventory and Analysis report. Our team worked with a slightly modified and reduced dataset of 10,786 of these inventoried trees (see Existing Tree Inventory Data Modification Summary in Appendices) ; this dataset is the foundation for the analysis conducted in this maintenance plan.

Each university district included in the urban forest management area is considered a maintenance zone. Identifying and creating maintenance zones to match university districts allows for this 10-year urban forest routine maintenance plan to retain consistency and to be used in conjunction with the current *Campus Master Plan*, including campus development, and the existing *Urban Forest Master Plan*.

Maintenance Evaluation Methods

Maintenance Evaluation Methods Concepts

We evaluated management prioritization at individual tree and per-district scales through the creation of two primary composite indices – a *Priority Tree Index* and a *Priority District Index*.

A composite index is a data analysis method by which multiple variables (indicators) are combined to create a single index variable. Indices offer opportunities to more easily interpret datasets that contain many variables that may otherwise be difficult to measure, with interpretable metrics allowing managers to make informed decisions with increased ease.

Examples of composite indices tree managers may be aware of range from simple – i.e., the *ISA Tree Risk Assessment Qualification (TRAQ) Risk Rating methodology (Matrices 1 and 2)* and various tree condition rating models (*Purdue Table 1*) – to more complex – i.e., *American Forest's Tree Equity Score* or the *Relative Performance Index*.

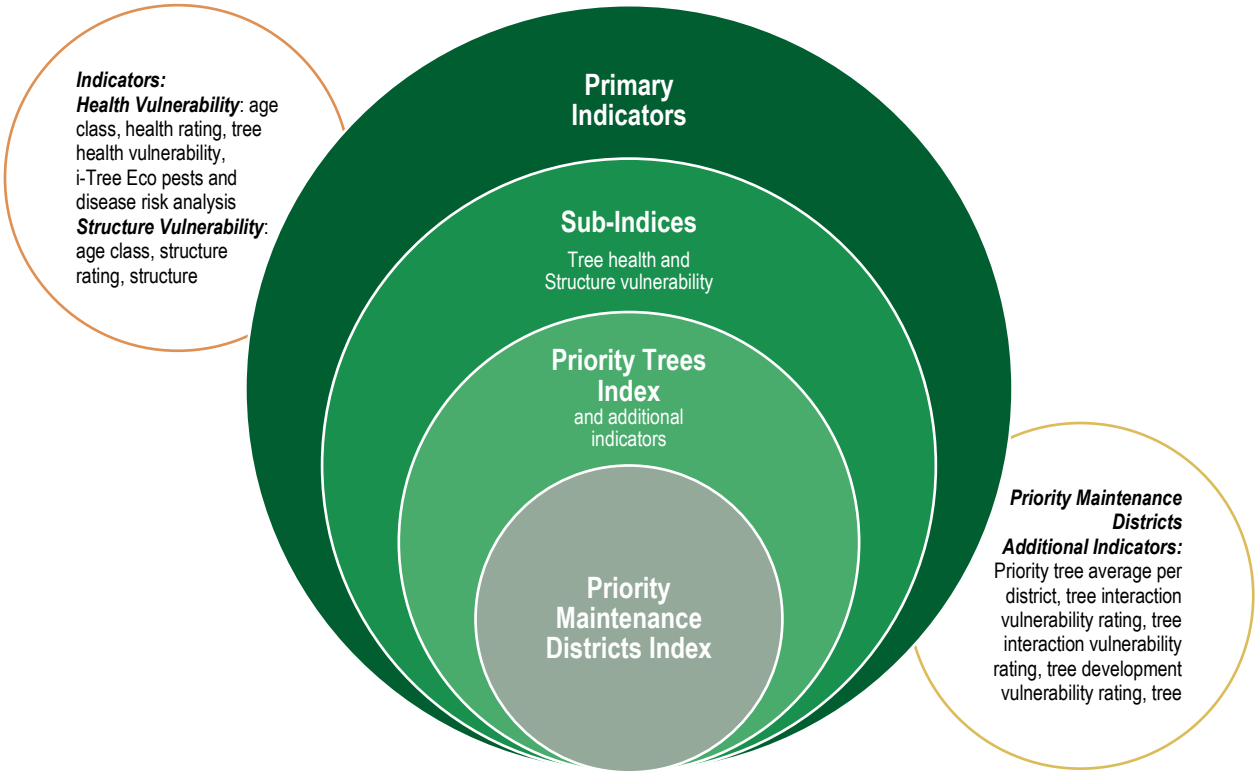


FIGURE 1: OVERVIEW OF ANALYSIS PROCESS

Primary Indicators

Our base-level datasets included provided and derived data. Virginia Tech management provided tree inventory and University district geospatial data; these sets of data included base-level characteristics on tree location, species, size, age, and condition. We derived other base-level data through surveys distributed to Virginia Tech stakeholders and local Bartlett arborists, as well as external sources such as i-Tree Eco Analysis.

Inventory Data (provided)
Tree inventory attributes provided by Virginia Tech that were used in our indices analysis included:

- Age Class
- Health
- Structure

Descriptions and definitions of these data can be found in the Virginia Tech Inventory and Analysis of Landscape Trees and Urban Forest on the Main Campus of Virginia Tech (*2018*), *Appendix B; Inventory Data Model (P. 42) and Tree Health and Structure Ratings (p. 50)*)

Supplemental Data (derived)
We incorporated supplemental data that we felt were valuable additional indicators for our indices. Descriptions and definitions of survey and i-Tree Data can be found in the Appendix (Tree Maintenance Districts Survey Summary and Results, Tree Health and Structure Survey Summary and Results, and i-Tree Ecosystem Analysis Report). Supplemental data includes:

- Survey Data
    - Tree health vulnerability
    - Tree structure vulnerability
    - Tree interaction vulnerability
    - Tree development vulnerability
    - Tree importance
- i-Tree Data
    - Pests and diseases, risk-weighted
- Derived
    - Priority tree average per district
    - Tree density per district (trees/acre)

Vulnerability analysis

To evaluate maintenance types and maintenance priorities for individual trees we first evaluated types of potential vulnerabilities within the inventory population. We evaluated tree health and structural vulnerability and then combined these two vulnerabilities into a general *vulnerability class* which is synonymous with '*priority class*'. Defining vulnerability at the individual tree and district level directly allowed us to achieve our maintenance plan goals of prioritization and cost projection.

To evaluate tree health and structural vulnerability we selected variables that we know contribute toward and impact tree health and structure.

Tree Health Vulnerability:
Available factors, data, and indicators within our dataset that we know predispose trees to abiotic and biotic disease and decline include health, age, and species susceptibility to the presence of pests and diseases. We know that trees under stress or exhibiting poor health are more vulnerable to pests and diseases. Similar inferences can be made for certain species of trees, for certain life stages of trees, and for other attributes.

Indicators considered in determining tree health vulnerability include: age class, health rating, i-Tee Eco Analysis of pests and diseases risk-weighted, and a tree health vulnerability survey of the Urban Forestry Team, university management, and additional stakeholders.

The outcome of analysis and combining these variables is an index of Tree Health Vulnerability; existing health condition, anticipated health condition resulting from pests and disease affects.

Trees that may require Integrated Pest Management (IPM) or Root Zone Improvement work(s) will have this work prescribed based on their health vulnerability class. Individual trees are prioritized according to their vulnerability class. All trees included in the IPM or Root Zone Improvement will require inspection, evaluation, and arboricultural works prescription if a health and situational condition exists that requires rectifying.

Tree Structure Vulnerability:
Available factors, data, and indicators within our dataset that we know predispose trees to structural failure and other maladies include structure, age, species susceptibility/failure profile/growth habit. We know that trees with poor structure, of a certain age class, as well as certain species due to growth tendencies and wood characteristics, tend to be more vulnerable to structural issues. Structure, in this case, is applied in the context of tree mortality and long-term viability. Failures of major parts and other structural defects can become an added stress to the tree. Failure may provide entry points or hospitable environments for pests and diseases, ultimately impacting overall health and structure. Tree structure, as it applies to the risk for campus use or property, is not factored into our structural vulnerability model, though we do acknowledge that structure can certainly have risk implications, depending on the tree's size and surroundings.

Similar to Tree Health Vulnerability, individual trees are prioritized according to their Structural Vulnerability class. All trees included in a Pruning, Removal, or Lighting Protection and Support System class will require inspection, evaluation, and an arboricultural works prescription if a structural and situational condition exists that requires rectifying.

Overall Vulnerability:
We combined tree health and structural vulnerability to achieve a combined classification of overall vulnerability. Combining the two sub-indices is essential in determining how to prioritize action, as tree health and structure are interrelated indicators of a tree's overall condition and overall vulnerability.

District Vulnerability:
To evaluate maintenance types and maintenance priorities for individual campus districts, we applied the overall vulnerability classifications for individual trees described above to each campus district. Applied to each district were additional spatial and social variables that we understand to be indicators of district vulnerability. The overall vulnerability classification for trees was averaged for each district. Tree density per district, as well as local feedback data from surveys relating to interaction, development, and contextual importance, were combined

with average tree vulnerability to achieve a per-district vulnerability classification or 'priority class'.

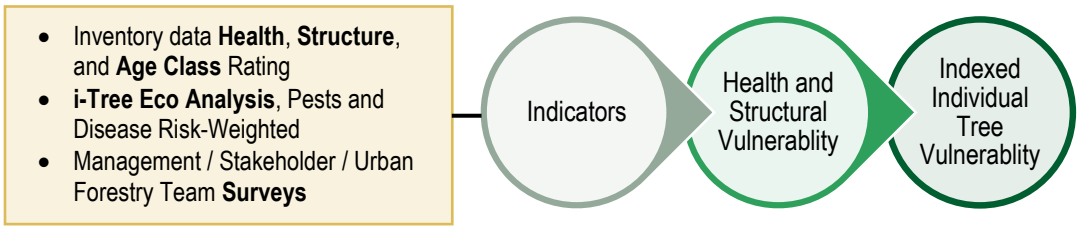


FIGURE 2: AN EXTRACT OF THE INDICES PROCESS MODEL

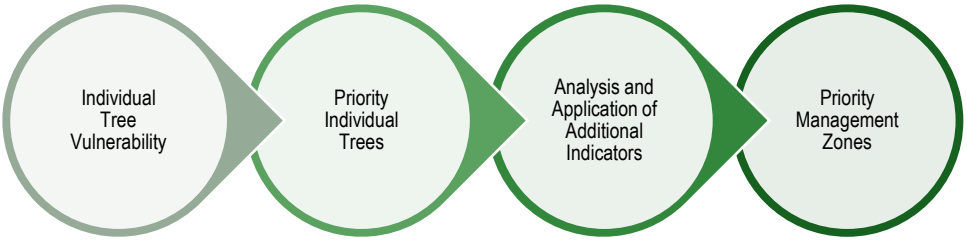


FIGURE 3: CONSIDERATION OF TREE VULNERABILITY AND ITS USE IN THE DETERMINATION OF POSSIBLE MAINTENANCE OPERATIONS AND PROJECTED COSTS

Prioritization

When combined, *Tree Health* and *Tree Structure Vulnerability* indices help identify trees of varying classes of overall vulnerability. Overall vulnerability, as it applies to maintenance, directly correlates to priority assignment. For example, a highly vulnerable tree should require intervention sooner than a lower vulnerability tree. Likewise, a higher vulnerability district requires sooner intervention than a lower vulnerability district.

This model provides us with a way to approximate which trees may need intervention sooner rather than later. The model also provides Virginia Tech managers with a classification system that generally identifies trees for various types of possible maintenance among various priority classes.

Priority Trees:
Tree Health Vulnerability, as it functions within the Priority Tree Index, helps identify trees that should be prioritized for:

- Health evaluation/verification.

- Pest and disease inspection, assessment, and identification of Integrated Pest Management treatments or other treatments; and
- Completion of potential pest and disease treatment.
- Root Zone Improvement treatment [Soil Rx (Soil Sampling and Analysis), Root Invigoration, and RCX (Root Collar Excavation.)]
- Projected potential costs for these treatments and management operations.

Tree Structure Vulnerability identifies trees that are prioritized for:

- Inspection, assessment, and identification of arboricultural works.
- Potential pruning operations, removal, lightning protection, and support system installation.
- Projected potential costs for these treatments and management operations.

Priority Maintenance Districts:
District *vulnerability class* is synonymous with *priority class*. Additional indicators on a district level, outlined in the *indicators* and *vulnerability analysis* sections, provide for the development of the *Priority Management Zone Index*. This index provides for the prioritization on a district level – which districts are more vulnerable than others and as a result should be prioritized for maintenance first. This priority index also sheds some light on the degree of potential maintenance operations within each maintenance district though maintenance needs will vary per district.

Priority Classification:
Management prioritization for individual trees and each district is distributed into the five (5) classes outlined below. We chose a normal distribution to split the population into five equal classes (quantiles), each containing 20% of the population. The reason for this distribution choice was to spread costs and level of effort over multiple years to avoid having some years that have unrealistic/unreasonable costs and actionable treatments.

TABLE 6: PRIORITY CLASSIFICATION

Class	Description
5	**Highest** priority; highest vulnerability, years 1 and 2
4	**High** priority; high vulnerability, years 3 and 4
3	**Medium** priority, medium vulnerability years 5 and 6
2	**Low** priority, low vulnerability years 7 and 8
1	**Lowest** priority, Lowest vulnerability years 9 and 10

Two (2) districts - Corporate Research Center and North End - within the plan boundaries do not have inventoried trees and were excluded from maintenance prioritization.

Descriptions and definitions of these data are provided in the appendices (Tree Maintenance Districts Survey Summary and Results & Tree Health and Structure Survey Summary and Results).

Costings and Maintenance Assignment

This plan does not directly recommend specific treatments that will be required for individual trees. Potential treatment types were assigned to individual trees based on various criteria available for analysis in the data set. See the criteria table for assignment details (Table 7).

Costs in our model are based on assumptions that the trees identified for treatments will require some or a combination of the identified treatments. Our expectation is that managers will be able to use our findings to direct professional on-campus inspections, and assessments of trees to determine whether treatment types identified in our model are warranted and produce prescriptions that are connected and consistent with the results.

Maintenance cost rates were derived from a local supplier, with the cost rates' reasonability corroborated by the Urban Forestry Team. Costs pertaining for costing rates used in this maintenance plan account for:

- Removal
- *Pruning Operations
- *Lightning Protection
- *Support Systems (Cabling, bracing, guying)
- *Root Zone Improvements (soil analysis, root invigoration, root crown excavation, etc.)
- *Integrated Pest Management (IPM) (treatments of pests and diseases)
- Monitor maintenance (base level field evaluation/verification)

** Costs averaged when multiple assignments per tree occurred.*

Maintenance Type Assignment
Trees identified for removal were not identified to receive any other type of maintenance.

Trees not identified for removal were assigned maintenance types according to the thresholds in the assignment table. Maintenance costs were averages for these trees based on the number of multiple maintenance types assigned.

All trees were assigned a base-level monitor maintenance cost to account for assumed field evaluation/verification.

TABLE 7: CRITERIA USED TO ASSIGN THE TYPE OF MAINTENANCE

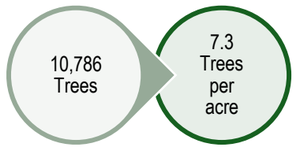
	Size Class				
Maintenance Type	**Small Tree (1-6")**	**Medium Tree (>6-14")**	**Large Tree (>14-28")**	**XL Tree (>28")**	**Assignment Variables**
Removal					Condition class: Very Poor
Pruning operations					Structure class: Fair, Poor
Support systems					Structure class: Fair, Poor
Lightning protection					Health class: Excellent
Root Zone Improvements					Health class: Fair, Poor
IPM					Health class: Excellent, Good, Fair, Poor
Maintenance evaluation					All trees

Maintenance Plan and Implementation

Total Trees and Tree Density

This maintenance plan uses tree inventory data provided by Virginia Tech and districts as defined in the 2018 Campus Master Plan. The number of trees included in this plan and trees per acre are based on the 24 included districts and are summarized as follows:

FIGURE 4: TREE SUMMARY



District Tree Density and Priority Class

The table, 'Table 8: District maintenance zones with prioritization, provides a summary of each district's priority ranking, total tree count, density, and priority class; districts have individual rankings and are also grouped into priority classes.

The Health Sciences district contains the highest number of trees (1736). The highest priority class districts are:

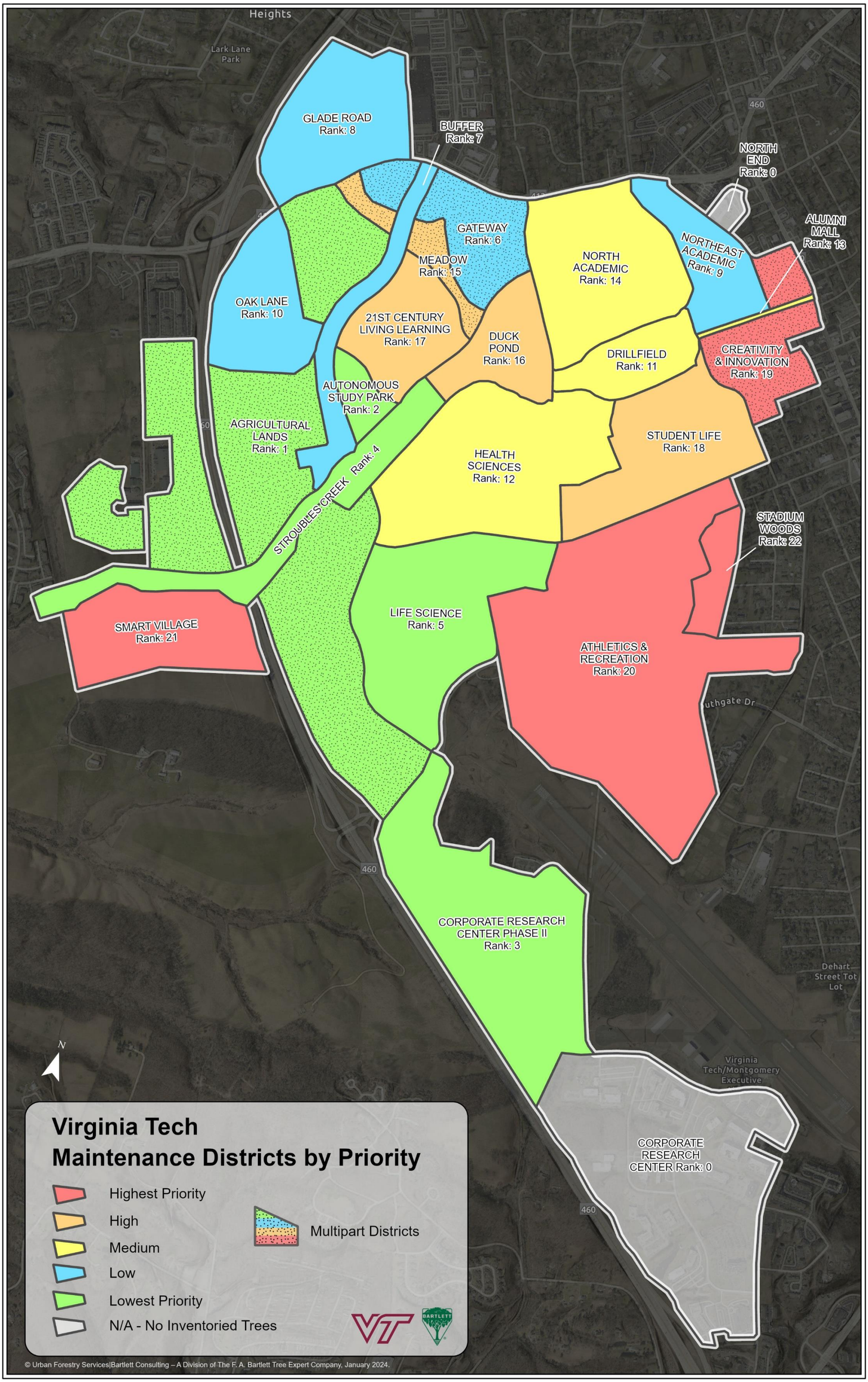
- Stadium Woods (highest density of trees)
- Smart Village
- Athletics & Recreation
- Creativity & Innovation

A higher density of trees does not necessarily equate with a higher priority rank or class. This is also true of the total number of trees within each district. This maintenance plan provides a detailed summary for each district, which accounts for the priority classes and maintenance types within each district.

The tree inventory dataset we were provided with identifies only a limited number of trees for arboricultural work (1,788; 1.6%). These findings can be reviewed in the Virginia Tech Inventory and Analysis of Landscape Trees and Urban Forest on the Main Campus of Virginia Tech (*2018*). This small percentage of the population does not account for the differing forms of pruning at different age classes, integrated pest management, and the management of the growth environment, plus proactive and other forms of maintenance operations. The inventoried and assessed tree conditions we observed in the dataset suggest that a larger percentage of the tree population likely requires maintenance operations to manage overall health and structure. The existing identified maintenance does not therefore provide a basis for a 10-year maintenance plan or associated projected costs for the same period. As such we have chosen not to include these past recommendations in our indices.

TABLE 8: DISTRICT MAINTENANCE ZONES WITH PRIORITIZATION

Priority Rank (0=Lowest, 22=highest)	District Name	District Code	Total trees	Tree Density (Trees per Acre)	Priority Class (1=Lowest, 5=Highest)
22	Stadium Woods	SWD	1484	106.1	5
21	Smart Village	SVD	22	0.4	5
20	Athletics & Recreation	ARD	1458	7.4	5
19	Creativity & Innovation	CID	500	13.6	5
18	Student Life	SLD	935	14.5	4
17	21st Century Living Learning	TCL	167	4.4	4
16	Duck Pond	DPD	466	15.0	4
15	Meadow	MED	87	6.1	4
14	North Academic	NAD	560	7.7	3
13	Alumni Mall	AMD	29	14.5	3
12	Health Sciences	HSD	1736	17.7	3
11	Drillfield	DRF	216	8.4	3
10	Oak Lane	OLD	536	12.8	2
9	Northeast Academic	NEA	222	7.1	2
8	Glade Road	GRD	84	1.5	2
7	Buffer	BUF	104	4.0	2
6	Gateway	GTW	576	14.9	2
5	Life Science	LSD	803	9.2	1
4	Stroubles Creek	SCD	92	2.1	1
3	Corporate Research Center Phase II	CRP	106	0.9	1
2	Autonomous Study Park	ASP	2	0.2	1
1	Agricultural Lands	ALD	601	2.6	1
0	Corporate Research Center	CRC	0	0.0	0
0	North End	NED	0	0.0	0


Heights
Lark Lane Park
GLADE ROAD Rank: 8
BUFFER Rank: 7
NORTH END Rank: 0
ALUMNI MALL Rank: 13
GATEWAY Rank: 6
MEADOW Rank: 15
NORTH ACADEMIC Rank: 14
NORTHEAST ACADEMIC Rank: 9
OAK LANE Rank: 10
21ST CENTURY LIVING LEARNING Rank: 17
DUCK POND Rank: 16
DRILLFIELD Rank: 11
CREATIVITY & INNOVATION Rank: 19
AUTONOMOUS STUDY PARK Rank: 2
AGRICULTURAL LANDS Rank: 1
STROUBLES CREEK Rank: 4
HEALTH SCIENCES Rank: 12
STUDENT LIFE Rank: 18
STADIUM WOODS Rank: 22
SMART VILLAGE Rank: 21
LIFE SCIENCE Rank: 5
ATHLETICS & RECREATION Rank: 20
CORPORATE RESEARCH CENTER PHASE II Rank: 3
Dehart Street Tot Lot
Virginia Tech/Montgomery Executive
CORPORATE RESEARCH CENTER Rank: 0
460
N
Virginia Tech
Maintenance Districts by Priority
Highest Priority
High
Medium
Low
Lowest Priority
N/A - No Inventoried Trees
Multipart Districts
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District Tree Health Vulnerability Summary

Tree Health Vulnerability analysis methods are described in the maintenance plan methods. The use of i-Tree Eco Analysis allowed for the identification of potential pests and diseases known within and surrounding Montgomery County with the potential to impact 65 of the 100 genera within the tree population. This input is factored into the tree health vulnerability classification. Table 'Table 9. Tree health vulnerability summary' and Graph 6. Tree health vulnerability provide a summary of the following:

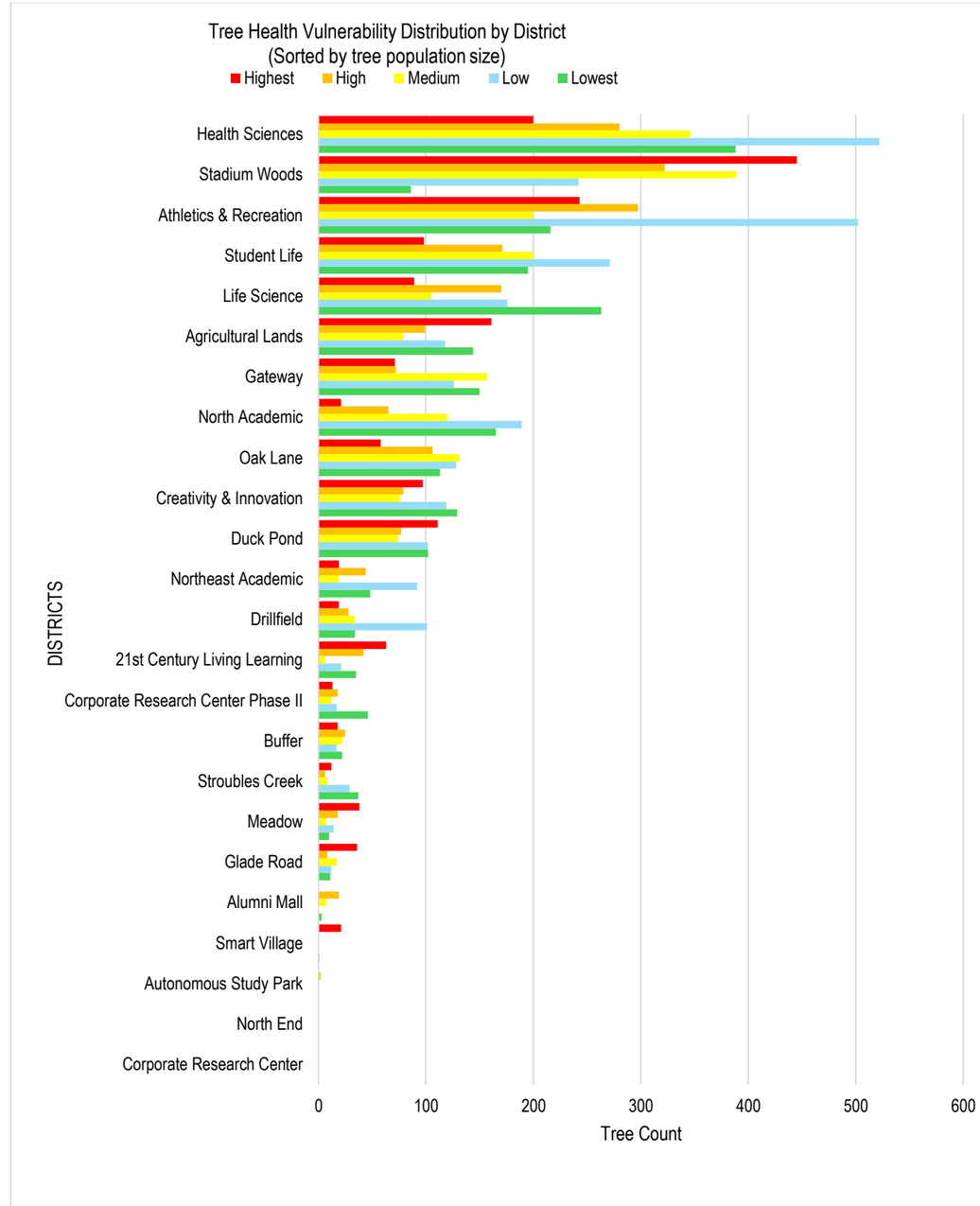
- Vulnerability class per district, with a count of trees in each district and class
- A comparative visualization of vulnerability by district, displaying the full spectrum for each district and class.

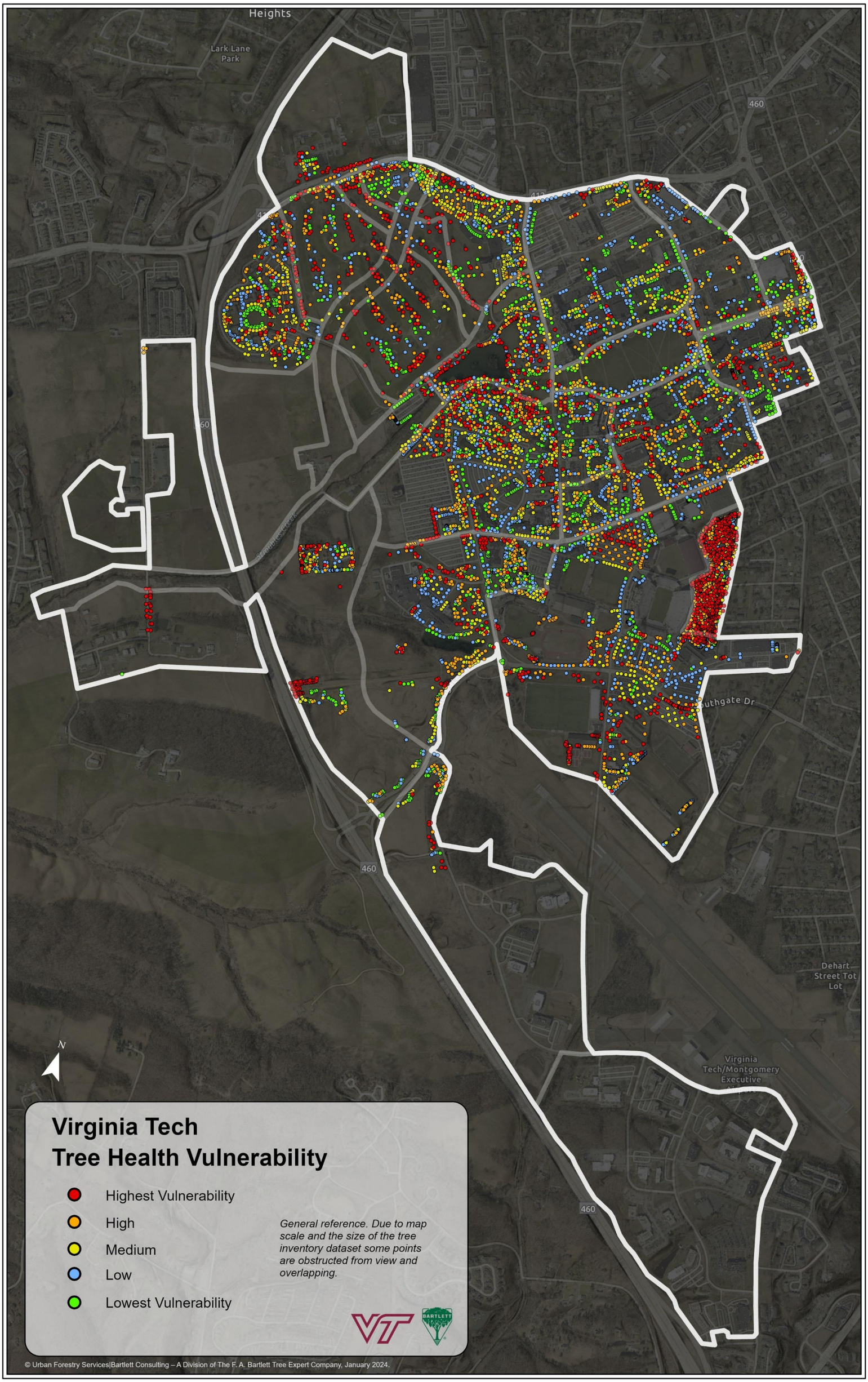
These figures can be used to readily understand the vulnerability of the tree population across all districts included in the maintenance plan. It also allows for an understanding of the health monitoring requirements, and potential integrated past management, and root zone improvements for each district. This plan does not provide specific individual prescriptions for integrated pest management (IPM) treatments. Prescriptions are not provided because of limitations with the dataset and Best Management Practices (BMPs) against providing a prescription without a diagnosis or prescriptive analysis. This plan provides an understanding of the potential vulnerabilities, quantity, and projected costs of treatments.

TABLE 9: TREE HEALTH VULNERABILITY SUMMARY

	Vulnerability Class					
Districts	**Lowest**	**Low**	**Medium**	**High**	**Highest**	**Tree Total**
Health Sciences	388	522	346	280	200	1736
Stadium Woods	86	242	389	322	445	1484
Athletics & Recreation	216	502	200	297	243	1458
Student Life	195	271	200	171	98	935
Life Science	263	176	105	170	89	803
Agricultural Lands	144	118	79	99	161	601
Gateway	150	126	157	72	71	576
North Academic	165	189	120	65	21	560
Oak Lane	113	128	131	106	58	536
Creativity & Innovation	129	119	76	79	97	500
Duck Pond	102	102	74	77	111	466
Northeast Academic	48	92	19	44	19	222
Drillfield	34	101	34	28	19	216
21st Century Living Learning	35	21	6	42	63	167
Corporate Research Center Phase II	46	17	12	18	13	106
Buffer	22	17	22	25	18	104
Stroubles Creek	37	29	8	6	12	92
Meadow	10	14	7	18	38	87
Glade Road	11	12	17	8	36	84
Alumni Mall	3	0	7	19	0	29
Smart Village	1	0	0	0	21	22
Autonomous Study Park	0	0	0	2	0	2
Corporate Research Center	0	0	0	0	0	0
North End	0	0	0	0	0	0
Grand Total	**2198**	**2798**	**2009**	**1948**	**1833**	**10786**

GRAPH 6: TREE HEALTH VULNERABILITY DISTRIBUTION BY DISTRICT





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District Tree Structure Vulnerability Summary

Tree Structure Vulnerability analysis methods are described in the maintenance plan methods. The tree structure vulnerability index is used to identify which trees may be more vulnerable than others concerning structural maladies and defects. Structural integrity has implications for treatment options such as removal, pruning, and support systems.

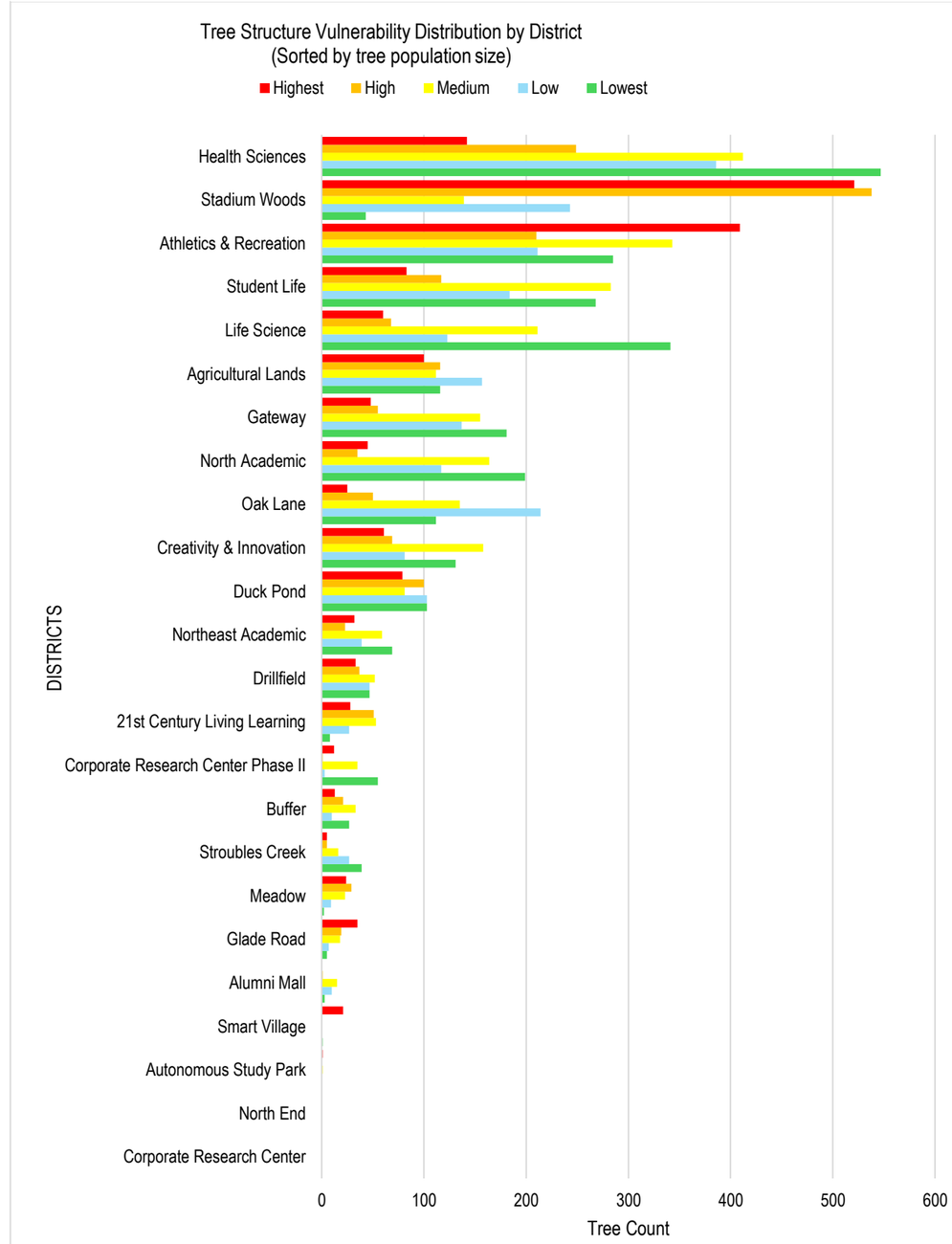
Maintenance operations addressing the structural vulnerability of trees is the costliest form of maintenance, as is shown in the Plan Costing section that follows. However, the benefits of intervention are that the tree's structural condition can be improved with potential benefits to future structural conditions and stability. In addition, the future maintenance costs of young or immature trees can be significantly reduced.

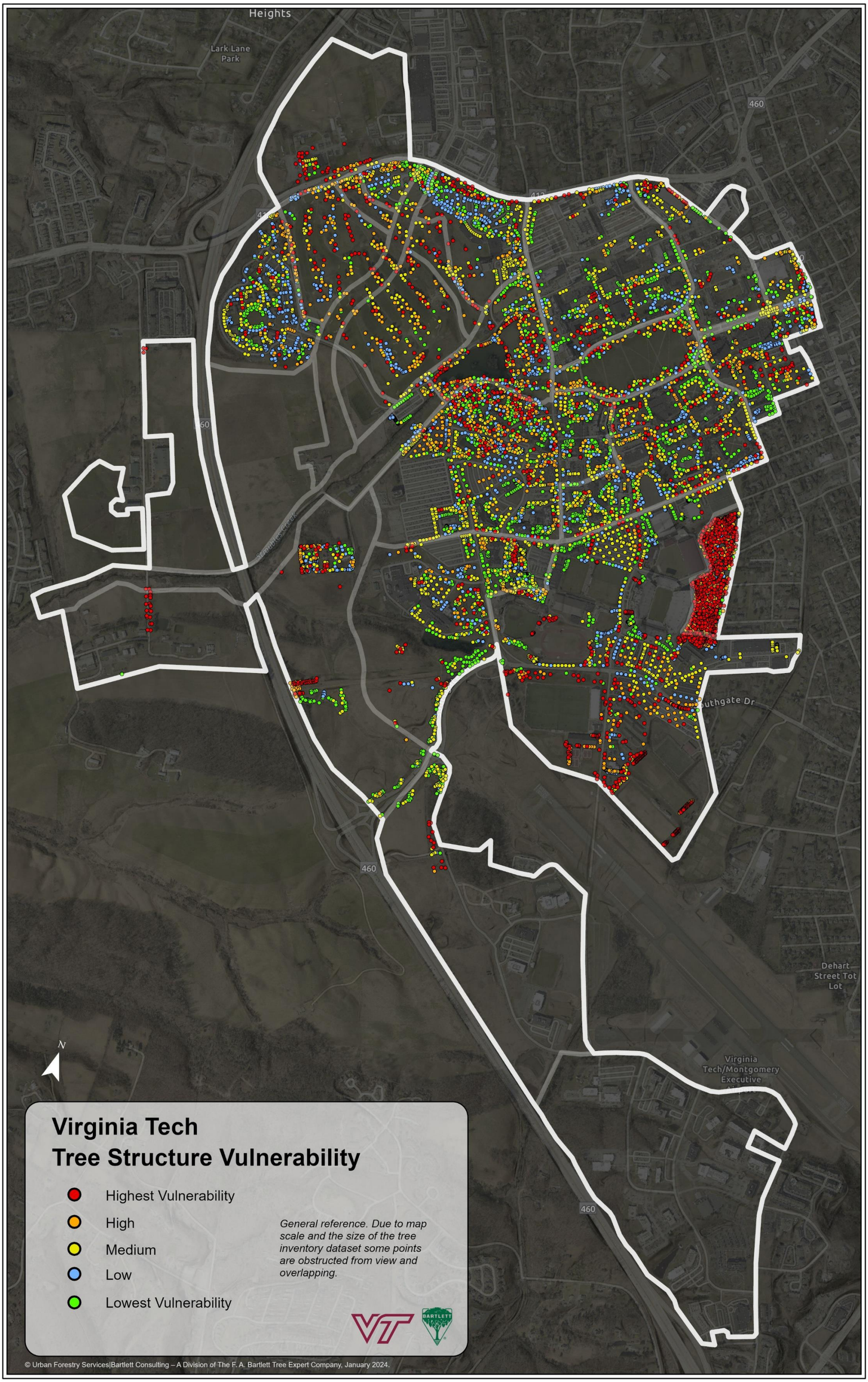
The implications of structural vulnerability require that the Urban Forestry Team be engaged in the inspection and assessment of trees at all classes of vulnerability. Prioritization helps identify trees requiring initial inspection and assessment and thereafter providing a manageable inspection interval.

TABLE 10: TREE STRUCTURE VULNERABILITY SUMMARY

	Vulnerability Class					
Districts	**Lowest**	**Low**	**Medium**	**High**	**Highest**	**Tree Total**
Health Sciences	547	386	412	249	142	1736
Stadium Woods	43	243	139	538	521	1484
Athletics & Recreation	285	211	343	210	409	1458
Student Life	268	184	283	117	83	935
Life Science	341	123	211	68	60	803
Agricultural Lands	116	157	112	116	100	601
Gateway	181	137	155	55	48	576
North Academic	199	117	164	35	45	560
Oak Lane	112	214	135	50	25	536
Creativity & Innovation	131	81	158	69	61	500
Duck Pond	103	103	81	100	79	466
Northeast Academic	69	39	59	23	32	222
Drillfield	47	47	52	37	33	216
21st Century Living Learning	8	27	53	51	28	167
Corporate Research Center Phase II	55	3	35	1	12	106
Buffer	27	10	33	21	13	104
Stroubles Creek	39	27	16	5	5	92
Meadow	2	9	23	29	24	87
Glade Road	5	7	18	19	35	84
Alumni Mall	3	10	15	1	0	29
Smart Village	1	0	0	0	21	22
Autonomous Study Park	0	0	1	0	1	2
Corporate Research Center	0	0	0	0	0	0
North End	0	0	0	0	0	0
Grand Total	**2582**	**2135**	**2498**	**1794**	**1777**	**10786**

GRAPH 7: TREE STRUCTURE VULNERABILITY DISTRIBUTION BY DISTRICT




Heights
Lark Lane Park
460
Southgate Dr
Dehart Street Tot Lot
Virginia Tech/Montgomery Executive
N
Virginia Tech
Tree Structure Vulnerability
Highest Vulnerability
High
Medium
Low
Lowest Vulnerability
General reference. Due to map scale and the size of the tree inventory dataset some points are obstructed from view and overlapping.
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District Tree Maintenance Prioritization

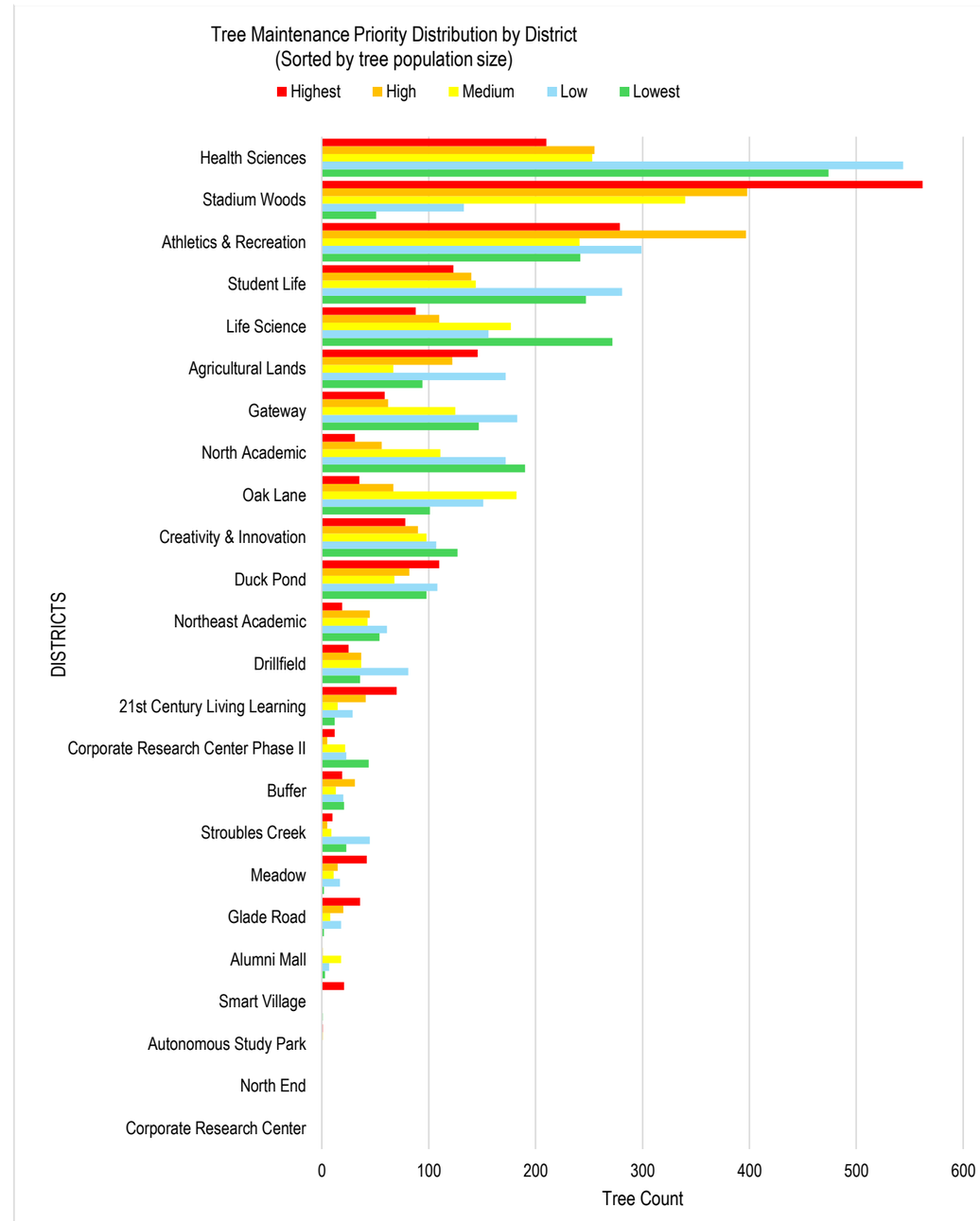
District tree maintenance prioritization is a combination of tree health and structural vulnerability. This is the overarching priority metric in this plan and is used to identify which trees need intervention over others when both factors are considered. Some trees will have both health *and* structural problems, some will have neither, and others will have varying combinations of each throughout the spectrum.

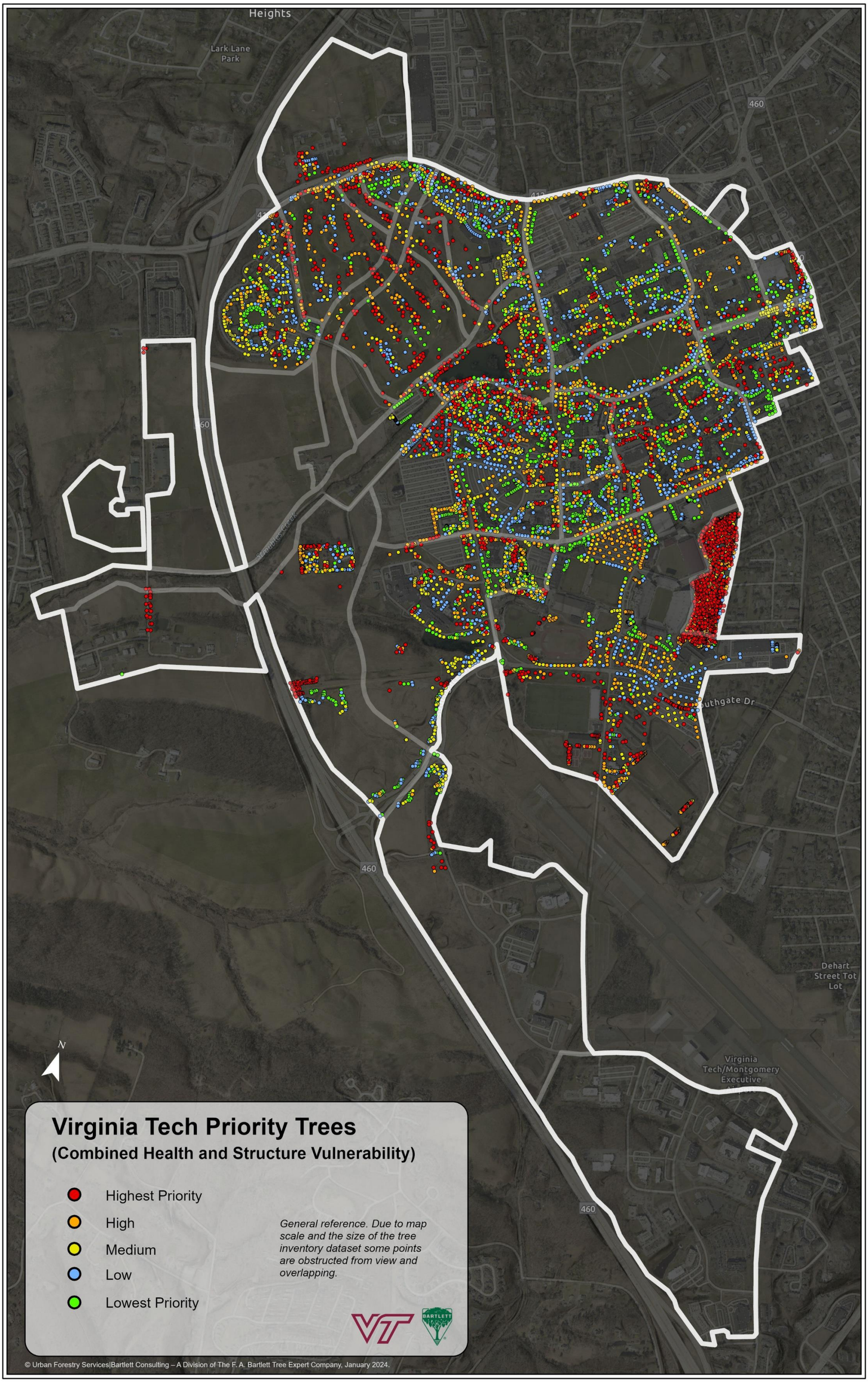
This plan provides for the prioritization of maintenance based on inputs discussed in the methods section. It allows for multiple forms of maintenance, if necessary, on the same individual tree, throughout the 10-year plan. Inputs such as health or structure are of primary importance, but prioritization also accounts for multiple other inputs. The graph, 'Graph 8. Tree Maintenance Priority Distribution by District' provides a graphical representation of the prioritization for all districts. The graph illustrates that some districts i.e., Health Sciences have a high number of trees with low and lowest prioritization. This affects cost projections, as shown in 'Table 11. Tree costing by district and prioritization summary'.

TABLE 11: TREE MAINTENANCE PRIORITIZATION FOR ALL DISTRICTS SUMMARY

	Priority Class					
Districts	**Lowest**	**Low**	**Medium**	**High**	**Highest**	**Tree Total**
Health Sciences	474	544	253	255	210	1736
Stadium Woods	51	133	340	398	562	1484
Athletics & Recreation	242	299	241	397	279	1458
Student Life	247	281	144	140	123	935
Life Science	272	156	177	110	88	803
Agricultural Lands	94	172	67	122	146	601
Gateway	147	183	125	62	59	576
North Academic	190	172	111	56	31	560
Oak Lane	101	151	182	67	35	536
Creativity & Innovation	127	107	98	90	78	500
Duck Pond	98	108	68	82	110	466
Northeast Academic	54	61	43	45	19	222
Drillfield	36	81	37	37	25	216
21st Century Living Learning	12	29	15	41	70	167
Corporate Research Center Phase II	44	23	22	5	12	106
Buffer	21	20	13	31	19	104
Stroubles Creek	23	45	9	5	10	92
Meadow	2	17	11	15	42	87
Glade Road	2	18	8	20	36	84
Alumni Mall	3	7	18	1	0	29
Smart Village	1	0	0	0	21	22
Autonomous Study Park	0	0	0	1	1	2
Corporate Research Center	0	0	0	0	0	0
North End	0	0	0	0	0	0
Grand Total	**2241**	**2607**	**1982**	**1980**	**1976**	**10786**

GRAPH 8: TREE MAINTENANCE PRIORITY DISTRIBUTION BY DISTRICT





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Plan Costing

This 10-year maintenance plan is projected to cost **$7,258,812**.

Work Planning

The figure, 'Figure 5. Cost projections for the 10-year maintenance plan', provides an overview of the cost projections. This is the total cost of all possible forms of maintenance, including proactive health and structural maintenance operations.

The table, 'Table 12. Priority class and biannual projected costs for the 10-year plan', provides cost projections of the maintenance plan in two-year increments. It is evident that prioritization of maintenance operations results in an initially higher cost in years one and two ($2,363,905.) In years nine and ten this cost is significantly less ($775,714.)

The type of maintenance that occurs for the highest priority trees is more expensive i.e., pruning and removal. This can be compared with the lower expense of maintenance required for the lowest priority trees, i.e. maintenance monitoring and integrated pest management. This is despite the higher number of trees in the lowest priority class. The form of maintenance operation significantly affects the projected costs over the 10-year plan.

In the first four years of the plan, the expenditure required to meet the prioritization of maintenance will need to be higher than the average expenditure in the last six years of the 10-year plan. It is typical for most maintenance plans to incur this initial higher expenditure.

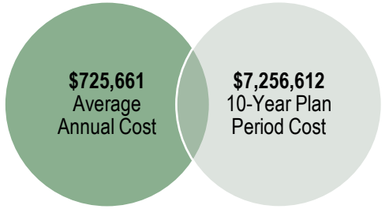


FIGURE 5: COST PROJECTIONS FOR THE 10-YEAR MAINTENANCE PLAN

TABLE 12: PRIORITY CLASS AND BIANNUAL PROJECTED COSTS FOR THE 10-YEAR PLAN

Priority Class	Years	Number of Trees (Quantile distribution)	Projected Cost
Highest Priority Trees	1 & 2	1,976	$2,363,905.00
High	3 & 4	1,980	$1,697,424.00
Medium	5 & 6	1,982	$1,140,736.00
Low	7 & 8	2,607	$1,278,833.00
Lowest	9 & 10	2,241	$775,714.00
	Totals	10,786	$7,256,612.00

The projected expenditure for this 10-year plan will reduce future costs of maintenance operations. The work is proactive and will result in a different form of maintenance in the future i.e., treatments to improve growing environment conditions. It is recognized that the tree population has a high number of smaller-diameter trees currently. Arboricultural maintenance operations undertaken in this 10-year plan should reduce costs as the trees develop in age and overall size i.e., pruning to improve structure, and/or health treatments for longer-term sustainability in terms of health and structural condition.

The table, 'Table 13. Tree costing by district and prioritization summary', provides a detailed description of the projected costs for each district for each prioritization class (priority class.) Factors such as current tree health and structural condition and the associated treatments, combined with age class, and size affect the priority class total projected costs, and the projected costs for each district over the 10-year plan period. In general, these projected costs are scheduled to decline over this period.

TABLE 13: TREE COSTING BY DISTRICT AND PRIORITIZATION SUMMARY

	Priority Class					
Districts	Lowest	Low	Medium	High	Highest	District Total
Athletics & Recreation	$49,766.50	$151,868.50	$167,569.33	$415,353.00	$375,143.83	$1,159,701.17
Stadium Woods	$8,707.33	$84,659.33	$98,599.67	$371,768.17	$573,988.83	$1,137,723.33
Health Sciences	$143,981.00	$228,603.50	$158,758.33	$184,963.83	$285,775.33	$1,002,082.00
Student Life	$78,192.00	$126,491.67	$86,129.33	$97,759.67	$144,771.17	$533,343.83
Agricultural Lands	$67,466.33	$93,934.00	$42,243.17	$97,917.50	$189,305.33	$490,866.33
Creativity & Innovation	$96,577.00	$76,591.33	$68,709.17	$91,742.00	$102,140.17	$435,759.67
Life Science	$62,483.00	$75,169.67	$112,646.50	$66,393.33	$84,836.17	$401,528.67
Duck Pond	$24,343.00	$56,379.83	$43,029.00	$58,263.50	$125,555.83	$307,571.17
Gateway	$43,599.00	$77,028.00	$55,212.00	$42,470.67	$77,570.50	$295,880.17
Oak Lane	$32,186.00	$67,373.17	$102,782.50	$57,355.83	$32,923.83	$292,621.33
North Academic	$68,177.00	$69,463.00	$61,095.67	$50,089.50	$37,326.33	$286,151.50
Drillfield	$15,850.00	$40,451.00	$33,467.00	$37,250.33	$31,930.50	$158,948.83
21st Century Living Learning	$10,233.00	$21,248.50	$9,382.00	$25,277.00	$78,834.33	$144,974.83
Corporate Research Center Phase II	$39,454.00	$32,918.00	$35,252.00	$9,266.50	$21,578.83	$138,469.33
Northeast Academic	$18,304.00	$23,173.00	$21,194.83	$39,139.67	$22,880.50	$124,692.00
Glade Road	$32.00	$20,226.50	$3,905.33	$16,364.00	$58,675.50	$99,203.33
Meadow	$32.00	$7,029.00	$5,714.00	$7,318.00	$55,800.33	$75,893.33
Buffer	$6,444.00	$9,437.00	$3,239.00	$24,630.33	$23,433.67	$67,184.00
Stroubles Creek	$9,823.00	$13,701.33	$5,806.17	$2,094.00	$10,419.00	$41,843.50
Alumni Mall	$48.00	$3,087.00	$26,001.00	$1,566.00	$0	$30,702.00
Smart Village	$16.00	$0	$0	$0	$30,039.83	$30,055.83
Autonomous Study Park	$0	$0	$0	$441.00	$975.00	$1,416.00
Corporate Research Center	$0	$0	$0	$0	$0	$0
North End	$0	$0	$0	$0	$0	$0
Grand Total	$775,714.17	$1,278,833.33	$1,140,736.00	$1,697,423.83	$2,363,904.83	$7,256,612.17

Management should consider the following:

- The costs for maintenance operations over 10 years is likely to increase (at minimum in line with inflation), but the costs associated with priority class will decrease over the 10 years as these will remain lower in comparison.
- New plantings will increase management and maintenance costs over this period. Costs are accounted for in the planting plan.
- Additional assessment is needed for non-inventoried trees.

Arboricultural Maintenance Tasks

This maintenance plan identifies seven (7) types of urban forestry and arboricultural maintenance operations. The table, 'Table 14. Quantity of trees requiring a range of maintenance types in each district', details the potential number of trees requiring these forms of maintenance over the 10 years of this plan. This table also provides a count of trees in each form of maintenance operation for each district.

The assignment of maintenance types is dictated by assignment methodology outlined in our methods section. The total number of trees and assigned maintenance types should be considered a potential quantity and not absolute. It is anticipated that the Urban Forestry Team will inspect, assess, and write needs-based maintenance operation plans for each priority class, district, individual tree, or group of trees.

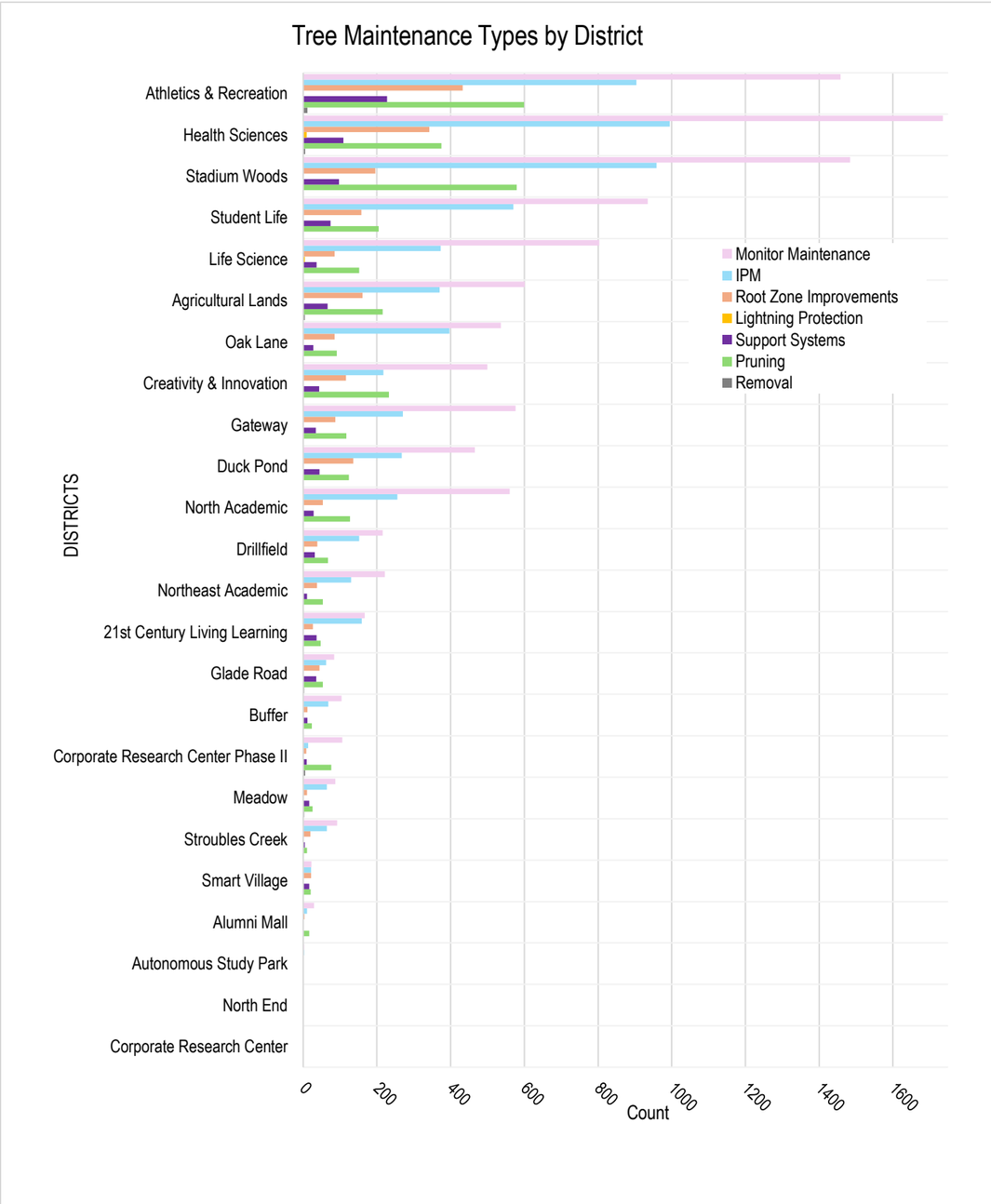
The projected costs in this plan also include a base level management cost for inspection and the management of internal works and contracted works.

TABLE 14: QUANTITY OF TREES REQUIRING A RANGE OF MAINTENANCE TYPES IN EACH DISTRICT

	Maintenance Type Quantity (count of trees assigned possible maintenance)							
Districts	**Removal**	**Pruning**	**Support Systems**	**Lightning Protection**	**Root Zone Improvements**	**IPM**	**Monitor Maintenance**	**Type Total**
Athletics & Recreation	11	599	228	0	433	904	1,458	3633
Health Sciences	5	375	109	9	342	995	1,736	3571
Stadium Woods	1	579	97	0	196	959	1,484	3316
Student Life	0	205	74	1	158	570	935	1943
Life Science	1	152	36	4	85	373	803	1454
Agricultural Lands	4	216	66	1	161	370	601	1419
Oak Lane	0	91	27	1	85	397	536	1137
Creativity & Innovation	1	233	43	0	116	218	500	1111
Gateway	0	117	34	1	87	270	576	1085
Duck Pond	1	124	44	1	136	267	466	1039
North Academic	0	127	28	1	53	255	560	1024
Drillfield	0	67	31	2	38	152	216	506
Northeast Academic	0	53	10	0	37	130	222	452
21st Century Living Learning	1	47	36	1	26	159	167	437
Glade Road	2	53	35	0	44	62	84	280
Buffer	1	23	11	1	11	68	104	219
Corporate Research Center Phase II	5	76	9	1	8	13	106	218
Meadow	2	25	16	0	10	64	87	204
Stroubles Creek	0	10	4	0	19	64	92	189
Smart Village	0	20	16	0	21	21	22	100
Alumni Mall	0	16	0	0	3	10	29	58
Autonomous Study Park	0	0	0	0	1	2	2	5
Corporate Research Center	0	0	0	0	0	0	0	0
North End	0	0	0	0	0	0	0	0
Grand Total	**35**	**3208**	**954**	**24**	**2070**	**6323**	**10786**	**23400**

Arboricultural Maintenance Tasks – Continued

GRAPH 9: TREE MAINTENANCE TYPES BY DISTRICT



The graph, 'Graph 9. Tree maintenance types by district', indicates the following:

- Prioritized listing of maintenance required, with the districts also prioritized in this chart.
- An indication of the amount of maintenance required.
- The form of maintenance operation

Pruning cycles are not provided. Instead, priority class schedules are provided. In addition, this plan does not specify the specific form of maintenance operation. For example, 'Pruning' or 'Pruning Operations' shall include individual tree assessment that accounts for the objective, including the pruning system to be applied, including specifications for the work to be completed. In addition, it is expected that some pruning may include uncommon forms such as 'retrenchment (regenerative) pruning' on older age class and larger dimensioned trees. This plan expects that the form of pruning shall be based on a professional assessment by Virginia Tech and its Urban Forestry Team.

The same concept shall be applied to each tree; all trees within a priority class must be subject to inspection, and the prescription and specifications written per the professional's assessment at the time of the inspection.

This maintenance plan assumes that Virginia Tech and its Urban Forestry Team will either complete urban forestry and arboricultural work to American National Standards Institute (ANSI) standards or will write contracts and retain contractors that will complete the work to these base industry standards. Examples include the following:

ANSI A300

- (Part 1)-2017 Revision of ANSI A300 (Part 1)-2008 (R2014) 'Tree, Shrub, and Other Woody Plant Management – Standard Practices (*Pruning*); referenced as 'Pruning' or 'Pruning Operations' in this maintenance plan.
- (Part 2)-2018 Soil Management
  - a.Assessment
  - b.Modification
  - c.Fertilization
  - d.Drainage
- Referenced as 'Root Zone Improvements' in this maintenance plan.
- (Part 3)-2013 Revision of ANSI A300 (Part 3)-2006; referenced as 'Support Systems' or 'Lightning Protection and Support Systems' in this maintenance plan.
- (Part 4)-2014 Lightning Protection Systems Revision of ANSI A300 (Part 4)-2008; referenced as 'Lighting Protection' or 'Lightning Protection and Support Systems' in this maintenance plan.
- (Part 8)-2013 Root Management; referenced as 'Root Zone Improvements' in this maintenance plan.

ANSI Z133

- Z133-2017 Safety Requirements; with application to tree removal operations ('removal') and pruning operations, plus all other urban forestry and arboricultural maintenance operations.

Arboricultural Maintenance Type Costs

Table ‘Table 15. Maintenance type cost’, provides a cost projection for all possible maintenance operations by district. The actual number of maintenance operations is expected to vary. This is because all maintenance operations shall be based on inspection and assessment by qualified personnel of the Urban Forestry Team.

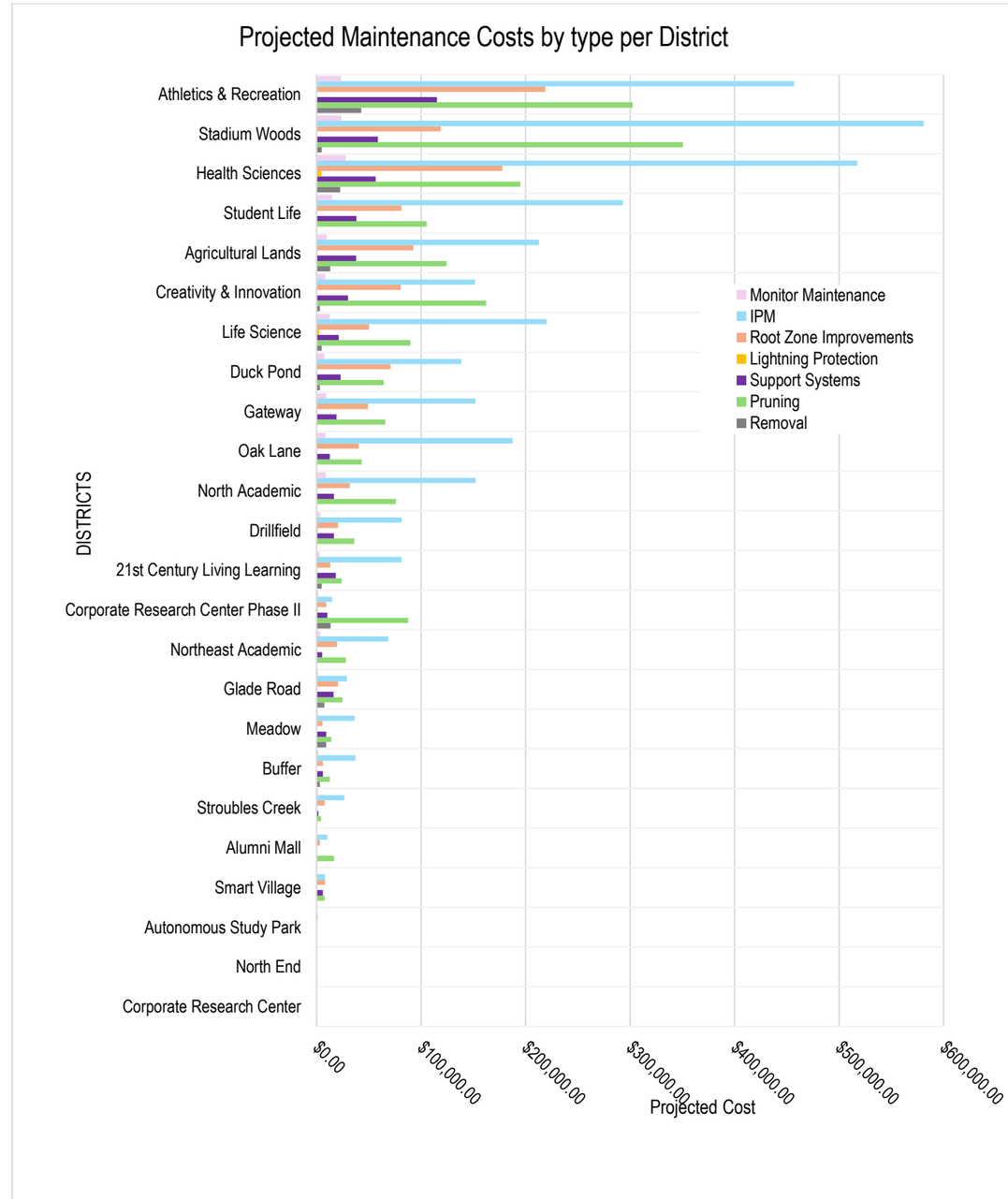
TABLE 15: MAINTENANCE TYPE COST

	Maintenance Type Cost (Projected costs of possible maintenance)							
Districts	**Removal**	**Pruning**	**Support Systems**	**Lightning Protection**	**Root Zone Improvements**	**IPM**	**Monitor Maintenance**	**Type Total**
Athletics & Recreation	$42,950.00	$302,661.96	$115,203.55	$0.00	$218,785.69	$456,771.97	$23,328.00	$1,159,701.17
Stadium Woods	$5,050.00	$350,666.35	$58,747.21	$0.00	$118,705.71	$580,810.06	$23,744.00	$1,137,723.33
Health Sciences	$22,550.00	$195,031.97	$56,689.29	$4,680.77	$177,869.15	$517,484.82	$27,776.00	$1,002,082.00
Student Life	$0.00	$105,425.28	$38,055.96	$514.27	$81,254.61	$293,133.71	$14,960.00	$533,343.83
Agricultural Lands	$13,000.00	$124,253.16	$37,966.24	$575.25	$92,614.62	$212,841.06	$9,616.00	$490,866.33
Creativity & Innovation	$3,250.00	$162,148.78	$29,924.45	$0.00	$80,726.43	$151,710.01	$8,000.00	$435,759.67
Life Science	$5,050.00	$89,710.56	$21,247.24	$2,360.80	$50,167.09	$220,144.98	$12,848.00	$401,528.67
Duck Pond	$3,250.00	$64,355.39	$22,835.78	$519.00	$70,583.33	$138,571.68	$7,456.00	$307,571.17
Gateway	$0.00	$65,893.34	$19,148.49	$563.19	$48,997.61	$152,061.54	$9,216.00	$295,880.17
Oak Lane	$0.00	$43,008.53	$12,760.77	$472.62	$40,172.80	$187,630.61	$8,576.00	$292,621.33
North Academic	$0.00	$75,869.23	$16,727.07	$597.40	$31,661.96	$152,335.85	$8,960.00	$286,151.50
Drillfield	$0.00	$35,924.21	$16,621.65	$1,072.36	$20,374.92	$81,499.69	$3,456.00	$158,948.83
21st Century Living Learning	$5,050.00	$23,980.98	$18,368.41	$510.23	$13,266.07	$81,127.14	$2,672.00	$144,974.83
Corporate Research Center Phase II	$13,550.00	$87,523.11	$10,364.58	$1,151.62	$9,212.96	$14,971.06	$1,696.00	$138,469.33
Northeast Academic	$0.00	$27,914.87	$5,266.96	$0.00	$19,487.74	$68,470.43	$3,552.00	$124,692.00
Glade Road	$7,400.00	$24,713.12	$16,319.98	$0.00	$20,516.55	$28,909.68	$1,344.00	$99,203.33
Meadow	$9,200.00	$14,195.94	$9,085.40	$0.00	$5,678.38	$36,341.61	$1,392.00	$75,893.33
Buffer	$3,250.00	$12,563.25	$6,008.51	$546.23	$6,008.51	$37,143.51	$1,664.00	$67,184.00
Stroubles Creek	$0.00	$4,162.01	$1,664.80	$0.00	$7,907.82	$26,636.87	$1,472.00	$41,843.50
Alumni Mall	$0.00	$16,683.03	$0.00	$0.00	$3,128.07	$10,426.90	$464.00	$30,702.00
Smart Village	$0.00	$7,616.37	$6,093.09	$0.00	$7,997.19	$7,997.19	$352.00	$30,055.83
Autonomous Study Park	$0.00	$0.00	$0.00	$0.00	$461.33	$922.67	$32.00	$1,416.00
Corporate Research Center	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
North End	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Grand Total	**$133,550.00**	**$1,834,301.40**	**$519,099.44**	**$13,563.74**	**$1,125,578.53**	**$3,457,943.04**	**$172,576.00**	**$7,256,612.15**

Arboricultural Maintenance Type Costs – Continued

The graph, 'Graph 10. Projected maintenance costs by type per district', provides a comparative visualization of the costs associated with each form of the maintenance operation. Districts can be compared, with some clear examples of health and structural vulnerabilities and their associated costs being significantly different.

GRAPH 10: PROJECTED MAINTENANCE COSTS BY TYPE PER DISTRICT

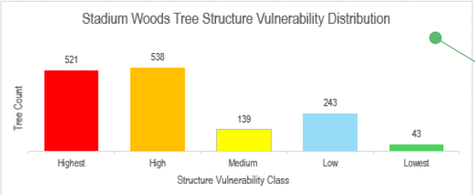


Part 3. District-Level Maintenance Plan and Cost Projections

The following is an explanation of how to use the following section of the maintenance plan and cost projections:

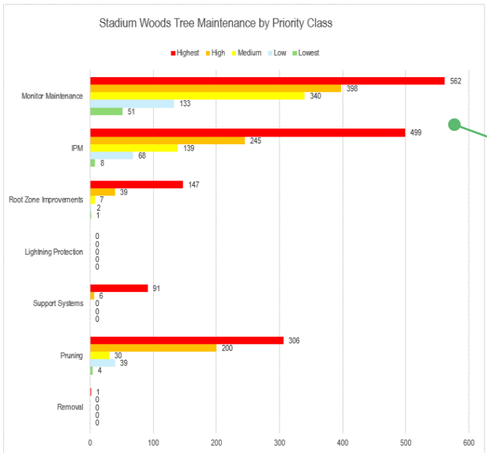
Stadium Woods

Priority Rank	Priority Class	Total trees	Tree density	Projected 10 Year maintenance cost	Projected annual average cost
22	Highest	1484	106.1	$1,137,723.33	$113,772.33



(Continued) **Stadium Woods**

Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	562	$573,988.83
High	3 & 4	398	$371,768.17
Medium	5 & 6	340	$98,599.67
Low	7 & 8	133	$84,659.33
Lowest	9 & 10	51	$8,707.33
	Totals	1,484	$1,137,723.33



District reference

Summary table: detailing district priority, total trees, tree density, projected 10-year maintenance cost, and projected average annual cost.

Health vulnerability chart: individual trees' vulnerability to health issues is assigned a vulnerability class, and the number of trees in each class is provided. This may be used to determine the potential amount of Integrated Pest Management and growth condition improvements required for this district.

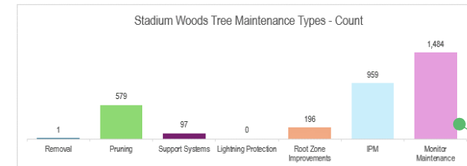
Structure vulnerability chart: individual trees' vulnerability to structural issues is assigned a class, and the number of trees in each class is provided. The potential amount of maintenance operations such as pruning, removal, and other arboricultural works may be projected for the district and its prioritization of the period of the maintenance plan.

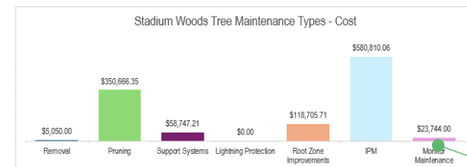
Management priority distribution chart: a count of trees in each priority class is provided. This is an indicator of the amount of arboricultural work and its prioritization over the 10-year maintenance plan period.

(Page 2) **Summary priority table**: a biannual table that provides a summary of the prioritized trees and projected costs over the 10-year plan. This illustrates the projected cost trend for maintenance operations.

(Page 2) **Management priority class chart**: a higher level of detail of prioritization of trees in the district and plan on a bi-annual basis. Providing a count of trees in each priority class and for each of the main forms of maintenance operations. This can be used to understand the projected costs and the possible amount of arboricultural work required in each district. This also indicates the projected balance of the amount and type of arboricultural work and its prioritization over the 10-year maintenance plan period.

	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	579	97	0	196	959	1,484	3316
Proj. Cost	$5,050.00	$350,666.35	$58,747.21	$0.00	$118,705.71	$580,810.06	$23,744.00	$1,137,723.33





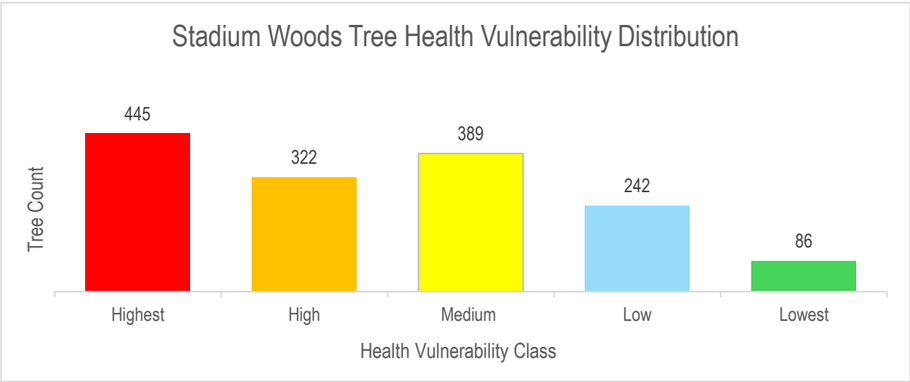
Summary maintenance type cost table: this is a count of the trees for each of the seven (7) main forms of maintenance operations. A predictive forecast of the potential cost of maintenance for each type, including all levels of prioritization. These costs are for the 10-year plan.

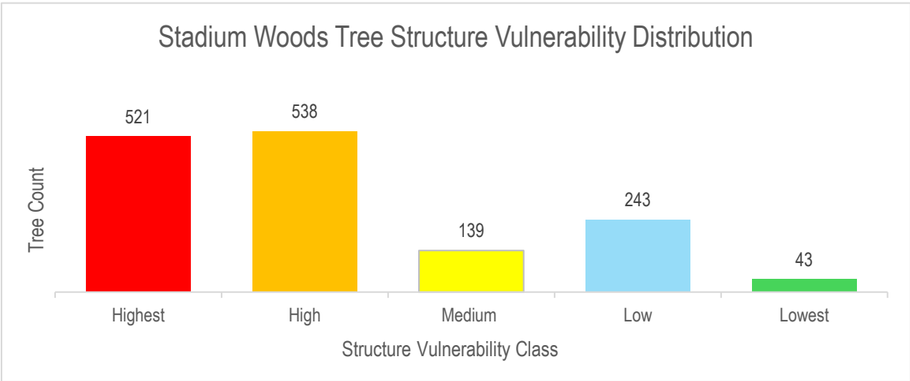
Maintenance type count chart detailing total number of trees requiring each of the seven forms of tree maintenance over the 10-year plan.

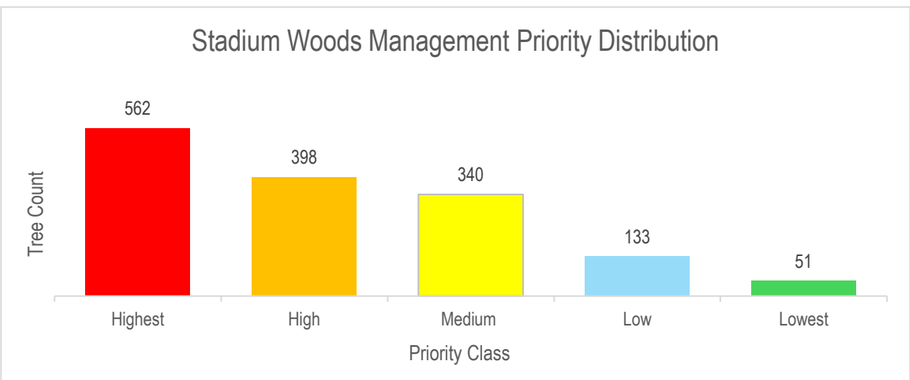
Maintenance type cost chart: detailing projected 10-year maintenance cost This table can be referenced with the '**Maintenance type count chart** for comparison, and to see the effect of costs of the different types of maintenance operations on the projected costs for the district.

Stadium Woods

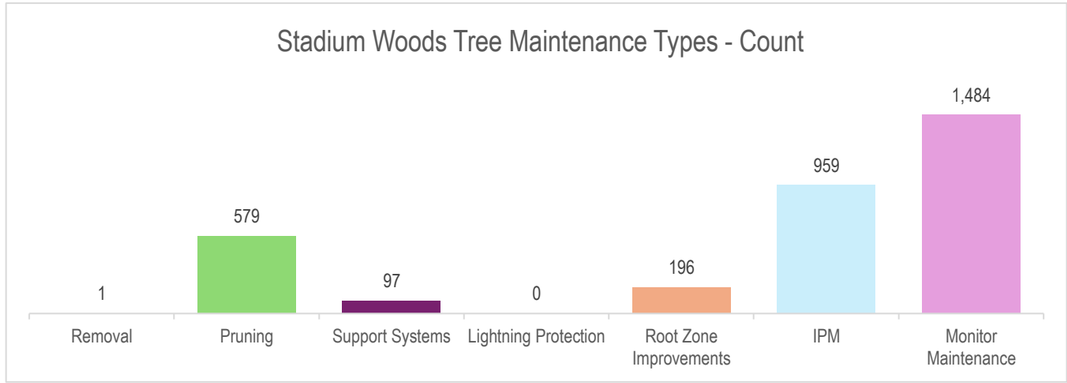
Priority Rank	Priority Class	Total trees	Tree density	Projected 10 Year maintenance cost	Projected annual average cost
22	Highest	1484	106.1	$1,137,723.33	$113,772.33

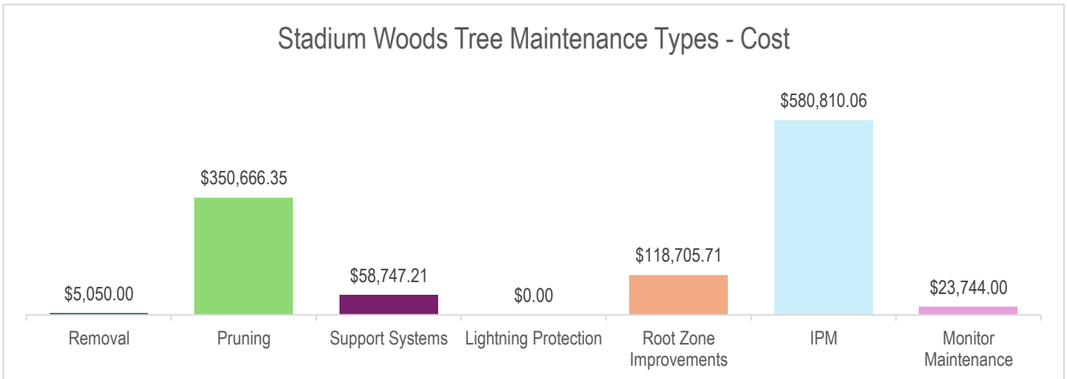






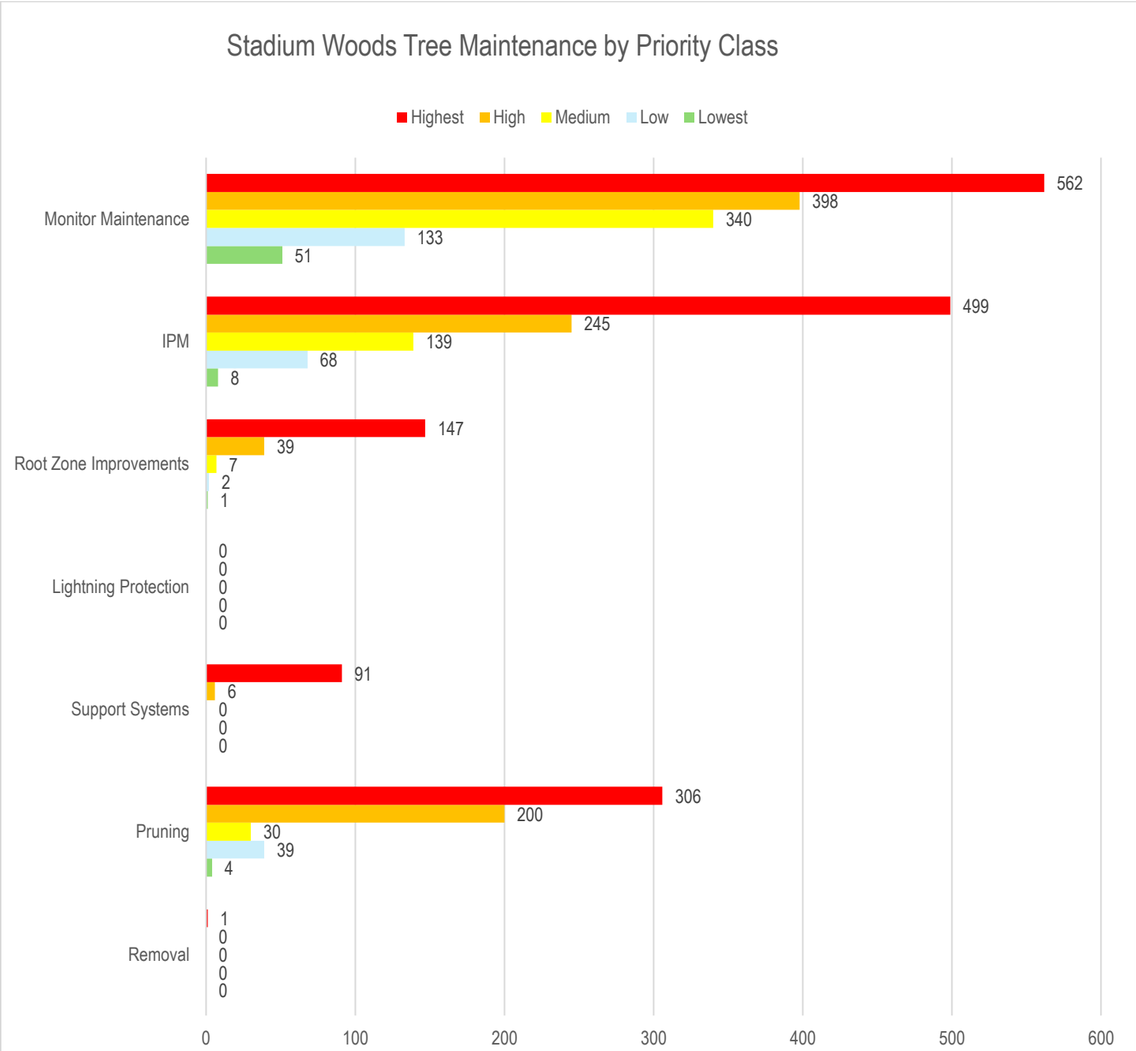
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	579	97	0	196	959	1,484	3316
Proj. Cost	$5,050.00	$350,666.35	$58,747.21	$0.00	$118,705.71	$580,810.06	$23,744.00	$1,137,723.33

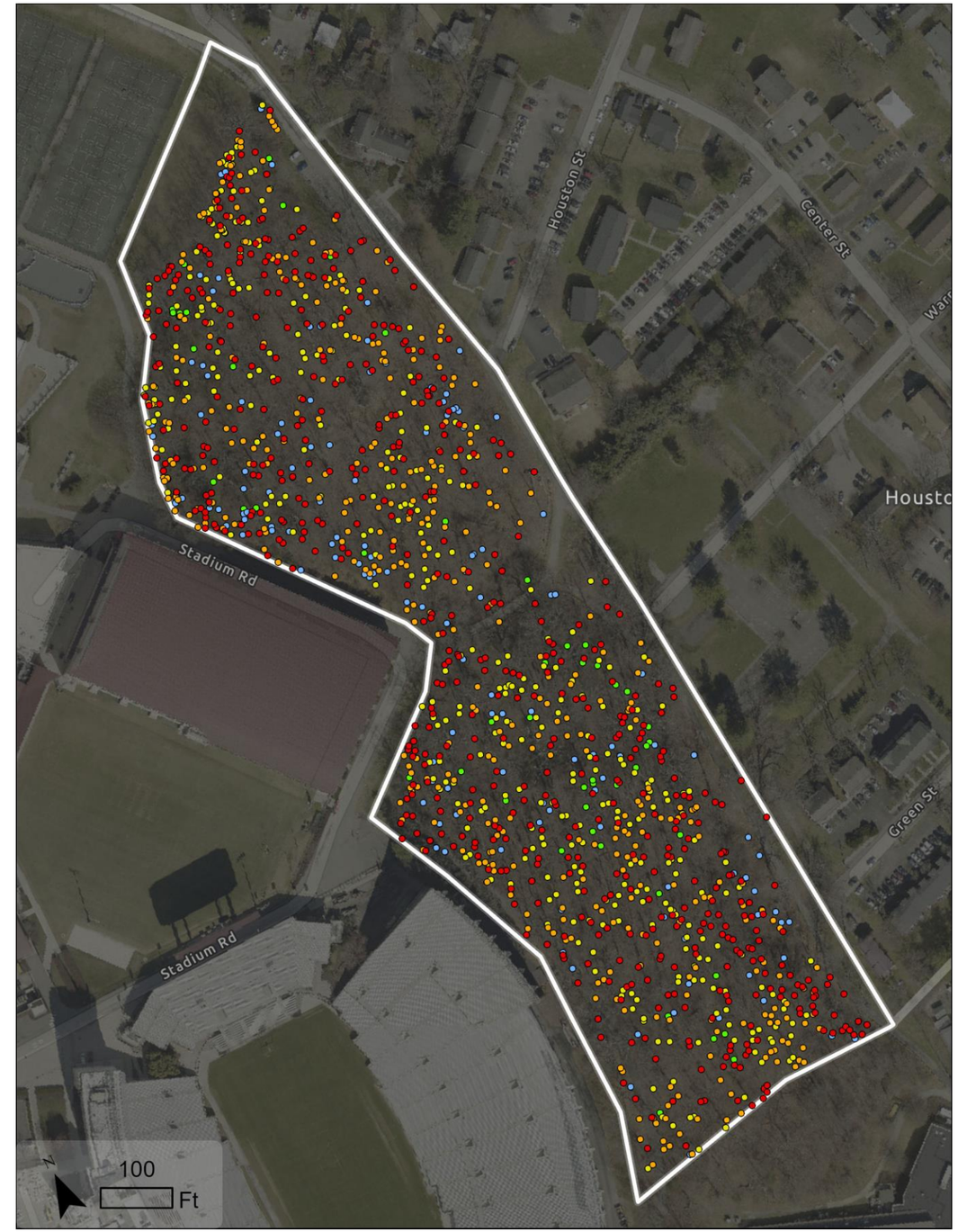




(Continued) Stadium Woods

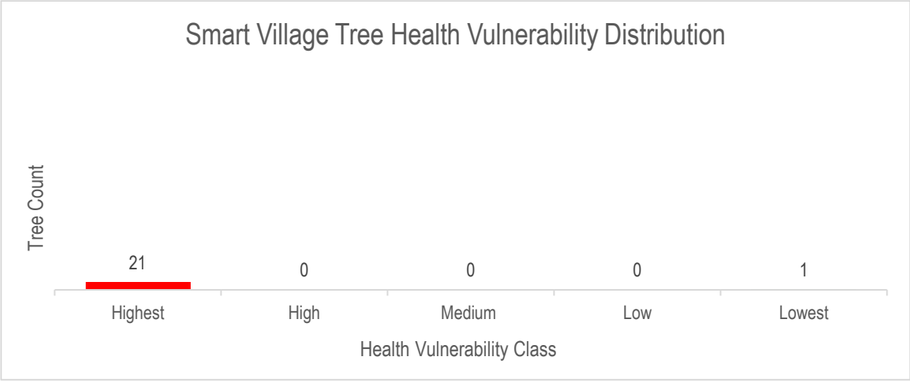
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	562	$573,988.83
High	3 & 4	398	$371,768.17
Medium	5 & 6	340	$98,599.67
Low	7 & 8	133	$84,659.33
Lowest	9 & 10	51	$8,707.33
	Totals	1,484	$1,137,723.33

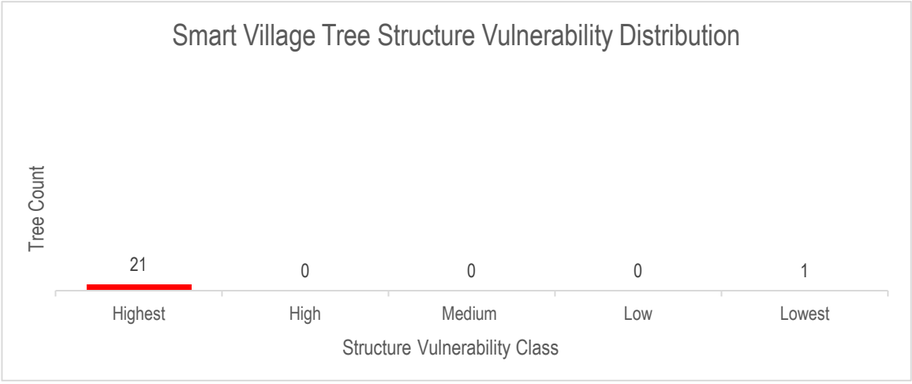


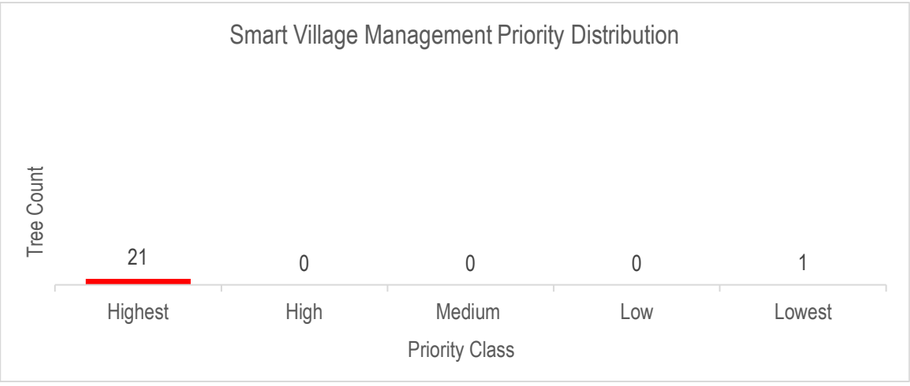


Smart Village

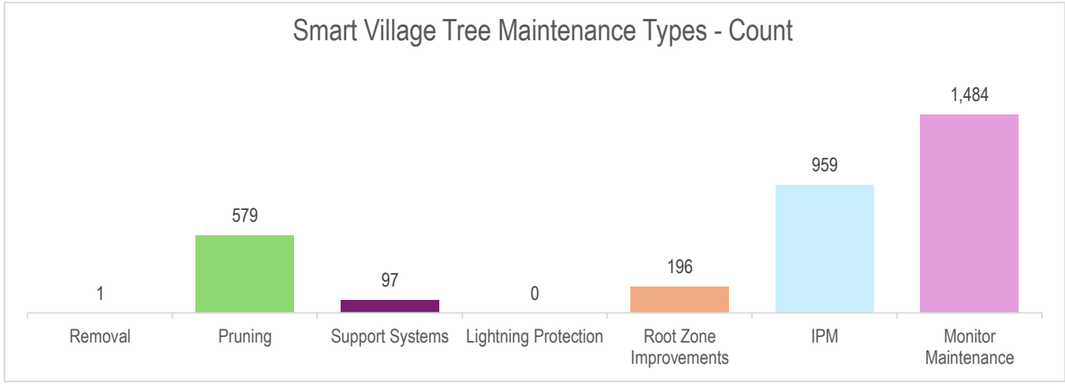
Priority Rank	Priority Class	Total trees	Tree density	Projected 10 Year maintenance cost	Projected annual average cost
21	Highest	22	0.4	$30,055.83	$3,005.58

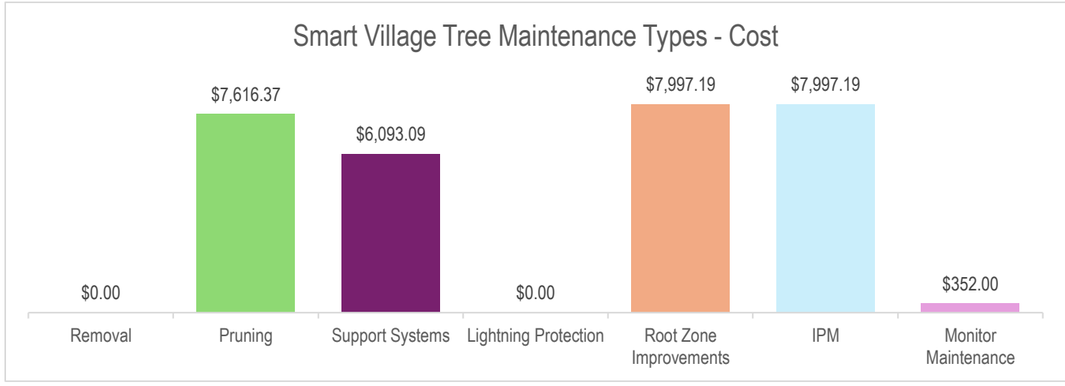






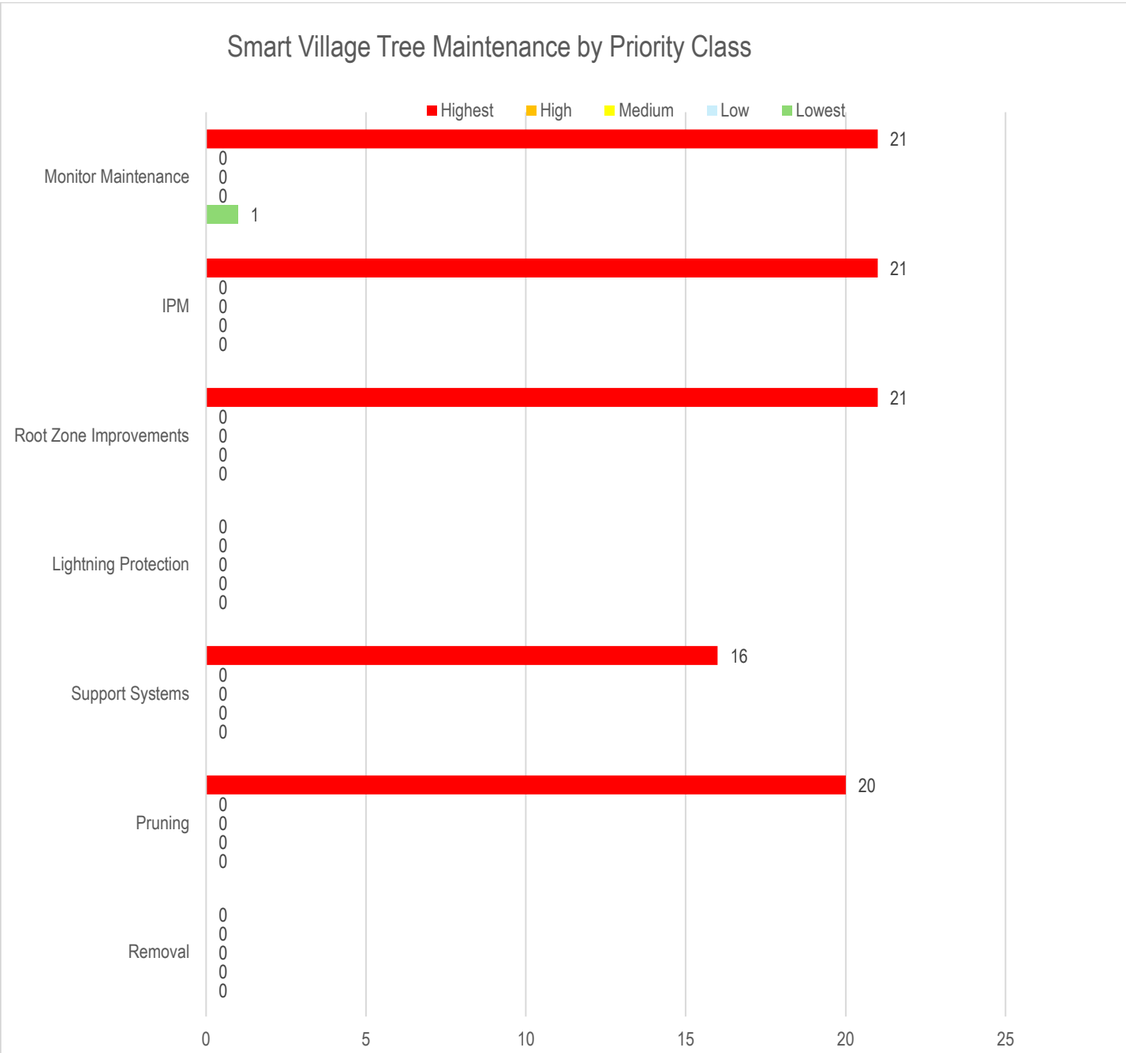
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	20	16	0	21	21	22	100
Proj. Cost	$0.00	$7,616.37	$6,093.09	$0.00	$7,997.19	$7,997.19	$352.00	$30,055.83





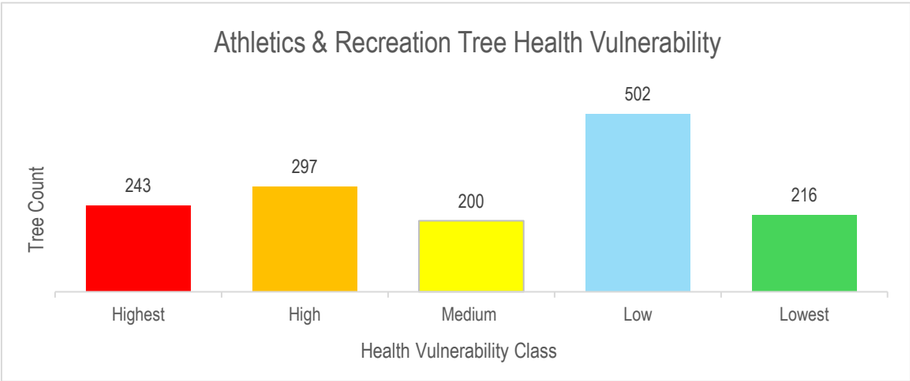
(Continued) Smart Village

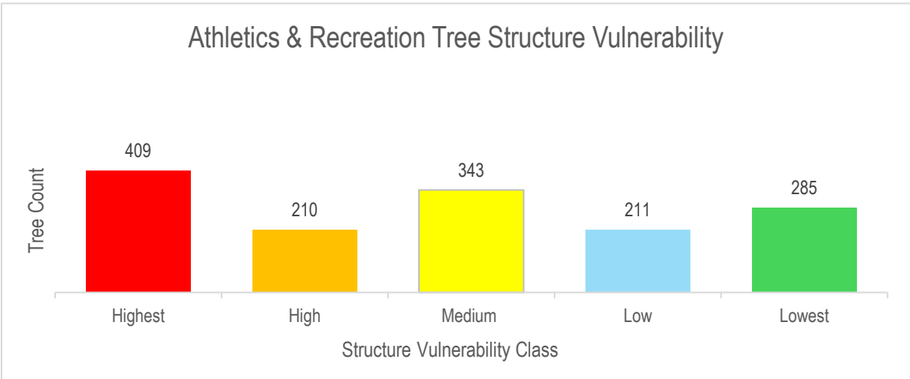
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	21	$30,039.83
High	3 & 4	0	$0.00
Medium	5 & 6	0	$0.00
Low	7 & 8	0	$0.00
Lowest	9 & 10	1	$16.00
	Totals	**22**	**$30,055.83**

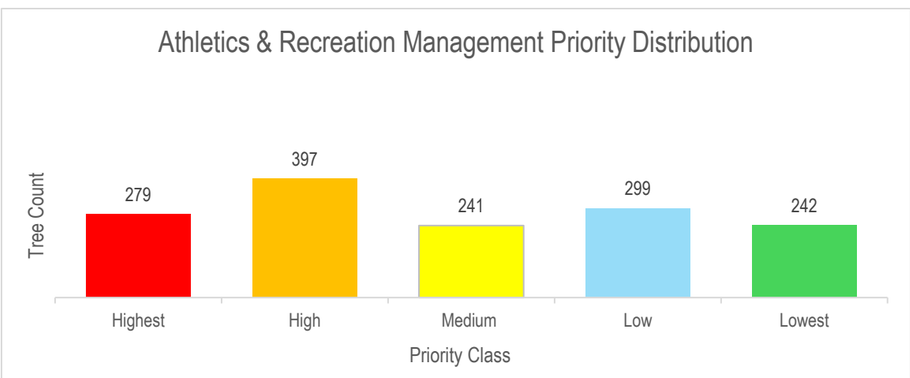


Athletics & Recreation

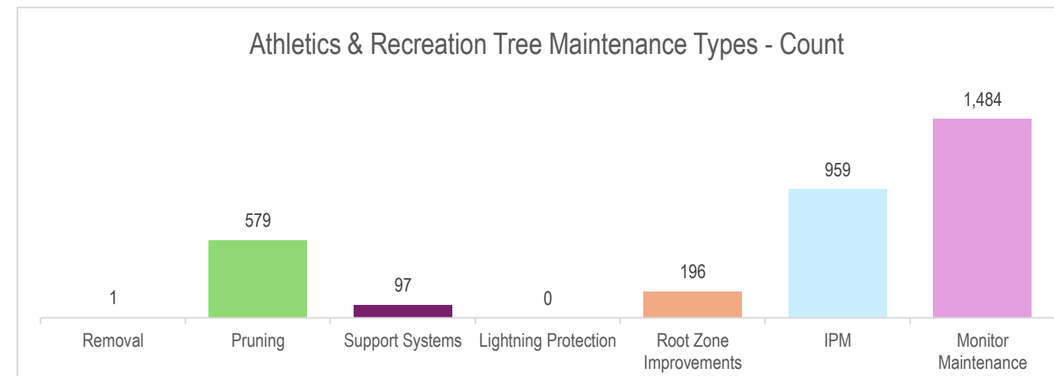
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
20	Highest	1458	7.4	$1,159,701.17	$115,970.12

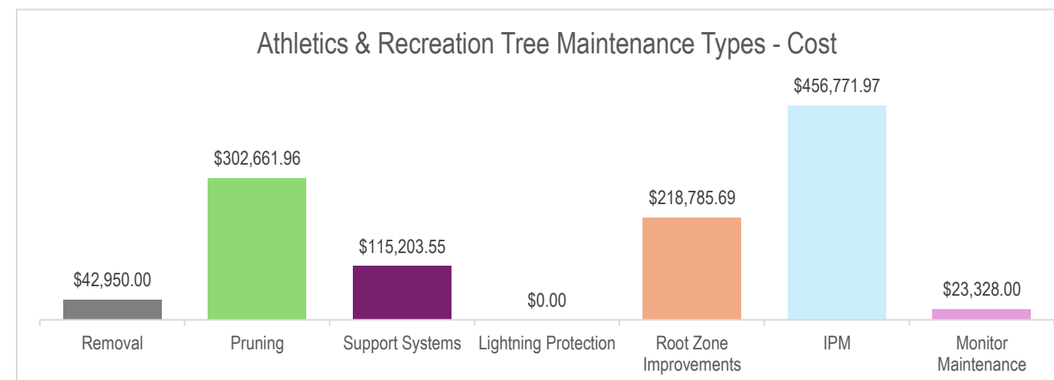






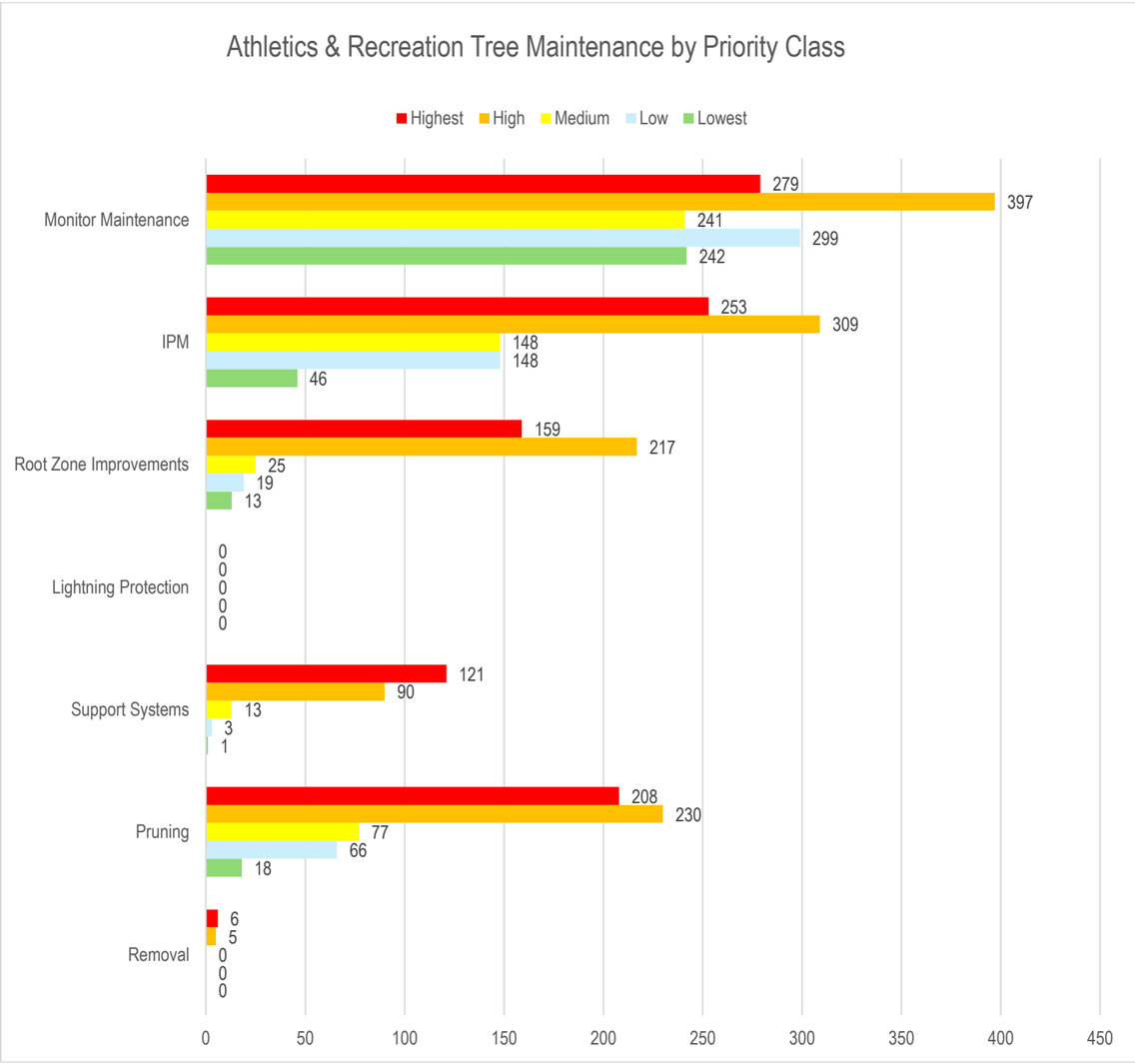
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	11	599	228	0	433	904	1,458	3633
Proj. Cost	$42,950.00	$302,661.96	$115,203.55	$0.00	$218,785.69	$456,771.97	$23,328.00	$1,159,701.17

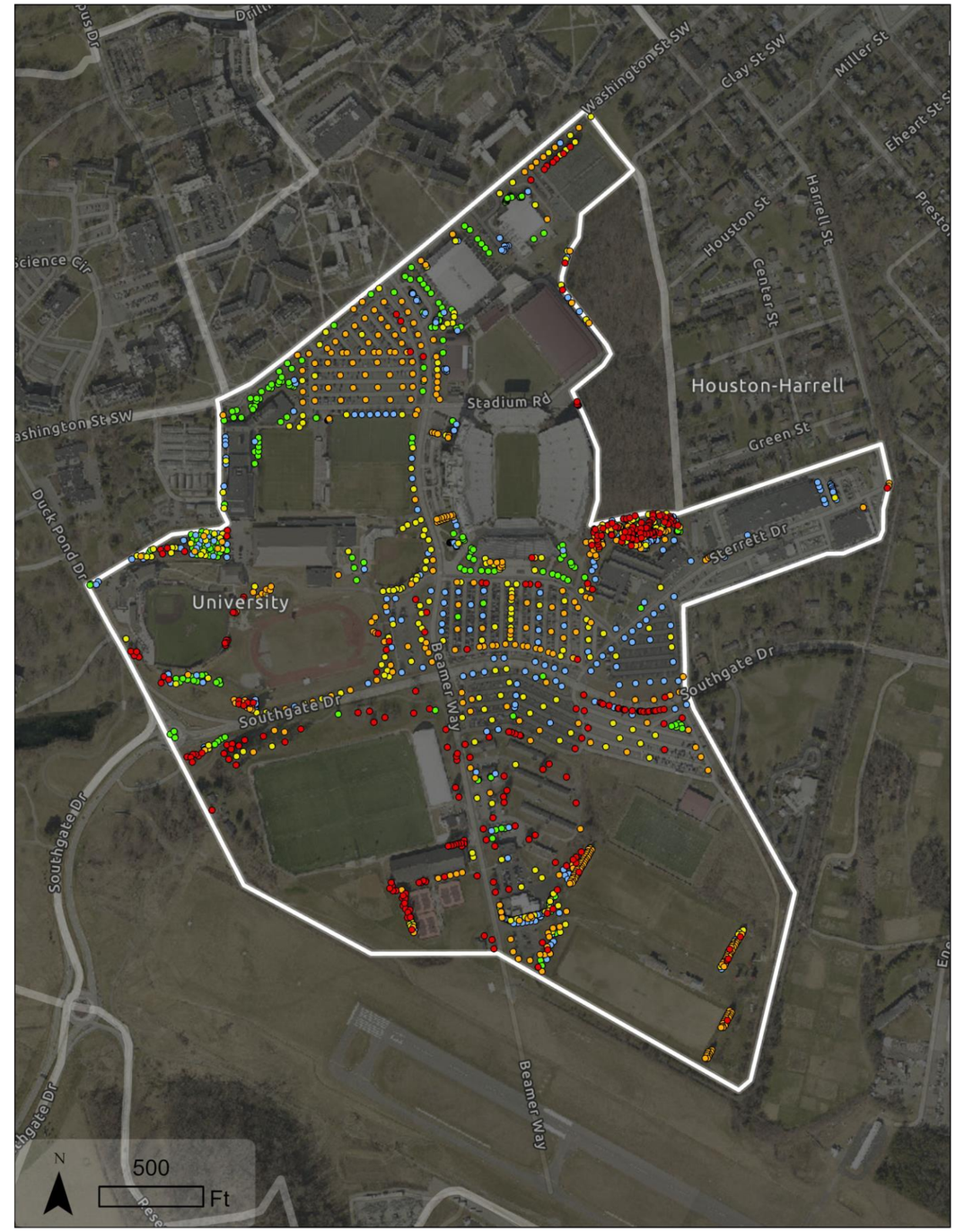




(Continued) Athletics & Recreation

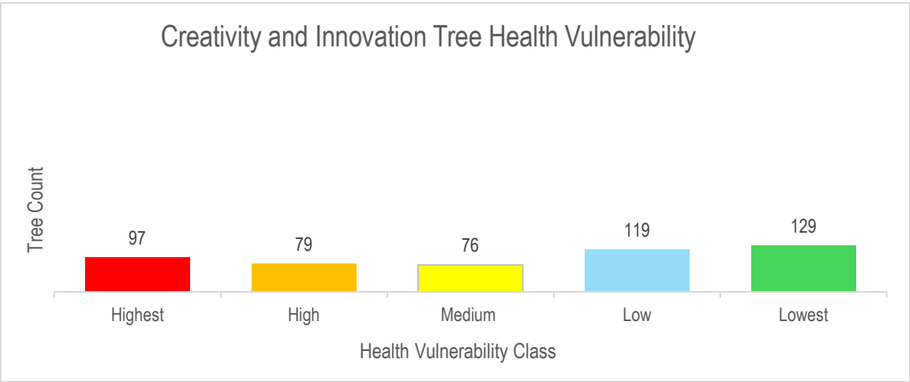
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	279	$375,143.83
High	3 & 4	397	$415,353.00
Medium	5 & 6	241	$167,569.33
Low	7 & 8	299	$151,868.50
Lowest	9 & 10	242	$49,766.50
	Totals	**1458**	**$1,159,701.16**

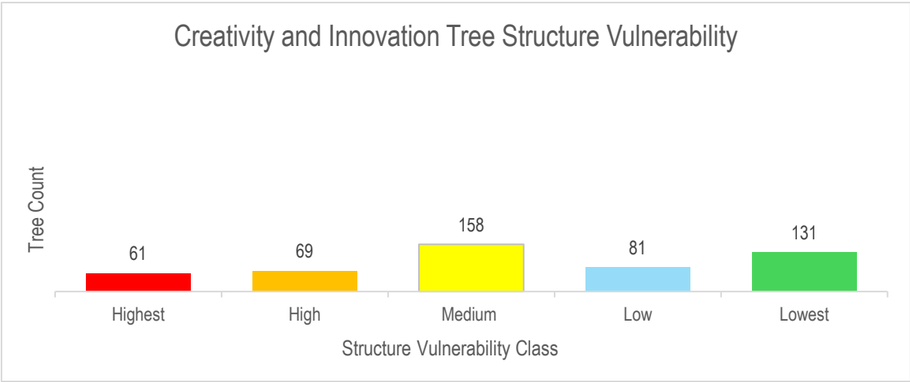


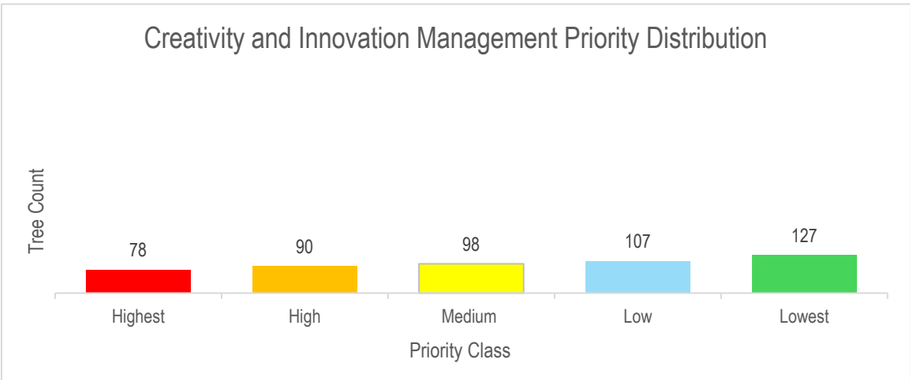


Creativity & Innovation

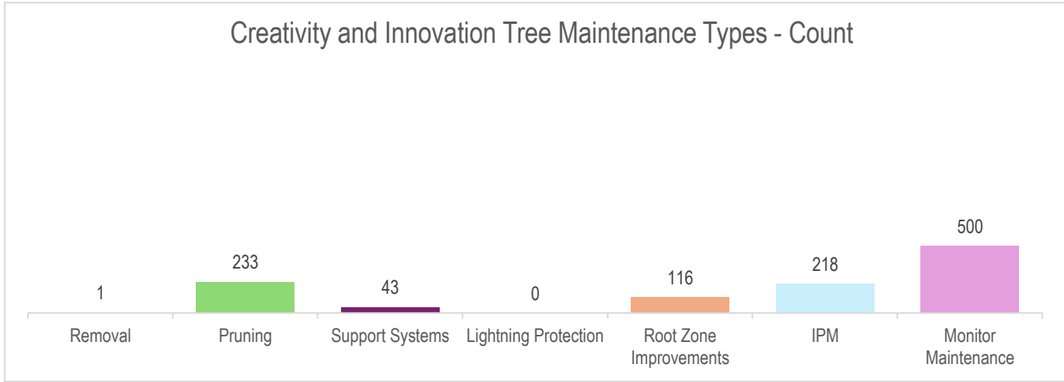
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
19	Highest	500	13.6	$435,759.67	$43,575.97

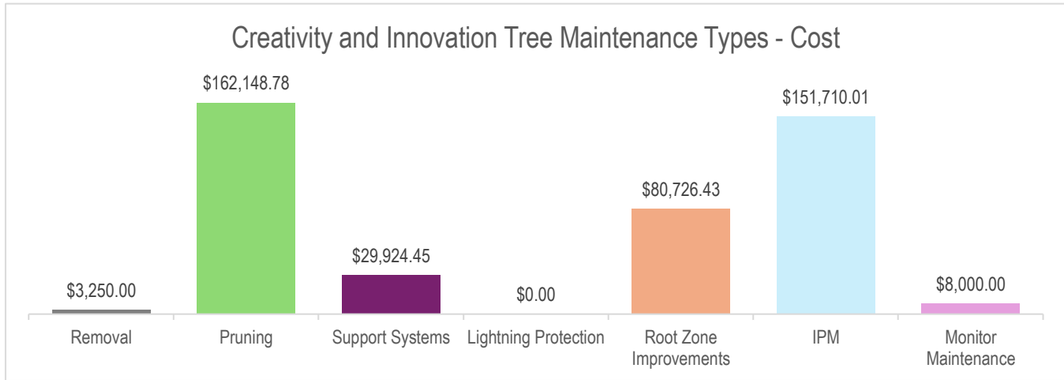






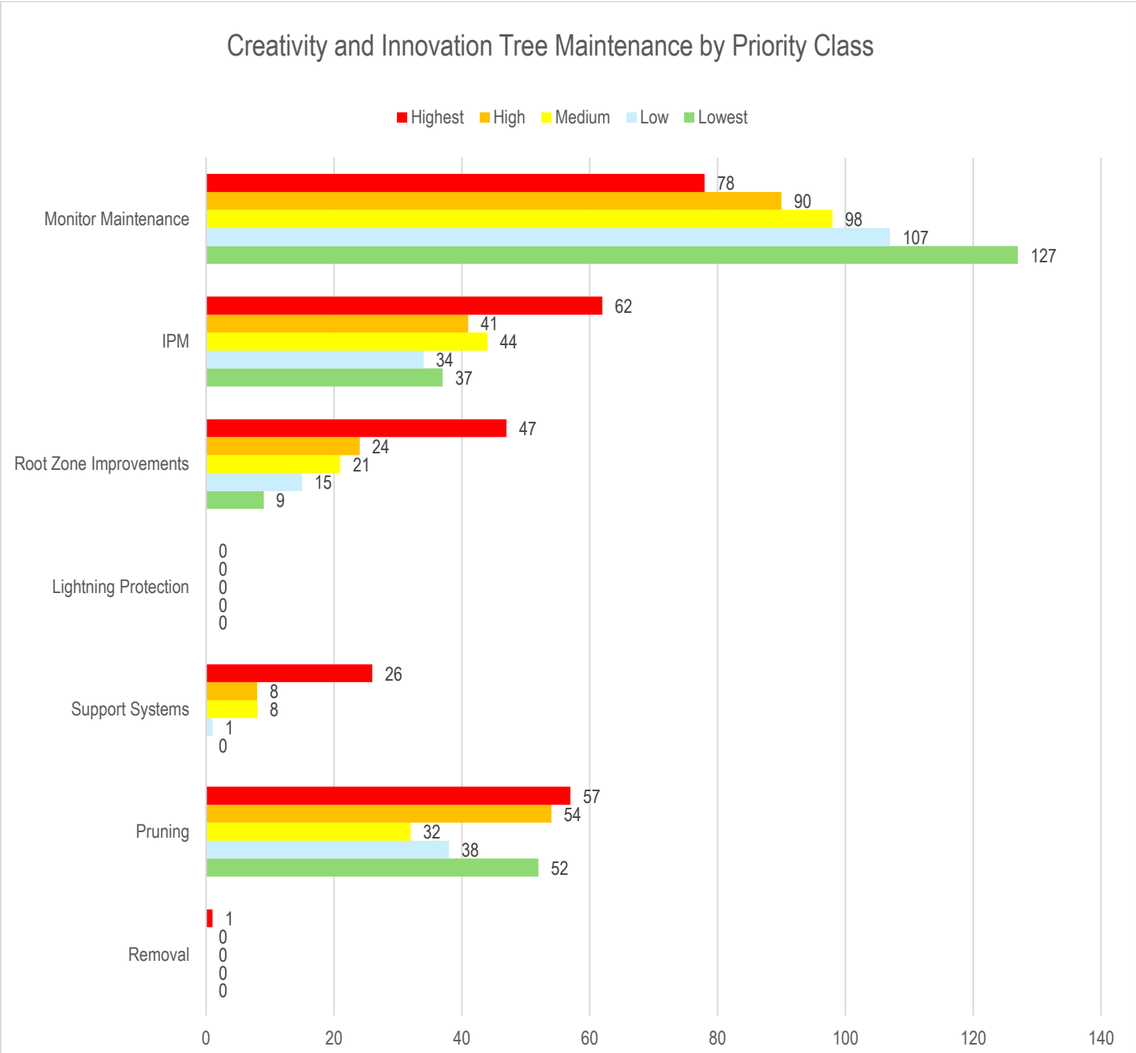
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	233	43	0	116	218	500	1111
Proj. Cost	$3,250.00	$162,148.78	$29,924.45	$0.00	$80,726.43	$151,710.01	$8,000.00	$435,759.67

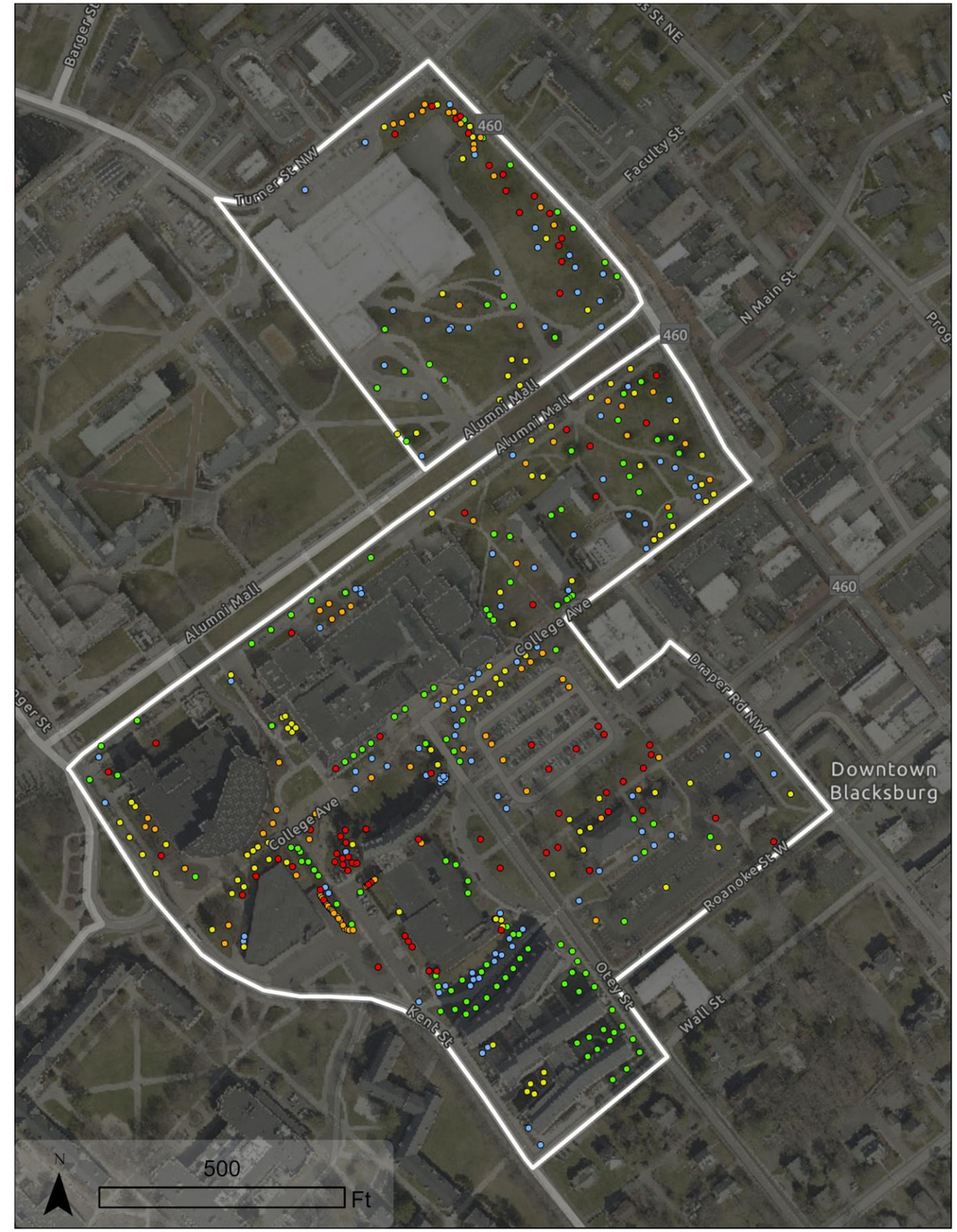




(Continued) Creativity & Innovation

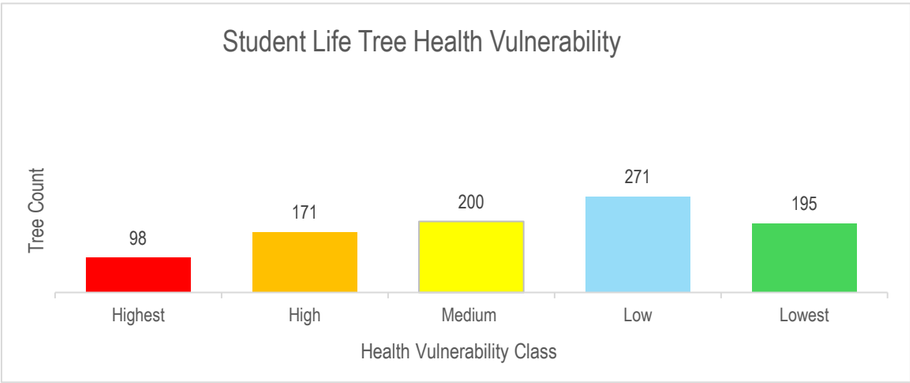
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	78	$102,140.17
High	3 & 4	90	$91,742.00
Medium	5 & 6	98	$68,709.17
Low	7 & 8	107	$76,591.33
Lowest	9 & 10	127	$96,577.00
	Totals	500	$435,759.67

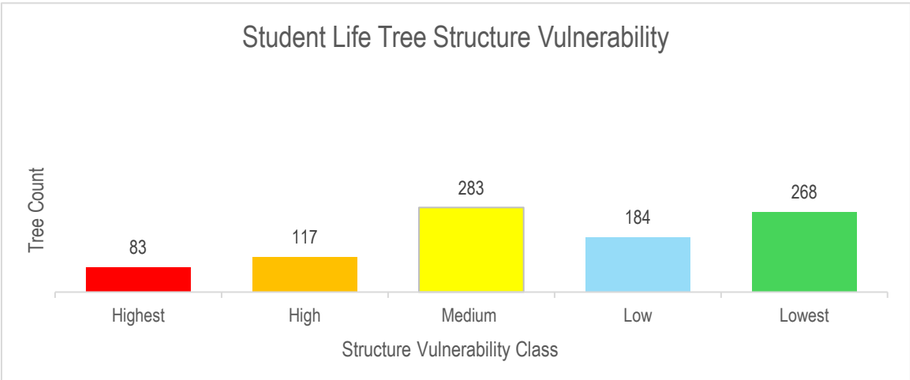


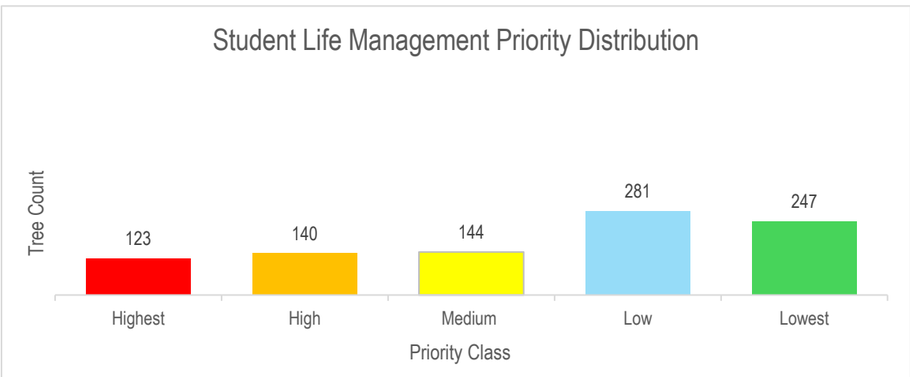


Student Life

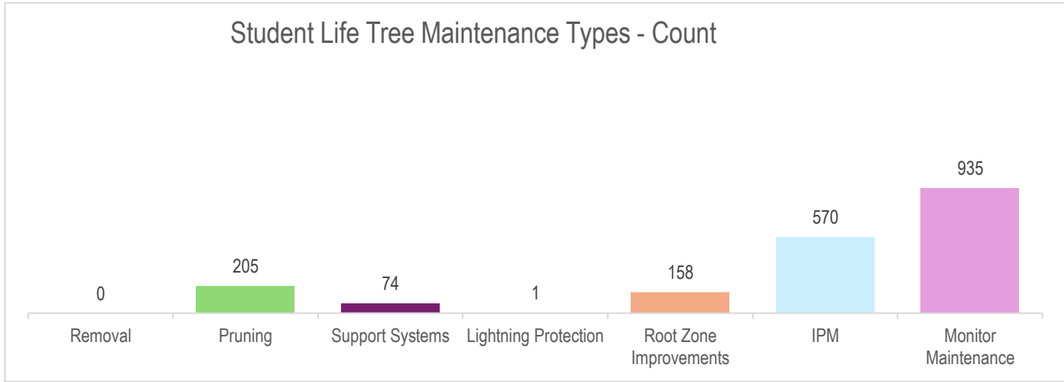
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
18	High	935	14.5	$533,343.83	$53,334.38

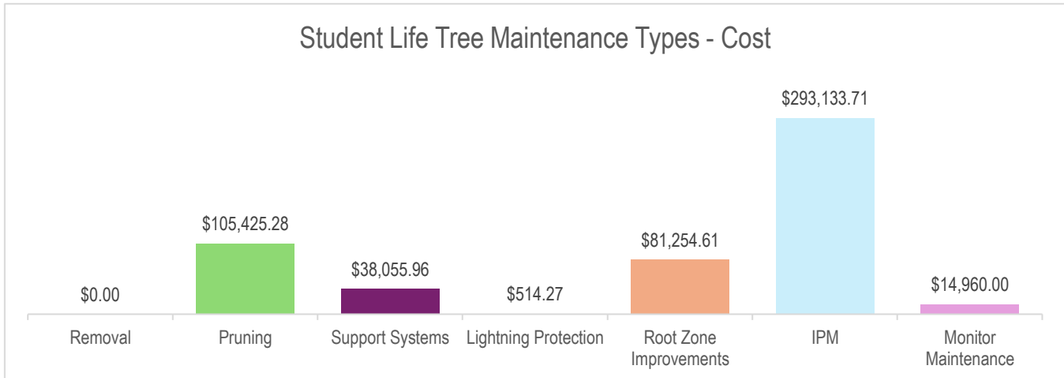






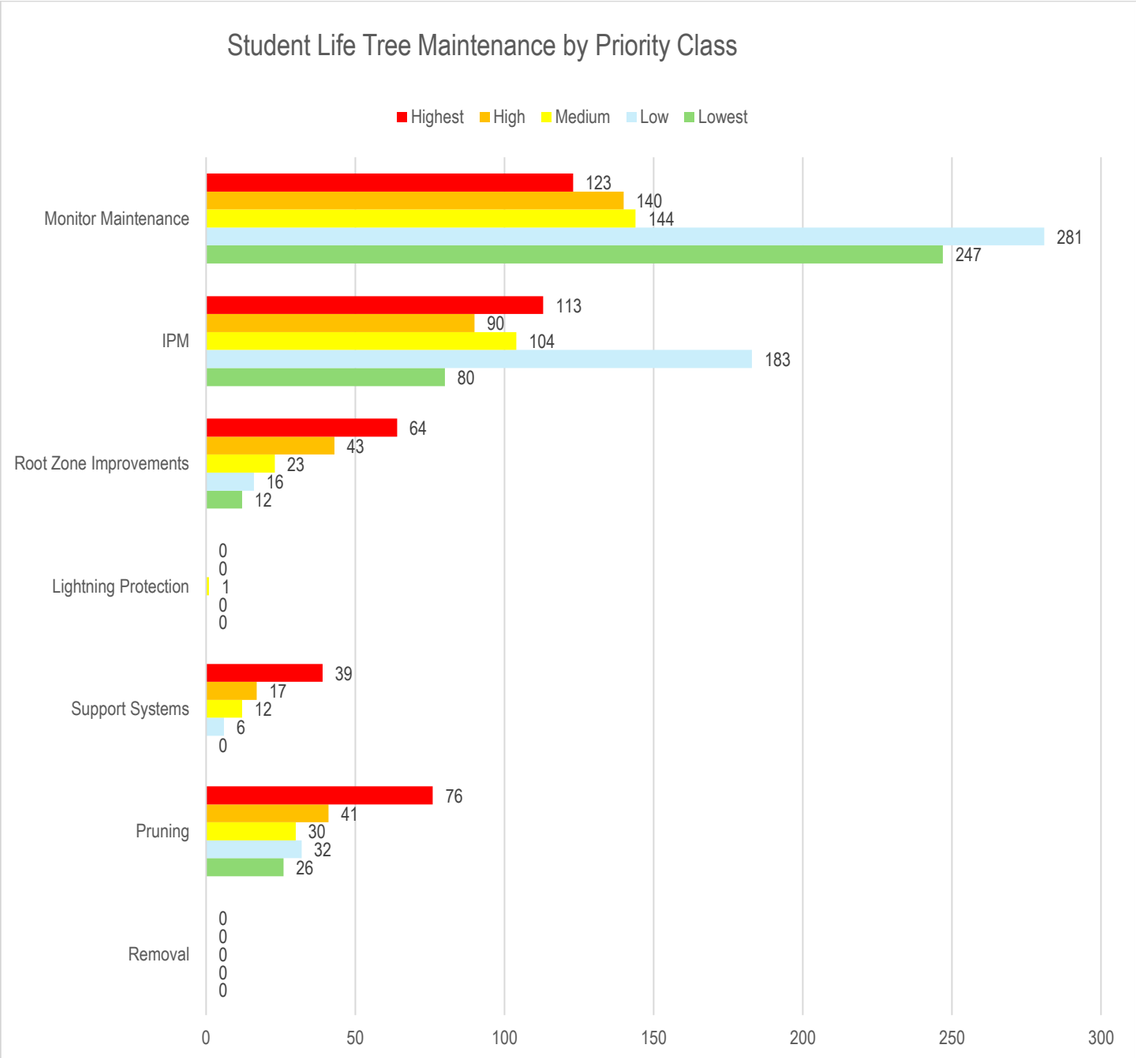
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	205	74	1	158	570	935	1943
Proj. Cost	$0.00	$105,425.28	$38,055.96	$514.27	$81,254.61	$293,133.71	$14,960.00	$533,343.83

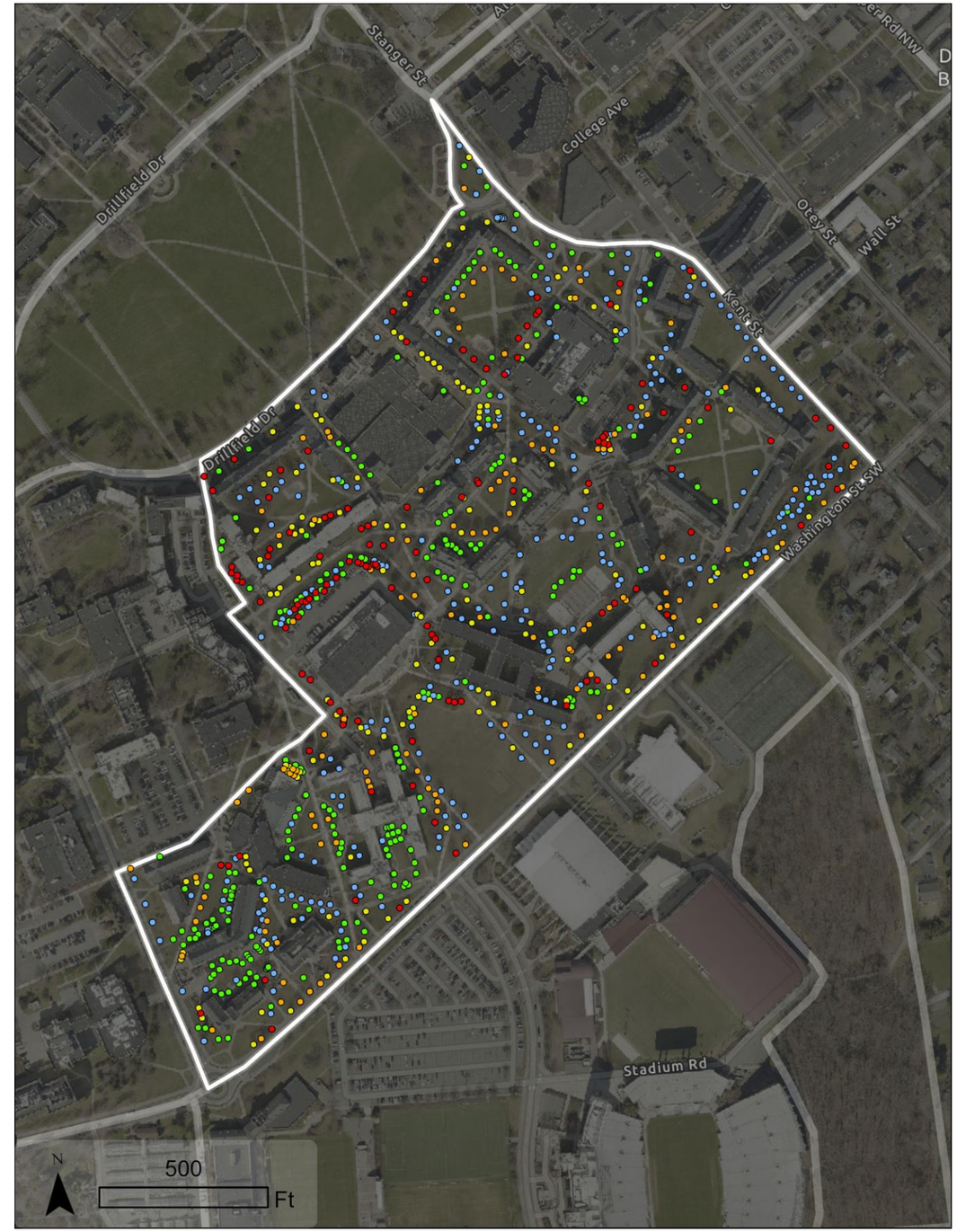




(Continued) Student Life

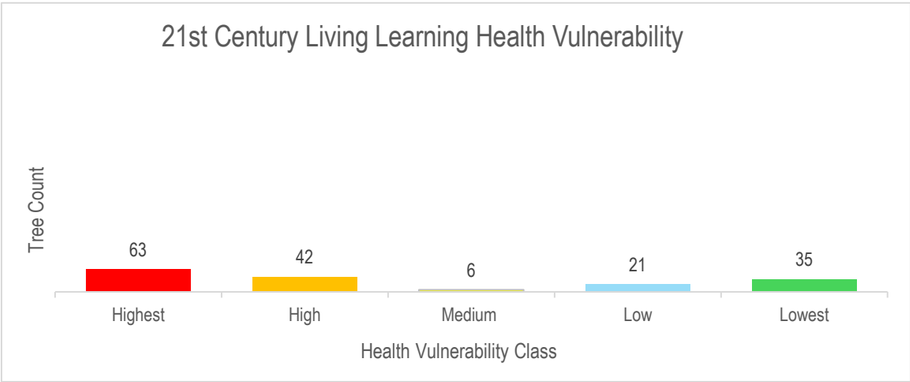
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	123	$144,771.17
High	3 & 4	140	$97,759.67
Medium	5 & 6	144	$86,129.33
Low	7 & 8	281	$126,491.67
Lowest	9 & 10	247	$78,192.00
	Totals	**935**	**$533,343.84**

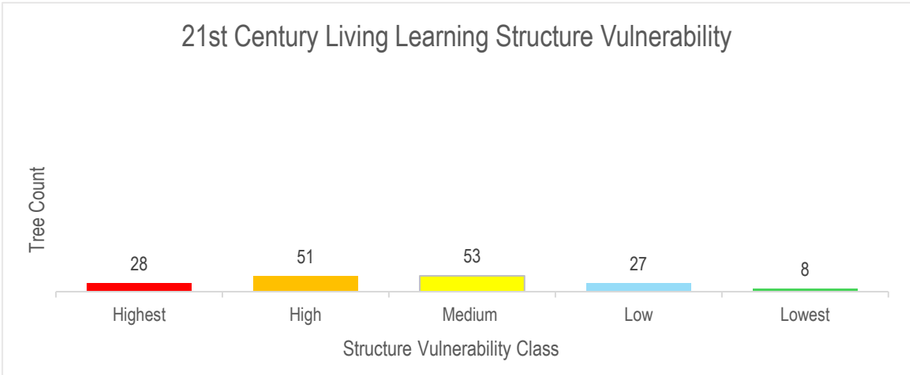


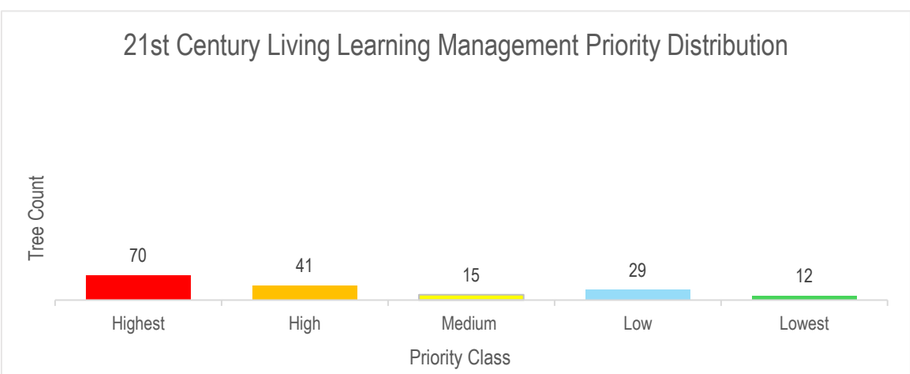


21st Century Living Learning

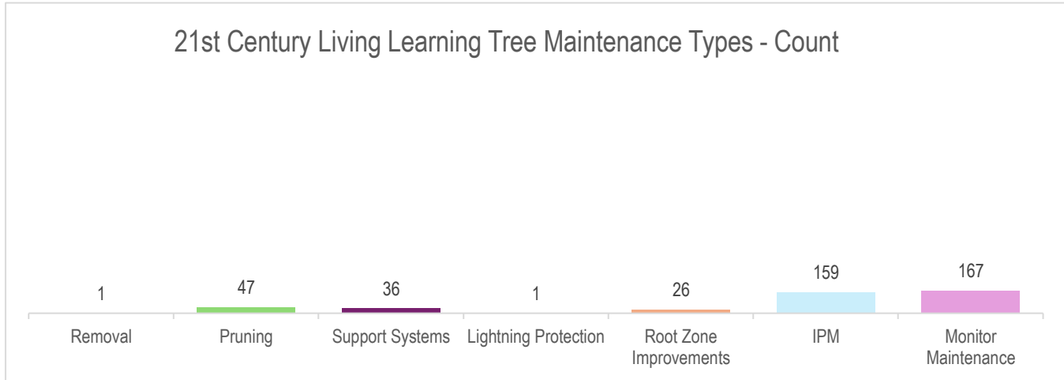
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
17	High	167	4.4	$144,974.83	$14,497.48

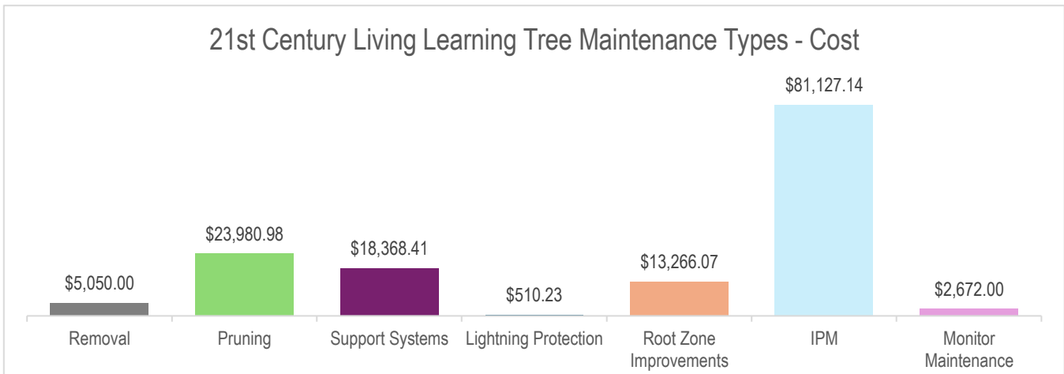






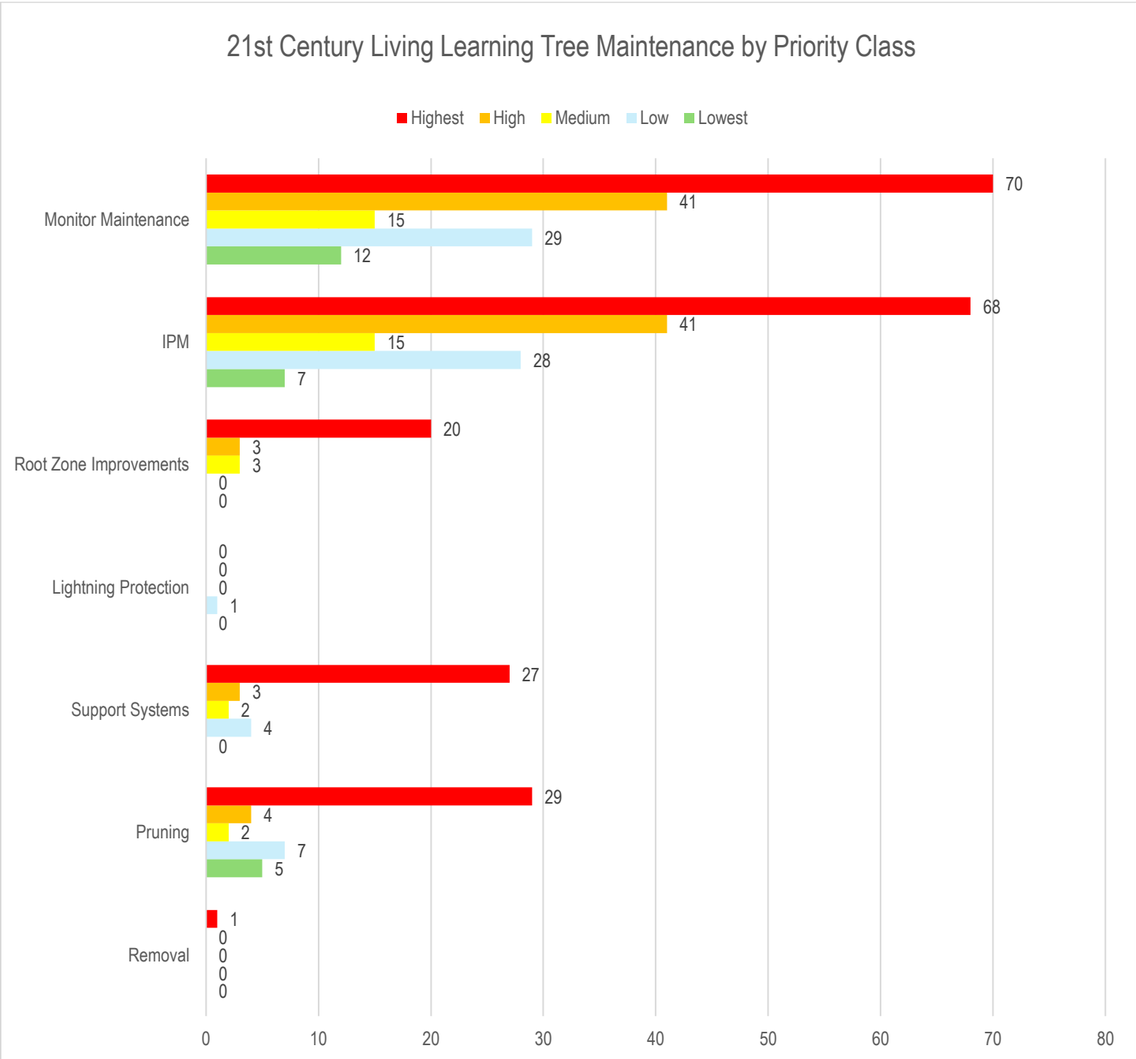
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	47	36	1	26	159	167	437
Proj. Cost	$5,050.00	$23,980.98	$18,368.41	$510.23	$13,266.07	$81,127.14	$2,672.00	$144,974.83

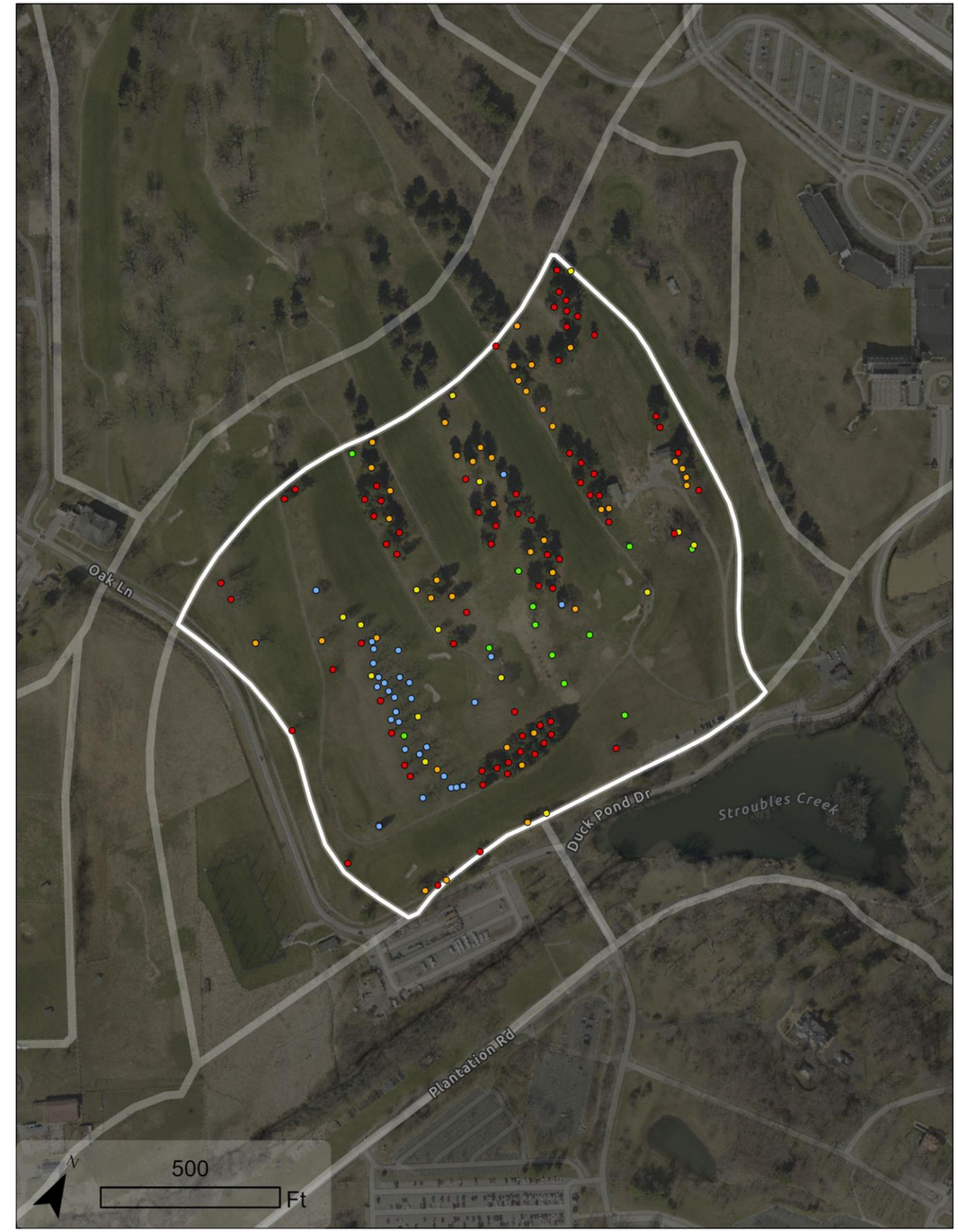




(Continued) 21st Century Living Learning

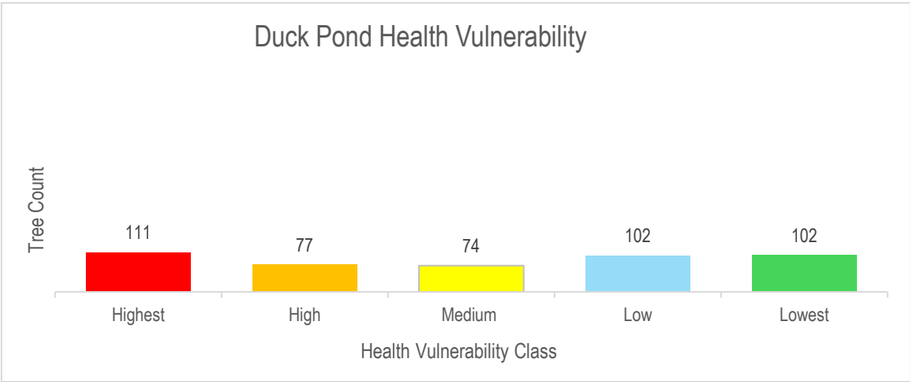
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	70	$78,834.33
High	3 & 4	41	$25,277.00
Medium	5 & 6	15	$9,382.00
Low	7 & 8	29	$21,248.50
Lowest	9 & 10	12	$10,233.00
	Totals	167	$144,974.83

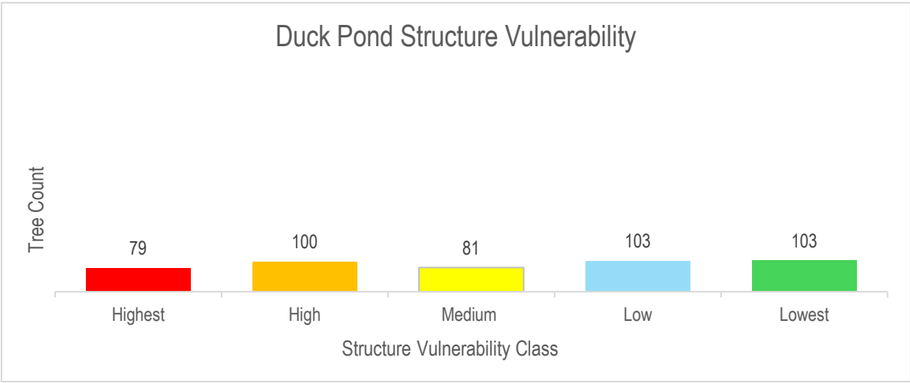


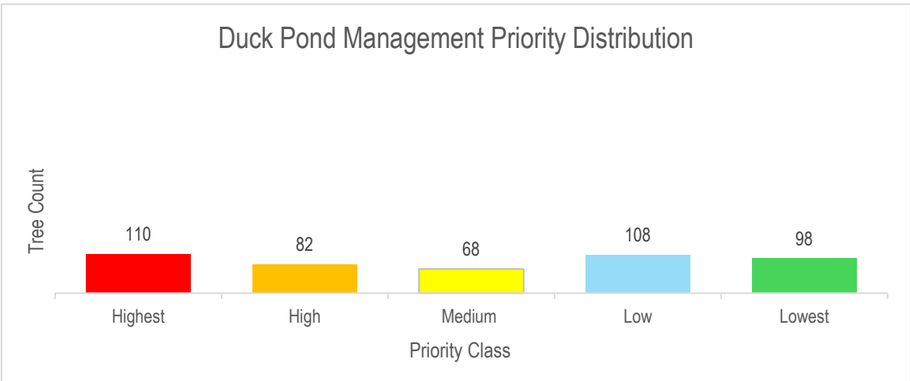


Duck Pond

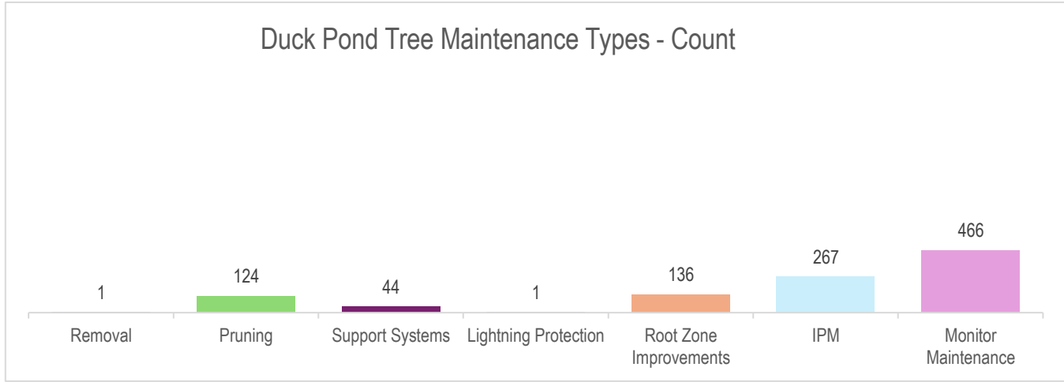
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
16	High	466	15	$307,571.17	$30,757.12

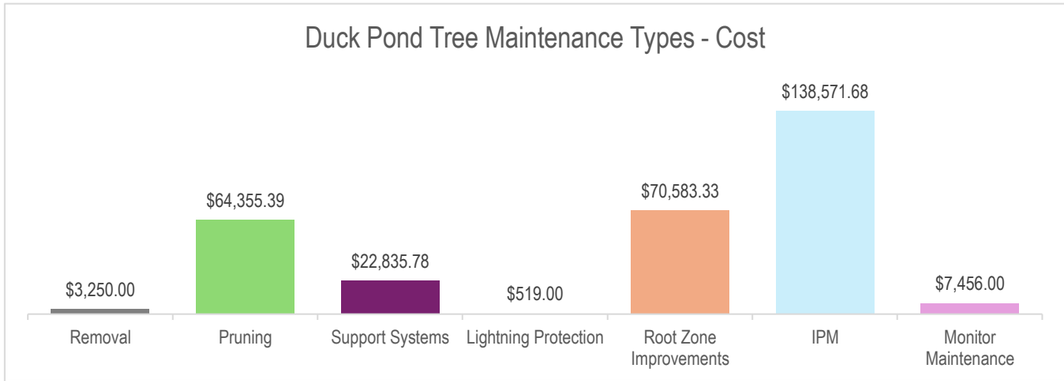






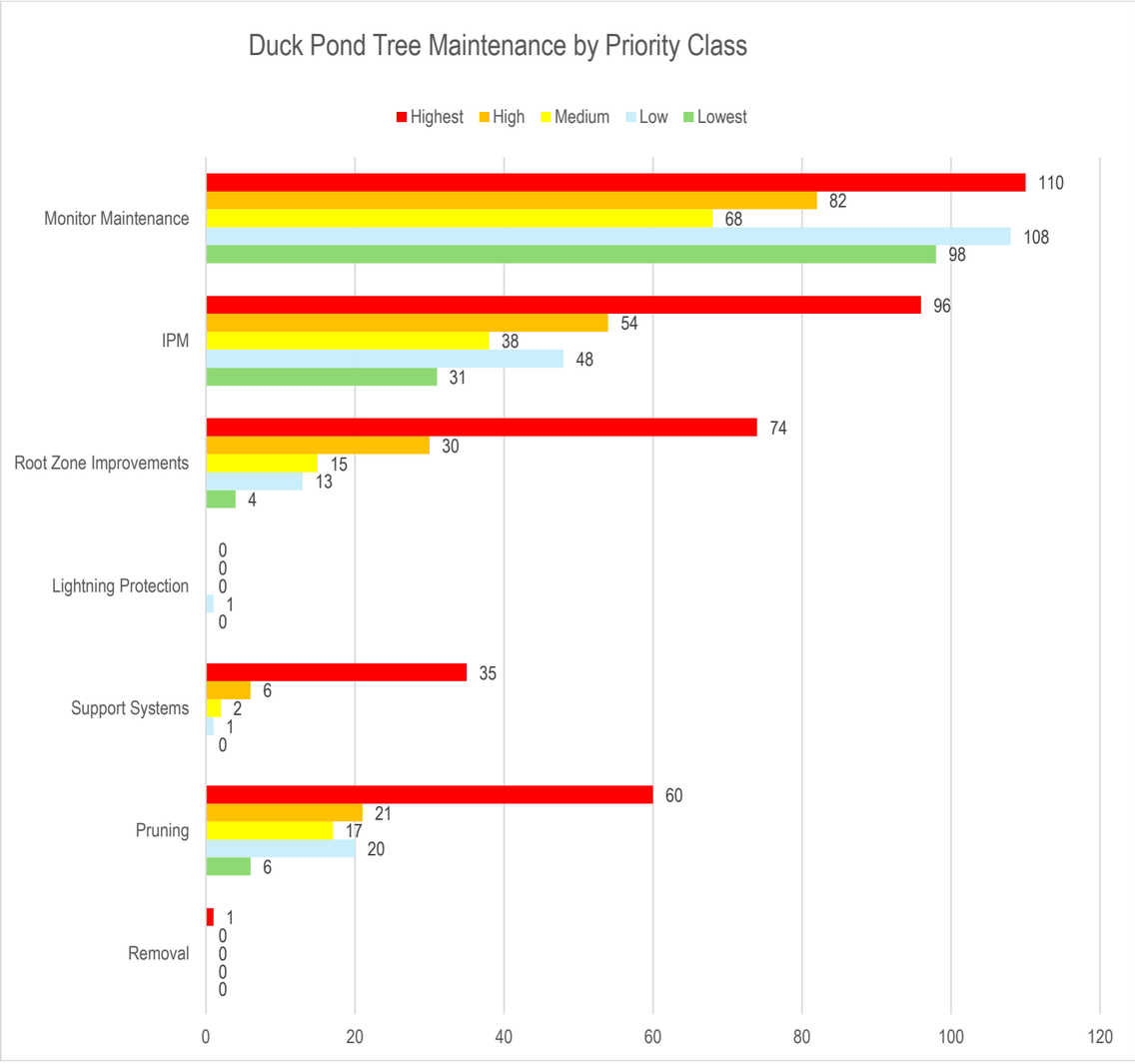
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	124	44	1	136	267	466	1039
Proj. Cost	$3,250.00	$64,355.39	$22,835.78	$519.00	$70,583.33	$138,571.68	$7,456.00	$307,571.17

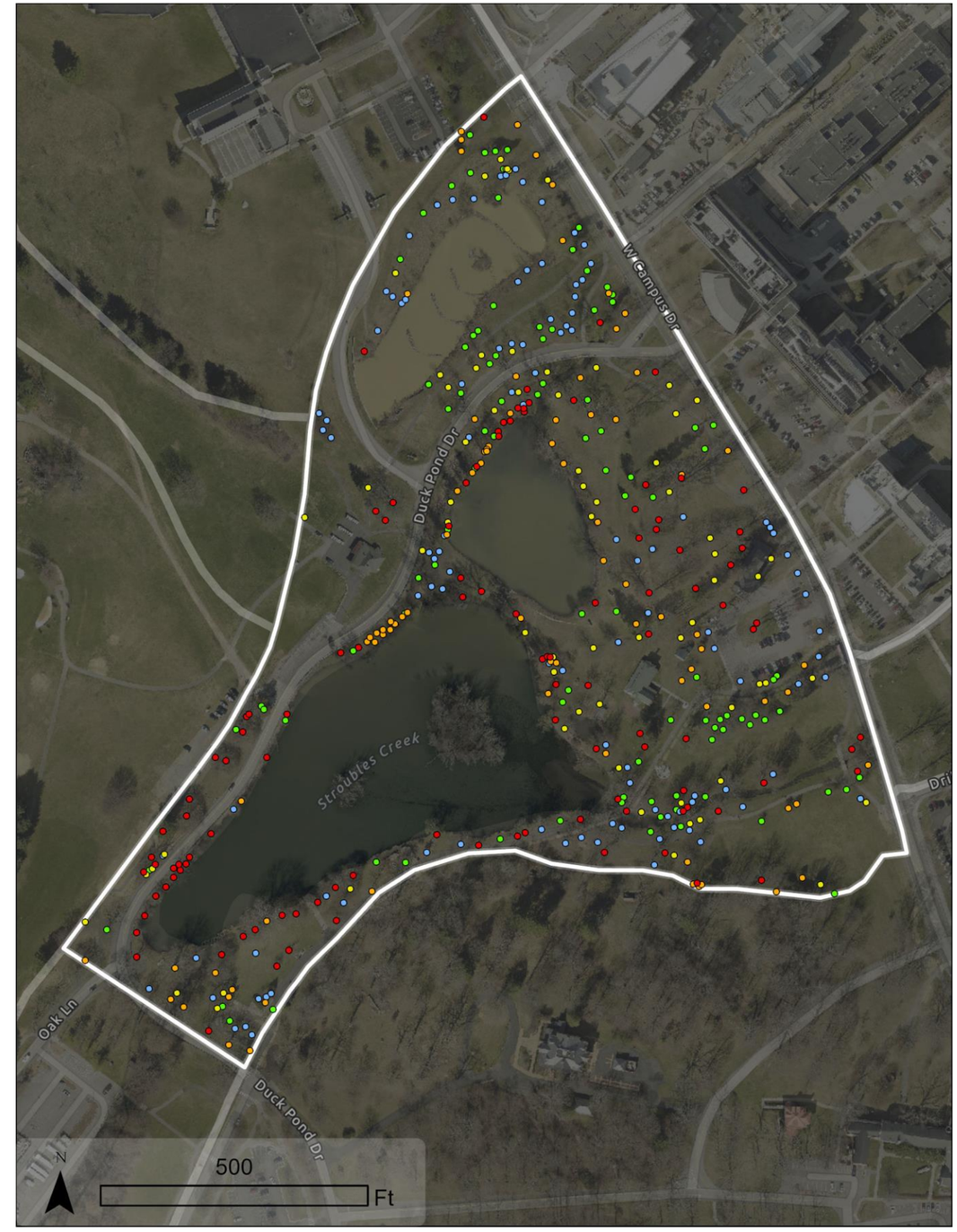




(Continued) Duck Pond

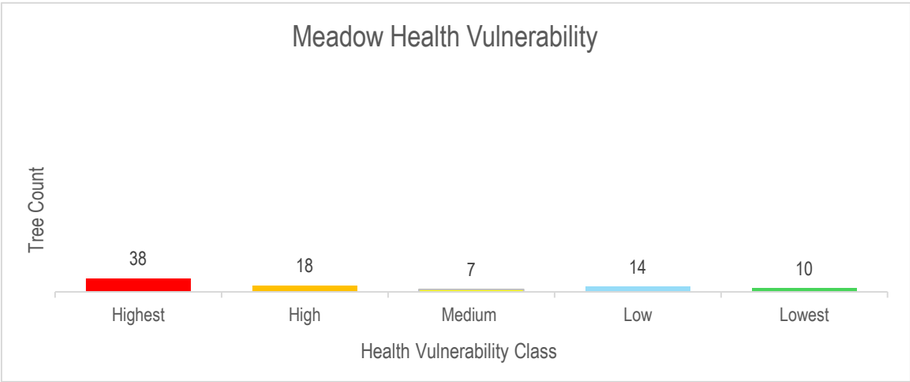
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	110	$125,555.83
High	3 & 4	82	$58,263.50
Medium	5 & 6	68	$43,029.00
Low	7 & 8	108	$56,379.83
Lowest	9 & 10	98	$24,343.00
	Totals	**466**	**$307,571.16**

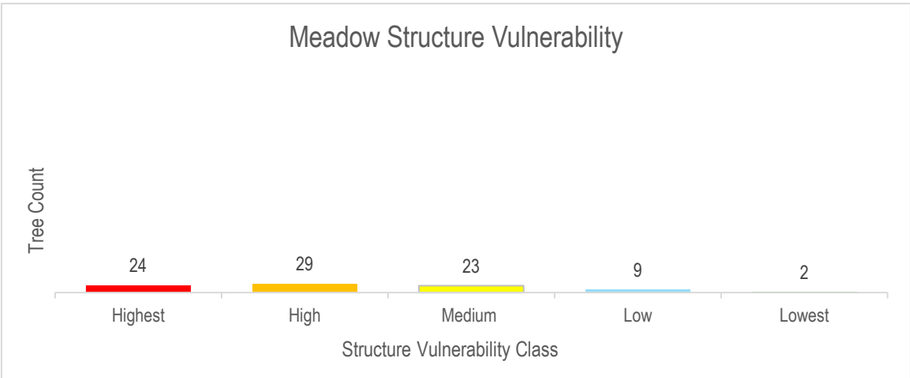


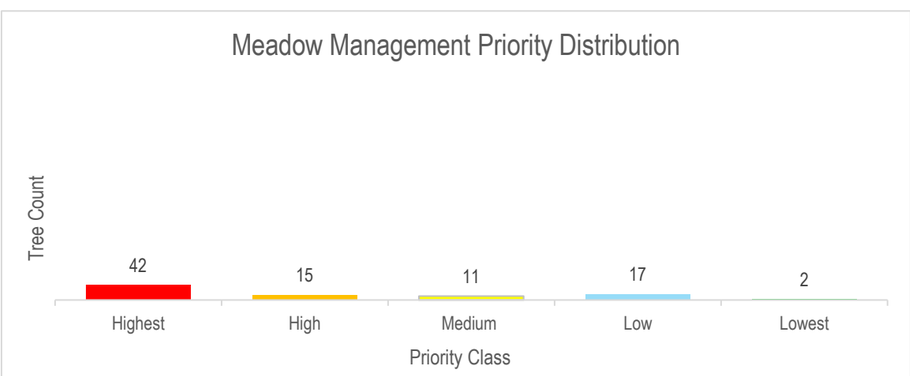


Meadow

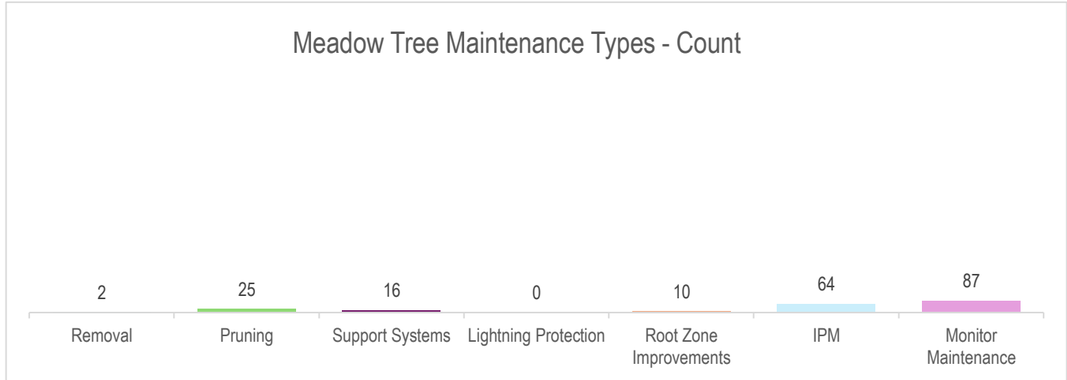
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
15	High	87	6.1	$75,893.33	$7,589.33

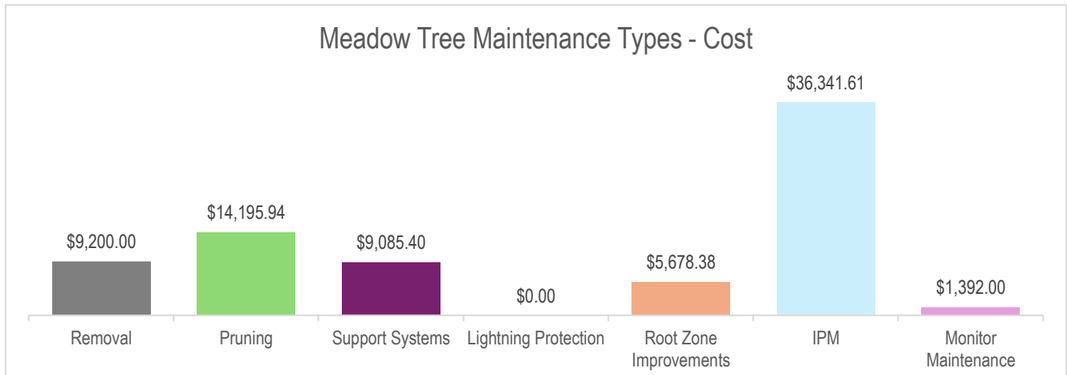






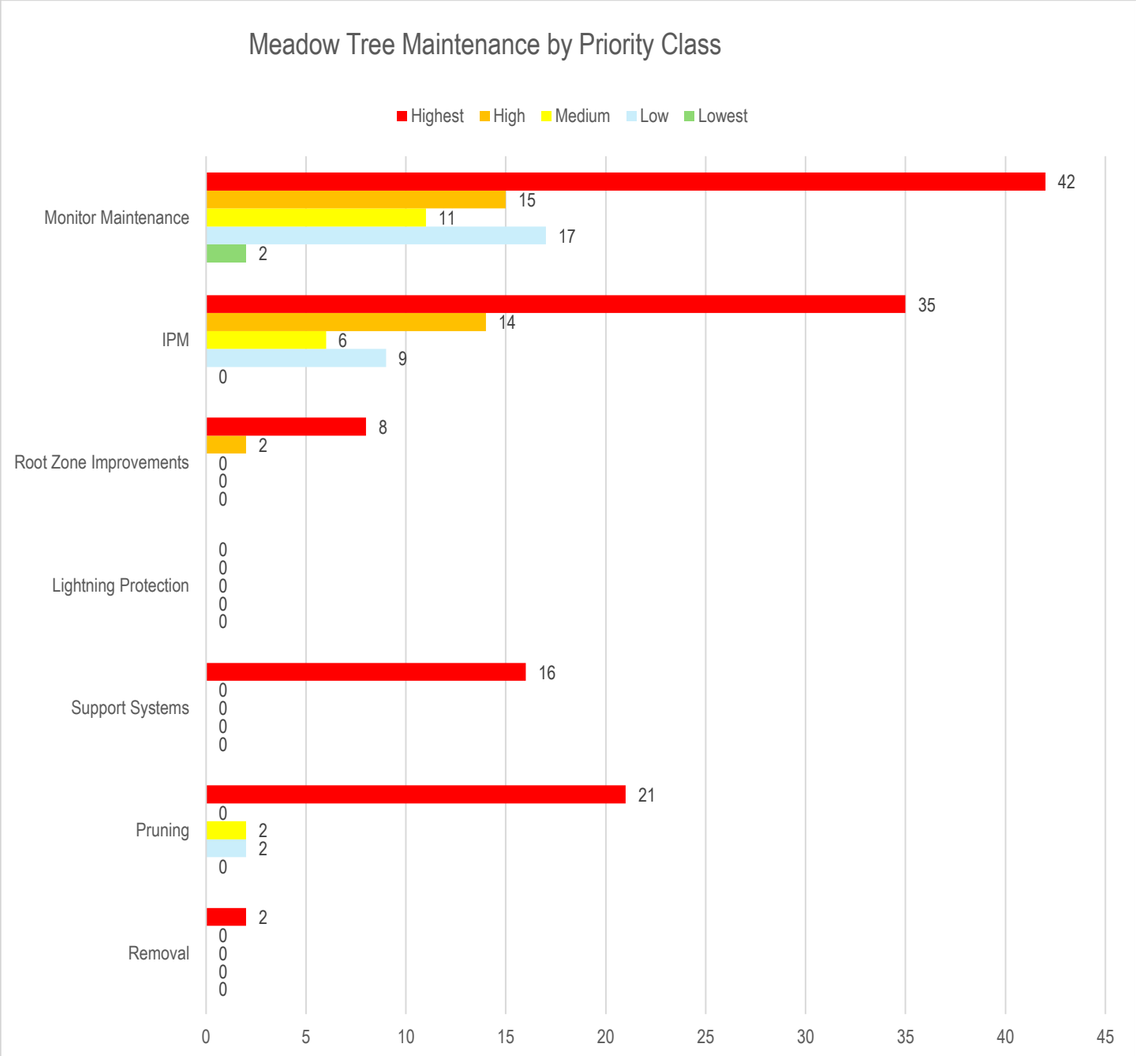
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	2	25	16	0	10	64	87	204
Proj. Cost	$9,200.00	$14,195.94	$9,085.40	$0.00	$5,678.38	$36,341.61	$1,392.00	$75,893.33

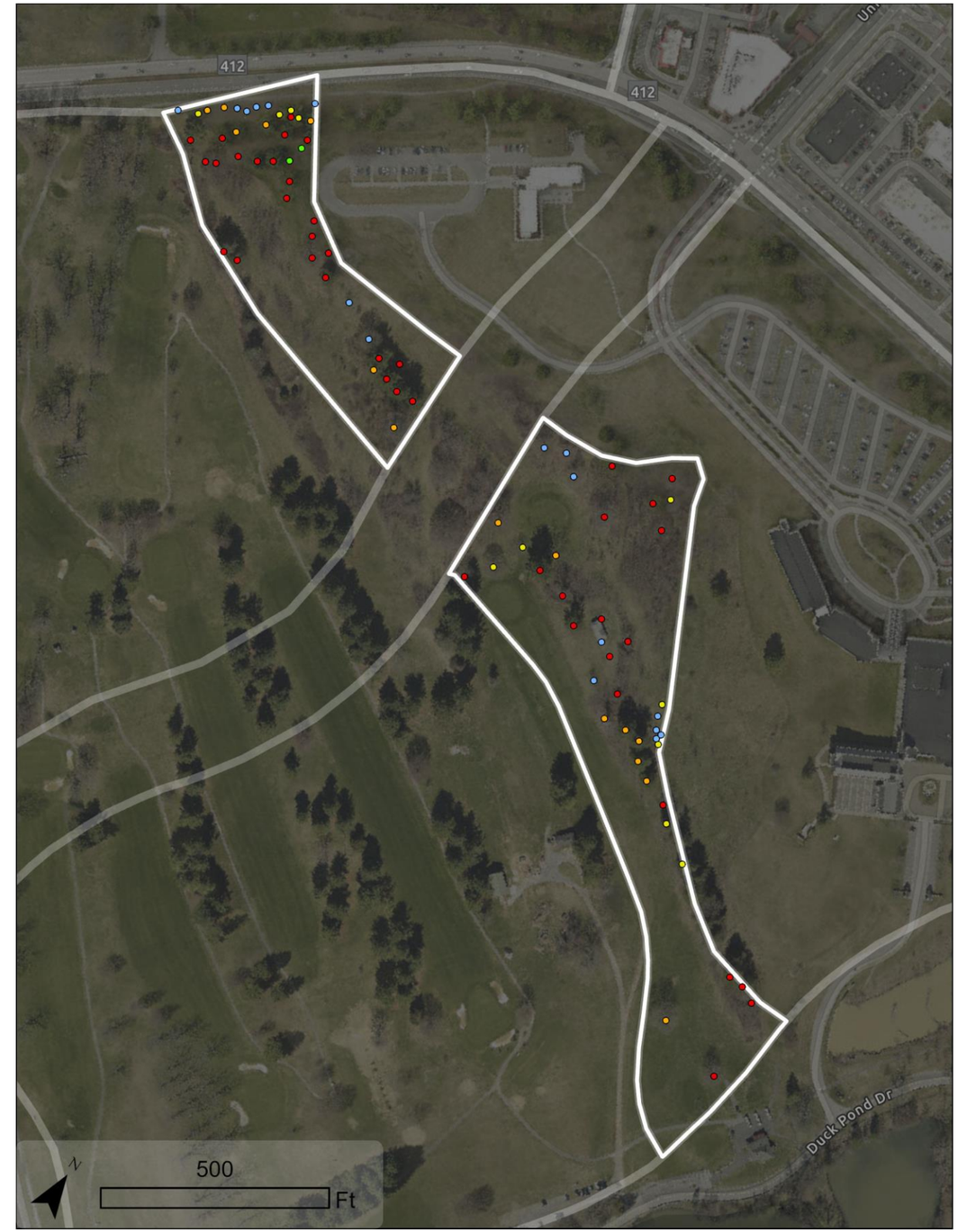




(Continued) **Meadow**

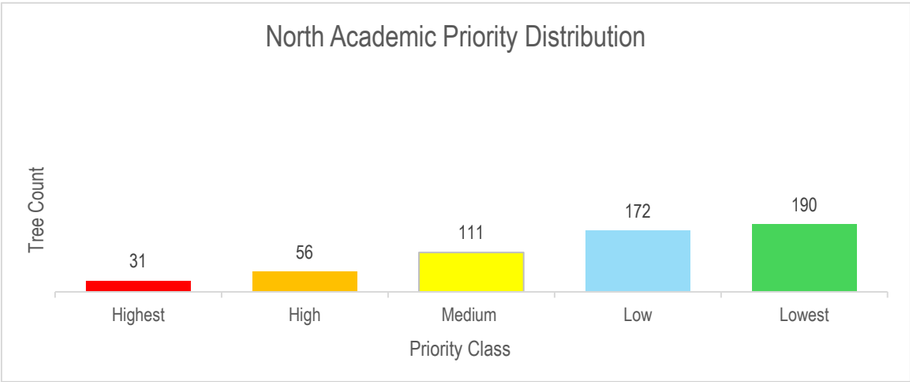
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	42	$55,800.33
High	3 & 4	15	$7,318.00
Medium	5 & 6	11	$5,714.00
Low	7 & 8	17	$7,029.00
Lowest	9 & 10	2	$32.00
	Totals	**87**	**$75,893.33**

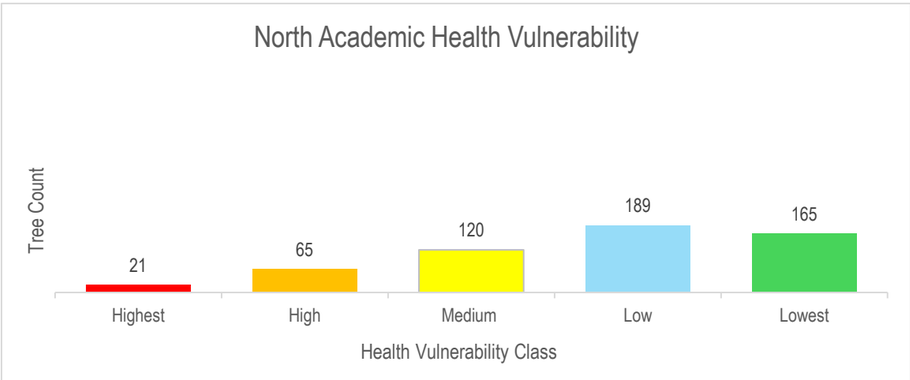


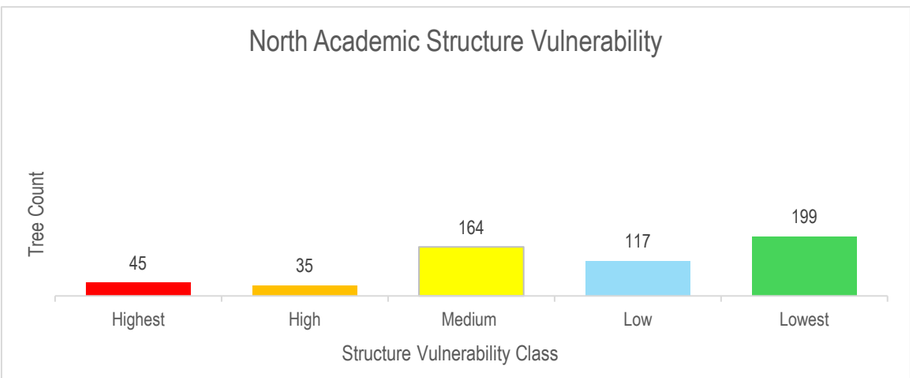


North Academic

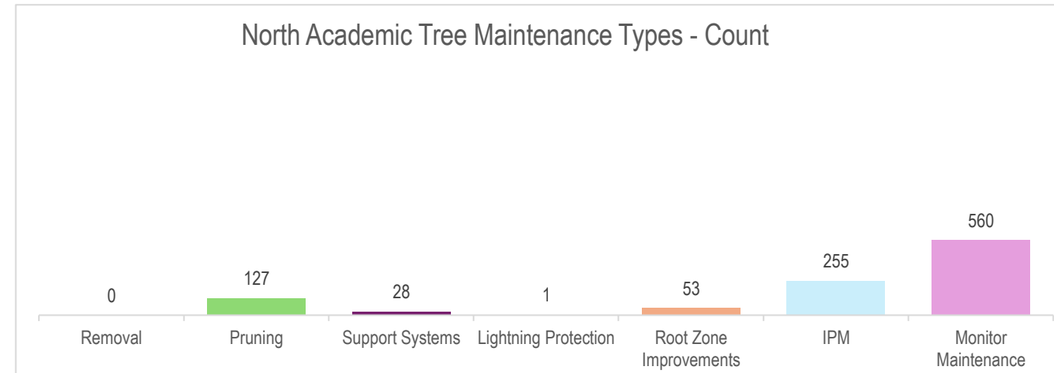
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
14	Medium	560	7.7	$286,151.50	$28,615.15

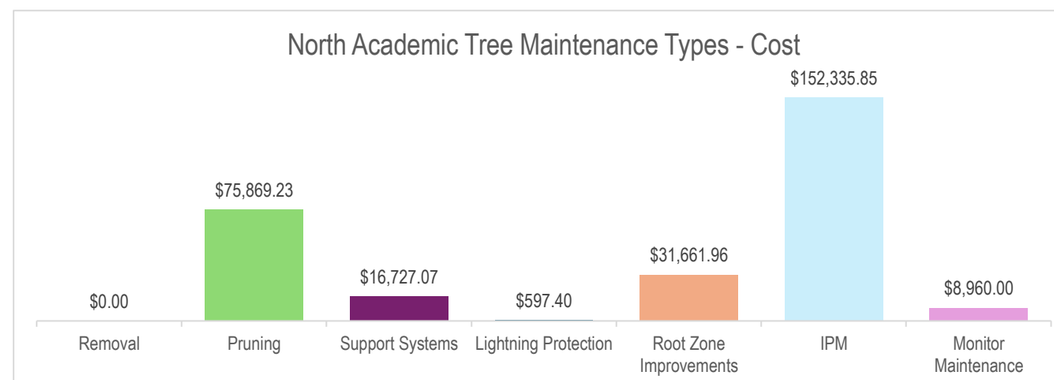






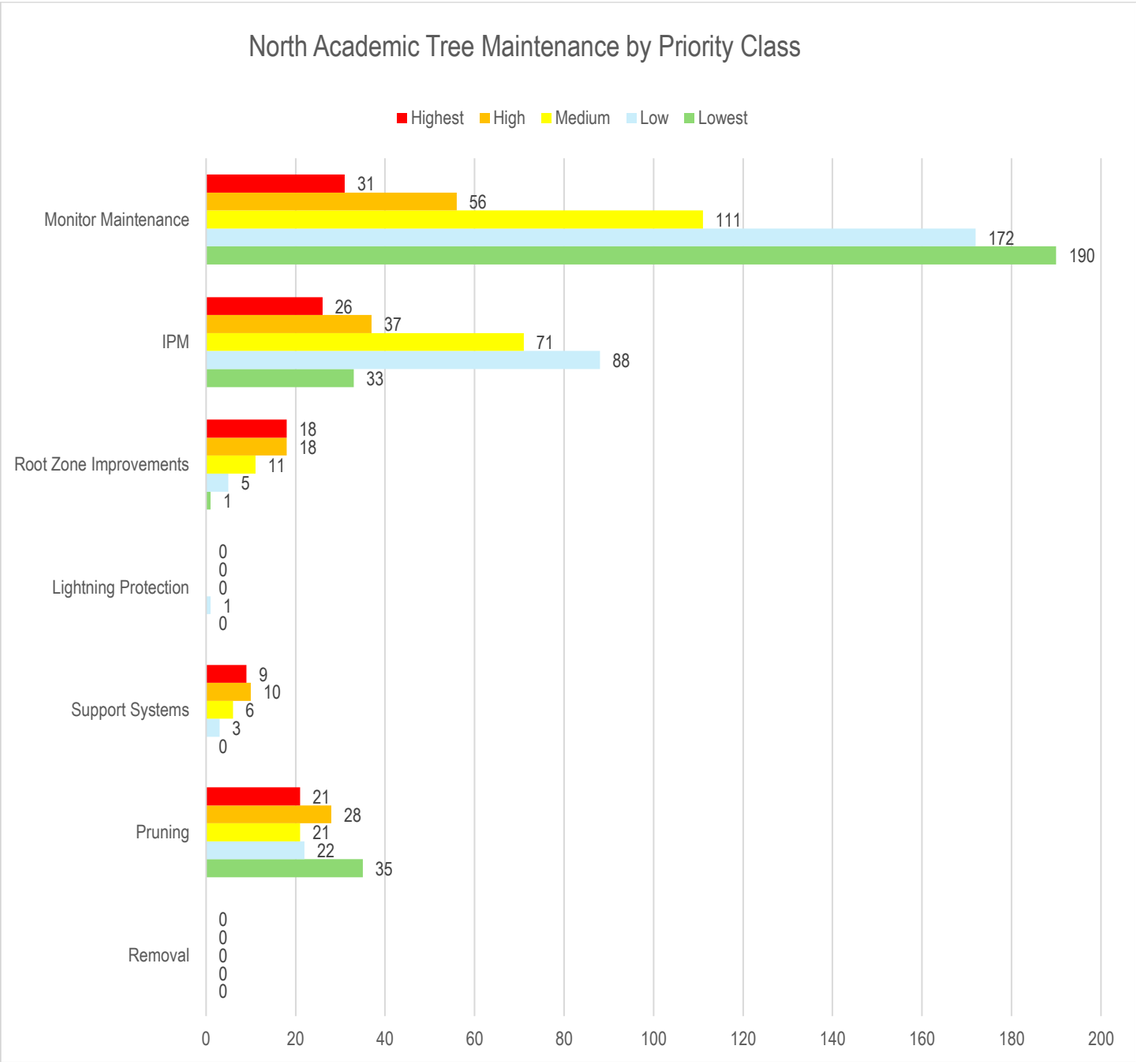
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	127	28	1	53	255	560	1024
Proj. Cost	$0.00	$75,869.23	$16,727.07	$597.40	$31,661.96	$152,335.85	$8,960.00	$286,151.50

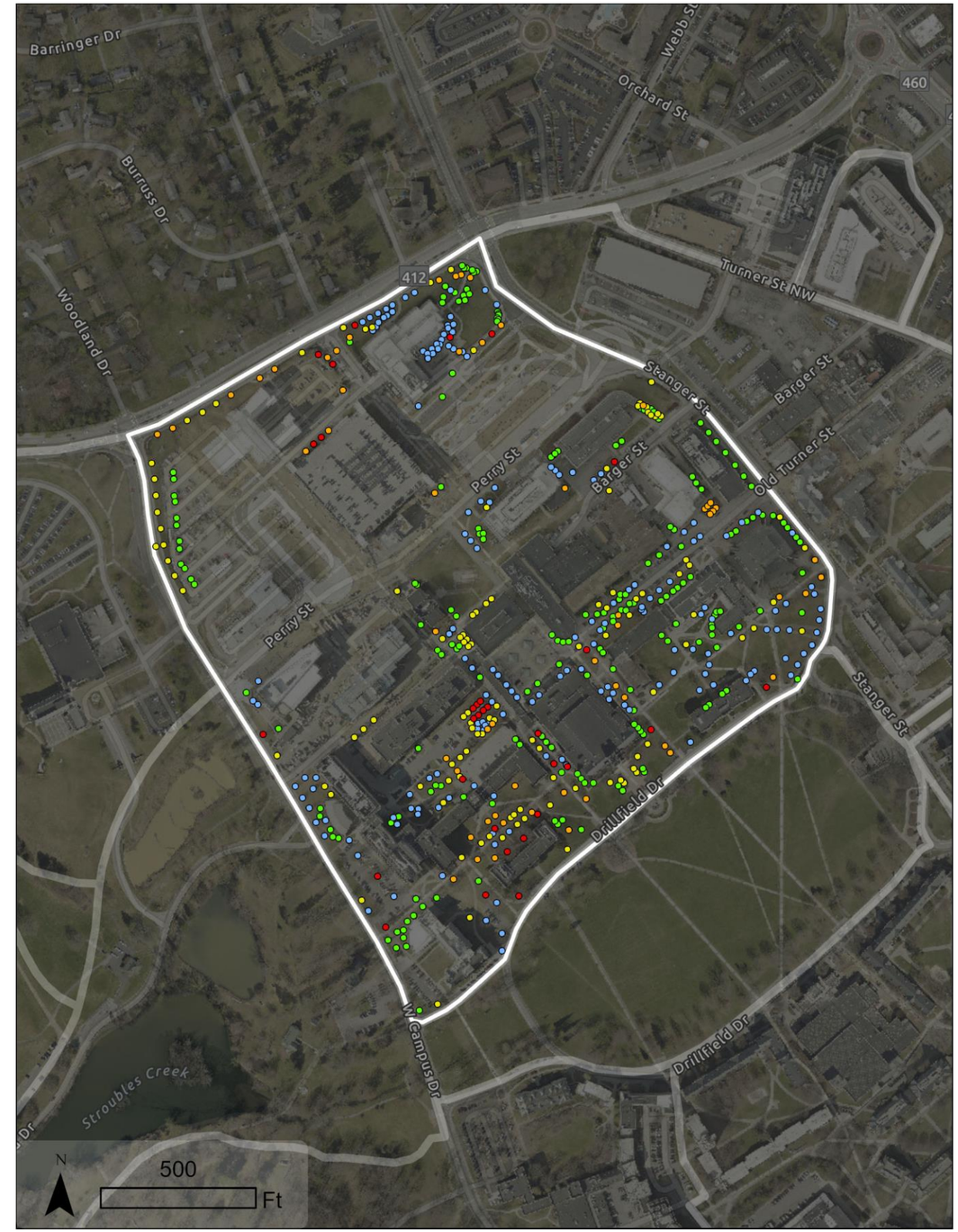




(Continued) North Academic

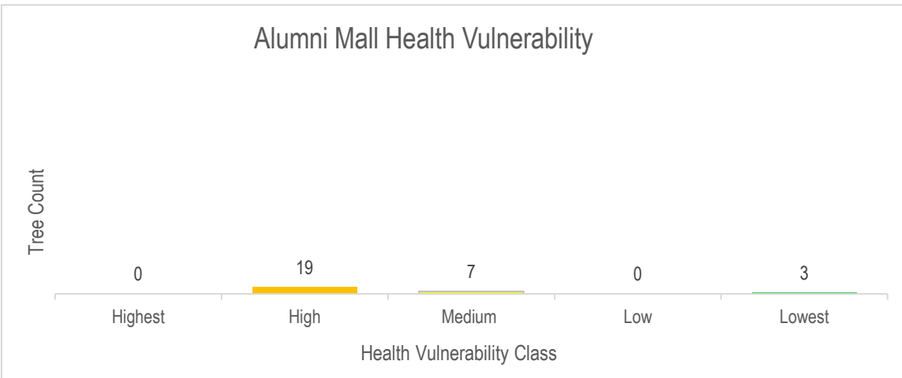
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	31	$37,326.33
High	3 & 4	56	$50,089.50
Medium	5 & 6	111	$61,095.67
Low	7 & 8	172	$69,463.00
Lowest	9 & 10	190	$68,177.00
	Totals	**560**	**$286,151.50**

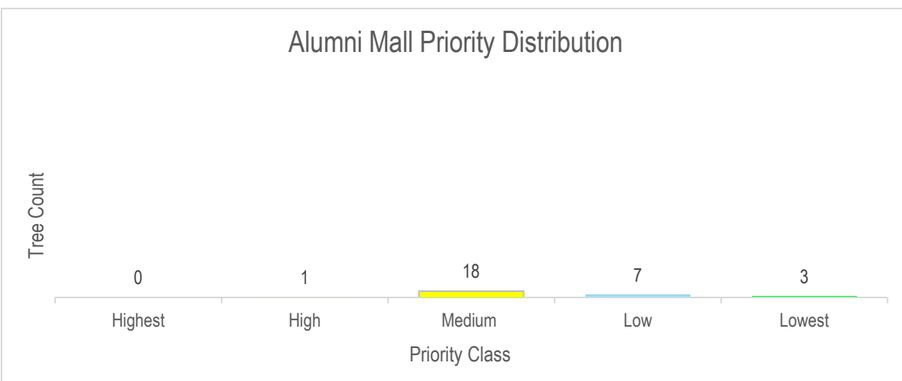


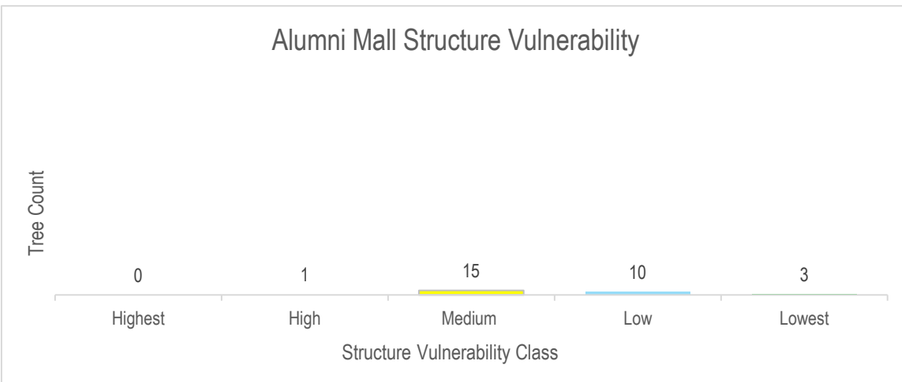


Alumni Mall

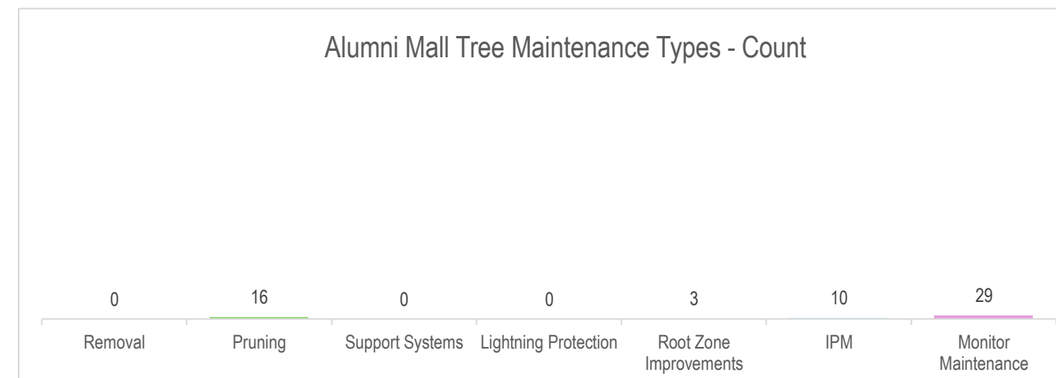
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
13	Medium	29	14.5	$30,702.00	$3,070.20

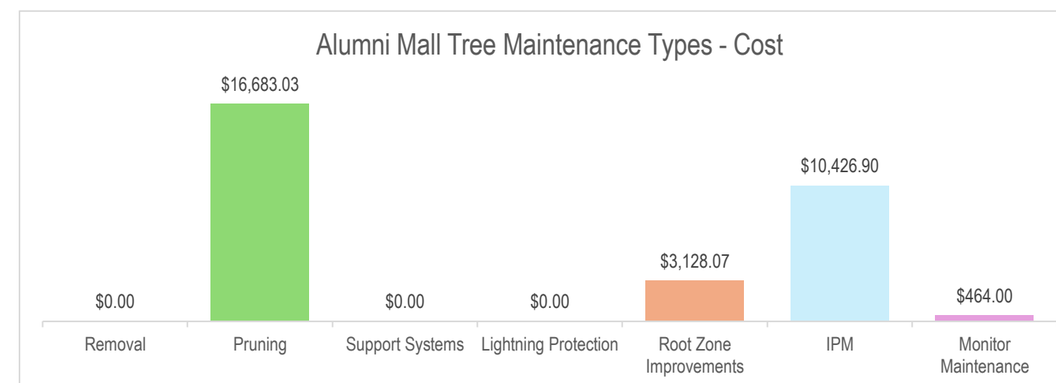






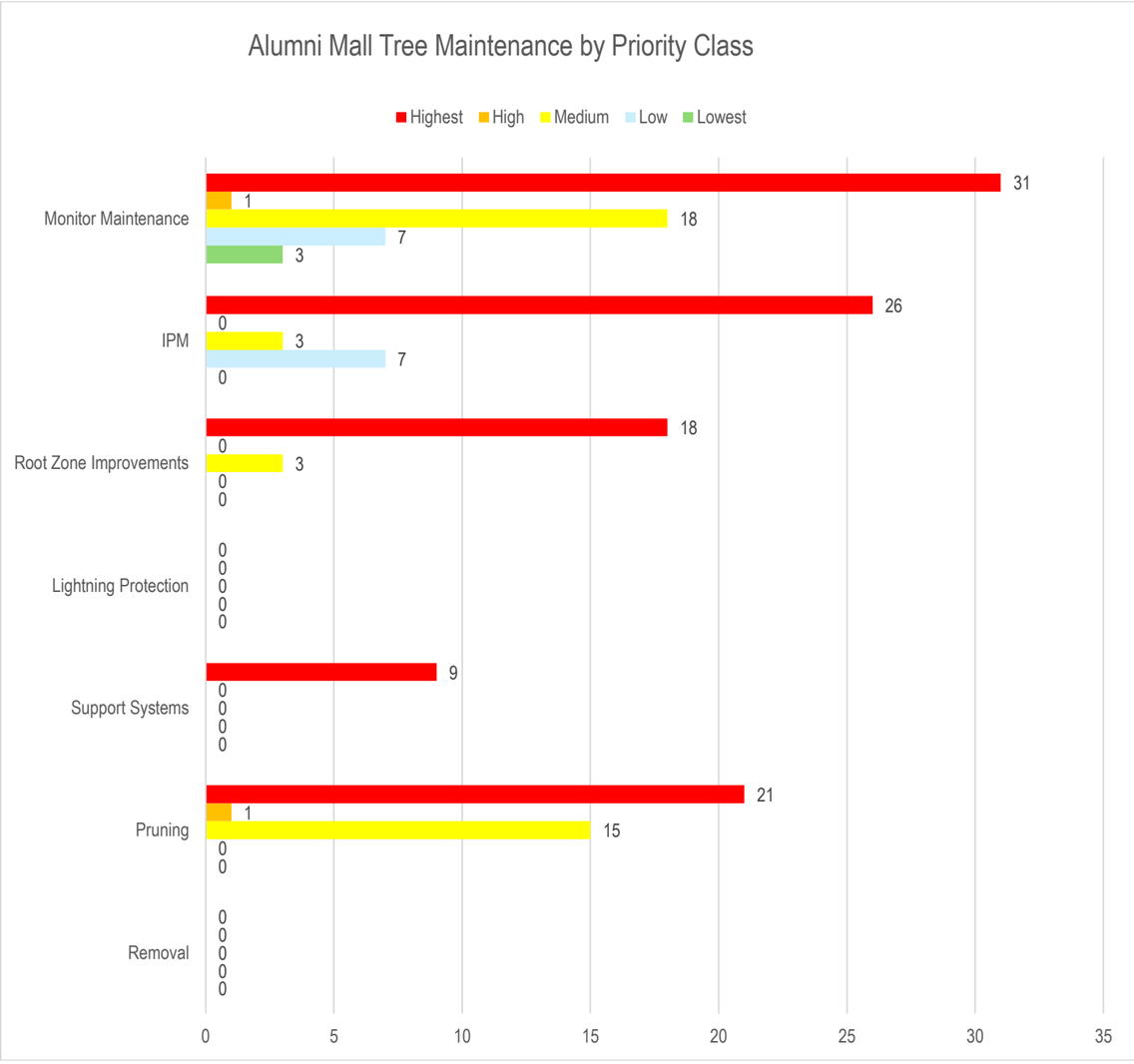
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	16	0	0	3	10	29	58
Proj. Cost	$0.00	$16,683.03	$0.00	$0.00	$3,128.07	$10,426.90	$464.00	$30,702.00





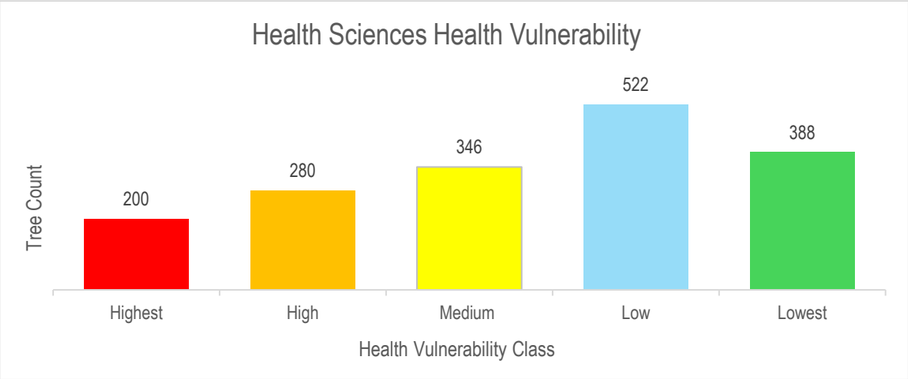
(Continued) **Alumni Mall**

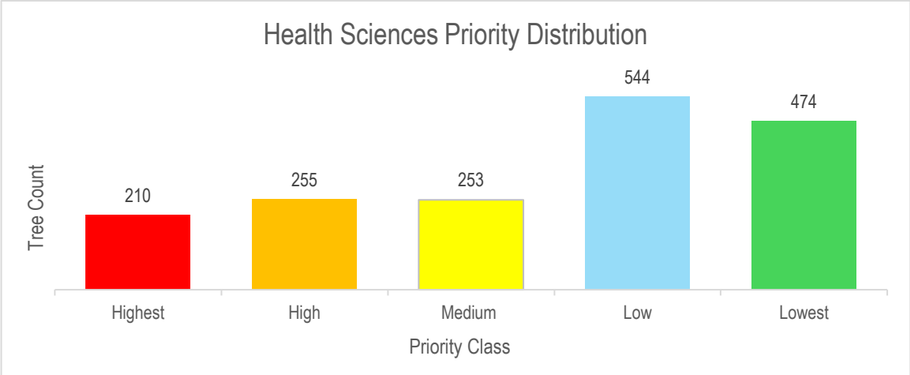
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	0	$0.00
High	3 & 4	1	$1,566.00
Medium	5 & 6	18	$26,001.00
Low	7 & 8	7	$3,087.00
Lowest	9 & 10	3	$48.00
	Totals	**29**	**$30,702.00**

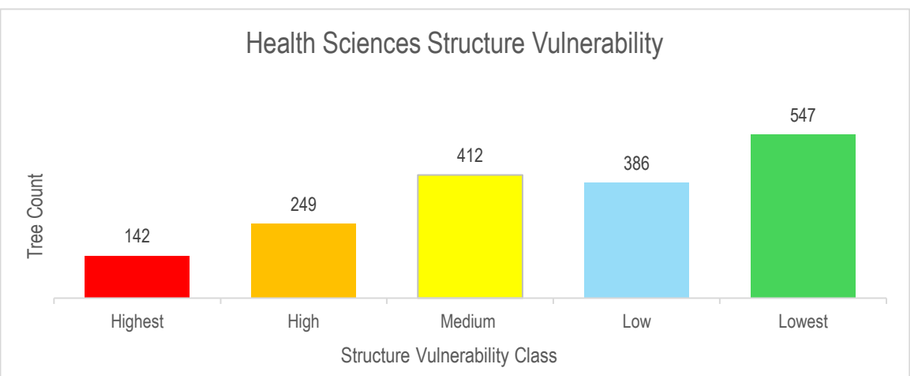


Health Sciences

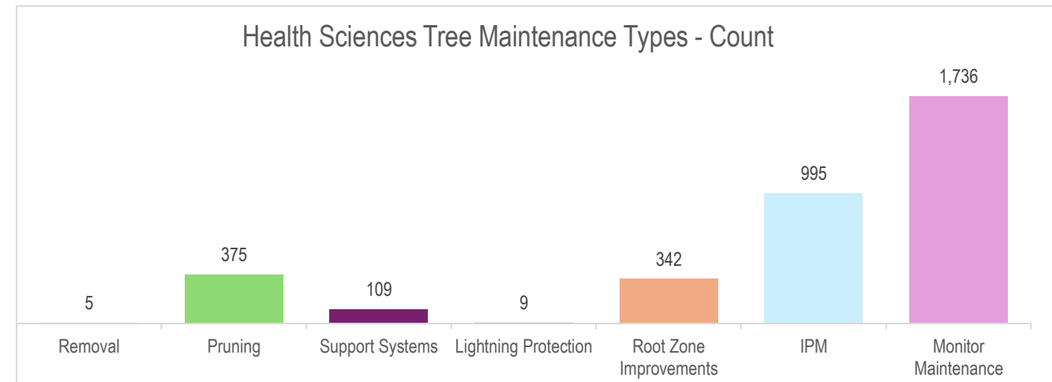
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
12	Medium	1736	17.7	$1,002,082.00	$100,208.20

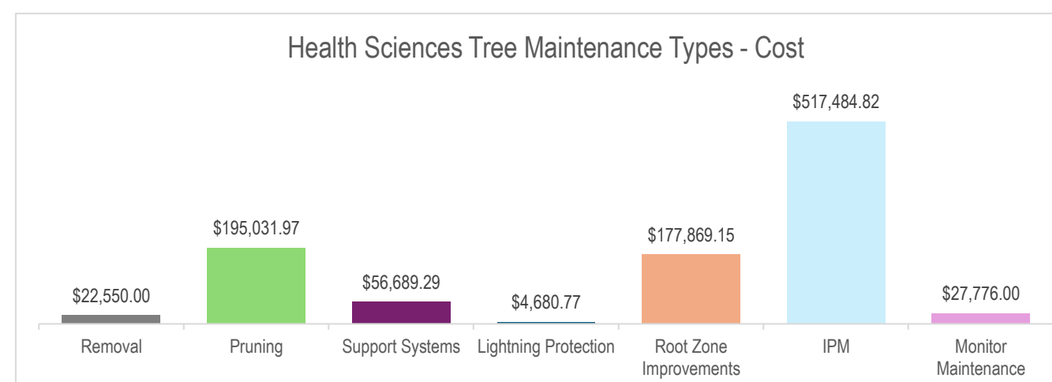






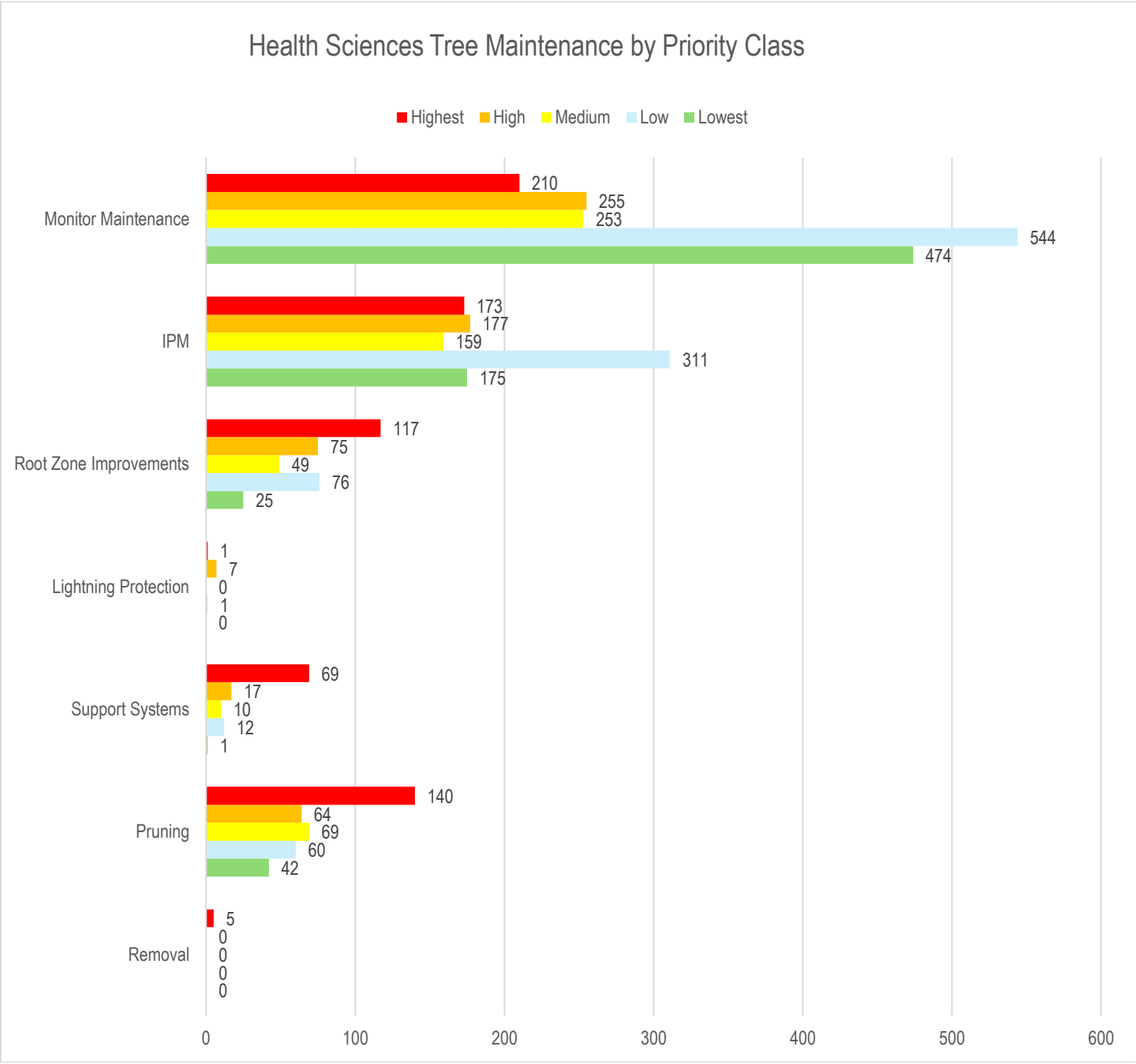
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	5	375	109	9	342	995	1,736	3571
Proj. Cost	$22,550.00	$195,031.97	$56,689.29	$4,680.77	$177,869.15	$517,484.82	$27,776.00	$1,002,082.00

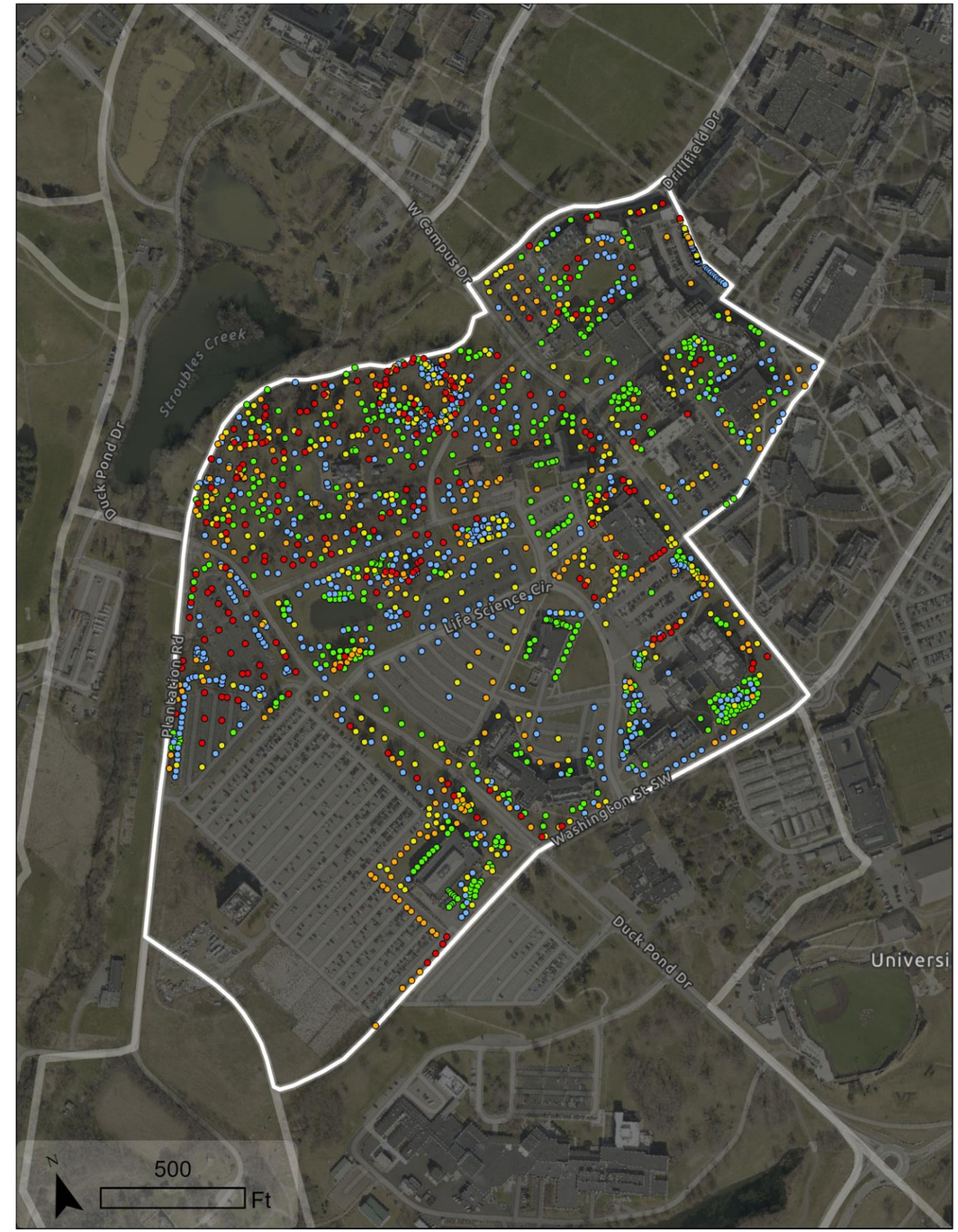




(Continued) Health Sciences

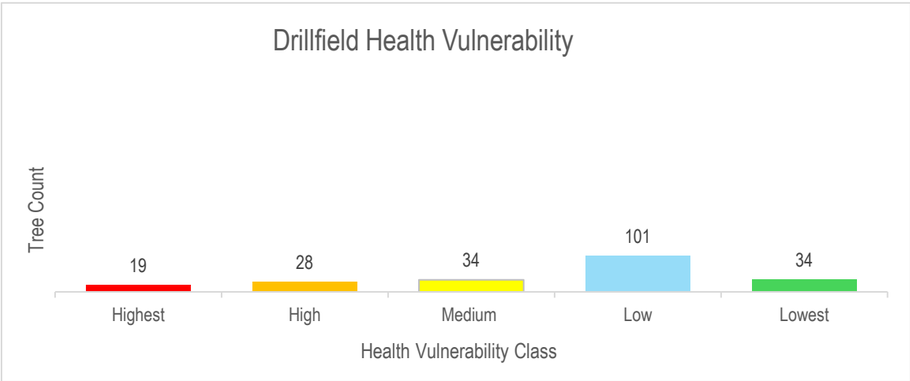
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	210	$285,775.33
High	3 & 4	255	$184,963.83
Medium	5 & 6	253	$158,758.33
Low	7 & 8	544	$228,603.50
Lowest	9 & 10	474	$143,981.00
	Totals	**1736**	**$1,002,081.99**

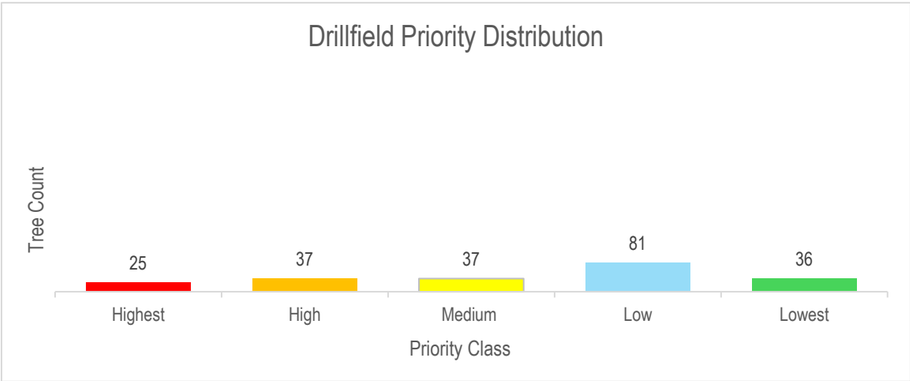


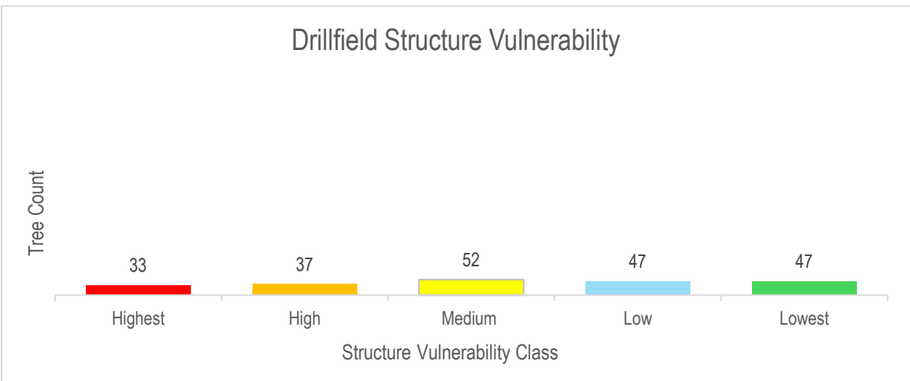


Drillfield

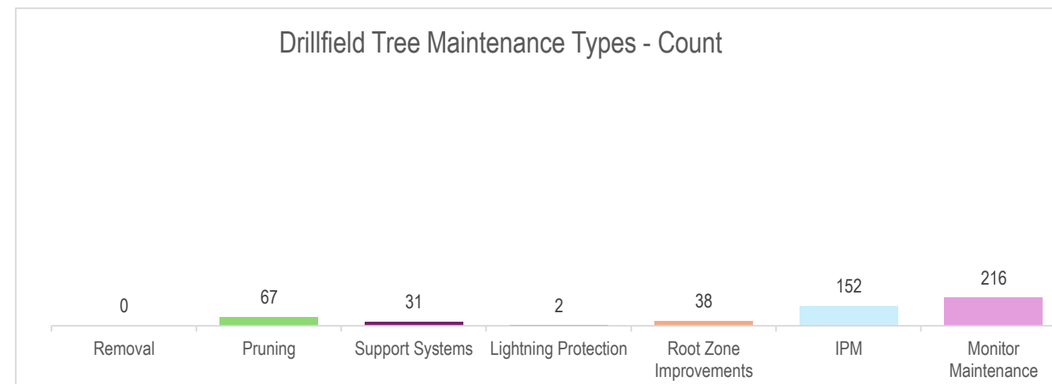
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
11	Medium	216	8.4	$158,948.83	$15,894.88

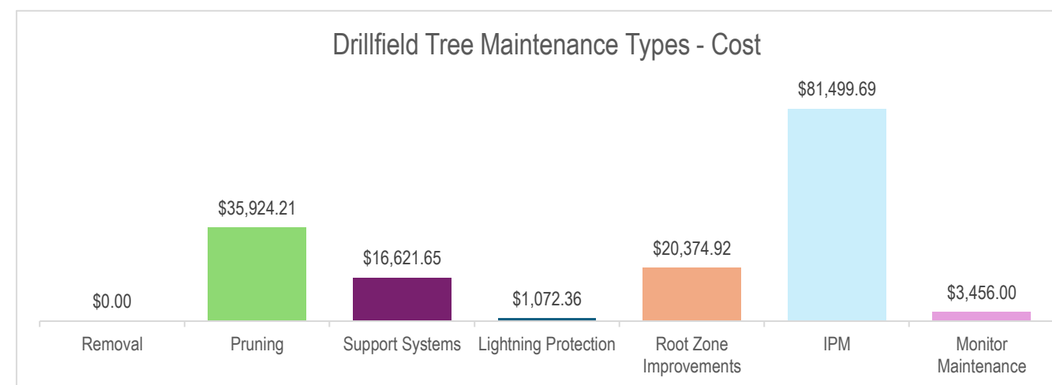






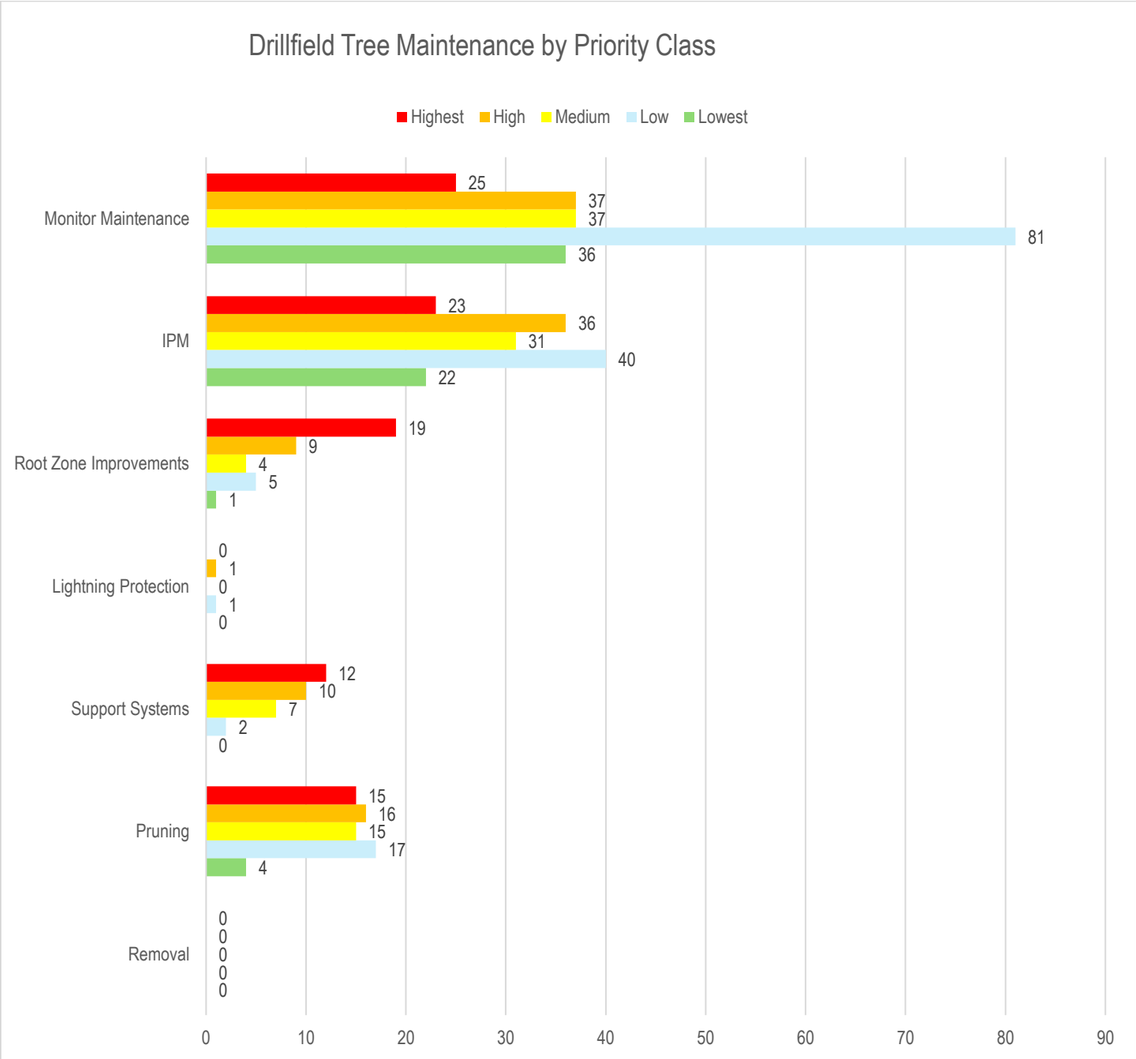
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	67	31	2	38	152	216	506
Proj. Cost	$0.00	$35,924.21	$16,621.65	$1,072.36	$20,374.92	$81,499.69	$3,456.00	$158,948.83

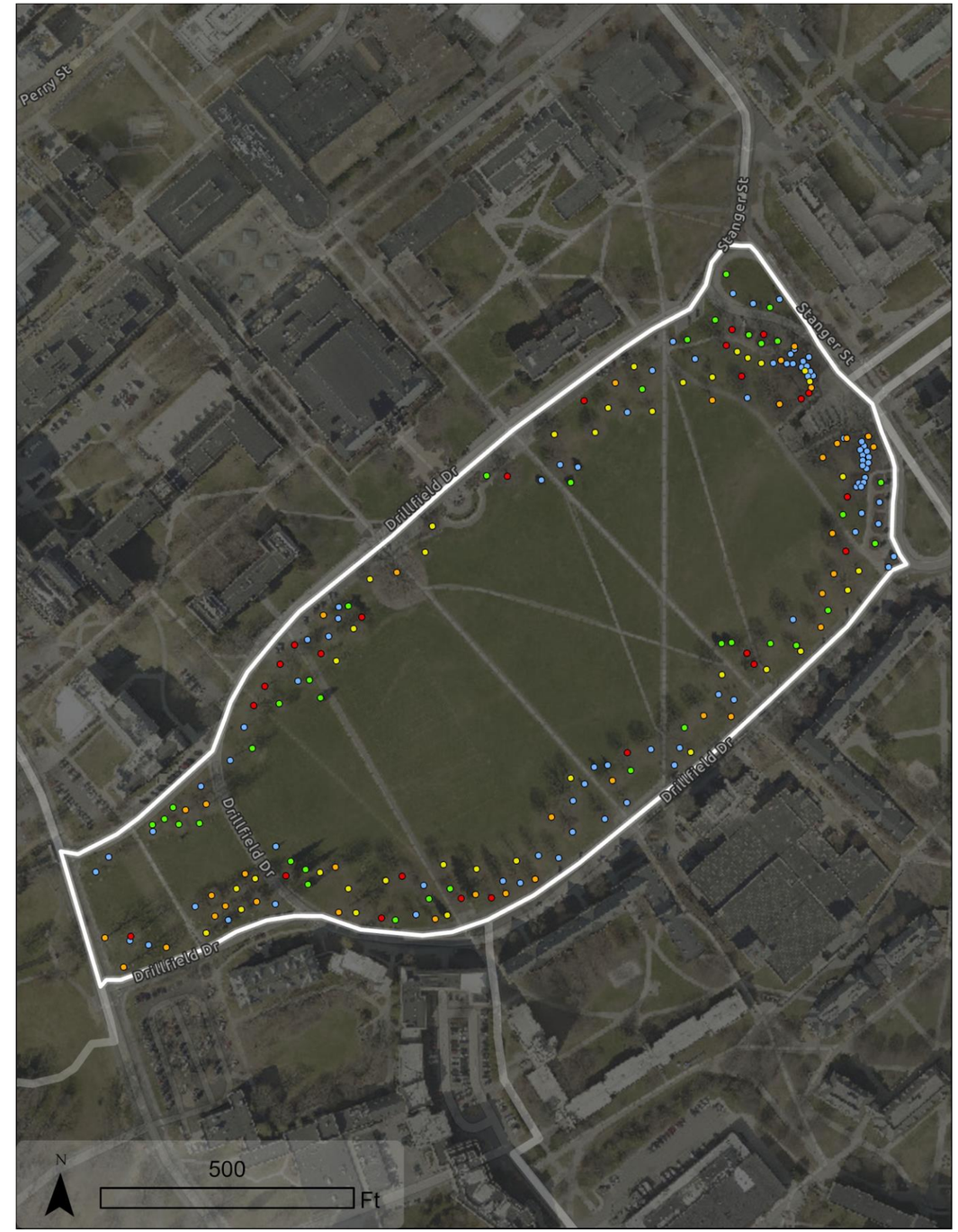




(Continued) **Drillfield**

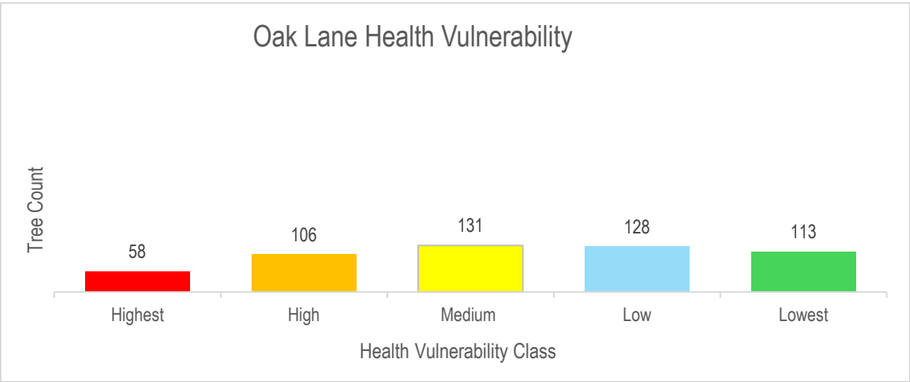
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	25	$31,930.50
High	3 & 4	37	$37,250.33
Medium	5 & 6	37	$33,467.00
Low	7 & 8	81	$40,451.00
Lowest	9 & 10	36	$15,850.00
	Totals	216	$158,948.83

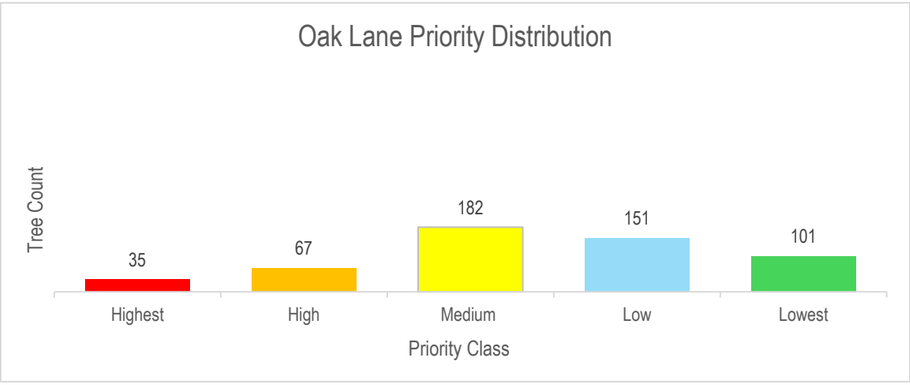


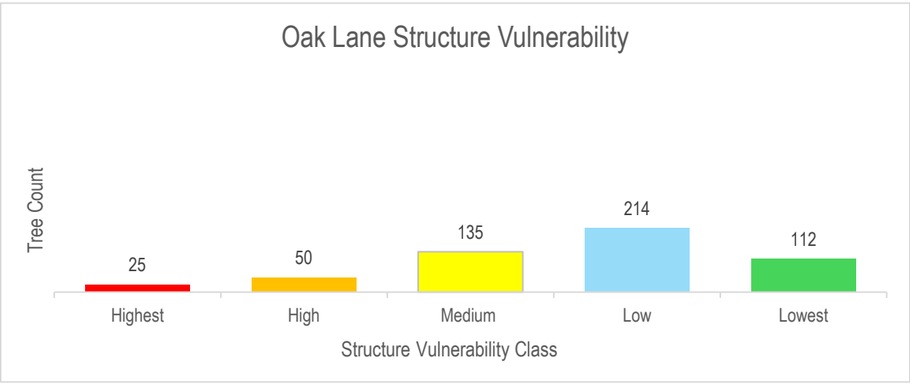


Oak Lane

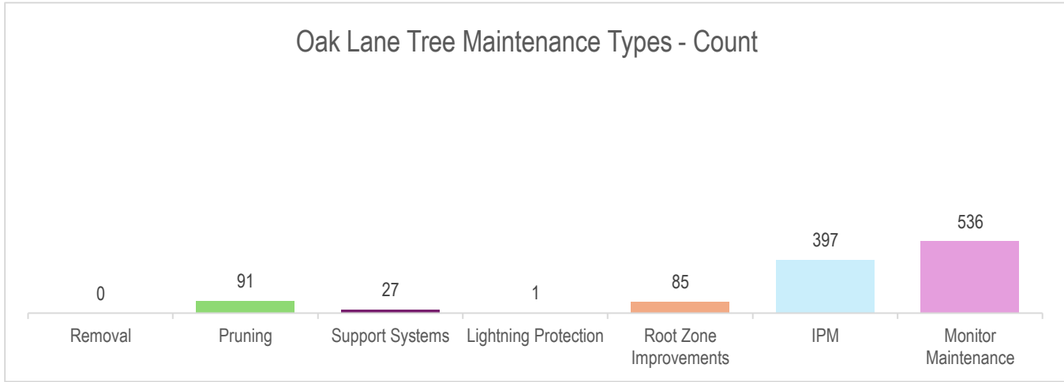
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
10	Low	536	12.8	$292,621.33	$29,262.13

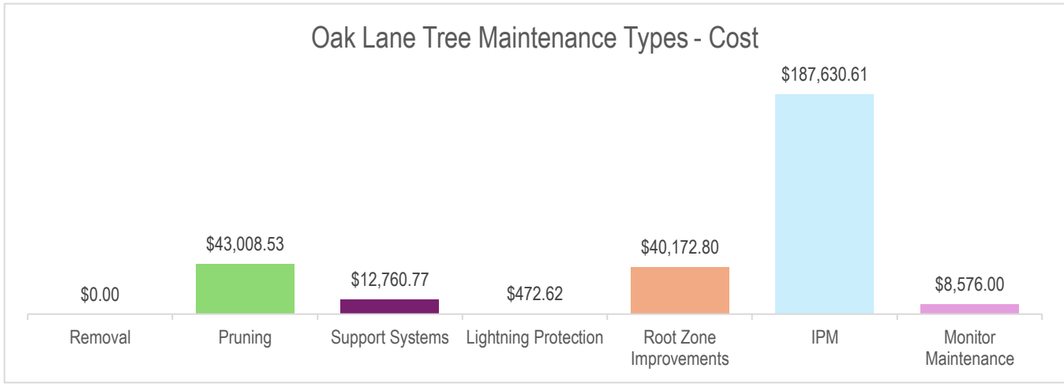






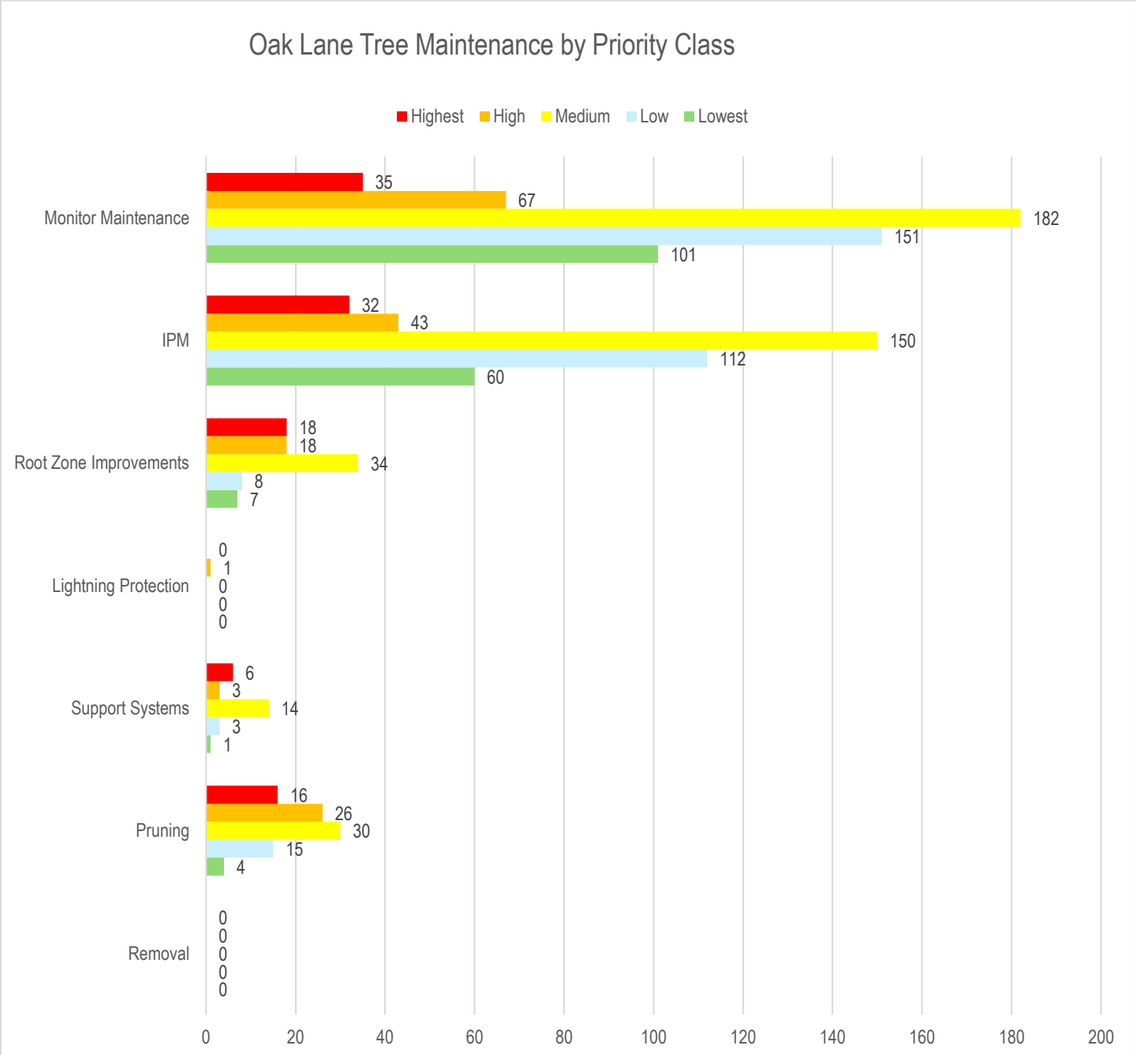
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	91	27	1	85	397	536	1137
Proj. Cost	$0.00	$43,008.53	$12,760.77	$472.62	$40,172.80	$187,630.61	$8,576.00	$292,621.33

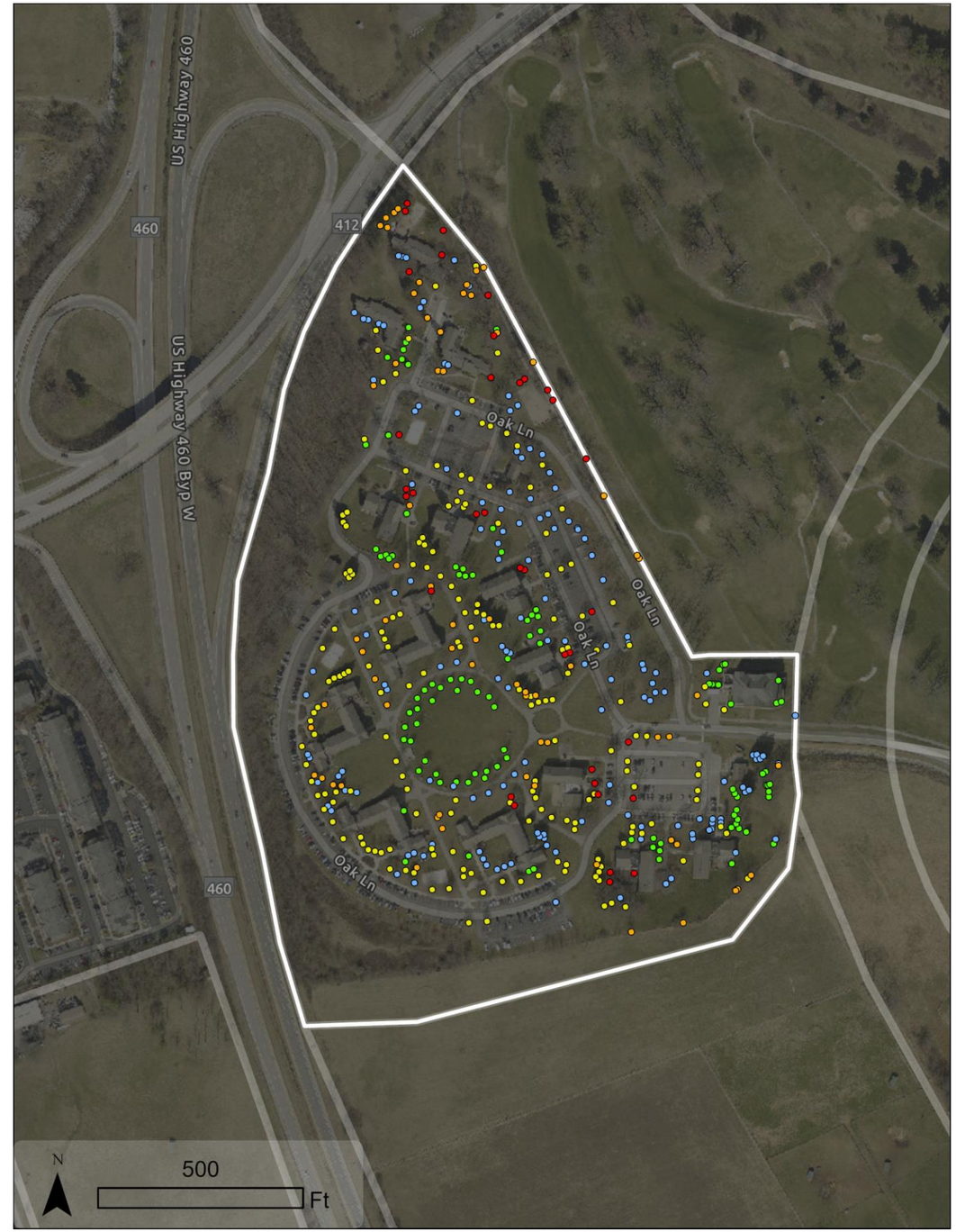




(Continued) Oak Lane

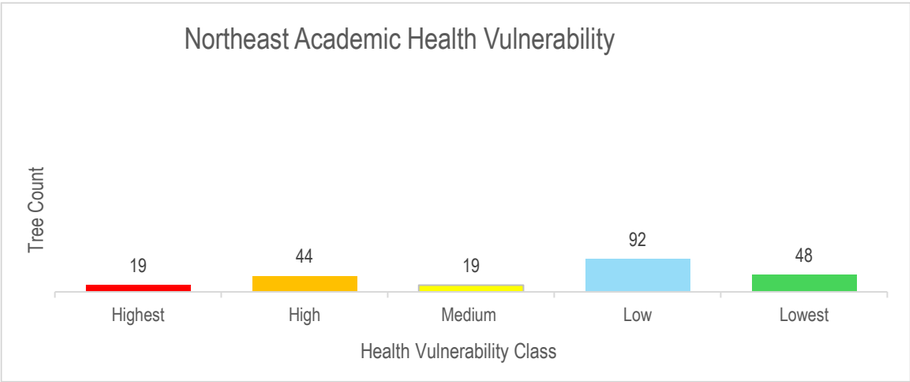
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	35	$32,923.83
High	3 & 4	67	$57,355.83
Medium	5 & 6	182	$102,782.50
Low	7 & 8	151	$67,373.17
Lowest	9 & 10	101	$32,186.00
	Totals	**536**	**$292,621.33**

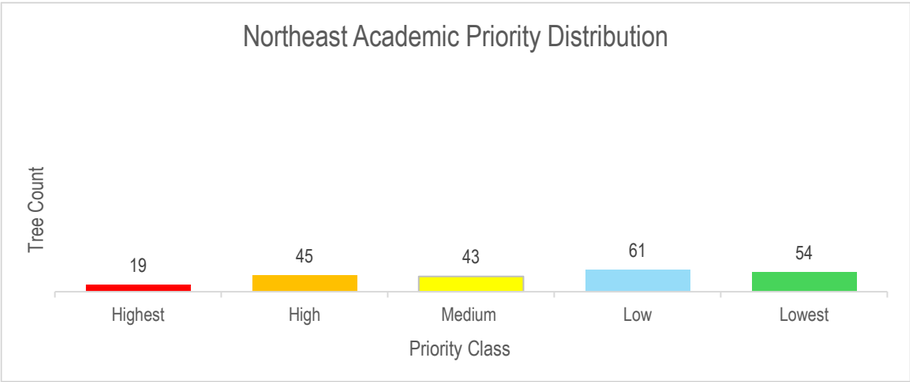


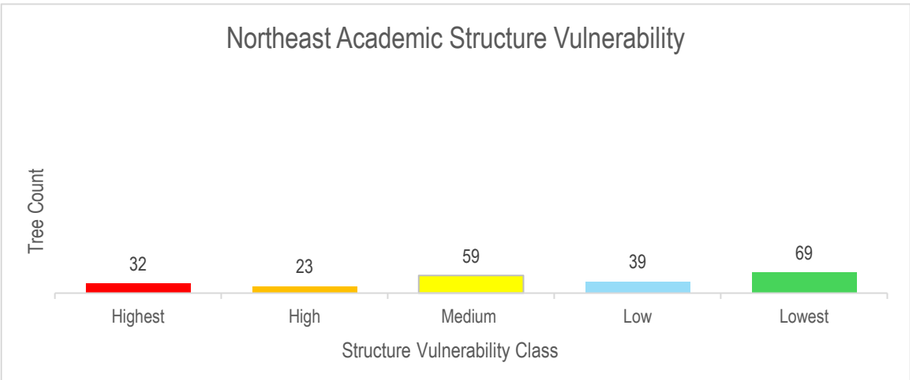


Northeast Academic

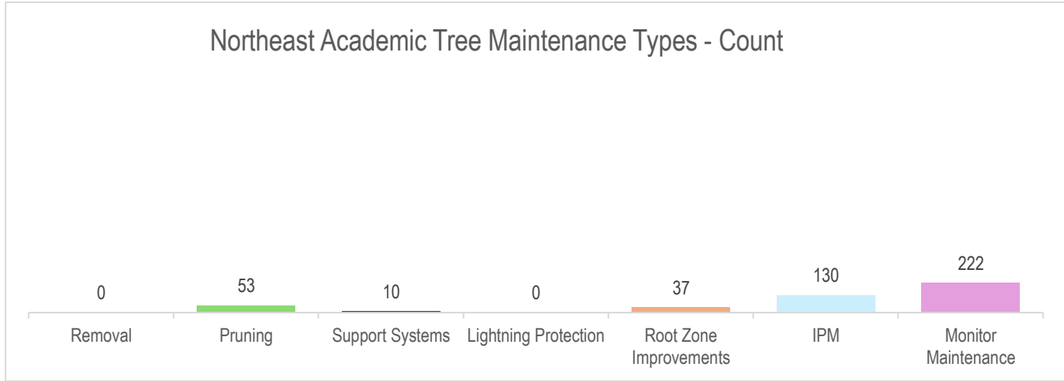
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
9	Low	222	7.1	$124,692.00	$12,469.20

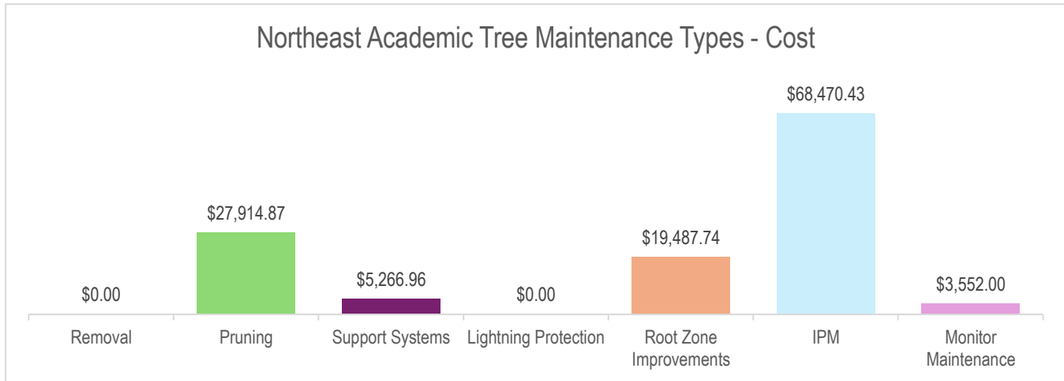






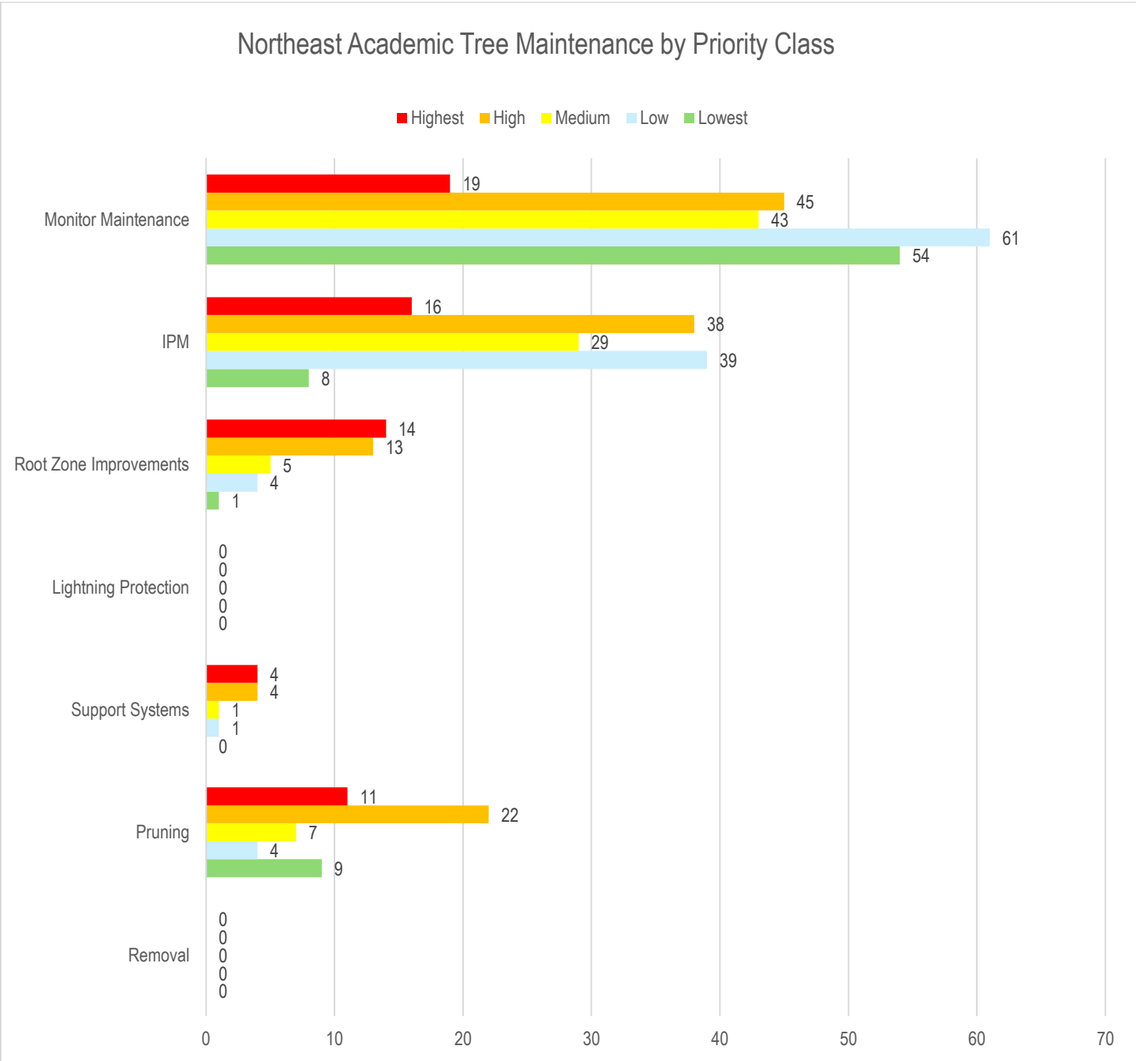
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	53	10	0	37	130	222	452
Proj. Cost	$0.00	$27,914.87	$5,266.96	$0.00	$19,487.74	$68,470.43	$3,552.00	$124,692.00

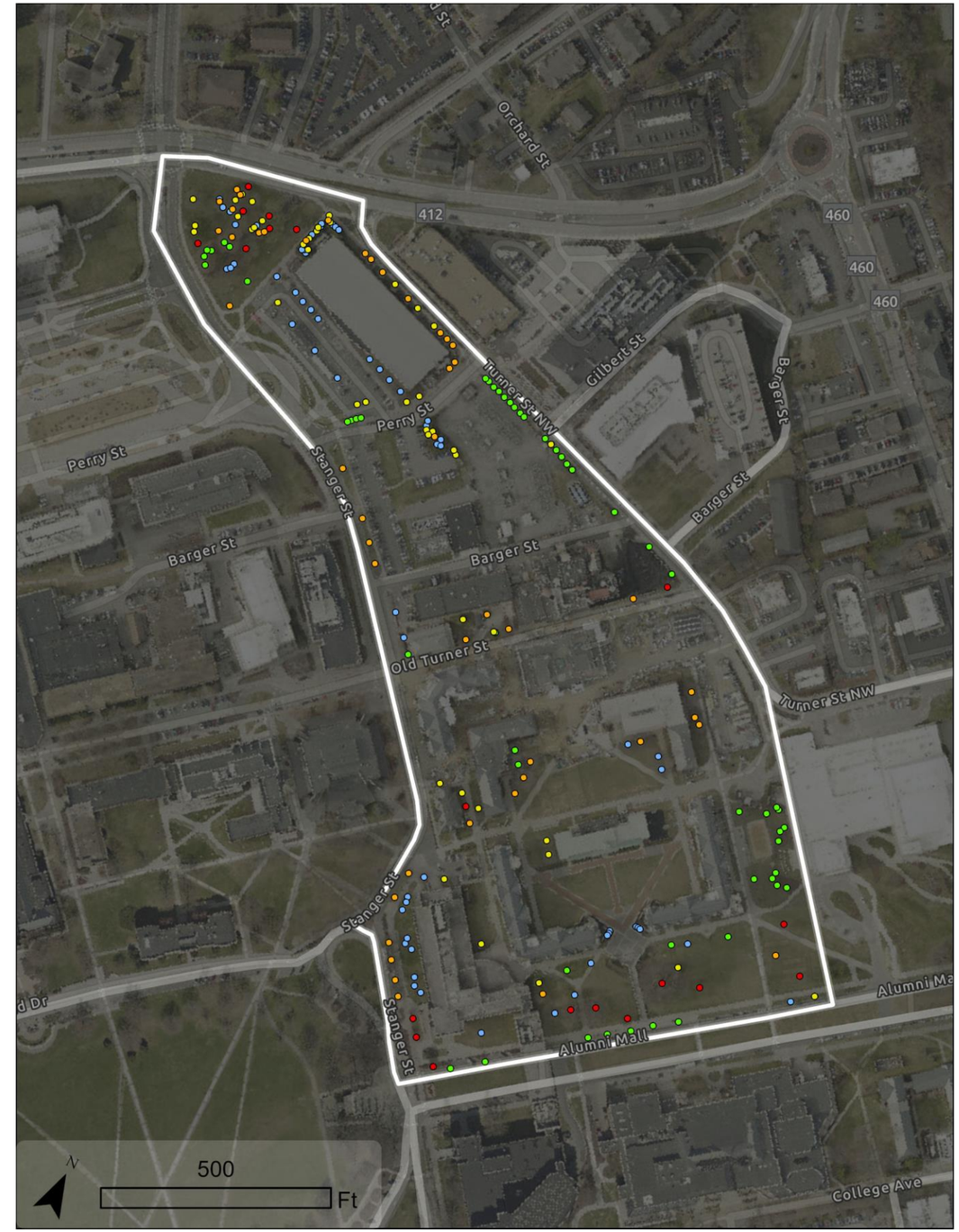




(Continued) Northeast Academic

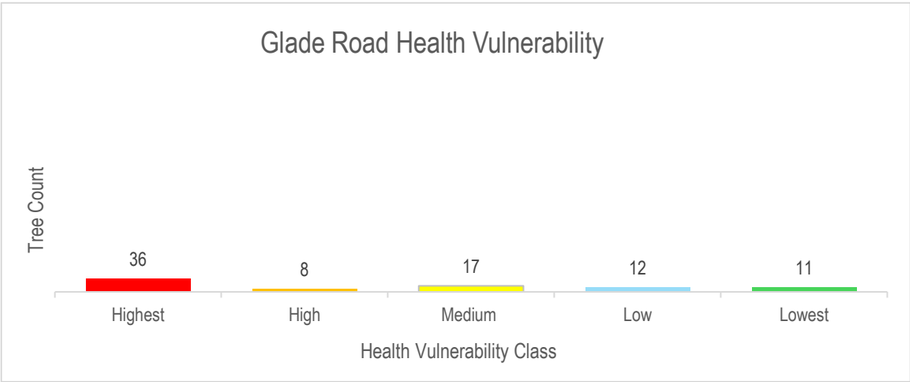
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	19	$22,880.50
High	3 & 4	45	$39,139.67
Medium	5 & 6	43	$21,194.83
Low	7 & 8	61	$23,173.00
Lowest	9 & 10	54	$18,304.00
	Totals	222	$124,692.00

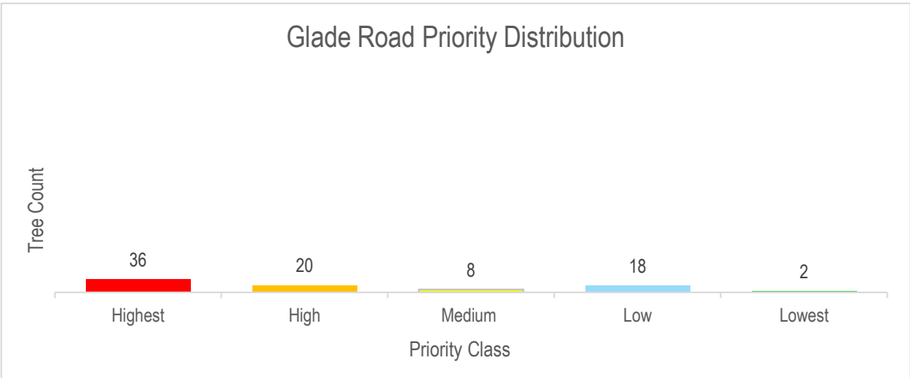


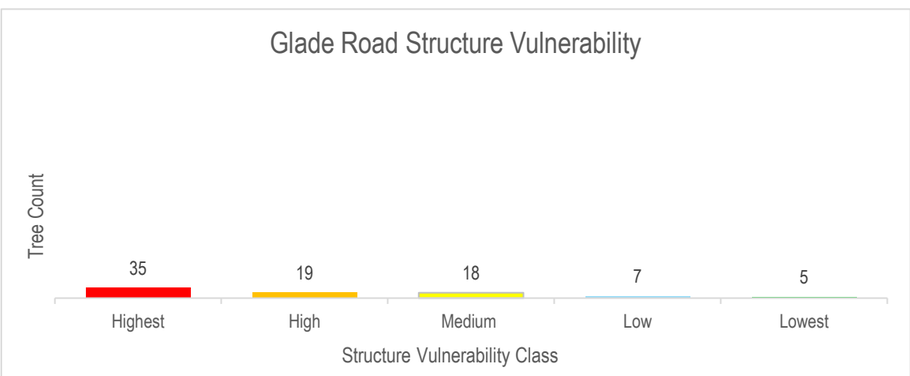


Glade Road

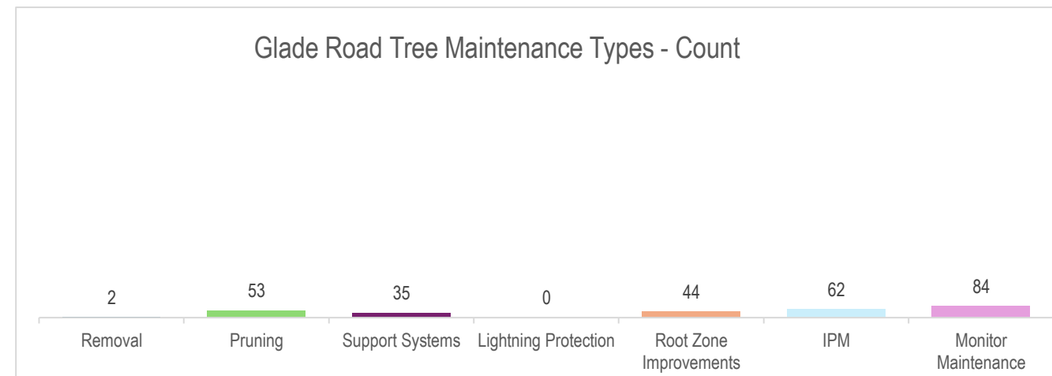
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
8	Low	84	1.5	$99,203.33	$9,920.33

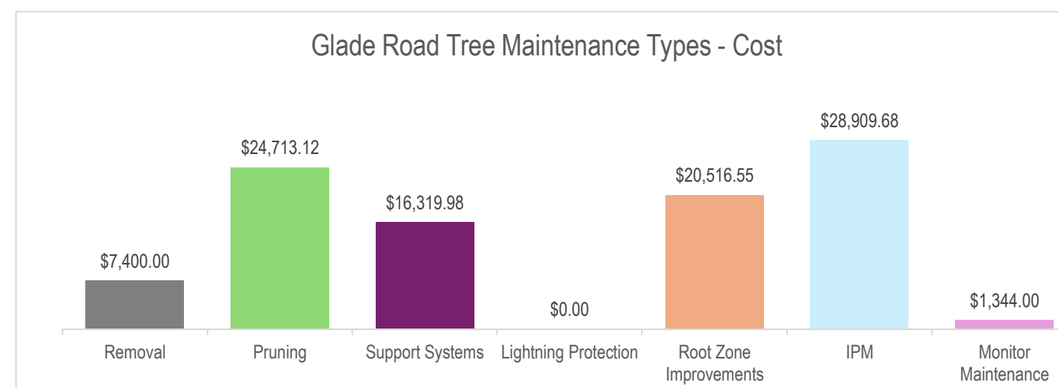






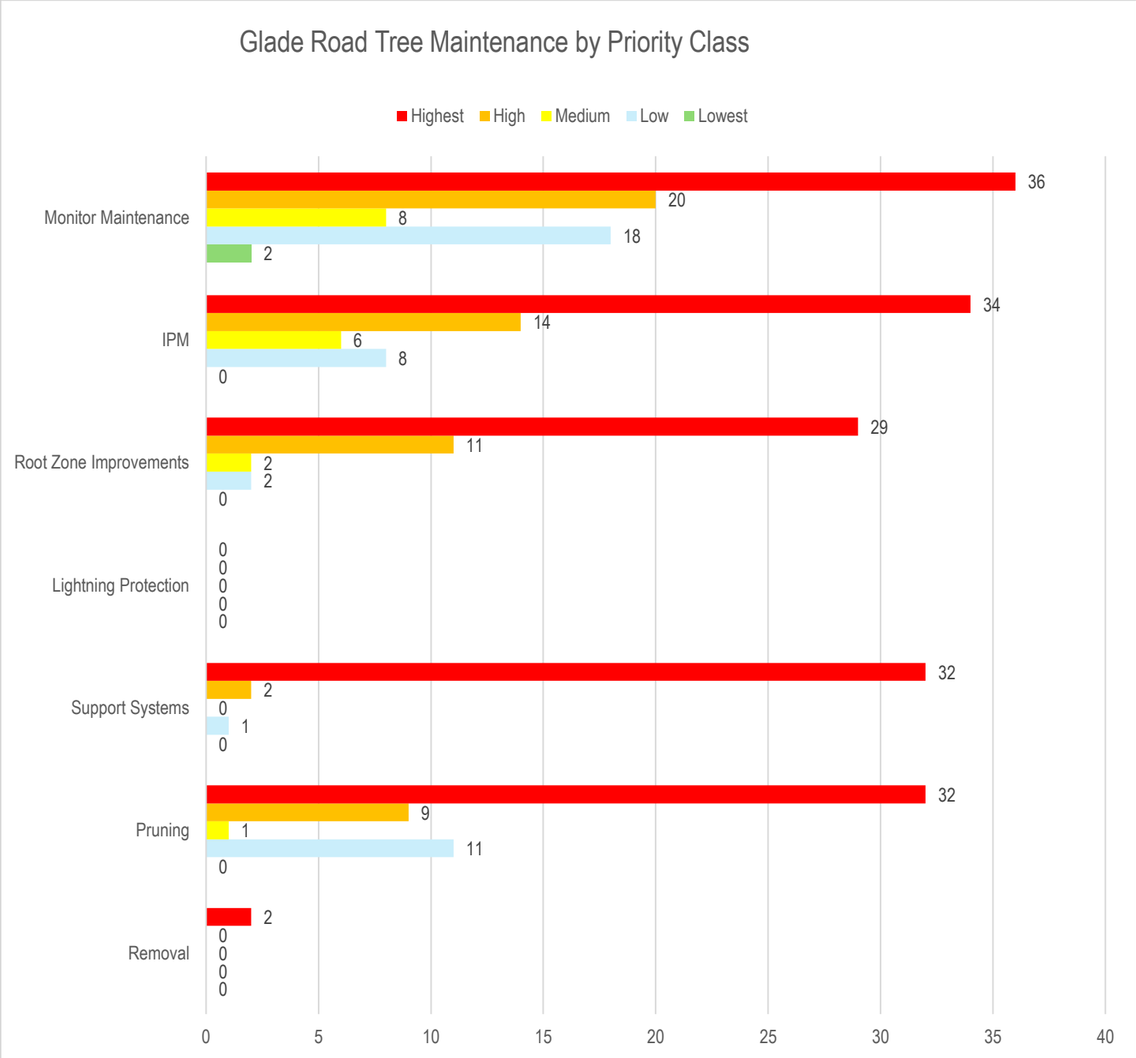
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	2	53	35	0	44	62	84	280
Proj. Cost	$7,400.00	$24,713.12	$16,319.98	$0.00	$20,516.55	$28,909.68	$1,344.00	$99,203.33





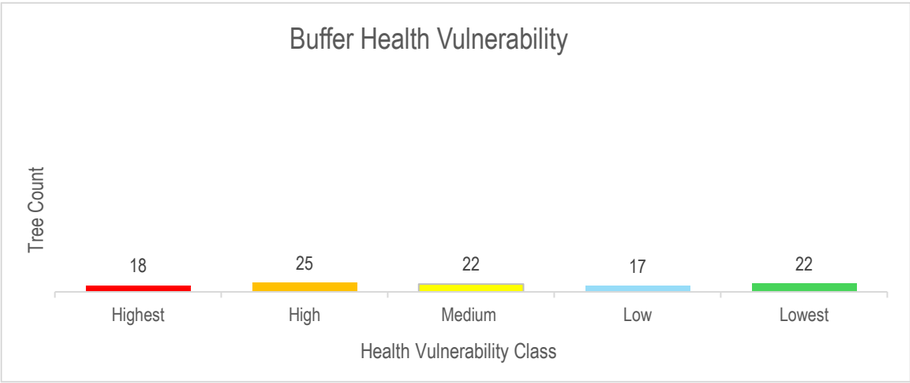
(Continued) Glade Road

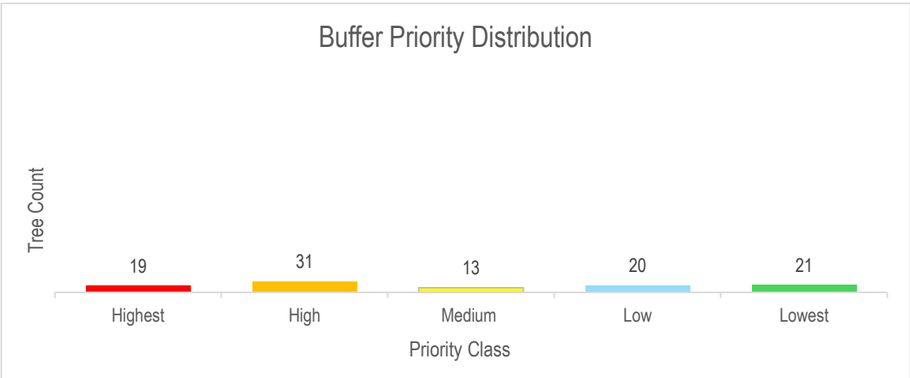
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	36	$58,675.50
High	3 & 4	20	$16,364.00
Medium	5 & 6	8	$3,905.33
Low	7 & 8	18	$20,226.50
Lowest	9 & 10	2	$32.00
	Totals	**84**	**$99,203.33**

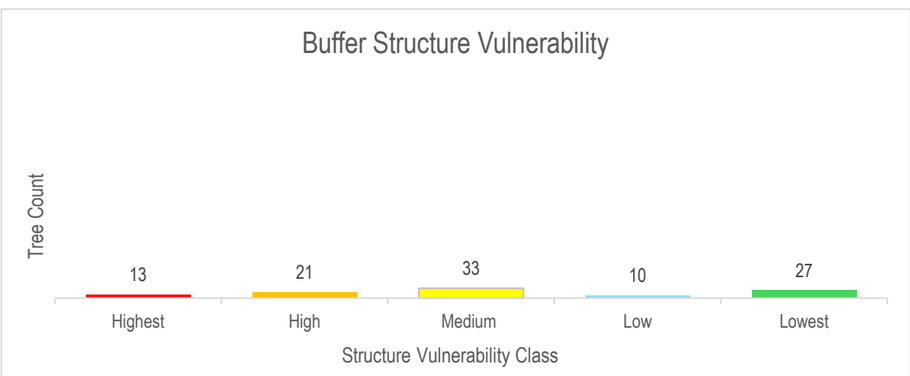


Buffer

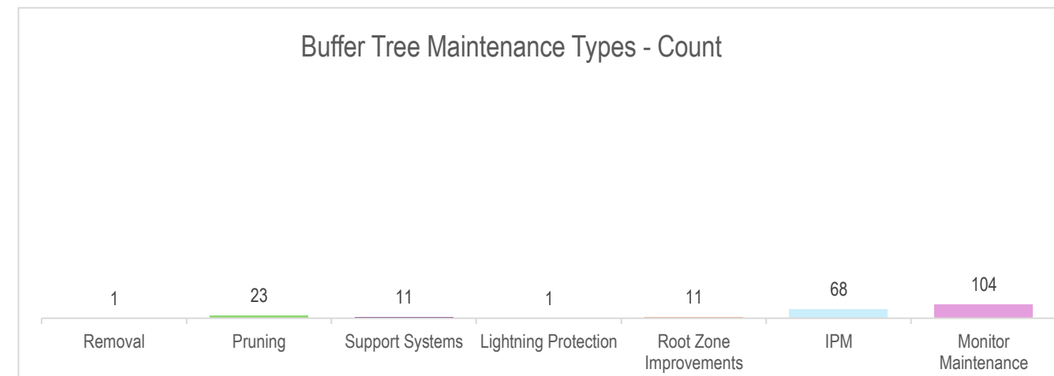
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
7	Low	104	4	$67,184.00	$6,718.40

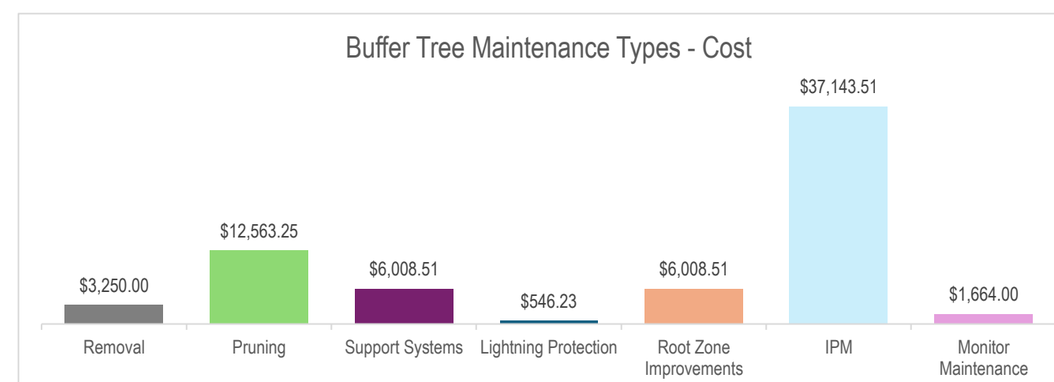






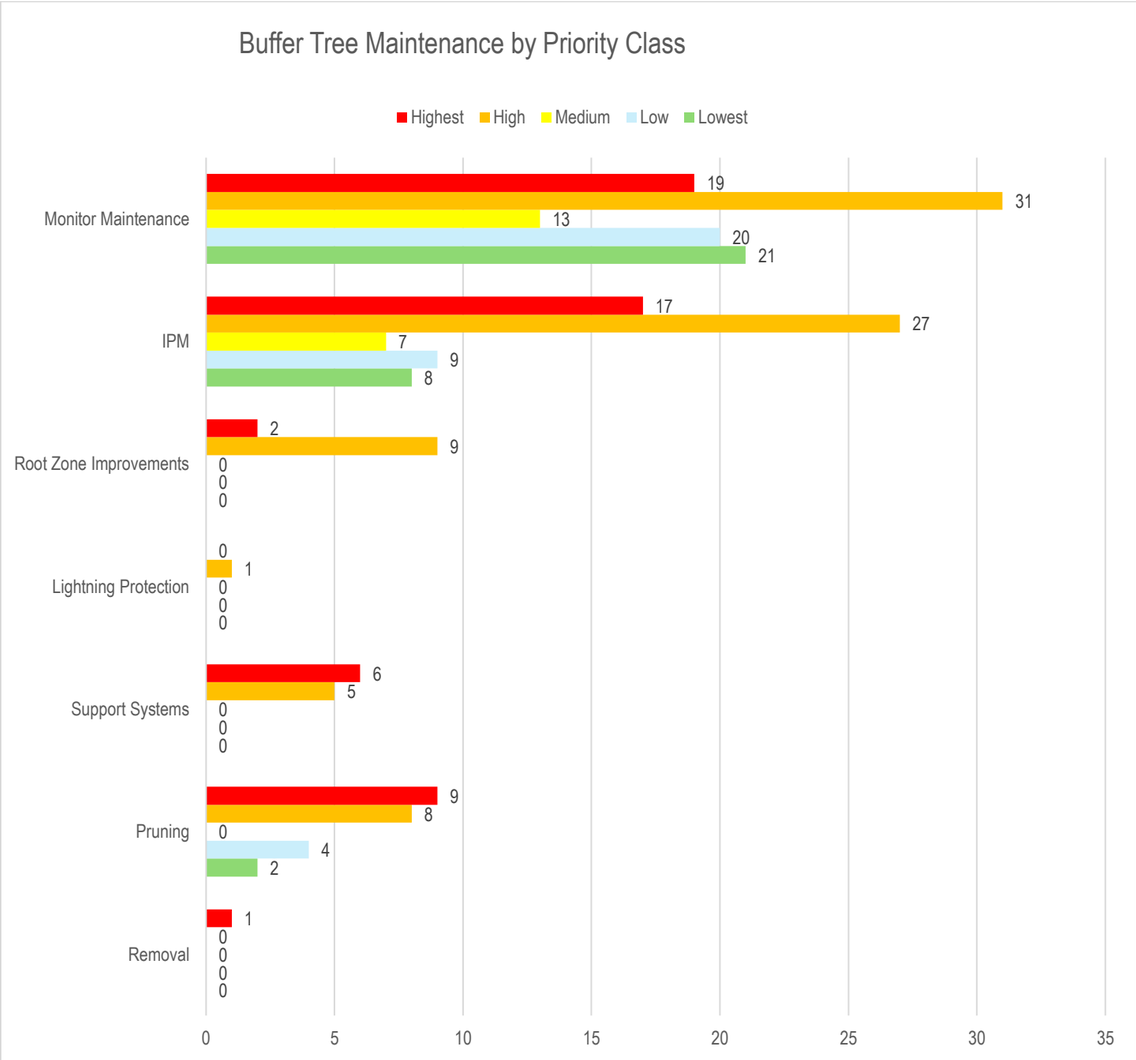
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	23	11	1	11	68	104	219
Proj. Cost	$3,250.00	$12,563.25	$6,008.51	$546.23	$6,008.51	$37,143.51	$1,664.00	$67,184.00





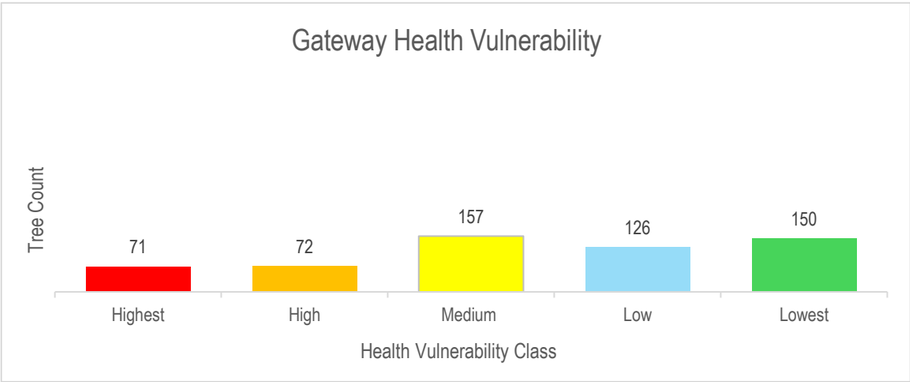
(Continued) **Buffer**

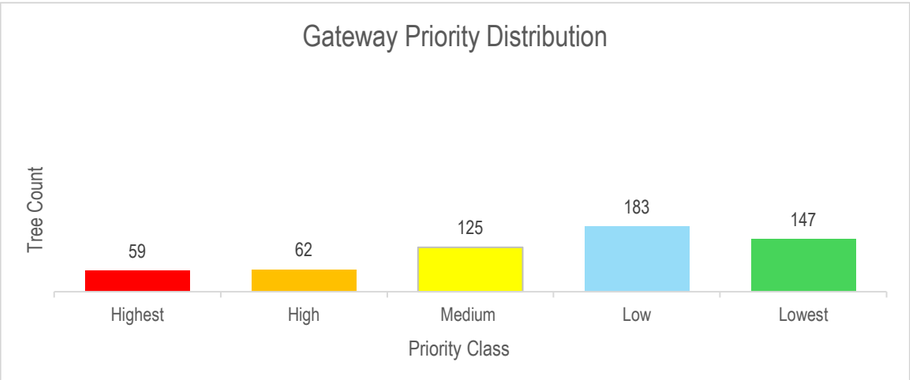
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	19	$23,433.67
High	3 & 4	31	$24,630.33
Medium	5 & 6	13	$3,239.00
Low	7 & 8	20	$9,437.00
Lowest	9 & 10	21	$6,444.00
	Totals	**104**	**$67,184.00**

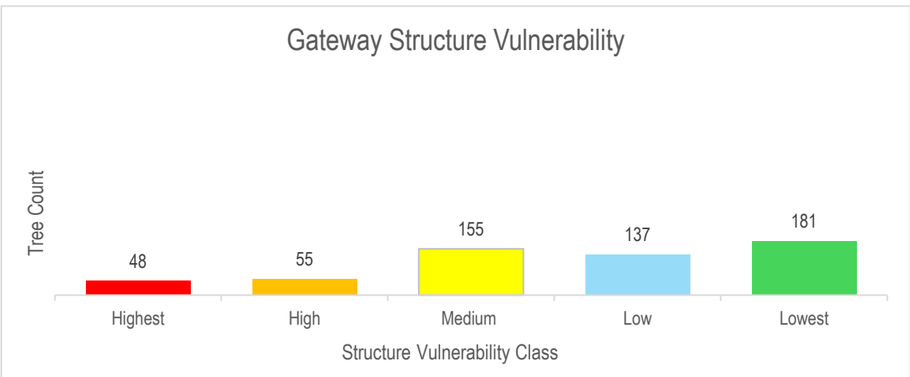


Gateway

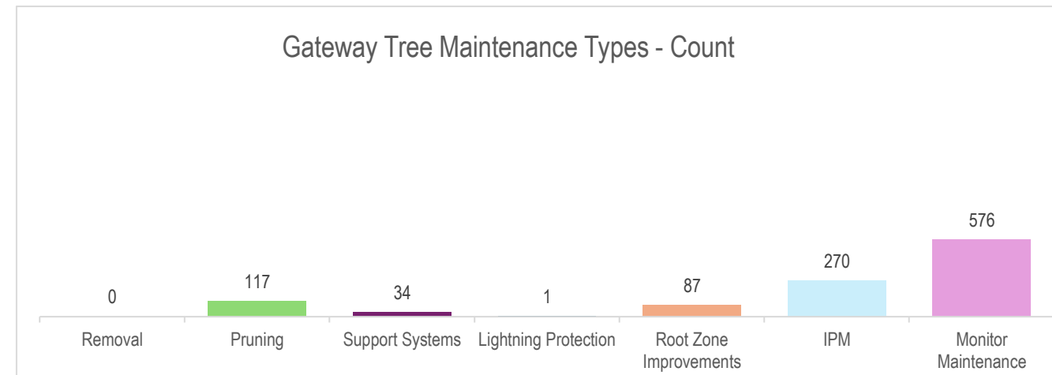
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
6	Low	576	14.9	$295,880.17	$29,588.02

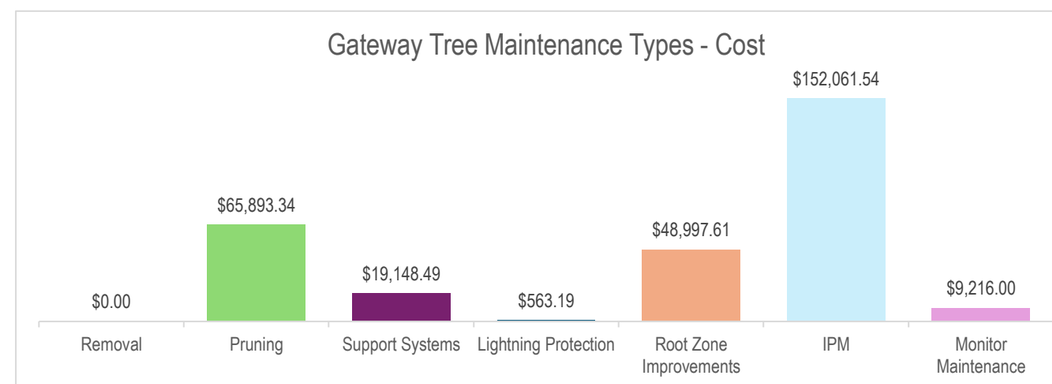






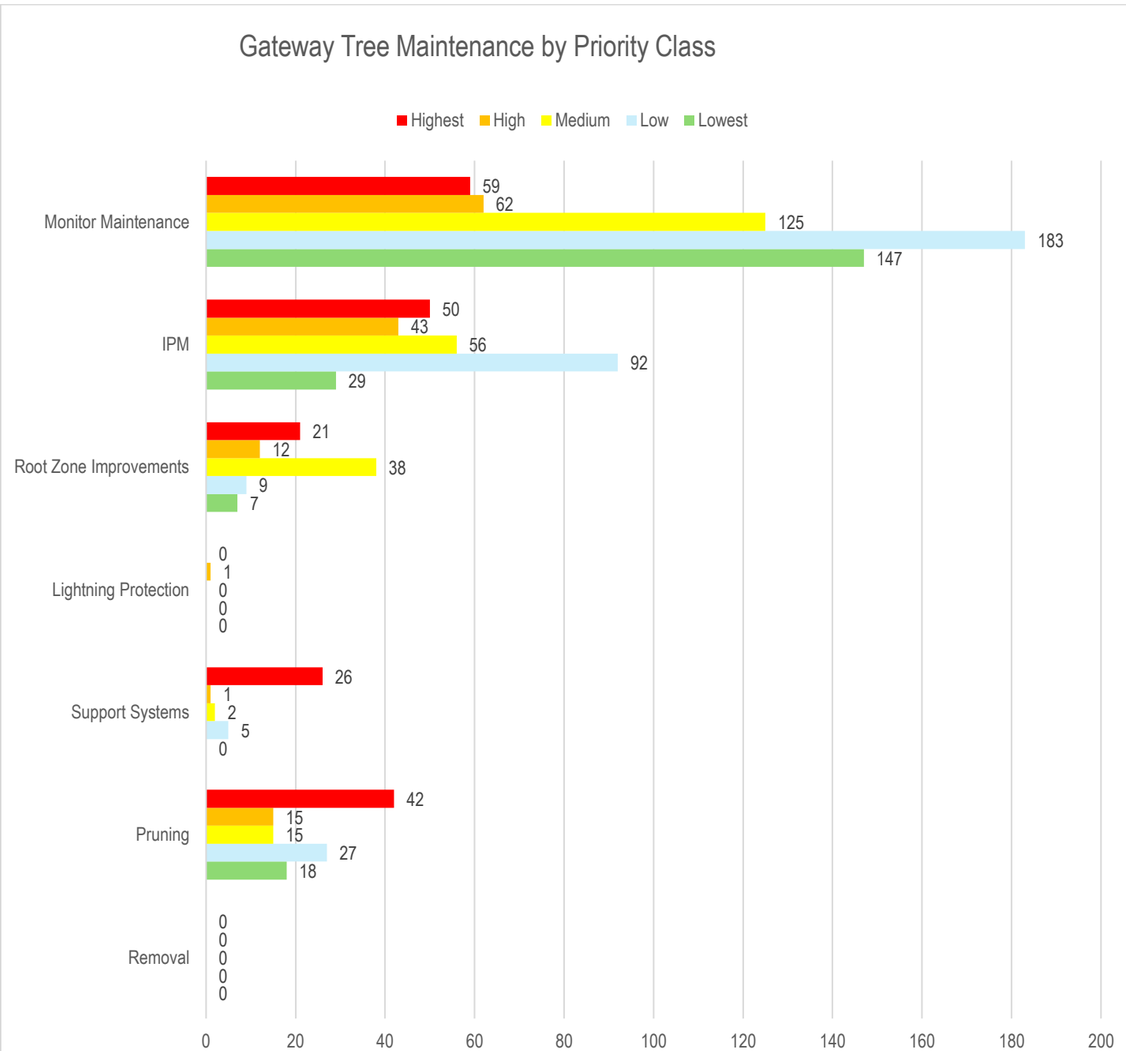
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	117	34	1	87	270	576	1085
Proj. Cost	$0.00	$65,893.34	$19,148.49	$563.19	$48,997.61	$152,061.54	$9,216.00	$295,880.17

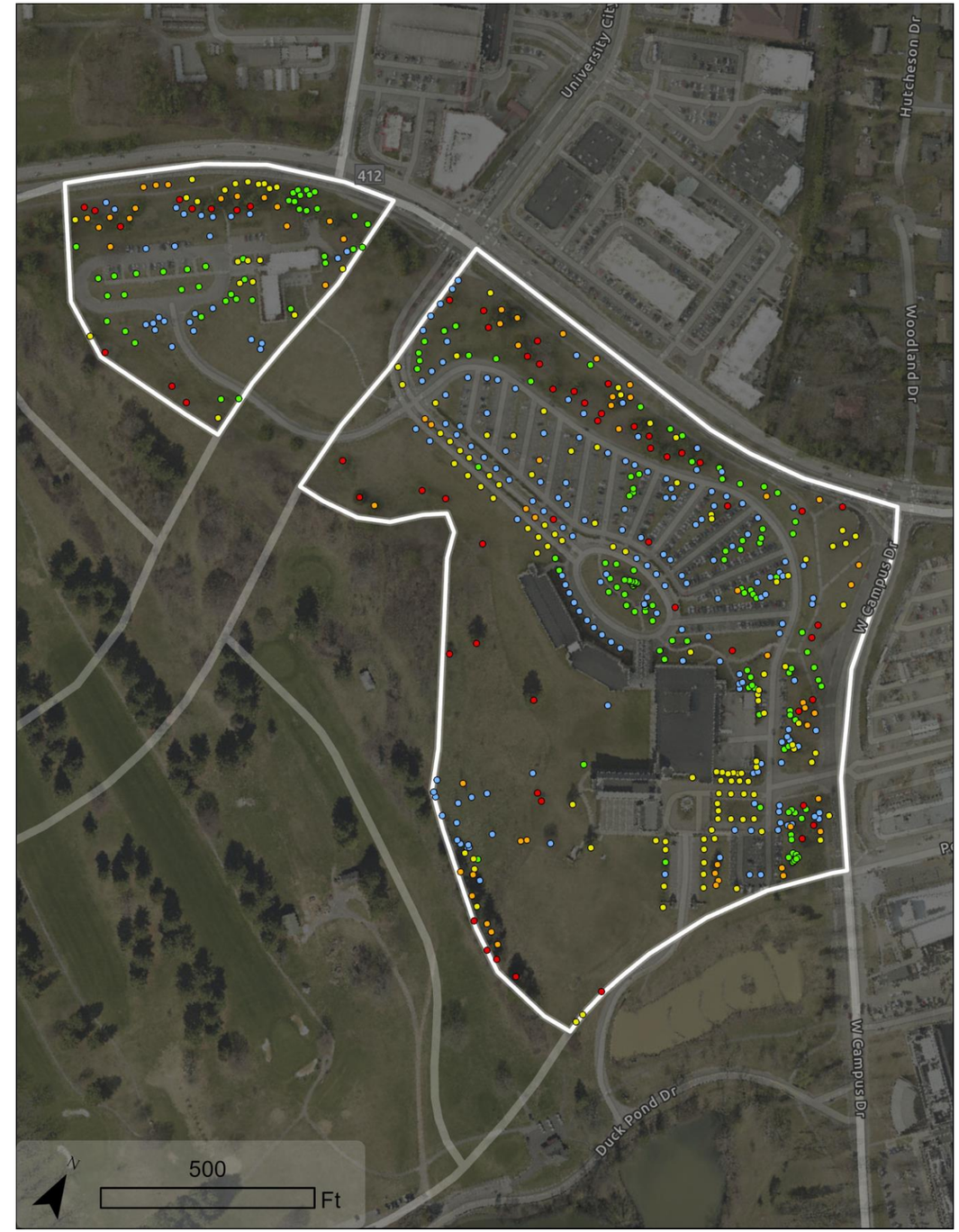




(Continued) Gateway

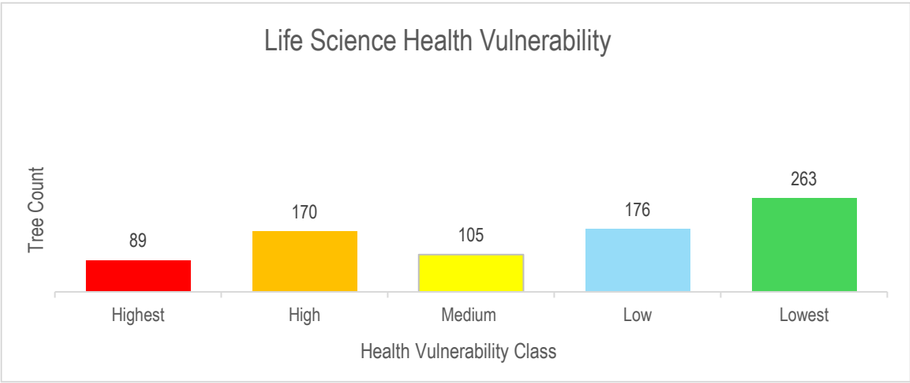
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	59	$77,570.50
High	3 & 4	62	$42,470.67
Medium	5 & 6	125	$55,212.00
Low	7 & 8	183	$77,028.00
Lowest	9 & 10	147	$43,599.00
	Totals	576	$295,880.17

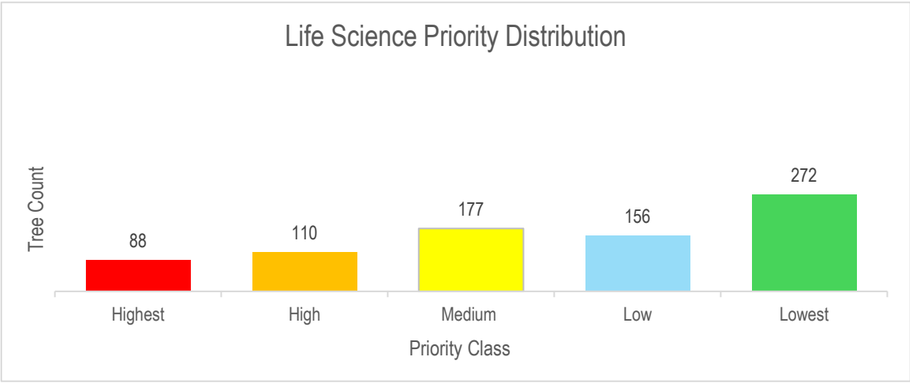


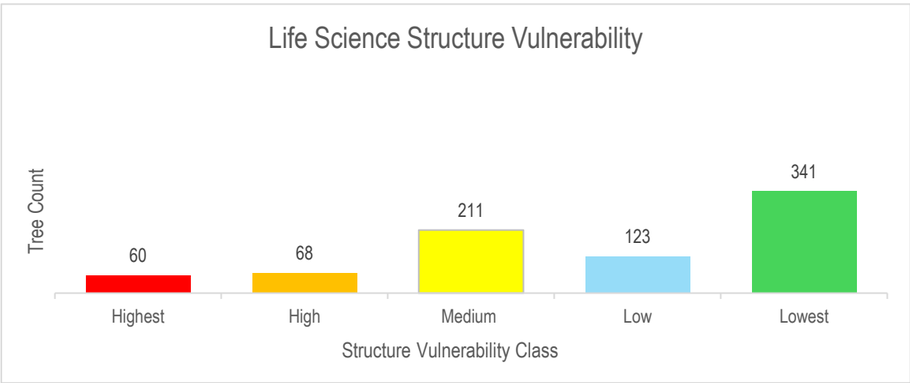


Life Science

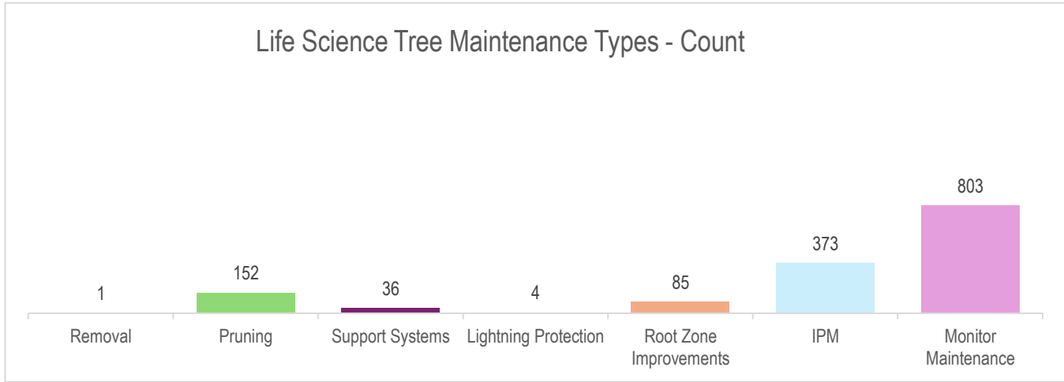
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
5	Lowest	803	9.2	$401,528.67	$40,152.87

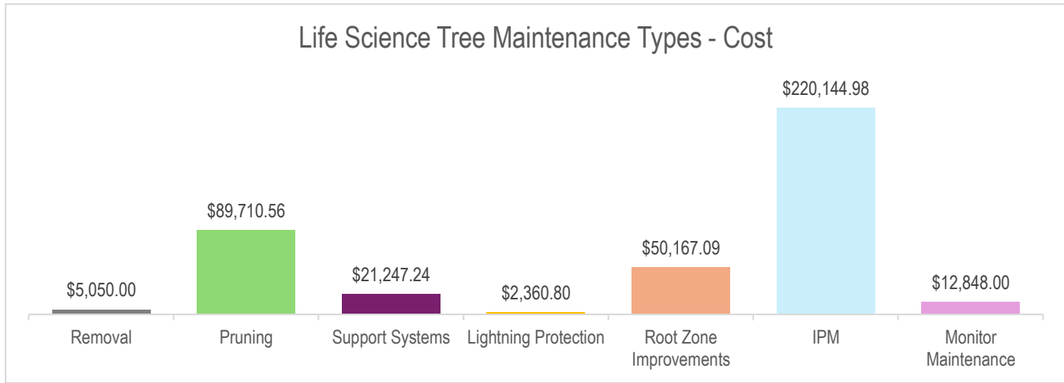






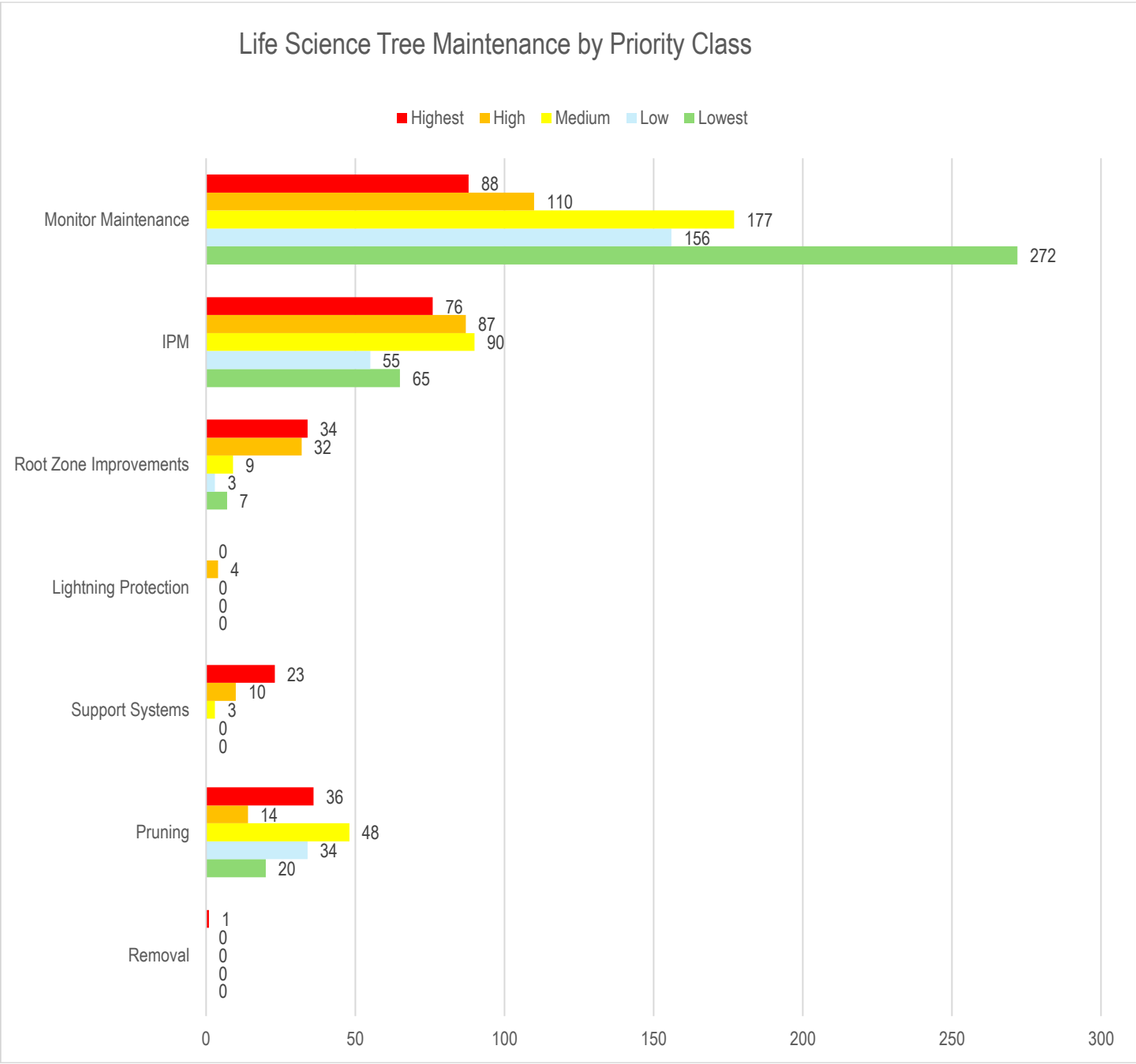
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	1	152	36	4	85	373	803	1454
Proj. Cost	$5,050.00	$89,710.56	$21,247.24	$2,360.80	$50,167.09	$220,144.98	$12,848.00	$401,528.67

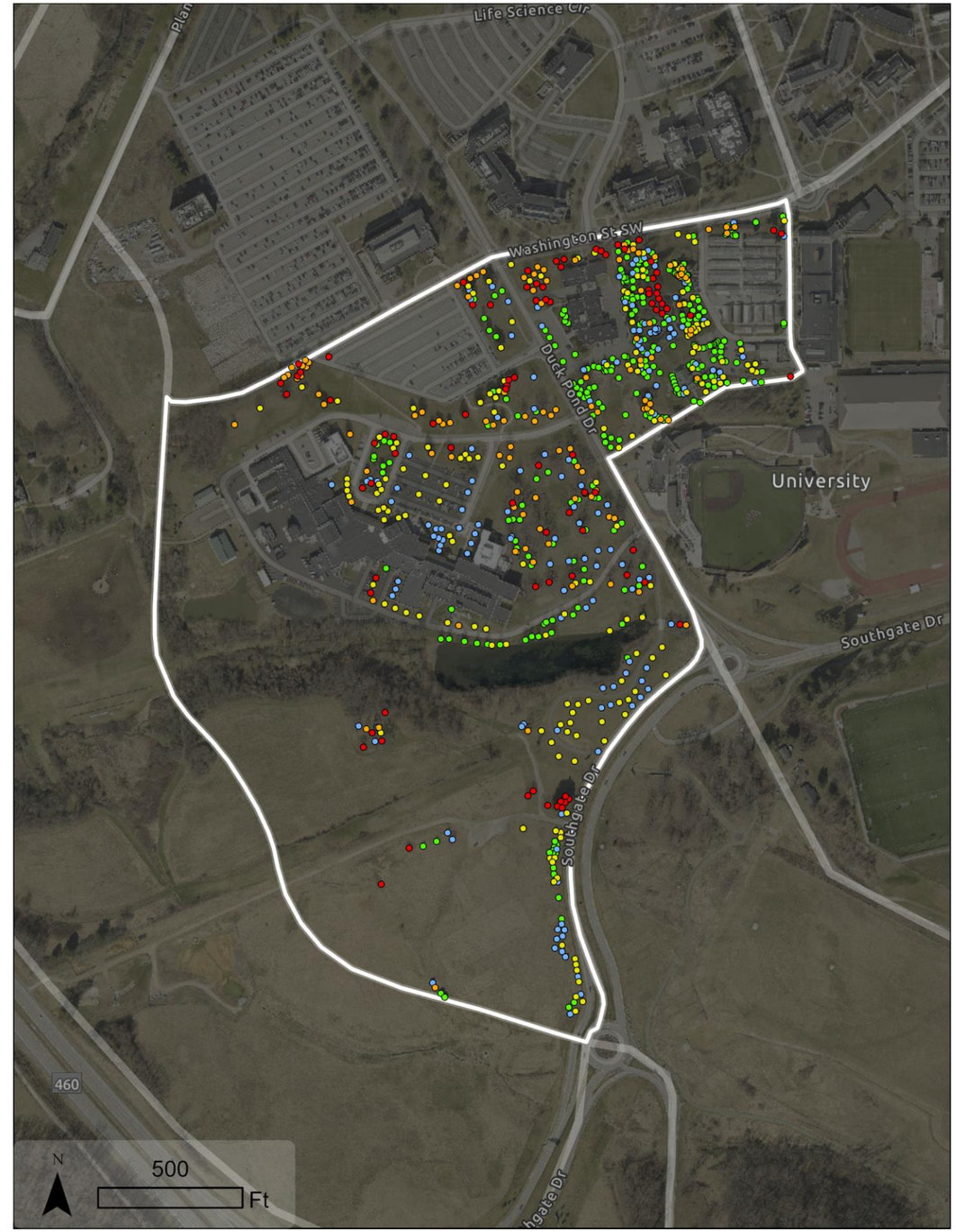




(Continued) Life Science

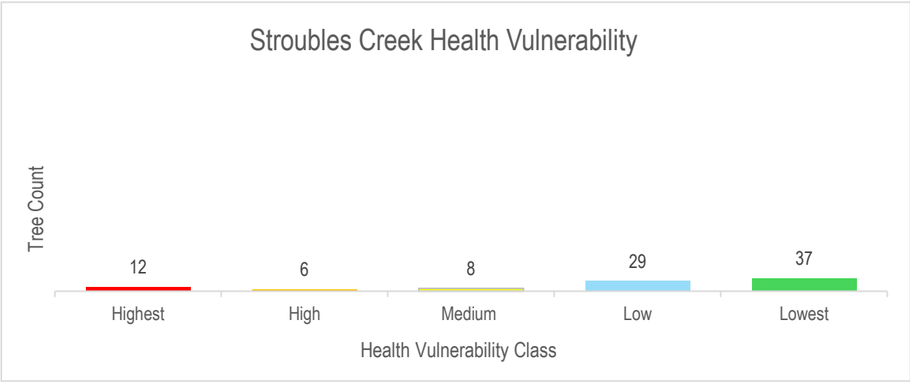
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	59	$77,570.50
High	3 & 4	62	$42,470.67
Medium	5 & 6	125	$55,212.00
Low	7 & 8	183	$77,028.00
Lowest	9 & 10	147	$43,599.00
	Totals	576	$295,880.17

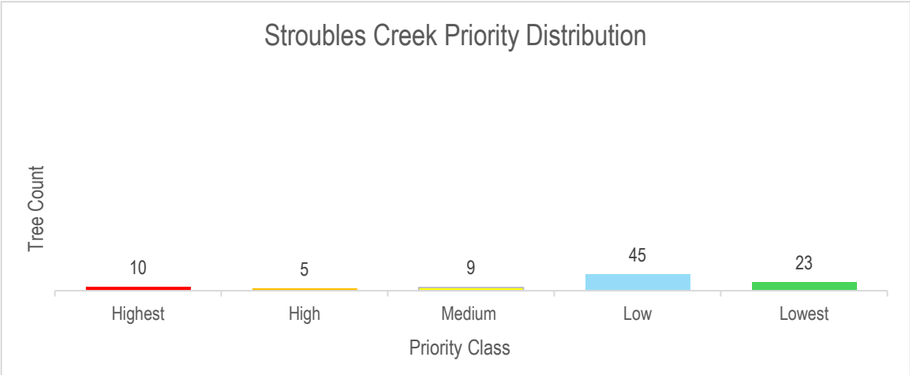


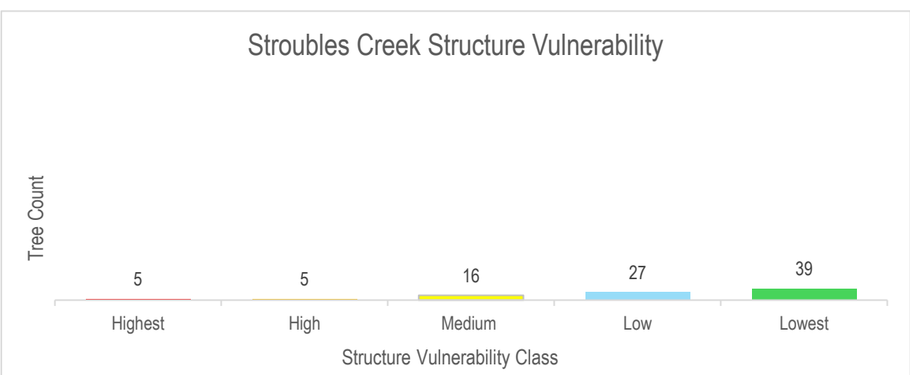


Stroubles Creek

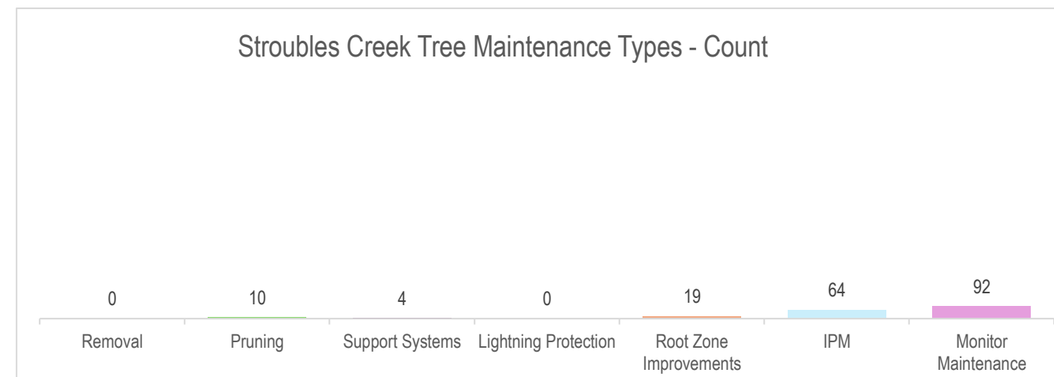
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
4	Lowest	92	2.1	$41,843.50	$4,184.35

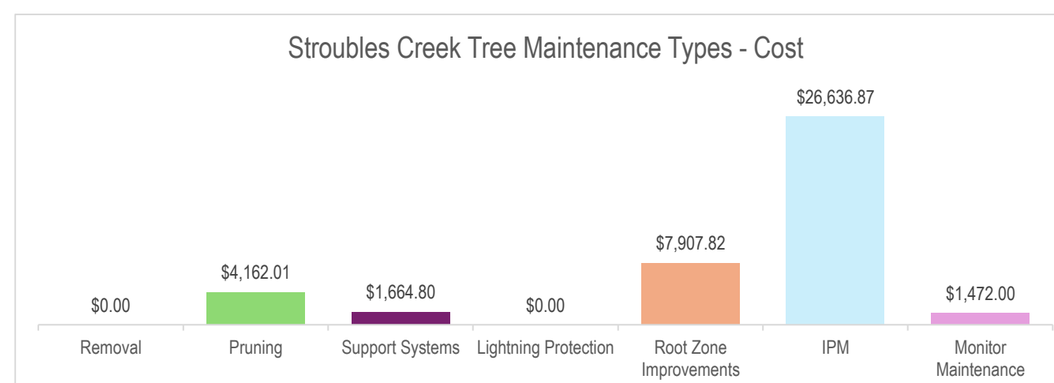






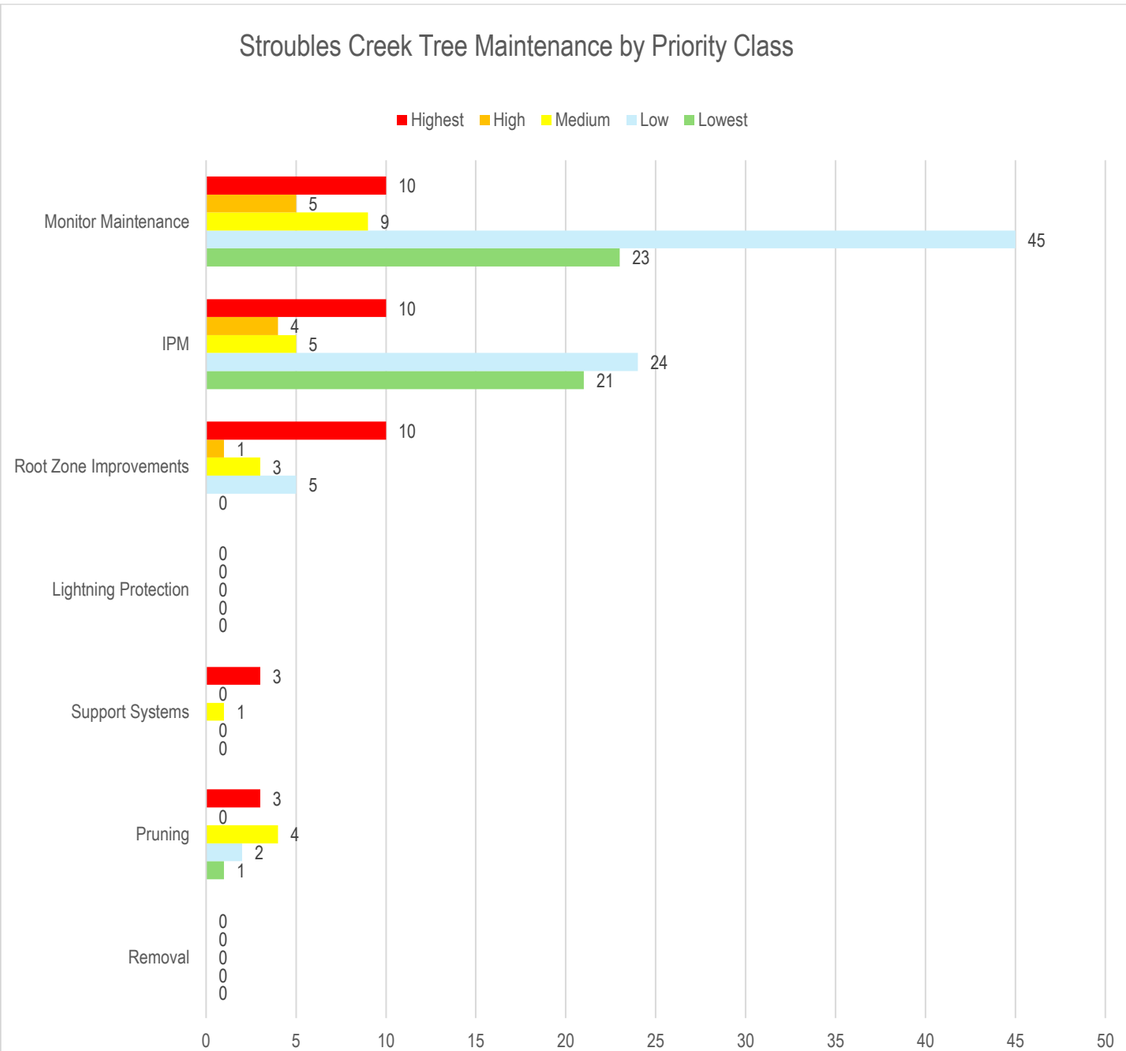
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	10	4	0	19	64	92	189
Proj. Cost	$0.00	$4,162.01	$1,664.80	$0.00	$7,907.82	$26,636.87	$1,472.00	$41,843.50

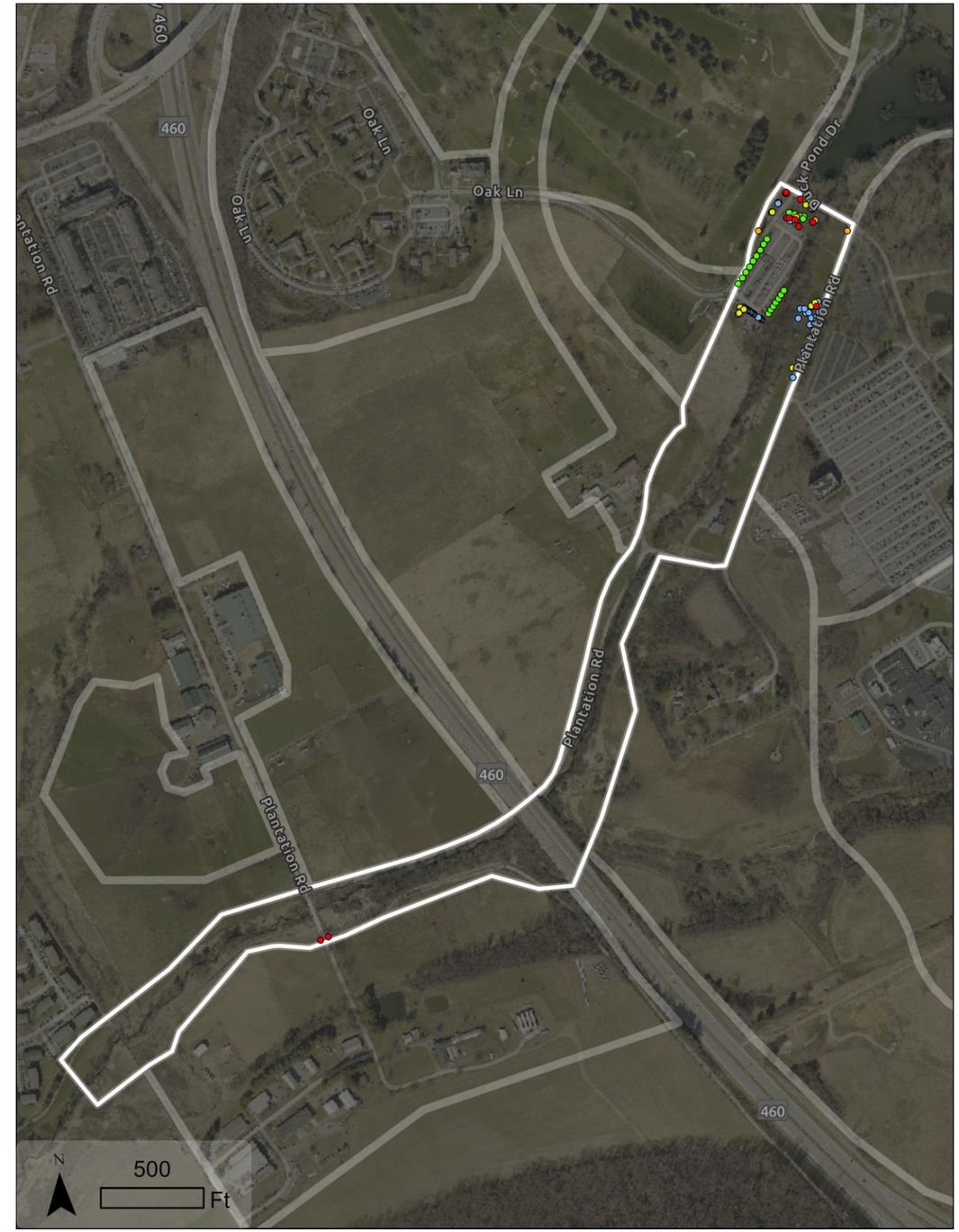




(Continued) Stroubles Creek

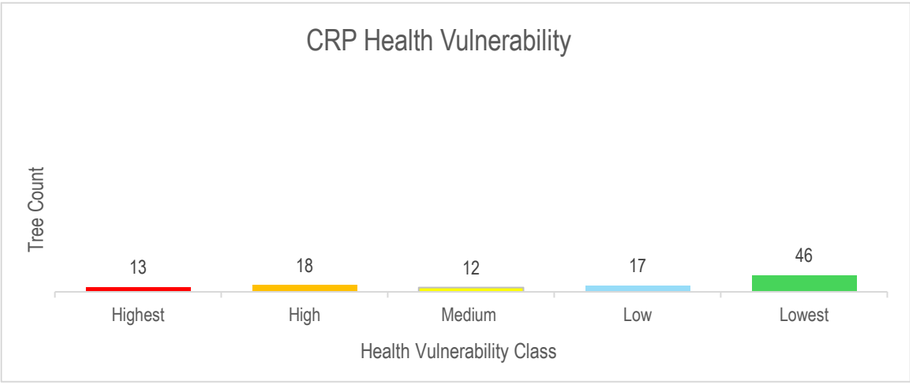
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	10	$10,419.00
High	3 & 4	5	$2,094.00
Medium	5 & 6	9	$5,806.17
Low	7 & 8	45	$13,701.33
Lowest	9 & 10	23	$9,823.00
	Totals	92	$41,843.50

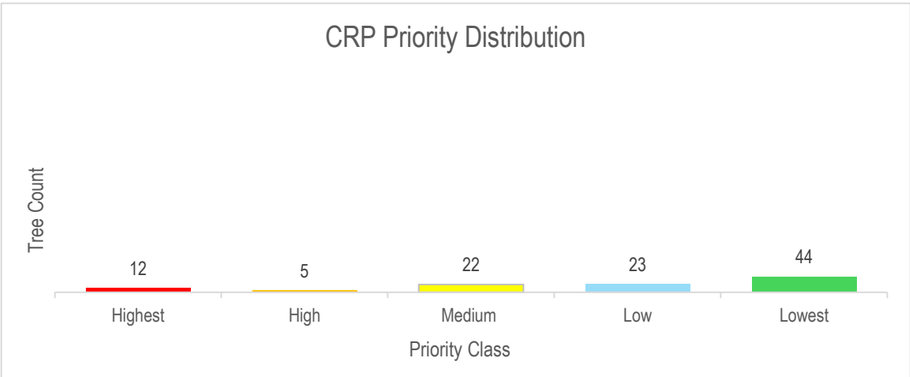


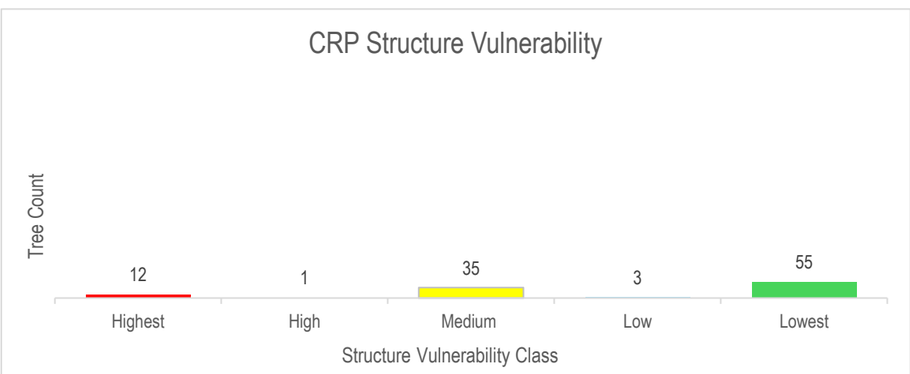


Corporate Research Center Phase II

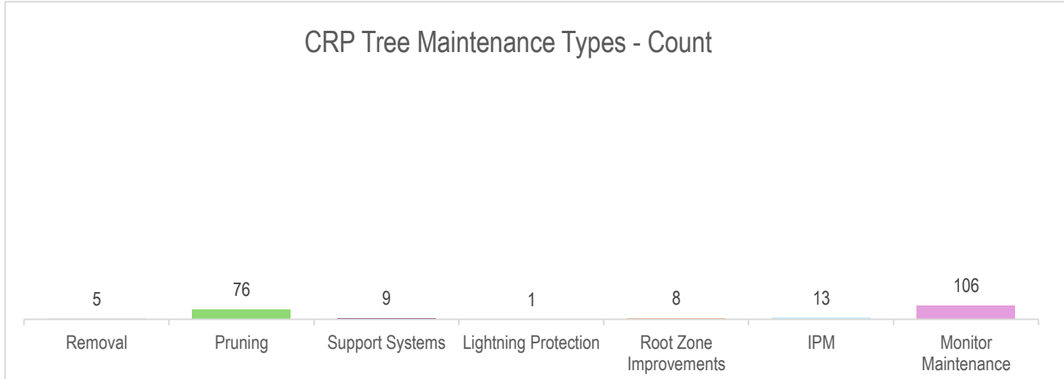
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
3	Lowest	106	0.9	$138,469.33	$13,846.93

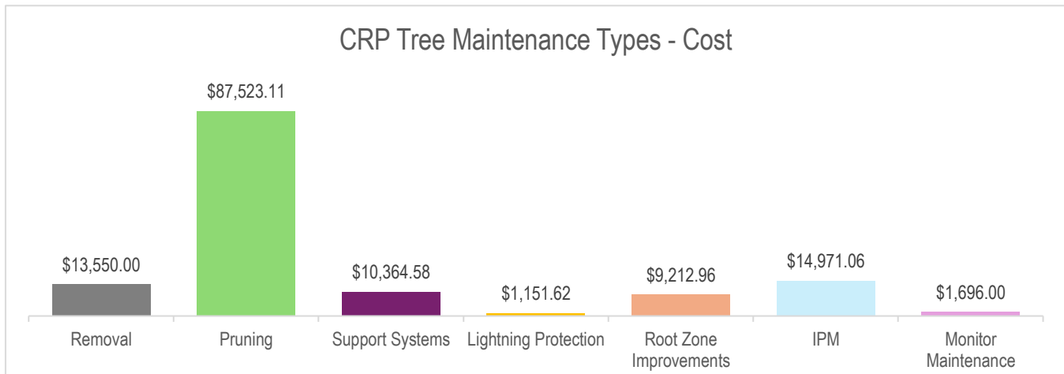






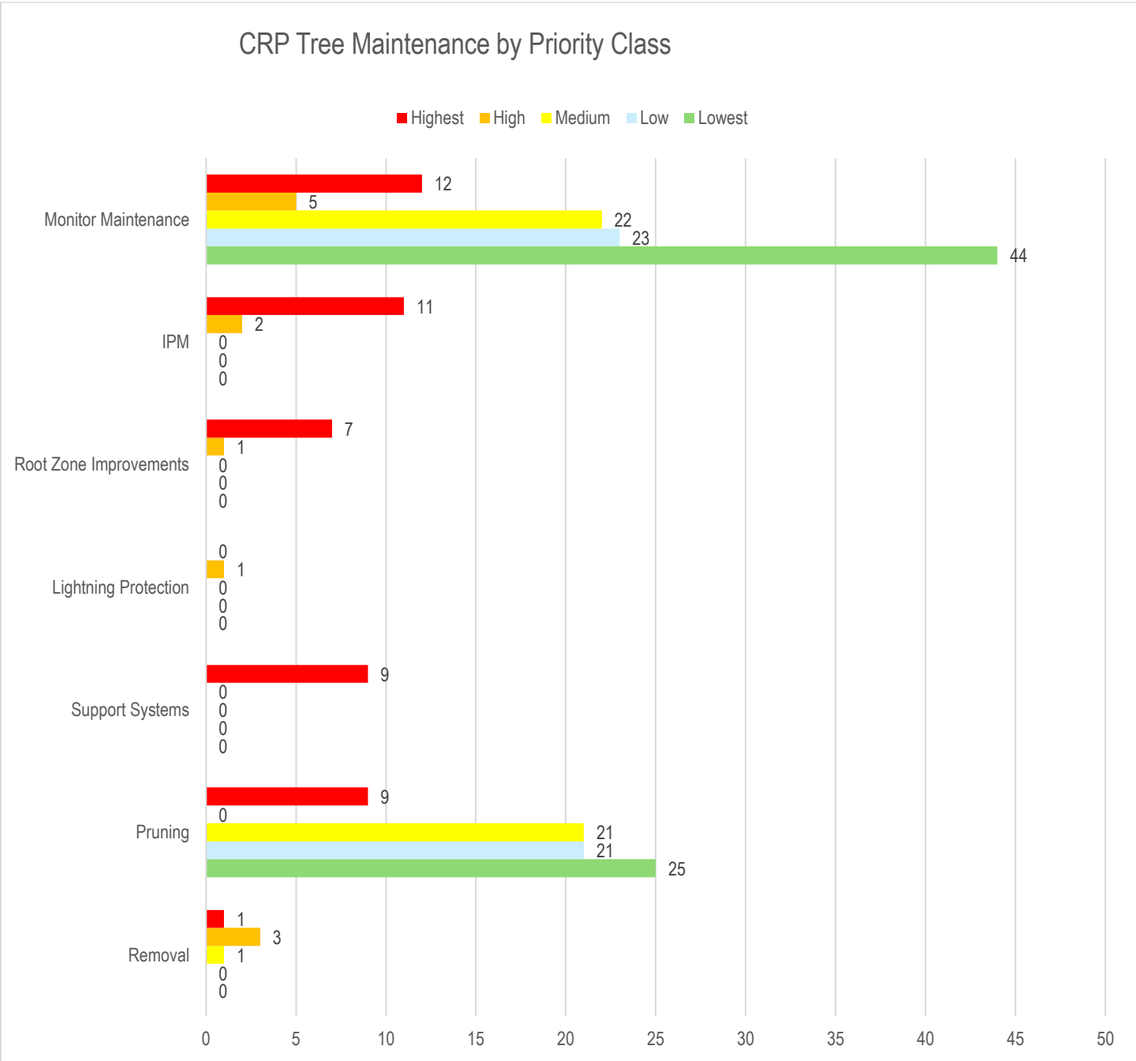
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	5	76	9	1	8	13	106	218
Proj. Cost	$13,550.00	$87,523.11	$10,364.58	$1,151.62	$9,212.96	$14,971.06	$1,696.00	$138,469.33

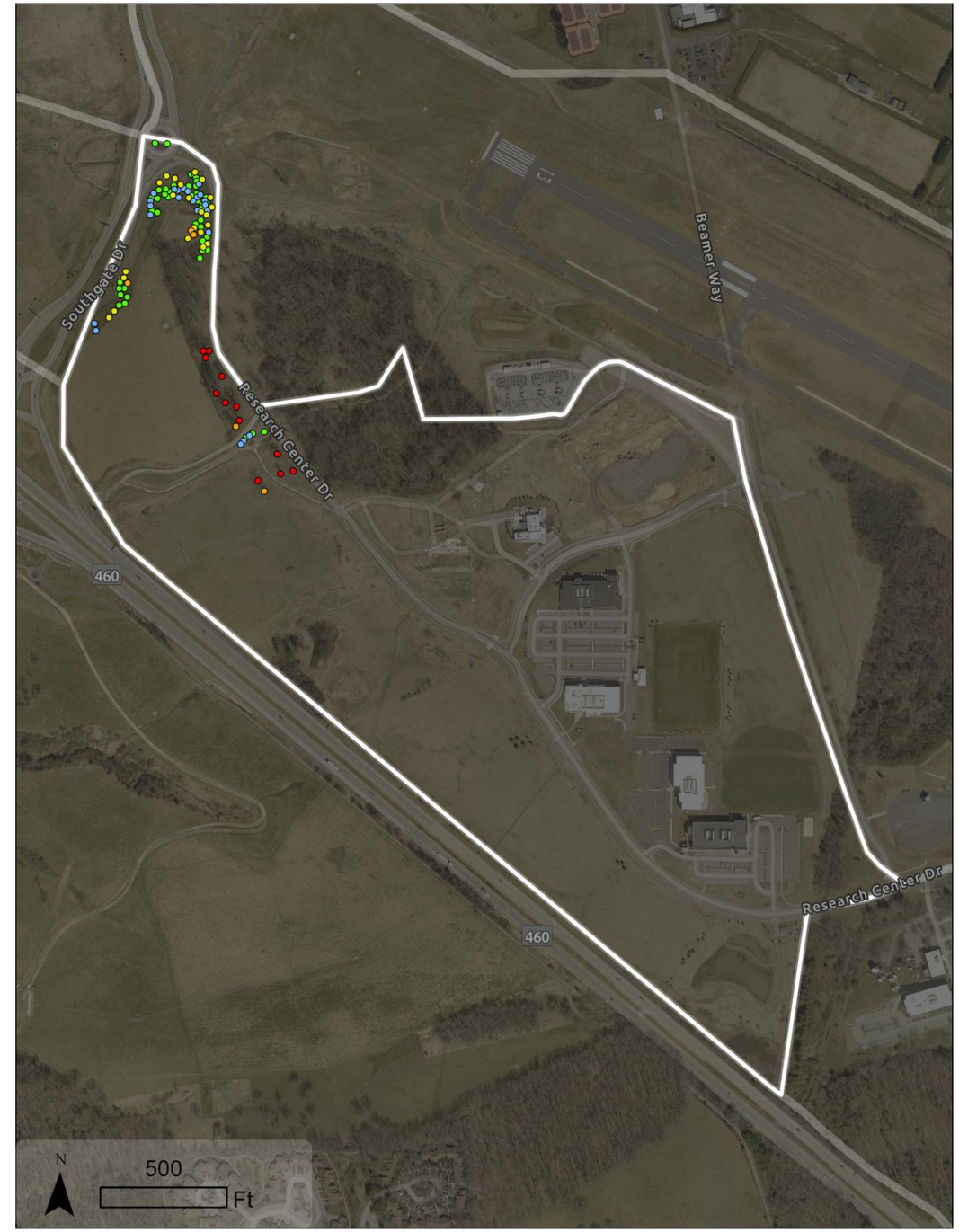




(Continued) Corporate Research Center Phase II

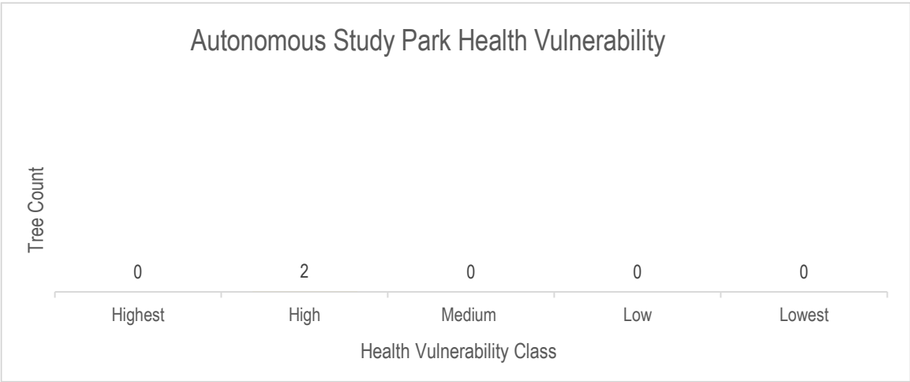
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	12	$21,578.83
High	3 & 4	5	$9,266.50
Medium	5 & 6	22	$35,252.00
Low	7 & 8	23	$32,918.00
Lowest	9 & 10	44	$39,454.00
	Totals	106	$138,469.33

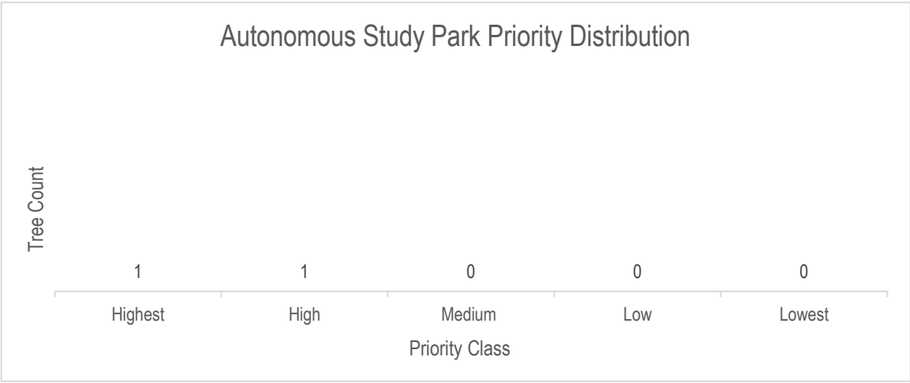


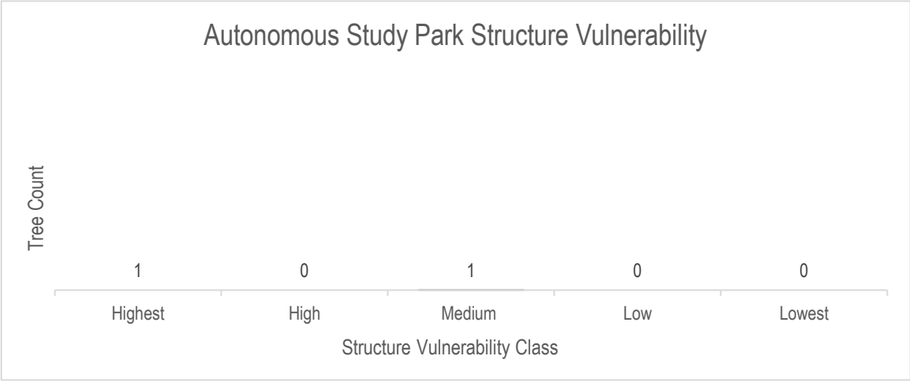


Autonomous Study Park

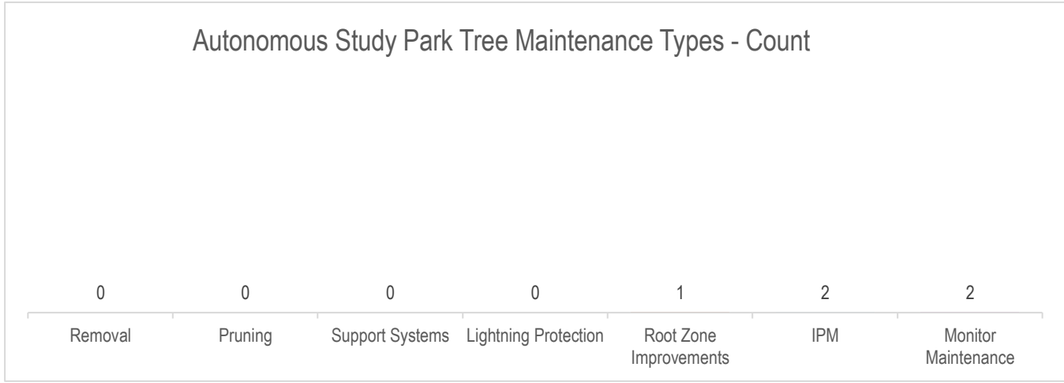
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
2	Lowest	2	0.2	$1,416.00	$141.60

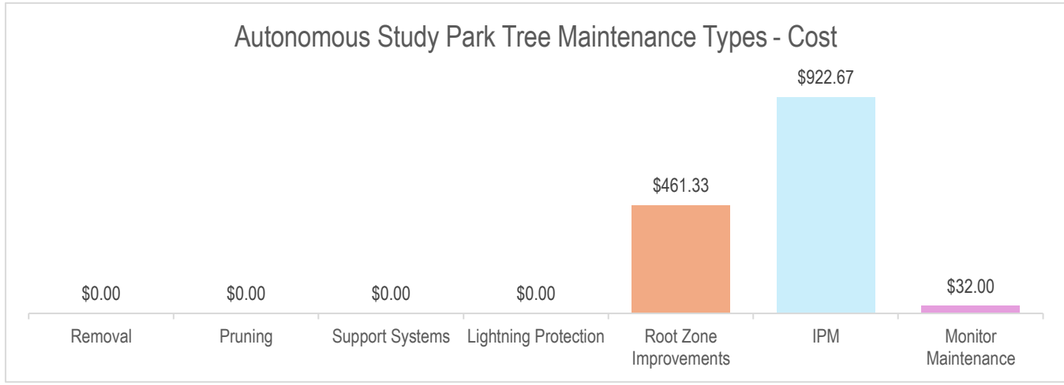






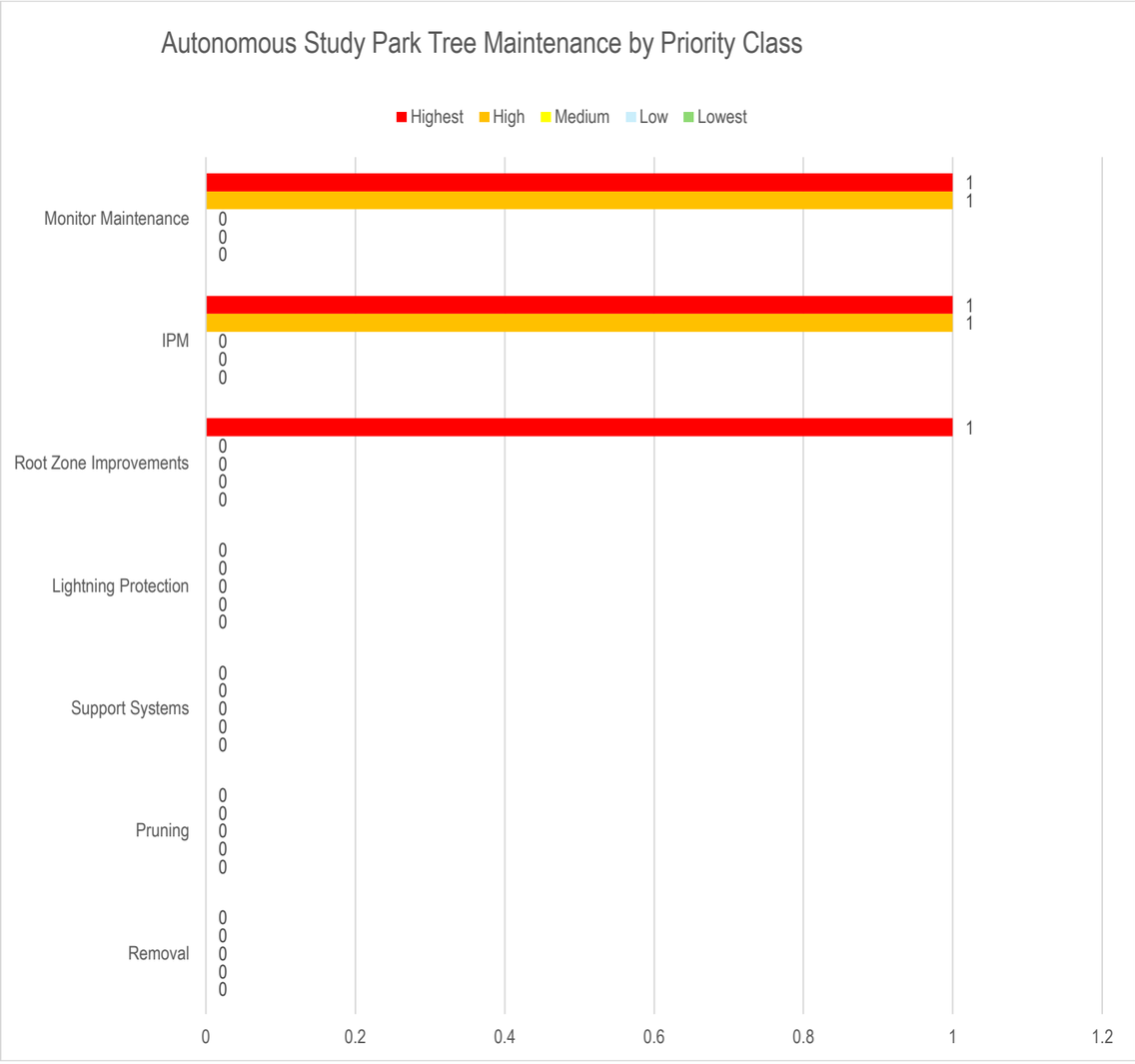
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	0	0	0	0	1	2	2	5
Proj. Cost	$0.00	$0.00	$0.00	$0.00	$461.33	$922.67	$32.00	$1,416.00





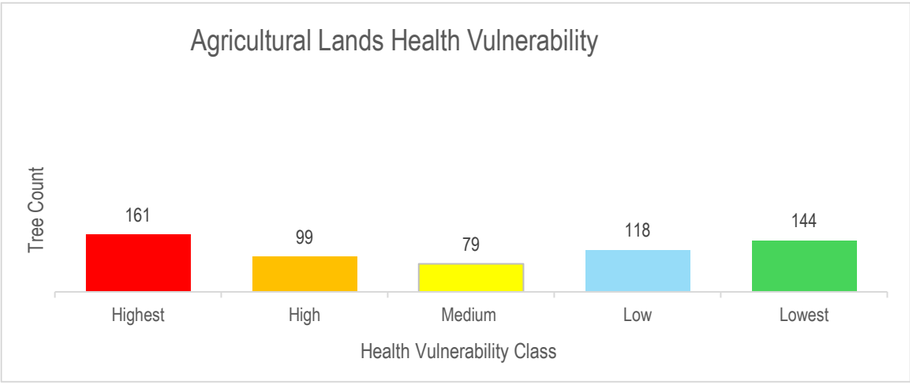
(Continued) Autonomous Study Park

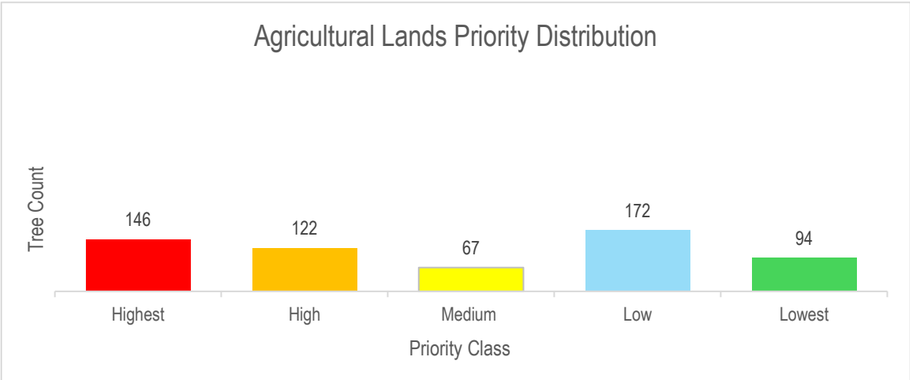
Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	1	$975.00
High	3 & 4	1	$441.00
Medium	5 & 6	0	$0.00
Low	7 & 8	0	$0.00
Lowest	9 & 10	0	$0.00
	Totals	2	$1416.00

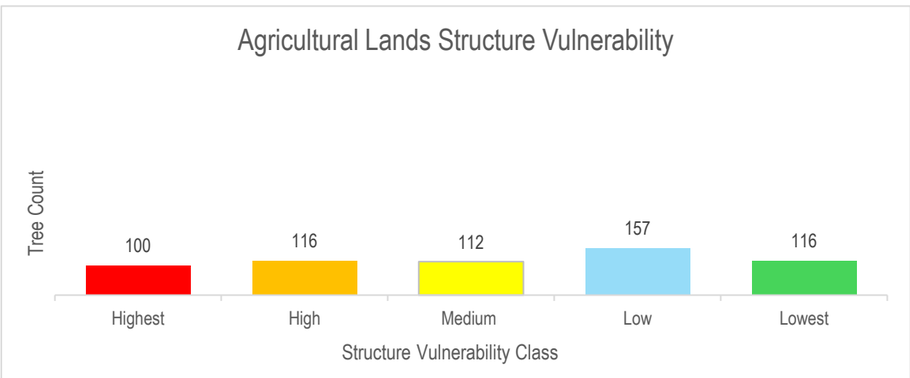


Agricultural Lands

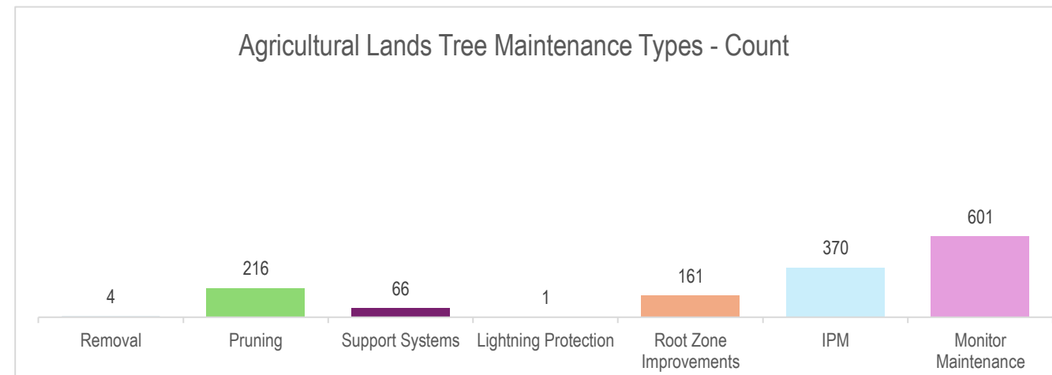
Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
1	Lowest	601	2.6	$490,866.33	$49,086.63

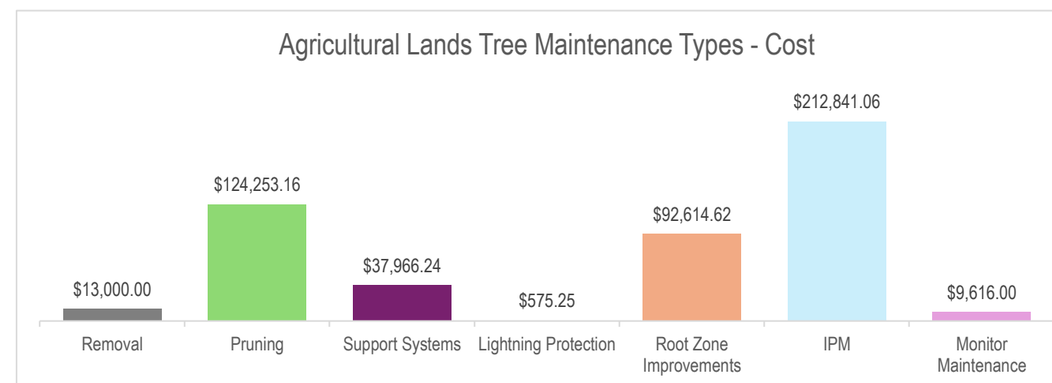






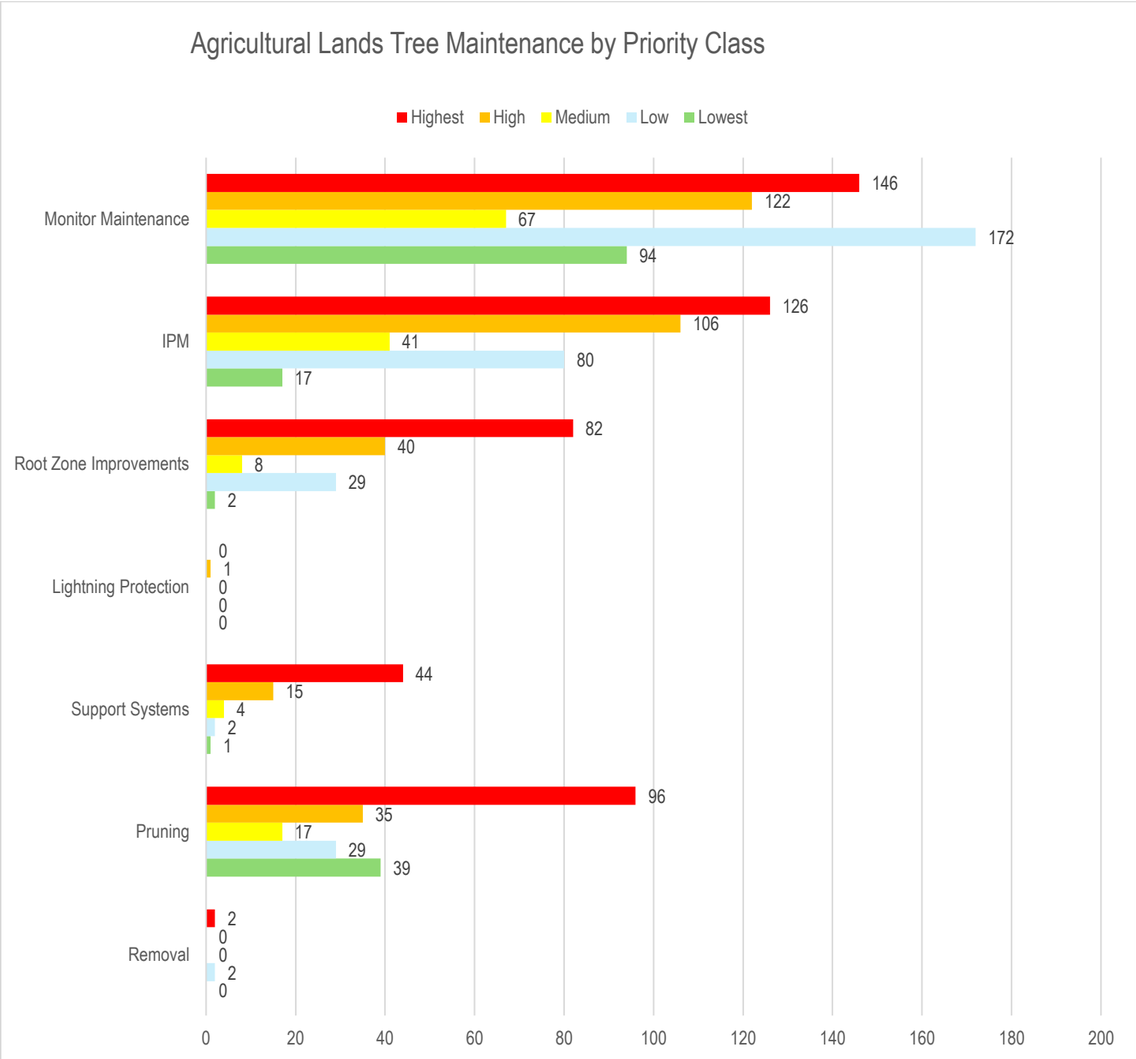
	Maintenance Type Cost (Projected costs of possible maintenance)							
	Removal	Pruning	Support Systems	Lightning Protection	Root Zone Improvements	IPM	Monitor Maintenance	Totals
Count	4	216	66	1	161	370	601	1419
Proj. Cost	$13,000.00	$124,253.16	$37,966.24	$575.25	$92,614.62	$212,841.06	$9,616.00	$490,866.33

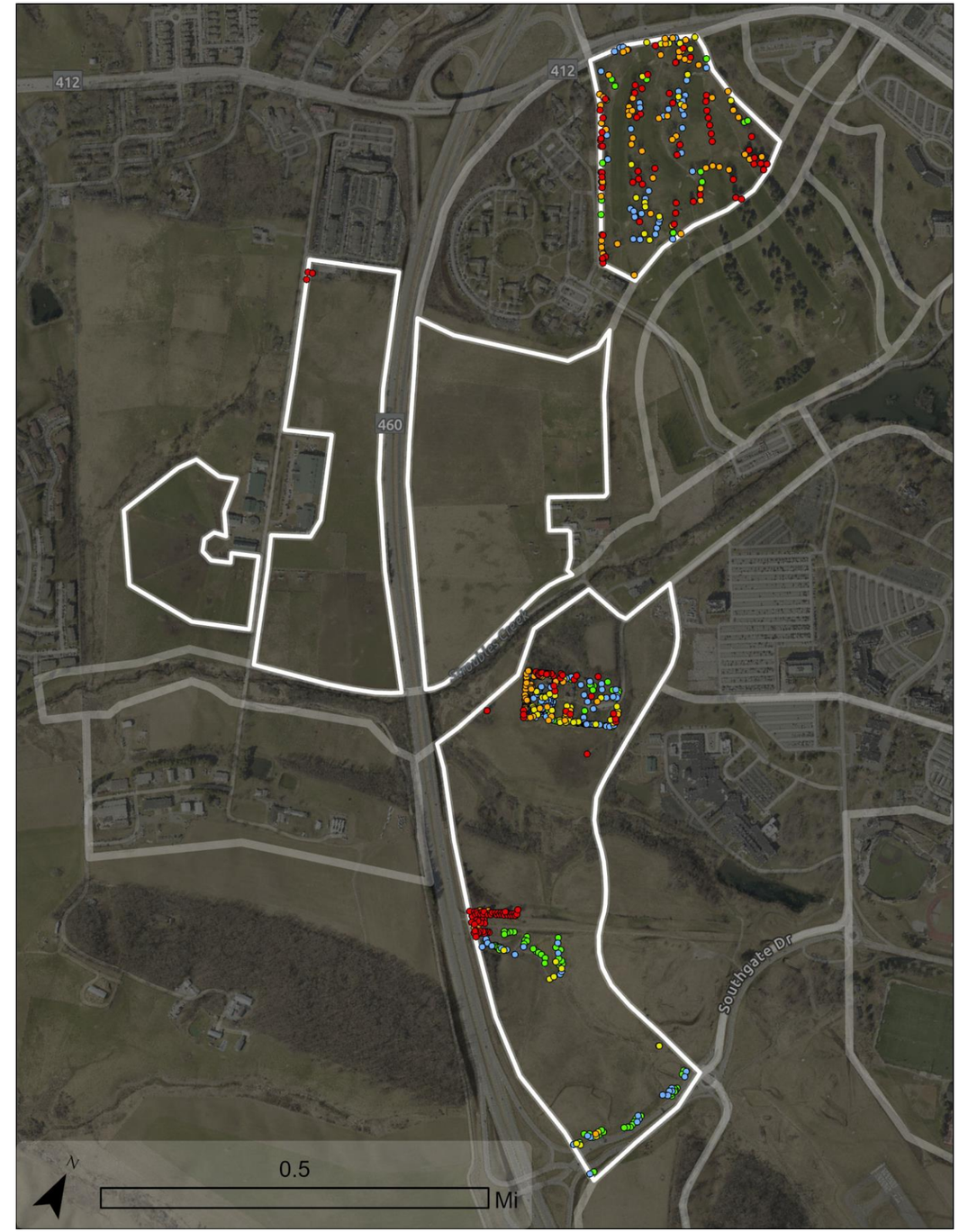




(Continued) Agricultural Lands

Priority Class	Years	Tree Count	Projected Cost
Highest Priority Trees	1 & 2	146	$189,305.33
High	3 & 4	122	$97,917.50
Medium	5 & 6	67	$42,243.17
Low	7 & 8	172	$93,934.00
Lowest	9 & 10	94	$67,466.33
	Totals	**601**	**$490,866.33**





Corporate Research Center

No inventory data.

Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
0	N/A	0	0	0	0

North End

No inventory data.

Priority Rank	Priority Class	Total trees	Tree density	Projected maintenance cost	Projected annual average cost
0	N/A	0	0	0	0

Maintenance Plan Management

- Trees are missing from the existing campus inventory for many of the district maintenance zones. This observation is evident throughout the campus but is most prevalent in the *Corporate Research Center* and *North End* Districts (see district maps)

- An existing management requirement should be to complete a comprehensive campus tree inventory and assessment that includes risk assessment. Effective management requires a complete tree inventory and an understanding of tree risk. The following are considerations in completing a tree inventory and assessment:
    - The inventory shall be completed by professionally experienced, credentialed, and qualified arborists. It is not advisable to utilize tree inventory data collected by unqualified and inexperienced individuals to make tree population management decisions.
    - Inventory may follow the same protocol utilized for 'Stewart, P. W., & Wiseman, P. E. (2018). *Inventory and Analysis of Landscape Trees and Urban Forests on the Main Campus of Virginia Tech.* Department of Forest Resources and Environmental Conservation, Virginia Tech. 56 p. Available online at https://vtechworks.lib.vt.edu/handle/10919/24279.'
    - A tree risk assessment should be included in the inventory. Currently, tree risk assessment is recommended on a three-year cycle (3). Tree risk assessment shall be completed to comply with ANSI A300 (Part 9)-2017 Tree Risk Assessment a. Tree Failure. Revision of ANSI A300 (Part 9)-2011.
    - Initial inventory and reporting costs are projected to be $275,000. Subsequent inventory and tree risk assessment is estimated to be 50% of the initial cost, $138,000 (for cycles two and three.)

Planting Plan

Tree Species Evaluation

The initial stage of the planting plan consisted of an analysis of the current population. Salient aspects of the inventory used to inform the planting plan were diversity at the genus and species level, and relative performance in the landscape of those groups. Diversity is key to a resilient urban forest and can always be improved. Relative performance of trees at the genus and species level highlights successful and poor performers and may be used to guide species selection efforts in future plantings.

Current Species Diversity

The Virginia Tech campus currently has a wide diversity of tree species. Overall, 263 individual species are described in the inventory data. However, many species are underrepresented. For example, 52 species were represented by a single tree. Two hundred and thirty (230) species were represented by 100 trees or fewer. Thirty-three (33) species are represented by more than 100 trees and described in the table below.

TABLE 16: REPRESENTATION OF SPECIES WITH MORE THAN 100 INDIVIDUALS

Species	Common Name	Count
Acer saccharum	Sugar maple	496
Quercus alba	White oak	429
Prunus avium	Sweet cherry	428
Acer rubrum	Red maple	399
Pinus strobus	Eastern white pine	399
Prunus serotina	Black cherry	313
Juglans nigra	Black walnut	311
Quercus rubra	Northern red oak	297
Quercus velutina	Black oak	252
Robinia pseudoacacia	Black locust	245
Amelanchier sp.	Serviceberry	241
Platanus x hispanica	London plane	229
Thuja occidentalis	Arborvitae	223
Prunus sp.	Cherry	209
Juniperus virginiana	Eastern red cedar	204
Picea abies	Norway spruce	195
Cornus florida	Flowering dogwood	193
Malus sp.	Apple	190
Taxodium distichum	Bald cypress	178
Quercus bicolor	Swamp white oak	169
Quercus phellos	Willow oak	166
Tilia cordata	Littleleaf linden	148
Betula nigra	River birch	148
Ulmus parvifolia	Chinese elm	140
Liriodendron tulipifera	Tulip tree	139

Species	Common Name	Count
Ulmus americana	American elm	138
Cercis canadensis	Eastern	126
Picea pungens	Blue spruce	120
Nyssa sylvatica	Black tupelo	119
Acer platanoides	Norway maple	116
Hesperocyparis arizonica	Arizona cypress	105
Liquidambar styraciflua	Sweetgum	105
Cornus kousa	Kousa dogwood	102

Note: *Amelanchier* sp., *Prunus* sp., and *Malus* sp. are only identified to the genus level.

Over 100 genera are represented in the inventory. Thirteen (13) genera are represented by a single tree. Seventy-three (73) are represented by 100 or fewer trees. Twenty-seven (27) genera are represented by more than 100 trees. *Acer* (1337 trees) and *Quercus* (1801 trees) were each represented by over 1000 trees. The below table describes the 27 genera that exceeded 100 individuals.

TABLE 17: REPRESENTATION OF THE 15 MOST COMMON GENERA

Genus	Count
Quercus	1801
Acer	1337
Prunus	997
Pinus	560
Ulmus	331
Cornus	329
Picea	328
Juglans	313
Amelanchier	286
Platanus	266
Robinia	245
Thuja	239
Juniperus	206
Betula	197
Malus	196
Tilia	185
Taxodium	178
Magnolia	164
Liriodendron	139
Fagus	133
Fraxinus	132
Cercis	127
Nyssa	125
Ilex	122
Crataegus	110

Genus	Count
Cupressus	106
Liquidambar	105

Relative Performance

Of all 10,786 trees included in the inventory, 65% were in excellent or good condition. Twenty-nine percent (29%) were in fair condition, 6% were in poor condition, and 0.5% (55 trees) were dead.

Performance was not uniform among species or genera. To highlight interspecific and intergeneric trends, condition was calculated as a proportion for each species. For ease of analysis, a subset of the 15 most populous species and genera were separated from the population at large.

A relative performance index (RPI) was also calculated for the tree species inventoried. This protocol was adopted from the Vibrant Cities Lab (http://www.vibrantcitieslab.com) and provides a metric of the benefits a tree species provides in a community. For a single species, the percentage of trees in excellent or good condition is divided by the percentage of all trees in excellent or good condition throughout the entire population. This system states that tree species with a RPI of 1.0 or higher will generally provide more benefits to the community, which may make them a better choice for new plantings.

Across the Virginia Tech campus, trees of different species performed differently to one another. Proportional condition and RPI ratings for the 15 most common species are reported in Table 18, below.

TABLE 18: PROPORTIONAL CONDITION OF THE 15 MOST COMMON SPECIES

Species	Dead	Poor	Fair	Good	Excellent	Total	RPI
Acer saccharum	0%	5%	30%	60%	4%	496	0.99
Quercus alba	1%	2%	13%	83%	1%	429	1.30
Prunus avium	0%	6%	18%	75%	0%	428	1.15
Acer rubrum	0%	2%	30%	66%	2%	399	1.04
Pinus strobus	2%	2%	12%	82%	3%	399	1.32
Prunus serotina	0%	10%	45%	45%	0%	313	0.69
Juglans nigra	0%	5%	34%	60%	0%	311	0.92
Quercus rubra	1%	6%	20%	71%	2%	297	1.12
Quercus velutina	1%	4%	21%	74%	0%	252	1.14
Robinia pseudoacacia	0%	9%	36%	55%	0%	245	0.84
Amelanchier sp.	0%	2%	20%	78%	0%	241	1.19
Platanus x hispanica	0%	2%	45%	52%	0%	229	0.80
Thuja occidentalis	3%	5%	26%	58%	9%	223	1.05
Prunus sp.	0%	3%	32%	66%	0%	209	1.00
Juniperus virginiana	1%	4%	41%	53%	1%	204	0.84
Totals	0%	6%	29%	63%	2%	10,786	1.00

Overall, common species were most frequently in either good or excellent condition. Notable exceptions were black cherry (*Prunus serotina*) and black locust (*Robinia pseudoacacia*), which had lower RPI ratings of 0.69 and 0.84 respectively. We recommend that species that are good performers, such as the other 13 of the 15 described above, continue to be planted. Cultivated varieties can be used to match tree attributes according to the site. Special consideration should be paid to current species diversity to ensure representation in the urban forest does not become unbalanced at the species or genus level.

As with species specific differences in performance, there were also genera specific differences. The proportional condition of the 15 most populous genera is reported in the table below.

TABLE 19: PROPORTIONAL CONDITION OF THE 15 MOST POPULOUS GENERA

Genus	Dead	Poor	Fair	Good	Excellent	Total	RPI
Quercus	1%	5%	20%	72%	2%	1801	1.14
Acer	0%	4%	28%	64%	3%	1337	1.03
Prunus	0%	7%	30%	63%	0%	997	0.96
Pinus	1%	5%	21%	70%	3%	560	1.13
Ulmus	0%	5%	36%	56%	2%	331	0.90
Cornus	0%	5%	31%	63%	0%	329	0.97
Picea	0%	3%	28%	62%	6%	328	1.05
Juglans	0%	5%	34%	60%	0%	313	0.92
Amelanchier	0%	2%	24%	73%	0%	286	1.12
Platanus	0%	3%	44%	53%	0%	266	0.81
Robinia	0%	9%	36%	55%	0%	245	0.84
Thuja	3%	5%	24%	61%	8%	239	1.07
Juniperus	1%	4%	40%	53%	1%	206	0.85
Betula	1%	7%	23%	70%	0%	197	1.07
Malus	0%	12%	54%	34%	1%	196	0.52
Totals	0%	6%	29%	63%	2%	10,786	1.00

At the genus level, most of the 15 most populous groups were mainly represented by good condition trees. Notable exceptions are trees in the *Malus* genus, which were mostly in fair condition (54%) and had a low RPI of 0.52. *Prunus* and *Robinia* also trended towards a greater proportion of fair condition trees with RPIs of 0.96 and 0.84 respectively. This is expected when considering the relatively poor performance of the two most populous species within the two genera (*Prunus serotina* and *Robinia pseudoacacia*). We recommend that these genera be placed at a lower priority when considering new planting selections.

Species Diversity

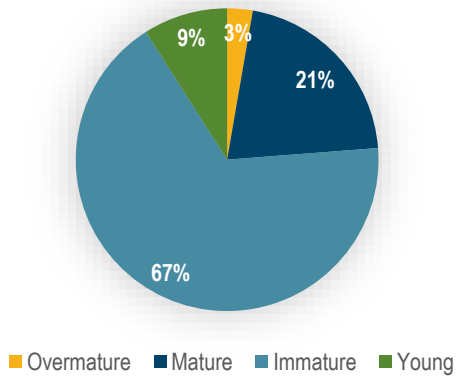
With the continuing spread of urbanization and exotic pests and in the face of climate change, tree resource diversification is imperative. Virginia Tech's Tree Planting Standards specify diversity thresholds of 5% of any one species, 10% of any one genus, and 15% of any family for new planting projects. Because we cannot predict when a new emergent pest may arrive, it is important to monitor regional pest outbreaks and adjust the planting pallet to reduce the potential for devastating insect or disease outbreaks on campus. Data were only available to the species and genus level. Our recommendations will be limited to that level of granularity.

The Virginia Tech tree population currently meets that general rule only at the species level. The most common species, sugar maple (*Acer saccharum*) accounts for approximately 4.6% of all trees. The most common genus, *Quercus*, accounts for approximately 17% of all trees. *Acer* also exceeds the guideline with 12% of the population. *Prunus* approaches the upper limit with 9%. It is unlikely that the existing tree resource will meet the 5%, 10%, 15% guidelines given the overrepresentation of *Quercus* and *Acer.* Future planting projects should be planned with these guidelines in mind.

We recommend that diversity be at minimum maintained, and preferably improved upon with future planting efforts. For example, less emphasis should be placed on species in the *Quercus, Acer,* and *Prunus* genera. A comprehensive species list has been included in the attachments which includes new species that we expect to both thrive in current conditions and be well adapted for future climate projections (see Recommended Species List in the Appendix). Some species of note that would be new to the campus have been discussed in greater detail (see Recommended Species Profiles in the Appendix).

Chronodiversity

Another important aspect of urban forest diversity is varying stages of development across the population. As old trees senesce and die, younger trees must be present to replace their functional contribution. It takes a number of years for a young tree to become established and provide meaningful benefits after planting. Trunk diameter can be reasonably associated with tree development. While more accurate measures of tree age exist, the scope of this project did not allow for those techniques to be warranted or practical. An important point to investigate is whether trees in the campus forest are disproportionately mature or overmature in development. If this were true, many trees may reach terminal biological maturity simultaneously, and naturally begin to decline and senesce in large groups. A potentially synchronized decline of large, overmature trees could present a risk to the canopy cover of the campus in future years, especially if insufficient numbers of young and semi-mature trees are present to replace them.



Graph 11: Proportion of trees in four age classes: young, immature, mature, and overmature.

Graph 11 shows the proportional representation of development stage of trees at Virginia Tech.

This figure shows a higher proportion of smaller young and immature trees, and lower proportions as trees become mature or overmature. This spread suggests that age distribution in the campus forest is appropriate and does not present a heightened risk as a result of any abnormally clustered large or overmature trees. Planting efforts should be ongoing to ensure that there are always young and developing trees ready to replace those that have reached the end of their life expectancy.

Urban Forest Master Plan Recommendations, provided by Jamie King, showed a figure that planting an area of 108 acres (39% of total plantable space) would accomplish the proposed 25% urban tree canopy goal. With a surplus of space to choose from, planting areas should be evaluated for suitability for canopy preservation and expansion and prioritized in the planting

plan. Consideration should also be given to the benefit contribution a new tree in a potential planting location may provide.

Trees provide hyper localized benefits near the planting location. We recommend prioritizing initial stages of planting in areas of the campus that have low canopy cover and high impervious surface cover. Additionally, areas that tend to be heavily trafficked by community members should be prioritized. Prioritizing these areas will allow people to immediately enjoy the benefits of the new trees. Planting in areas with either adequate canopy cover or low use will not be as beneficial.

Byers and Wiseman conducted an i-Tree Canopy analysis of the campus in 2020 and identified the most common ground cover types and tree cover estimations of several areas across the campus. The Virginia Tech Campus Urban Forest Master Plan quantified plantable acres across the campus. Areas described as high priority by Byers and Wiseman include:

- The Northeast and Upper Quad. The area had 8.2% canopy cover. Planting space here, however, was limited to 2.8 acres. While planting space is limited, benefits of trees here will be immediately realized by people in the densely populated area. This area should be prioritized for planting.
- The North Academic District. The area had approximately 10% canopy cover. There were 10 plantable acres. This district has a particularly dense community presence and should be prioritized for planting.
- The Creativity and Innovation, Student Life, and Life Sciences Districts had an average canopy cover of approximately 17% canopy cover. These districts had a combined total of 28.9 acres of plantable space. New trees would be adjacent to community activities, class and lab work, dining, student housing, and office spaces. Benefits will be enjoyed by many people and immediately realized.
- The Athletic and Recreation District. This area had the lowest canopy cover campus-wide at 4.5%. The analysis described 26.5 plantable acres. While the benefit of more trees in this area will be lower than more densely populated areas of the campus, the wide range of planting space makes this a priority area for trees.
- The Meadow had 20 acres of plantable space and approximately 28% canopy cover. While planting in this area would increase the single campus-wide canopy cover metric, trees would provide less benefit here than in more densely populated areas such as the far northeast of the campus. It may, however, provide a unique opportunity to create a naturalized landscape along Stroubles Creek.
- Oak Lane had 28.9% canopy cover and approximately 4.8 plantable acres. This area is home to several residences for Greek life and non-Greek associations. However, the area has also been recently approved for widespread development. As such, we recommend that this area be placed at a lower priority level for planting until development is complete. The large project may provide a valuable opportunity for new plantings, but will also likely remove many existing mature trees.

Approximately 93 acres of plantable space were identified in the above districts, combined. To reach the plantable space goals to meet canopy cover of 108 acres, approximately 15 acres of trees must also be installed elsewhere in a best-case scenario. More than likely, the amount will be higher due to adjustments of plantable space once site-specific details can be reviewed.

The remaining districts, the Ag Belt and 21st Century Living-Learning District, are less ideal. Despite having large areas of identified plantable space, their prevailing land use (i.e. agricultural and golf course) precludes widespread tree planting. Benefits of trees on an individual level will be less meaningful here due to the low use nature. Planting in these areas will likely be delayed until areas are redeveloped, particularly the conversion of the 21st Century Living-Learning District to a residential area from the current golf course. Plantings should be prioritized in the higher use areas, and the remainder needed to reach the campus-wide canopy goals should be planted here.

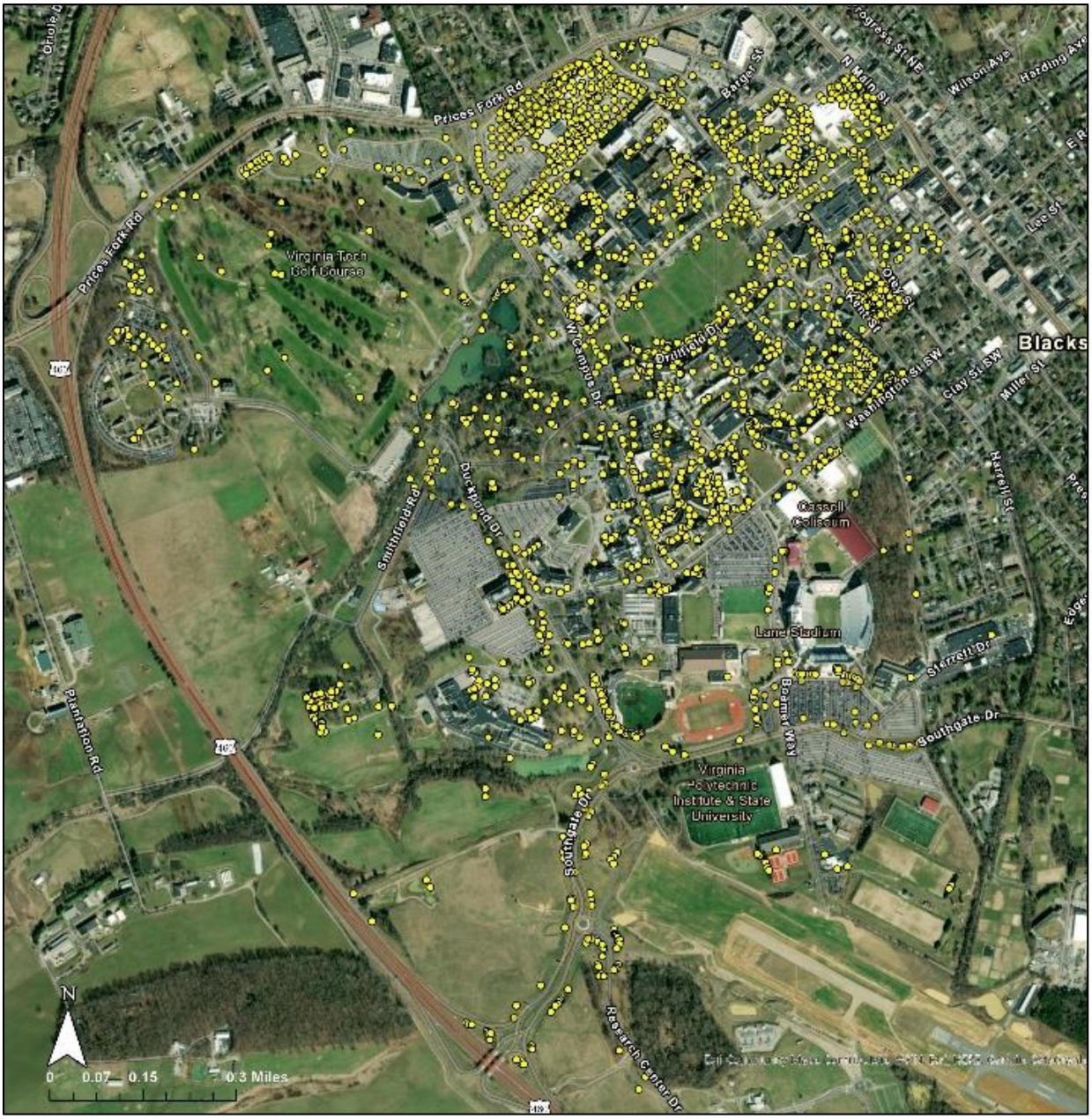
Canopy Creation

We have taken two approaches to identifying potential areas of focus for planting efforts: i) an inventory-based evaluation; and ii) a construction plan-based evaluation.

Inventory Based

To approach an inventory-based evaluation of potential planting sites, we analyzed the GIS shapefile for trees on the Virginia Tech campus in ESRI ArcPro. Since tree removals and dead trees were inventoried and GPS located, they may be reasonable sites for targeted replacement tree plantings.

First, points were filtered by attribute. A subset layer was created containing only points whose “Status” was marked as either dead, removed, snag, or stump within the main campus area. This subset consisted of 2,426 points (Map 1).

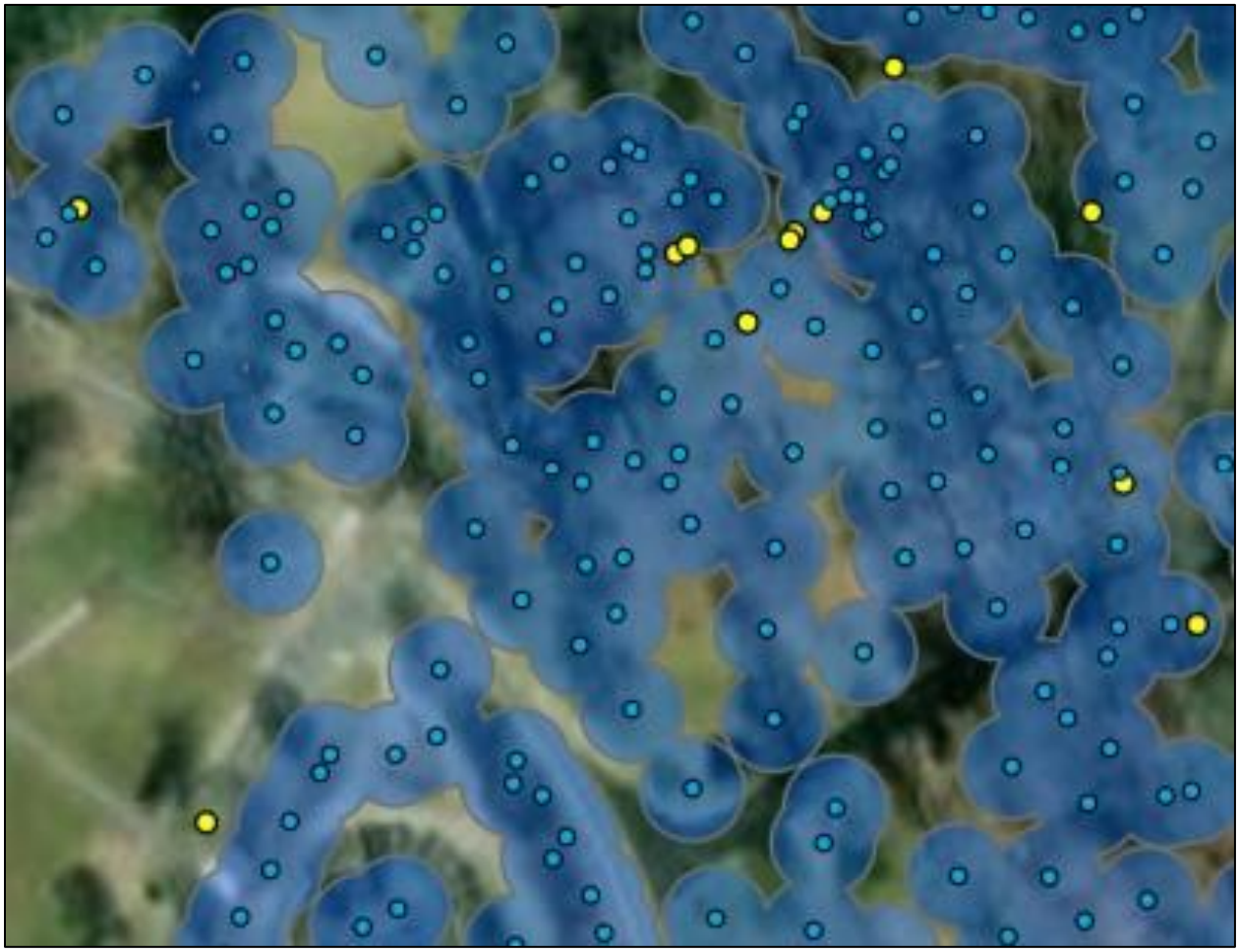


MAP 1: INVENTORY POINTS WITH THE STATUS DEAD, REMOVED, SNAG, OR STUMP (YELLOW)

In the next step, a 25-foot buffer was created around living trees (Map 2). We determined that planting new trees within this distance from an existing tree may result in eventual competition for space, light, and resources that may lead to less than ideal tree condition and structure as the new plantings develop.

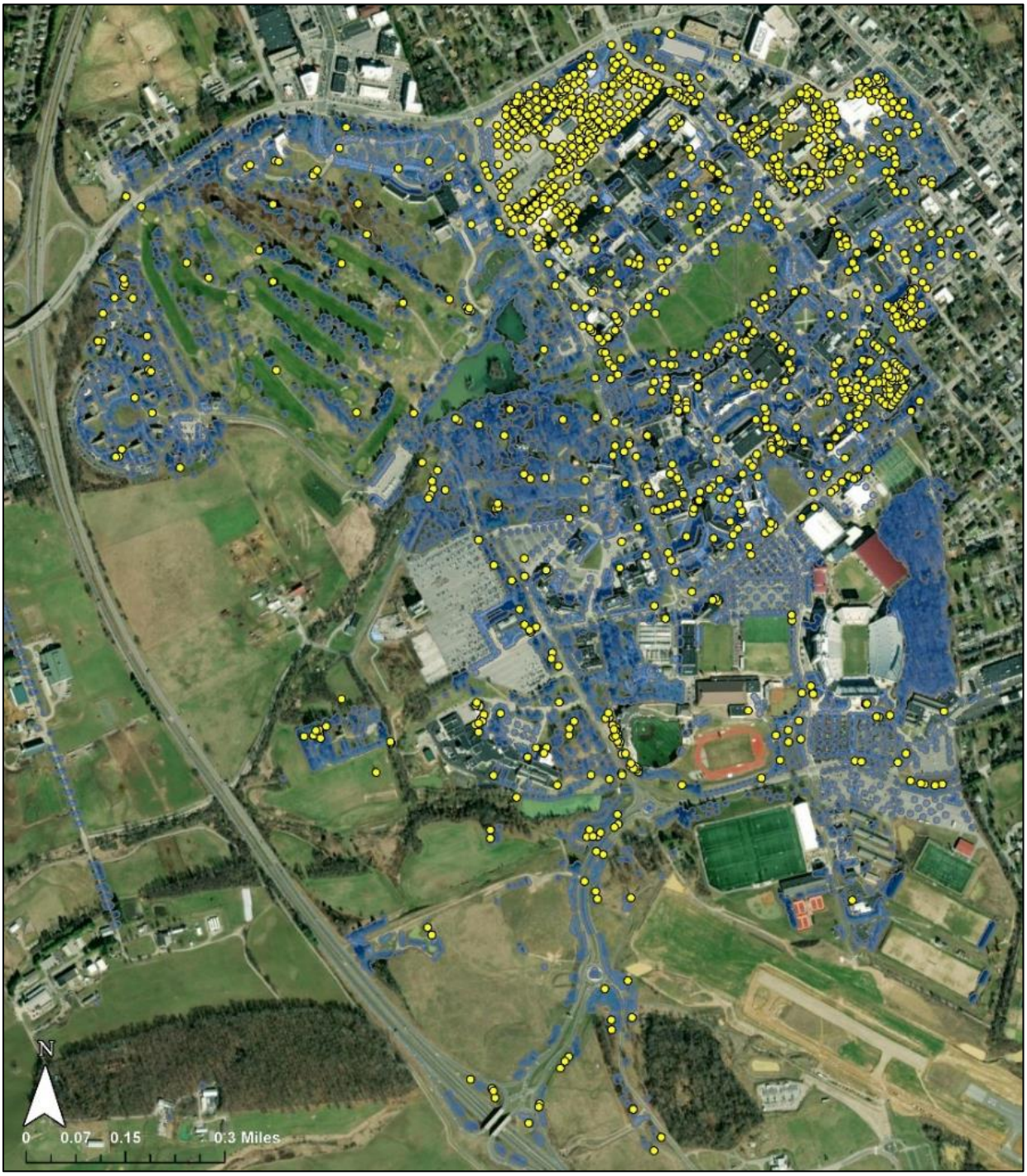
MAP 2: 25-FOOT BUFFER AROUND INVENTORY POINTS WITH THE STATUS ALIVE (PURPLE)

Any potential replacement sites that fell within this buffer were then removed from consideration (Map 3). This resulted in a total of 1,271 points that may be suitable sites for replacement trees that are at least 25 feet away from trees with the “Status” alive.



MAP 3: CLOSE-UP OF POTENTIAL TREE REPLACEMENT SITES (YELLOW) OVERLAYED WITH LIVING TREE BUFFER (PURPLE).

Map 4, below, shows a high-level overview of the 1,271 potential replacement tree sites. These should be inspected in person to determine final feasibility. Where they pose low risk to people and property, snags, dead trees, and stumps may be beneficial to preserve for their value to urban wildlife. In general, larger snags, stumps, or dead trees with greater textural and structural diversity are more beneficial.



MAP 4: POTENTIAL TREE REPLACEMENT SITES (YELLOW) THAT LIE FURTHER THAN 25 FEET FROM LIVING TREES (PURPLE).

Most of the potential replacement sites that are suitable distances away from existing trees are concentrated in the northeast of the campus. This area is comprised of the North Academic District, the Northeast and Upper Quad District, and the Creativity and Innovation District. As discussed in earlier, the i-Tree Canopy analysis found that these areas are good candidates for priority planting due to the currently low canopy cover and high traffic for students, faculty, and community members. In particular, the North Academic District had only 10% current canopy cover but 10 acres of plantable space. Both infill planting and replacement planting should be prioritized in this area. A shapefile spreadsheet describing individual locations and GPS points is attached as an appendix.

Construction Based

Background

The Urban Forestry Team and Campus Landscape Architect follow the Campus Master Plan and the Urban Forest Master Plan when planning, coordinating, and implementing tree planting projects on campus. Most trees planted are part of large capital construction projects. Some smaller planting projects are completed each year as part of tree replacement, Arbor Day, commemorative tree, riparian buffer programs. Given the historical importance of capital improvement plantings, we recommend that these be targeted in the future as continued opportunities to plant new trees.

High-level estimates of future development locations were provided for review. Figure 6, below, shows the campus as envisioned for the year 2047, with many proposed buildings pictured in addition to existing structures.

FIGURE 6: VIRGINIA TECH CAMPUS ENVISIONED FOR THE YEAR 2047. PROPOSED BUILDINGS IN RED, EXISTING BUILDINGS IN WHITE (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Proposed development appears to consist of a mix of renovation of existing structures, infill development, and some demolition of structures without replacement. More structures are proposed for the east side of the campus and the Student Life Village in the west. Most of the remainder of the west is reserved for open green space and agricultural use.

Discussion

Additional renovation appears to be planned for the east side of the campus. New buildings are generally near or attached to existing structures. This includes the North Academic District, the Northeast and Upper Quad District, the Creativity and Innovation District, and the Student Life District. While space may be limited for planting, the benefits provided by trees will be the greatest in this area due to the high use nature of the buildings and proposed greenspaces. Benefits of trees are hyper localized, and this is the most densely developed and ostensibly the most frequently trafficked area of the campus.

The central and west areas of the campus will be developed differently. This area includes the Life Sciences and Technology District, the Meadow, the 21st Century Living-Learning District, the Ag Belt (including the golf course) and Oak Lane. Much of this area is not currently developed. Large areas of greenspace are present in both the 21st Century Living-Learning District, the Intelligent Infrastructure Corridor, and several other periphery districts. While benefits of new trees planted in these areas may be less impactful than those in the densely

developed areas of the campus, the open spaces present good opportunities for canopy cover creation should the proposed projects be realized.

Given the uncertain nature of the proposed development projects in future years, several approaches may be considered. Good candidates for immediate planting may be in those areas where there are no plans for development. Tree species selected in these areas should be long-lived, large, and can be slow growing. Since these areas, ostensibly, may not be disturbed through the year 2047, successful plantings in these areas will be assets to the goal of 25% canopy cover by 2050. This approach is more applicable to the heavily developed eastern portion of the campus.

At the same time, the uncertain nature and long potential timeframe of the 2047 development plan allows opportunities for planting in areas where development may occur. Some projects may not come to fruition. The projects that do come to fruition may be designed to incorporate existing trees into the design. However, these areas would benefit from different species selection than those not identified for development. Here, select species that are fast growing and species with a shorter lifespan, such as birch, poplar, etc. While benefits may be temporary, short-term benefits of fast-growing trees may be enjoyed in the interim.

While planting is an important part of reaching a canopy goal, preservation of existing trees is equally as important. Large, established trees offer far more benefits than newly planted saplings. While preserving trees in the construction process is difficult, incorporation of them into the design should be prioritized wherever possible.

To this end, continuing the relationship with capital construction projects is vital. They have historically been the largest drivers of canopy creation across the campus via new plantings. At the same time, capital improvements may also be the largest threat to existing tree cover. The Urban Forestry Team should strive to be involved early in the design process to ensure the maximum trees are incorporated into projects and that the design of infrastructure around the trees fosters a suitable and sustainable environment for the trees to reach maturity.

The 2018 Campus Master Plan final draft was reviewed to understand the broad scope of construction within each district across the campus. Given the distinct nature of each campus district and the proposed work within it, each is discussed separately below.

Academic District:

Several new facilities and major renovations to existing buildings are proposed in the Academic District (Figure 7). This district is already densely developed. The site of future buildings 1, 3, 4, and 5 currently consists of parking lots, particularly Prices Fork lots 5 and 6 and Perry Street lot 1. Future buildings 8 and 9 appear to lie within the Derring parking lot. Future building 10 lies within parking lot P2. These development areas are excellent candidates to incorporate large tree plantings into the design phase of the project. Since the site is currently mostly paved with few trees in parking lot islands, proposed development may be able to increase overall tree numbers. Tree species selected in these areas should be long-lived, large, shade trees and may be slow growing.

Future building 6 lies on a lawn to the east of Goodwin Hall. While not an ideal long-term planting area, this may be a candidate for planting fast-growing, shorter-lived species for short-term canopy gains given the far-focused project planning timeline of 2047. This site should be planted early to allow for the longest functional life span for new trees.

The remaining proposed buildings either occupy the same footprint as existing structures, lie within areas with considerable existing tree cover, or are small additions to existing buildings that offer limited opportunity for canopy cover increase (buildings 2, 7, 11, 12). Mitigation planting for lost canopy during the construction process should be considered.

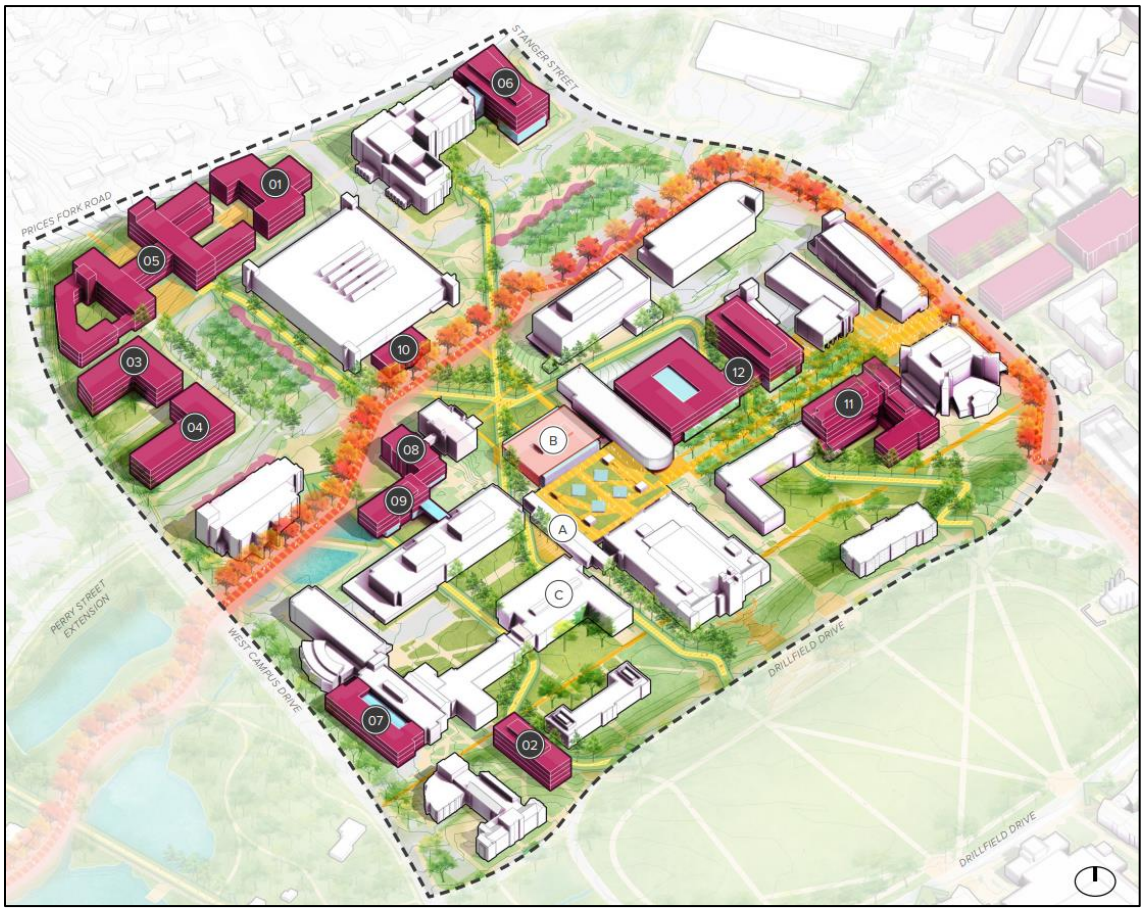


FIGURE 7: PROPOSED DEVELOPMENT PLANNED IN THE NORTH ACADEMIC DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Northeast & Upper Quad District:

The Northeast & Upper Quad District consists of historic buildings in the Upper Quad and various functional use areas like the power plant and electrical substation (Figure 8). The Master Plan proposes new buildings 1, 2, and 3 in areas that replace current structures and will likely remove established trees around the existing Femoyer Hall when it is replaced. Opportunities for tree planting may be limited given the propensity for hardscape cover in these areas.

Planting associated with these projects may be best focused on the lawn areas to the east of the three buildings. The considerable open space around Lane Hall in the Upper Quad may create a planting option, however this area's historic nature and association with the Corps of Cadets may preclude converting lawns to treed spaces.

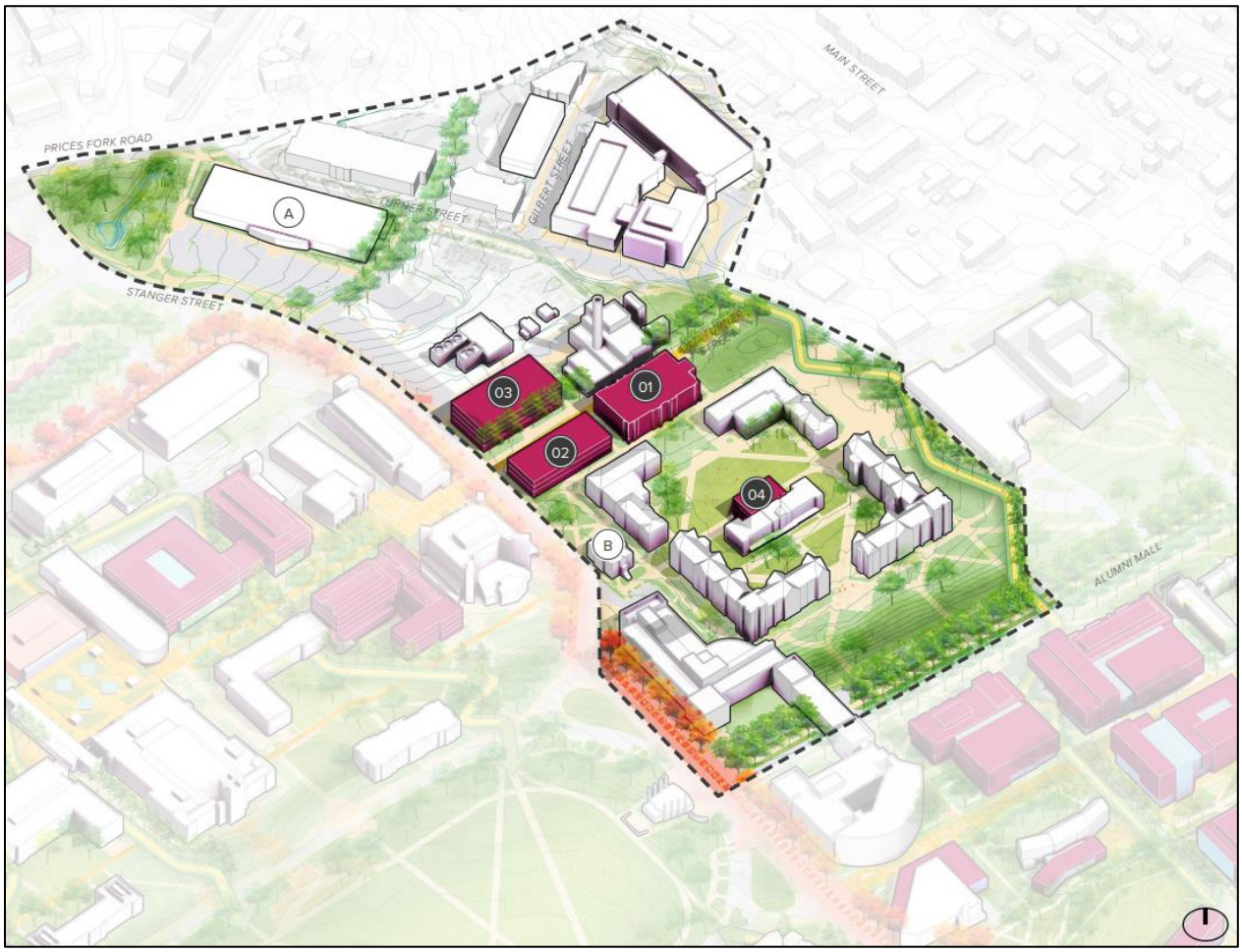


FIGURE 8: PROPOSED DEVELOPMENT PLANNED IN THE NORTHEAST & UPPER QUAD DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Creativity and Innovation District

The Creativity and Innovation District (CID) is envisioned as a signature new activity hub on the eastern edge of the campus. This area abuts downtown Blacksburg. As such, tree cover in this area has immense potential for benefits not only to students, faculty, and staff, but to the greater community of Blacksburg as well. However, planned development within this district is extensive (Figure 9). Considerable tree canopy may be lost under the proposed building footprints, particularly proposed buildings 2, 3, 5, 6, and 7.

Proposed buildings 1 and 4 offer some opportunities for tree planting. The Graduate Life Center appears to be planned to be replaced with a much smaller faculty club (building 4). While building 1 is fairly large, the area appears to already have been cleared according to 2023 aerial imagery on Google Earth. Considerable green space could be planted around this building with an emphasis on large shade trees in the new CID Green.

Henderson Lawn and the lawns around the Moss Arts Center are located at the northeast end of this district. These areas are not proposed for construction of new buildings. These would be ideal places to infill to augment the existing tree cover in the short term. Focus on large spreading shade trees.

FIGURE 9: PROPOSED DEVELOPMENT PLANNED IN THE CREATIVITY AND INNOVATION DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Student Life District

The Student Life District is the residential area to the south of the Drillfield. Large residence halls are interspersed within a series of quads. Development in this district is limited to only two structures: New Owens Hall and New Slusher Hall (Figure 10). These new buildings lie roughly within the footprints of the existing structures. As such, opportunities to include trees within the design may be slightly limited. A green roof is identified for the new Slusher Hall and may offer an opportunity for limited canopy cover.

Since construction is limited, planting in this district should focus on improvement of existing quads and other greenspaces. Species that are large and long-lived should be prioritized. Dietrich Lawn, Eggleston Quad, President's Quad, and the Prairie (Fitness) Quad seem to be the best candidates in terms of available space for new trees. Since they will largely be undisturbed, they should be prioritized for early planting.

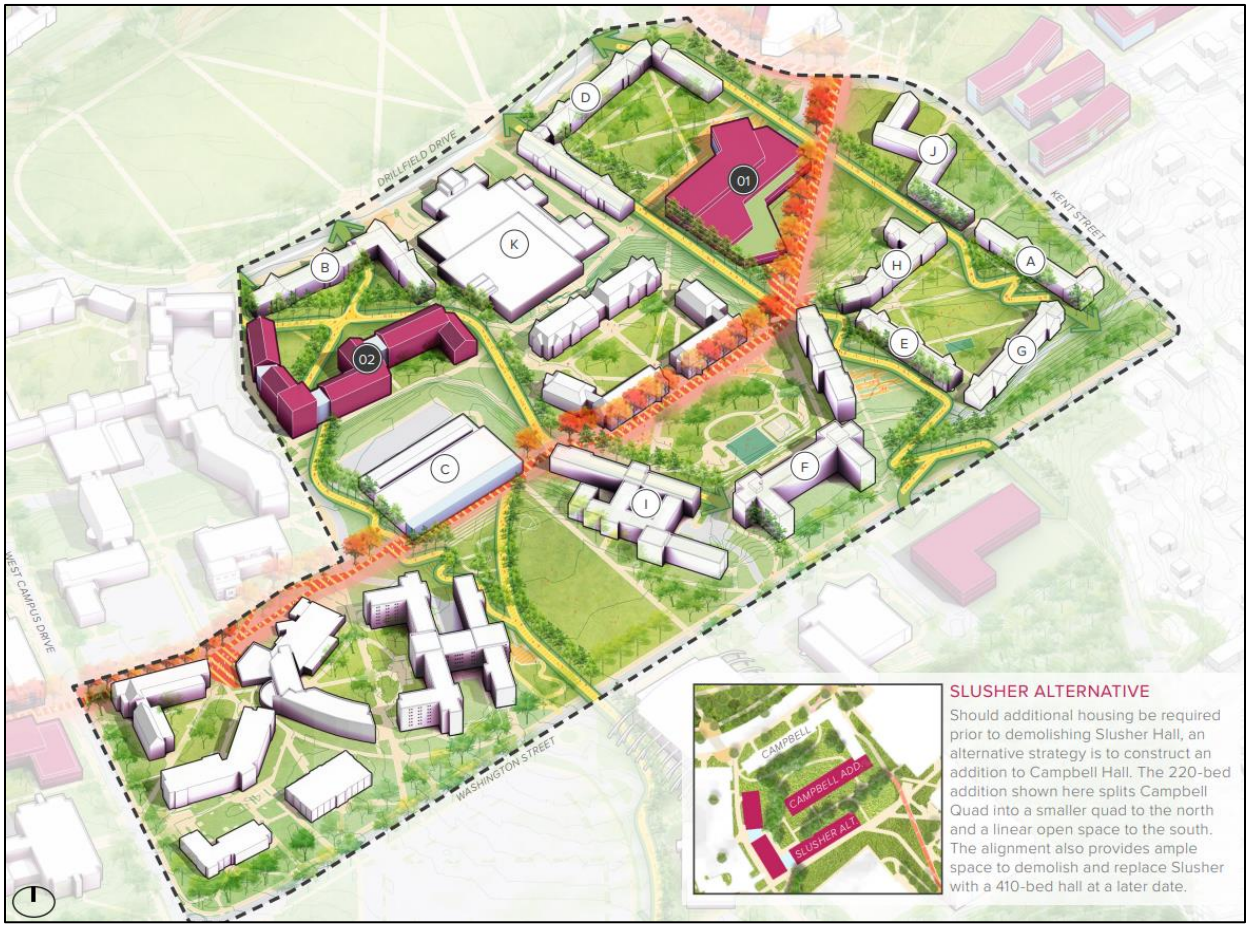


FIGURE 10: PROPOSED DEVELOPMENT PLANNED IN THE STUDENT LIFE DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Life Sciences and Technology District

The Life Sciences and Technology District houses much of the University's research facilities. The Master Plan states that it lacks the sense of place necessary to highlight its importance to the University. The district encompasses a large area of forested greenspace to the south of the duck pond, but tree cover appears sparse throughout the areas between buildings.

The Duckpond Road parking lot offers a large opportunity for future tree planting to be incorporated into the design of several buildings and associated landscaping (Figure 11). New buildings 7, 8, 9, 13, 14, and 15 appear to lie within the lot's footprint on the north side of Washington Street. Building 6 and part of building 5 appear to be within the section of the lot that is to the south of Washington Street. The benefits of planned planting in these areas will only be realized once the projects are near completion.

Buildings 3, 11, and 12 appear to be within the Litton Reaves Extension Lot and Lot 8. Building 10 lies within the Hillcrest Extension Lot. Building 2 lies within lot P17. Building 17 lies mostly within the Steger Hall parking lot. These buildings offer similar opportunities to those proposed for the current Duckpond Road lot for long-term planting once construction is realized.

Buildings 4, 11, and part of building 5 are depicted currently on sparsely treed green lawns. The sites of these buildings may present opportunity for short-term gains in canopy cover with fast-growing trees. The benefits of trees here may be enjoyed earlier than those previously described.

Building 18 offers little opportunity for new planting. The proposed alignment extends the Veterinary Medicine building into a tree lawn. Building 16 is a small chiller plant expansion and offers similarly little opportunity for tree cover gains.

Areas outside of development may be infill planted, prioritizing long-lived and large tree species. However, many of the areas proposed for development projects throughout the District are already heavily treed. The most promising areas for infill plantings appear to be the lawns near the Veterinary Medicine building and the Institute for Critical Technology and Applied Science, and open areas to the west of W Campus Drive and north of Grove Lane.

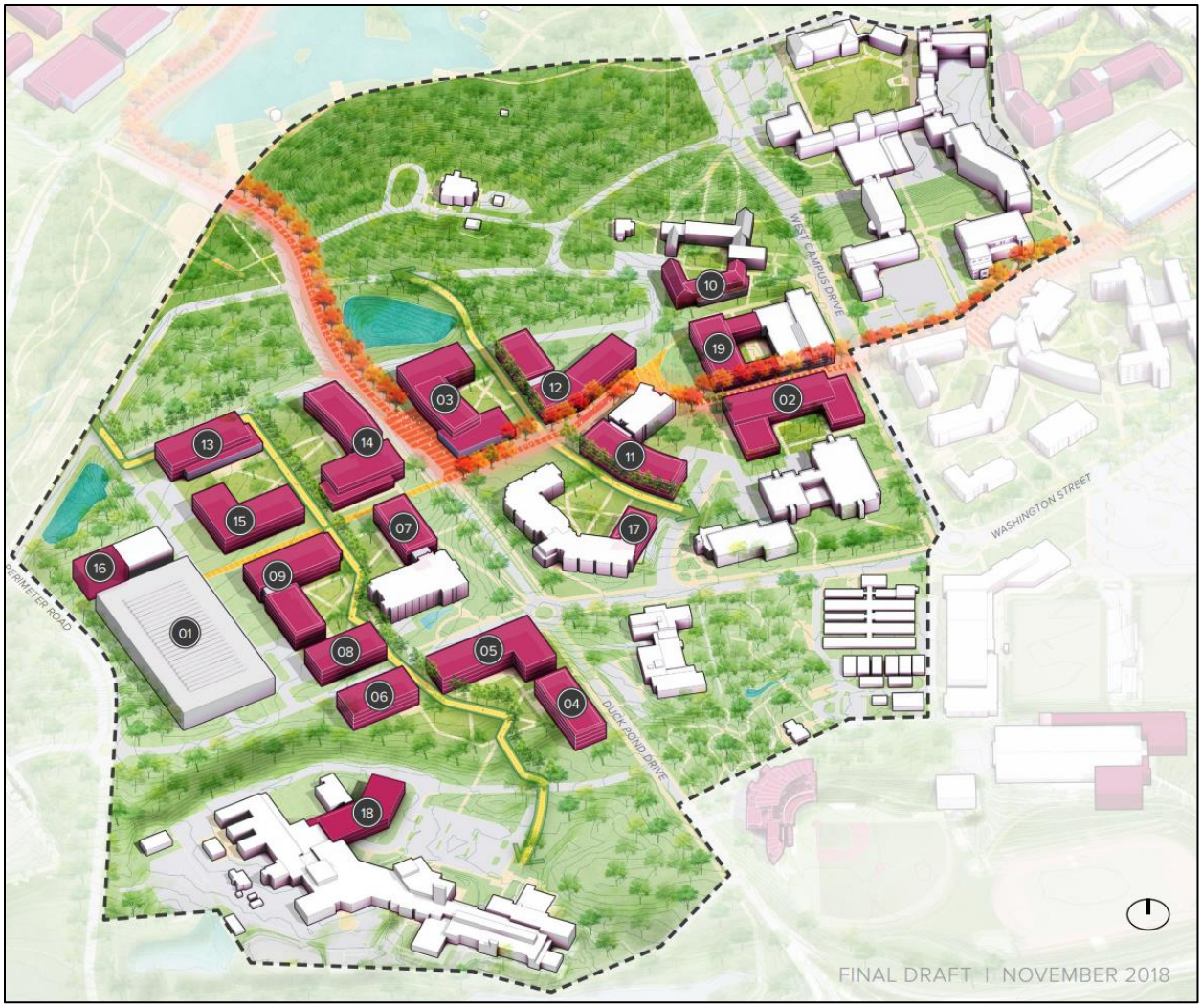


FIGURE 11: PROPOSED DEVELOPMENT PLANNED IN THE LIFE SCIENCES AND TECHNOLOGY DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

21st Century Living-Learning District

The 21st Century Living-Learning District is envisioned as a new residential neighborhood. The proposed site is currently the University's golf course (Figure 12). As such widespread plantings are not as feasible as in other districts in the short term. Some sporadic infill planting may be possible within the current tree rows within the golf course, however the benefits of additional trees in this area will be far less than plantings in more densely populated areas of campus.

Canopy cover planning should also focus on retaining existing trees and groups of trees where possible by incorporating them into the design. Once the project is completed, new trees could be installed.

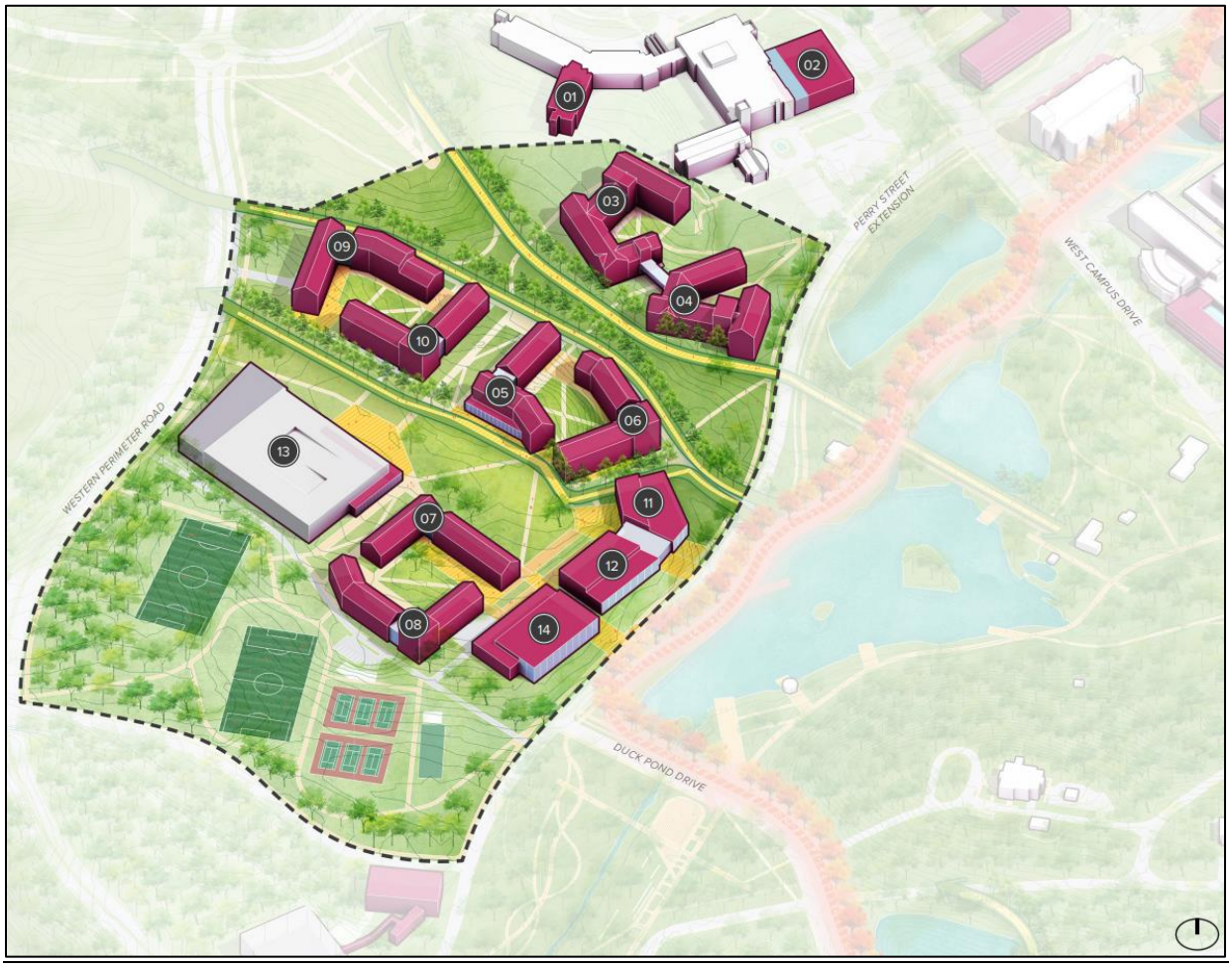


FIGURE 12: PROPOSED DEVELOPMENT PLANNED IN THE 21ST CENTURY LEARNING-LIVING DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Intelligent Infrastructure Corridor

The Intelligent Infrastructure Corridor is proposed to connect existing assets and the proposed few facilities (Figure 13). The corridor runs across a wide range of areas, from the southwest of the campus below the Ag Belt to the northeast side of the campus in the North Academic District. The southwest appears to be the location of additional testing and research facilities, village housing, and new lab facilities. There appears to be limited space for tree planting due to the existing structures and trees surrounded by agricultural fields.

The alignment of the travel path connecting this area to the northeast campus region follows Smithfield Road and Stroubles Creek. Along this length, there are many opportunities for planting to increase canopy cover before planned improvements are underway. Given the relatively light level of development along the thin strip, planting should be prioritized for short-term canopy increases. Native riparian species may be good choices to foster a more naturalized environment.

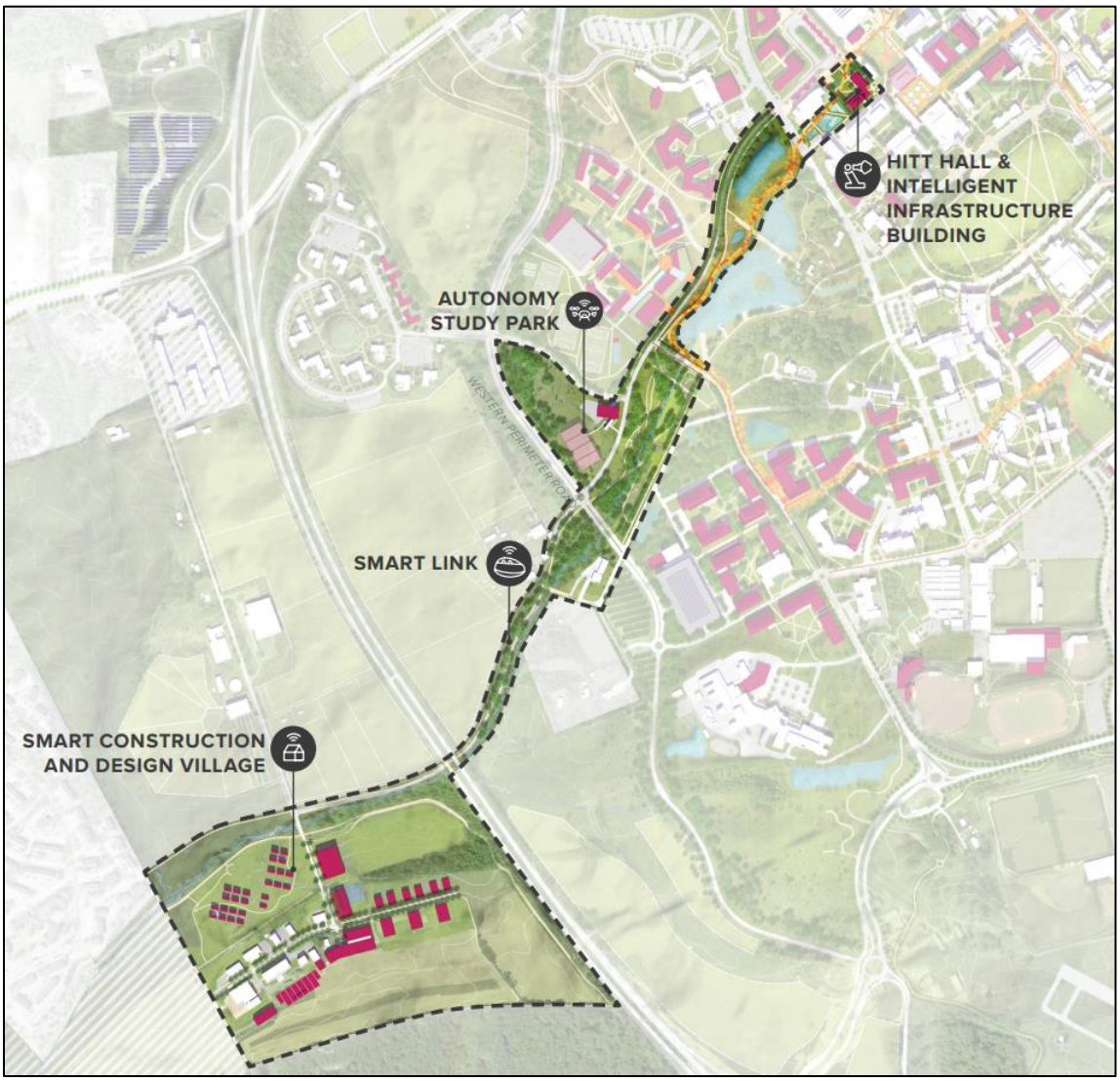


FIGURE 13: PROPOSED DEVELOPMENT PLANNED IN THE INTELLIGENT INFRASTRUCTURE CORRIDOR (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Peripheral Districts:

The Master Plan groups three remaining areas into the category “Peripheral Districts”:

Athletics and Recreation

The Athletics and Recreation District extends from Washington Street to the south to include Lane Stadium and other sports venues in the south campus area (Figure 14). It also includes recreation fields and facilities to the south of Southgate Drive. Most of the development appears to be internal renovations to existing structures. Tree planting opportunities in the north of the district seem to be limited to the lawns to the northeast of the tennis courts, around the basketball practice facility, and west of lot 1 near Washington Road. Some street trees may be able to be planted along the road. The south end of the district appears to have wide stretches of plantable space between and around fields, trails, and the perimeter.

FIGURE 14: PROPOSED DEVELOPMENT PLANNED IN ATHLETICS AND RECREATION DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Glade Road

Glade Road is a prominent, mostly agricultural greenspace on the north side of campus beyond Prices Fork Road. It includes several agricultural and animal-handling facilities today. Plans are currently conceptual and include various options such as facilities for various colleges, conversion to retail space, homes, and/or other revenue generation sources (Figure 15). Unlike other areas, this District is planned to be developed in future agreements between the Virginia Tech Foundation and private developers. New trees could be incorporated into the design of any developments but may be delayed until far into the future.

Given the early, conceptual nature of plans, this may be a candidate for planting and growing trees in the interim planning period. Short term gains of canopy could be realized. Limiting factors here would be the overhead electrical easement and current agricultural land use which should be incorporated into planting plans. Given the low use nature of the site, the benefits of new trees here will be less than those planted in denser areas.

FIGURE 15: PROPOSED DEVELOPMENT PLANNED IN THE GLADE ROAD DISTRICT (CREDIT: VIRGINIA TECH, OFFICE OF UNIVERSITY PLANNING)

Oak Lane District (Student Life Village)

The Oak Lane District contains residential areas for Greek and non-Greek organizations. It is comprised of 18 buildings, recreational facilities, and a pavilion. New development is proposed throughout the district and expands into the golf course area. The new district will be known as the Student Life Village (Figure 16).

Housing will first be expanded to the northeast as part of the newly approved Student Life Village (Figure 16, green). Phase 1 includes the construction of four residential complexes, dining, recreation, transit plaza, and a village trail. The area is currently part of the golf course and appears to have many mature trees. Opportunities for preservation of trees in this area may be scarce, given the intensity of the proposed work. Planting efforts here should focus on collaboration with the design team to maximize the number of trees installed associated with the new structures.

Later phases expand to the south further into the golf course and current footprint of Oak Lane. The final version of the village could include up to 5,000 new beds throughout several building complexes. Development will be intense, and tree preservation in this area will likely be challenging. Short-term gains in canopy cover may be realized in this area, but additional areas across campus should be identified for replacements before construction begins. Here, select species that are fast growing and with a shorter lifespan, such as birch, poplar, etc. While benefits may be temporary, short-term benefits of fast-growing trees may still be enjoyed in the interim and assist in reaching overarching campus canopy cover goals. Prioritize areas near long-term buildings (Figure 16, blue) over mid-term buildings (Figure 16, purple) to allow more time for tree development. When development occurs, collaborate with the design team to maximize the amount of new tree installations.

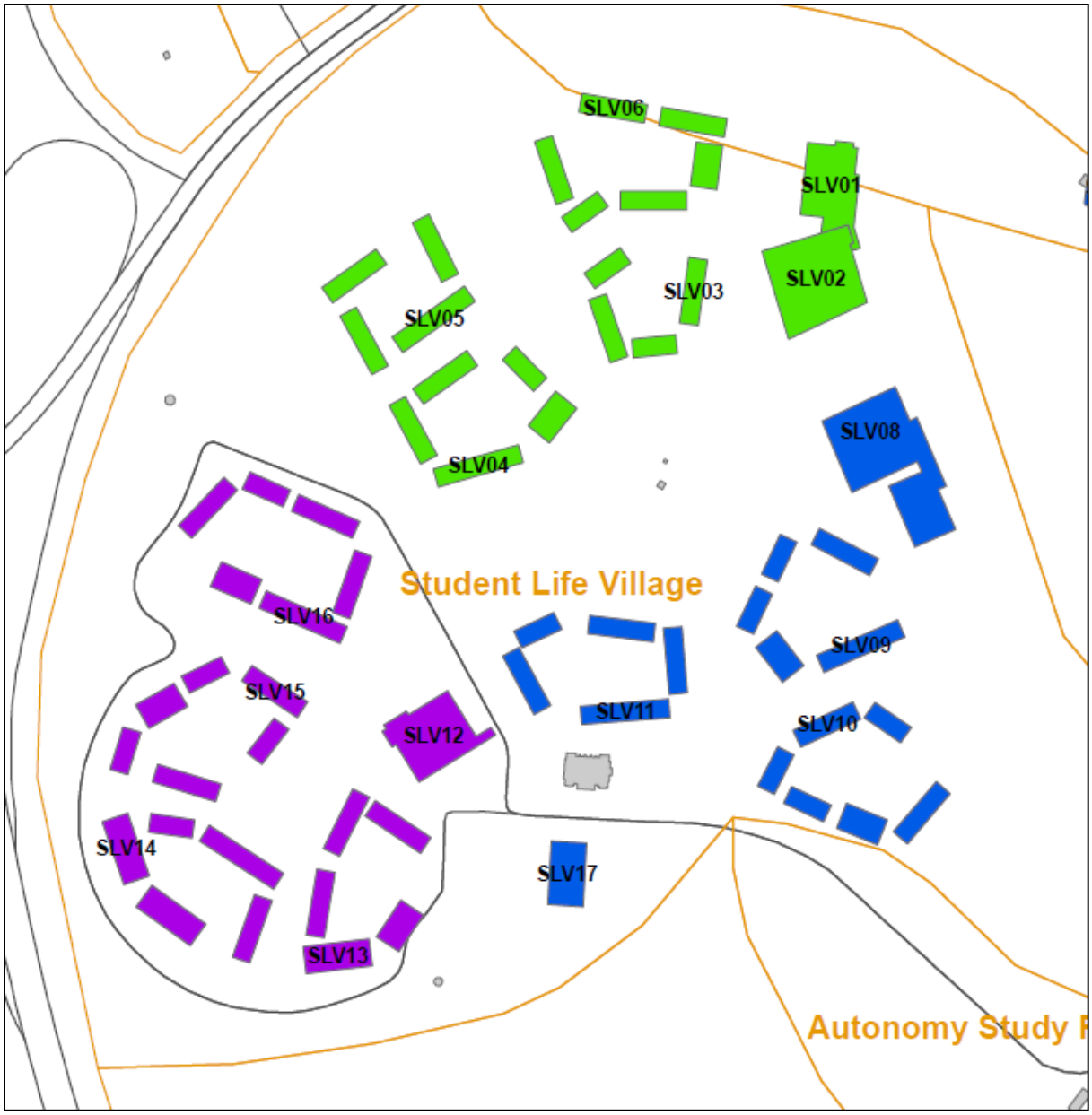


FIGURE 16: PROPOSED DEVELOPMENT PLANNED IN THE STUDENT LIFE VILLAGE. APPROVED STRUCTURES ARE IN GREEN. FUTURE

The area to the northwest of the proposed development appears to remain untouched as an ecological buffer along Highway 460 and Prices Fork Road. This area should be prioritized for tree preservation and infill planting where space allows.

Implementation

The Virginia Tech Campus currently has 17% canopy coverage, with a goal of 25% by 2050. To achieve that goal campus staff will need to focus on planting mid to large-maturing trees in the initial planting efforts, allowing time for development. Mid-project plantings may begin to introduce moderate-sized trees. Smaller-maturing and/or shorter-lived species should be reserved for the final planting seasons. New plantings will also need to factor in the replacement of trees that die or are removed within the same time period.

The current 17% canopy coverage is made up of 10,731 living trees found in the GIS database. On average, each tree accounts for approximately 0.16%. Jamie King estimated that approximately 120 trees are removed per year across the campus. Three canopy coverage goals are described below with rough estimations of yearly planting numbers: Ideal (planting period of 6 years), Moderate (planting period of 8 years), or Minimal (planting period of 10 years).

Given the project timeline of 10 years, an ideal intensity would allow for several years to monitor new plantings and assess needs to replace those that have died or will not mature into assets to the campus. Establishment typically takes 3 – 5 years, and the ideal planting period of 6 years allows for a 4-year buffer to evaluate all new plantings. The moderate planting period of 8 years allows for a 2-year buffer to evaluate all new plantings. The minimal planting period of 10 years does not allow for a buffer period.

We have also included an estimation for maintaining the current level of 17% canopy cover. Annual planting targets range from 120 per year to replace removed trees to 962 trees per year under the ideal tier. Estimations are based on a maximum 10-year planting period. Under the ideal and moderate plans, some years at the end of the 10-year period will only have replacement trees to account for attrition.

TABLE 20: CANOPY COVERAGE GOALS AND PLANTING ESTIMATIONS CATEGORIZED BY PLANTING INTENSITY

Virginia Tech Campus, Virginia	
Current Canopy	
Current canopy cover (%)	17
Current trees	10731
Ideal Intensity	
Goal canopy cover (%)	25
Estimated total trees to reach 25%	15781
Expected new trees	5050
Ideal planting intensity (years)	6
Expected new plantings per year	842
Replacement plantings per year	120
Total plantings per year (years 1 - 6)	962
Replacement trees per year (years 7 - 10)	120
Moderate Intensity	
Goal canopy cover (%)	25
Estimated total trees to reach 25%	15781
Expected new trees	5050
Moderate planting intensity (years)	8

Expected new plantings per year	631
Replacement plantings per year	120
Total plantings per year (years 1 - 8)	751
Replacement trees per year (years 9 - 10)	120
Minimal Intensity	
Goal canopy cover (%)	25
Estimated total trees to reach 25%	15781
Expected new trees	5050
Minimal planting intensity (years)	10
Expected new plantings per year	505
Replacement plantings per year	120
Total plantings per year (years 1 - 10)	625
Maintenance Intensity	
Maintenance canopy cover (%)	17
Expected total trees	10731
Replacement trees per year (years 1 - 10)	120

How much will this cost

Virginia Tech budgets $600 per tree for planting. The overall goal is to plant and maintain 5,050 trees over 10 years. Different schedules for planting and associated costs have been broken into three different scenarios: ideal, moderate, and minimal planting schedules. The three intensities were created to help estimate how the campus could achieve that goal. The most effective way to reach the canopy goals is to front load the planting giving trees the most time possible to reach maturity, as described in the previous section.

Accounting for maintenance is important as it is a crucial part of a successful planting program. Canopy goals are unlikely to be reached without the successful establishment of newly planted trees. Establishment is largely dependent on maintenance within the first 3 – 5 years after planting, including watering and structural pruning. To understand the full cost of adding trees to the urban forest, maintenance costs need to be included.

A tree becomes a part of the annual maintenance budget the first year after it is planted. Annual costs are approximately $46.25 per tree. The maintenance cost recurs each year after the tree is planted, cumulatively doubling after year three, tripling after year four, and so on until the end of the planting period. Trees planted earlier in the project timeline will have more associated maintenance costs as a simple factor of having been in the landscape longer than those planted later.

If planting is frontloaded, overall maintenance costs will be higher due to this consideration. More replacement trees for attrition will also be planted and additional maintenance expenses will be accrued in the last few years before the end of the 10-year project timeline.

In the ideal intensity scenario, 962 trees would be planted annually for the first six years adding 120 trees in years seven, eight, nine, and 10. Combined, this would total 5,530 trees planted. The cost of planting and maintenance for the ideal intensity timeline would be $4,942,507.50.

In the moderate intensity scenario, 751 trees would be planted annually for the first eight years, with 120 trees planted in years nine and 10. Over 10 years with moderate planting intensity, 5,290 trees would be planted for a total cost of $4,832,035.00.

In the minimal intensity scenario, 625 trees would be planted each year for a 10-year period. Since planting extends over the whole project timeline, no additional trees would be planted for attrition as in the ideal or moderate intensities. Over the 10-year period, 5,050 trees would be planted for a total cost of $4,675,781.25.

Annual budget estimates are individually detailed over the project timeline for each scenario in Table 21, following page.

TABLE 21: ANNUAL COST ESTIMATES FOR IDEAL, MODERATE, AND MINIMUM PLANTING INTENSITIES

Virginia Tech Campus, VA										
Ideal Intensity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Maint. cost		$44,493	$88,985	$133,478	$177,970	$222,463	$266,955	$272,505	$278,055	$283,605
Planting cost	$577,200	$577,200	$577,200	$577,200	$577,200	$577,200	$72,000	$72,000	$72,000	$72,000
Annual budget	$577,200	$621,693	$666,185	$710,678	$755,170	$799,663	$338,955	$344,505	$350,055	$355,605
									Total cost to plant 5050 trees + 480 planted for attrition	**$5,519,708**
Moderate Intensity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Maint. cost		$34,734	$69,468	$104,201	$138,935	$173,669	$208,403	$243,136	$277,870	$283,420
Planting cost	$450,600	$450,600	$450,600	$450,600	$450,600	$450,600	$450,600	$450,600	$72,000	$72,000
Annual budget	$450,600	$485,334	$520,068	$554,801	$589,535	$624,269	$659,003	$693,736	$349,870	$355,420
									Total cost to plant 5050 trees + 240 planted for attrition	**$5,282,635**
Minimum Intensity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Maint. cost		$28,906	$57,813	$86,719	$115,625	$144,531	$173,438	$202,344	$231,250	$260,156
Planting cost	$375,000	$375,000	$375,000	$375,000	$375,000	$375,000	$375,000	$375,000	$375,000	$375,000
Annual budget	$375,000	$403,906	$432,813	$461,719	$490,625	$519,531	$548,438	$577,344	$606,250	$635,156
									Total cost to plant 5050 trees	**$5,050,781**

Conclusions

Virginia Tech, a leader in urban forestry education, established the goal of increasing tree canopy cover to 25% by the year 2050. To assist the Urban Forestry Team in building a roadmap to achieve this goal, Bartlett Consulting has provided 10-Year Tree Maintenance and Planting Plans. Our objective was to provide recommendations for proactively managing the existing urban forest and to identify planting opportunities to further increase canopy cover. These plans are based on extensive review of additional resources and documents provided by Virginia Tech including the existing campus tree inventory and urban tree canopy assessment and align with the existing Urban Forest Master Plan and Campus Master Plan.

The 10-year Maintenance Plan prioritizes tree maintenance and inspection zones based on the campus districts outlined in the Campus Master Plan. Tree health and structure ratings from the existing campus tree inventory and stakeholder survey results were incorporated into a vulnerability analysis to guide prioritization. This district-level prioritization ensures a balanced distribution of costs over the 10-year plan by incorporating both spatial and social variables. The 10-year maintenance plan is projected to cost $7,258,812, encompassing various forms of maintenance including tree removal, pruning, structural support, lightning protection, soil care, plant health care, and monitoring. Cost projections, developed in collaboration with the Urban Forestry Team and other local arborists, show higher initial expenses to address both proactive and reactive needs. However, these costs decrease over time as proactive measures, particularly for smaller-diameter trees, reduce the long-term need for reactionary work. Overall, the plan provides a comprehensive strategy for maintaining a healthy and structurally sound urban forest on the Virginia Tech campus.

The 10-year Planting Plan identifies high priority areas for planting and projects costs required to achieve the campus canopy goal. Existing tree inventory data was evaluated based on diversity and relative performance to identify species for future plantings. Further analysis of the existing tree inventory, tree canopy assessment, and future development plans identified possible planting sites and highlighted the importance of preserving existing tree canopy during construction projects. The plan provides three scenarios—ideal, moderate, and minimal— that consider different planting schedules and maintenance projections strategic planting over six, eight, or 10 years. In the ideal scenario, 962 trees are planted yearly for six years, totaling 5,530 trees at a cost of $4,942,507. This ideal approach frontloads planting efforts and prioritizes maintenance for successful canopy expansion while considering the varying opportunities across different campus districts.

It is important to note that both plans are intended to be dynamic documents and should be updated periodically as the urban forest and surrounding campus landscape evolves. With continued proactive planning and further investment in both tree maintenance and planting over the next 10 years, Virginia Tech will be well on their way to achieving their goal of 25% canopy cover by 2050.

Appendices

Tree Maintenance Districts Survey Summary and Results

Tree Health and Structure Survey Summary and Results

Existing Tree Inventory Data Modification Log

i-Tree Ecosystem Analysis Report

Recommended Species List

Recommended Species Profiles

Tree Maintenance Districts Survey Summary and Results

This survey was distributed to a total of 60 campus stakeholders including faculty, staff, students, community members, and local arborists on November 28, 2023. A total of 29 responses were submitted for a response rate of 48%. The introduction and results of the survey are be presented below:

"In 2018, the Virginia Tech Campus Master Plan was updated and included the delineation of several Master Planning Districts. For the Urban Forest Maintenance Plan, we've decided to utilize the same delineations for our tree maintenance zones. Please provide a vulnerability rating for each district for tree interaction and future development to help us prioritize inspections and maintenance. Also, please provide an importance rating based on how significant the trees in each district are in your opinion.

For Tree Interaction Vulnerability, consider how often people, vehicles, or infrastructure are underneath or near the trees within each district. If a district has relatively little infrastructure and is not commonly visited, then a Tree Interaction Vulnerability Rating of Very Low would be appropriate. If a district has lots of infrastructure and is heavily trafficked on an average school day, then it should receive a Tree Interaction Vulnerability Rating of Very High.

For Tree Development Vulnerability, consider the evolution and growth of campus over the next 10 years and areas where construction impacting existing trees is mostly likely to occur. If a district has been identified for preservation and no construction has been planned, then a Tree Development Vulnerability Rating of Very Low would be appropriate. If a district includes several current or planned construction projects, then it should receive a Tree Development Vulnerability Rating of Very High.

For the Tree Importance Rating, consider how significant the trees within each district are to you personally and the campus at large. If a district contains few trees of little value or unique characteristics, then it should receive a Tree Importance Rating of Very Low. If a district contains your favorite tree, multiple historic or champion trees, or is critical for teaching purposes, then it should receive a Tree Importance Rating of Very High."

Districts	Tree Interaction Vulnerability	Tree Development Vulnerability	Tree Importance Rating
21st Century Living Learning	2.72	4.03	3.14
Agricultural Lands	2.31	2.90	3.14
Alumni Mall	4.17	2.72	4.07
Athletics & Recreation	4.28	3.52	3.55
Autonomous Study Park	1.90	2.45	2.34
Buffer	2.66	3.59	3.14
Corporate Research Center	3.17	3.59	3.41
Corporate Research Center Phase II	2.62	3.59	3.17
Creativity & Innovation	4.24	3.55	3.90
Drillfield	4.24	2.48	4.52
Duck Pond	3.83	2.79	4.55
Gateway	3.10	3.21	3.52

Districts	Tree Interaction Vulnerability	Tree Development Vulnerability	Tree Importance Rating
Glade Road	2.59	3.24	2.86
Health Sciences	3.62	3.38	3.97
Life Science	3.10	3.24	3.76
Meadow	2.28	3.55	3.24
North Academic	4.34	3.66	3.86
North End	3.03	2.59	2.76
Northeast Academic	4.03	3.34	3.66
Oak Lane District	3.66	3.52	3.55
Smart Village	2.41	3.07	2.90
Stadium Woods	3.10	2.72	4.69
Stroubles Creek	2.62	2.97	4.07
Student Life	4.28	3.31	4.24

Tree Health and Structure Survey Summary and Results

This survey was distributed to a total of 40 campus stakeholders including faculty, staff, students, community members, and local arborists on November 28, 2023. A total of 15 responses were submitted for a response rate of 38%. The introduction and results of the survey are be presented below:

"For each genus currently in the Virginia Tech campus tree inventory, please provide a vulnerability rating for both health and structure based on your local knowledge and experience.

For Tree Health Vulnerability, consider how often you observe trees on campus within each genus in decline due to pests, pathogens, or abiotic disorders. If most trees observed within a genus are growing well and have healthy foliage, then a Tree Health Vulnerability Rating of Very Low would be appropriate. If a genus is the target host to an invasive pest with a high mortality rate, then it should receive a Tree Health Vulnerability Rating of Very High.

For Tree Structure Vulnerability, consider how often you observe trees on campus dropping branches, breaking apart, or completely falling over. If most trees within a genus are largely intact and rarely fall apart, then a Tree Structure Vulnerability Rating of Very Low would be appropriate. If a genus is notoriously prone to breakage during ice storms, then it should receive a Tree Structure Vulnerability Rating of Very High."

Genus	Tree Health Vulnerability Rating	Tree Structure Vulnerability Rating
Acer	2.47	3.27
Aesculus	2.33	2.07
Amelanchier	2.60	2.07
Betula	2.60	2.47
Carpinus	1.93	1.87
Carya	1.80	1.93
Catalpa	1.80	2.20
Celtis	1.93	2.13
Cercis	3.00	2.53
Chamaecyparis	1.93	1.87
Chionanthus	2.40	2.20
Cladrastis	2.27	2.67
Cornus	3.00	2.20
Crataegus	2.87	1.93
Cryptomeria	2.13	1.87
Cupressus	2.40	2.07
Fagus	3.07	2.53
Fraxinus	4.47	3.47
Ginkgo	1.47	1.60
Gleditsia	2.53	2.00
Gymnocladus	1.80	1.93
Hamamelis	1.87	1.87
Ilex	2.47	1.93

Genus	Tree Health Vulnerability Rating	Tree Structure Vulnerability Rating
Juglans	2.33	2.27
Juniperus	2.53	1.93
Lagerstroemia	2.87	2.07
Larix	3.20	2.13
Liquidambar	1.73	2.00
Liriodendron	2.07	2.53
Magnolia	2.07	2.00
Malus	3.33	2.27
Metasequoia	1.93	1.93
Morus	2.27	2.53
Nyssa	1.87	1.73
Ostrya	1.67	1.53
Parrotia	1.67	1.60
Phellodendron	2.47	2.47
Picea	3.33	2.20
Pinus	2.80	2.87
Platanus	3.13	2.60
Prunus	3.00	2.47
Pyrus	3.00	3.73
Quercus	2.73	2.27
Robinia	2.53	2.47
Salix	2.80	3.47
Sassafras	2.33	2.00
Taxodium	1.73	1.87
Thuja	2.47	2.07
Tilia	2.40	2.53
Tsuga	4.13	2.20
Ulmus	3.67	3.20
x Hesperotropsis	3.47	2.67
Zelkova	2.00	2.80

Existing Tree Inventory Data Modification Summary

- Removed trees without a health class (70 trees)
- Removed trees with “Removed” status (2282 trees)
- Removed trees with “Stump” status (68 trees)
- Removed trees that fell outside of management zones (445 trees)
- Removed duplicate (1 tree)
- Gave trees that have the duplicate tree ID numbers but different locations, distinct tree ID numbers (5 trees)
- Changed empty statuses to “Alive” (2 trees)
- Changed unknown common names with unknown species to the i-Tree name (24 trees total)
    - Hardwood (19 trees)
    - Conifers (5 trees)
- Changed trees with “Dead” status to have Maintenance Recommendations for “Removal”, excluding dead trees that already have the recommendation (13 trees)
- Changed trees with “Snag” status to have Maintenance Recommendations for “Monitor” (8 trees)
- Any trees that are listed with “Dead” or “Snag” statuses and did not have a health class of “Dead” were changed to reflect that (55 trees)
- Changed scientific name to match i-Tree upload standards (448 trees)
- Changed blank structure rating to “Dead” (1 tree)
- Provided trees with missing Age Class values, values based on tree species and DBH (38 trees)

i-Tree Ecosystem Analysis Report

(see attached files)

Recommended Species List

(see attached files)

Recommended Species Profiles

(see attached files)