Report:
Thurston County, WA
Urban Forest Data Development

Completed January 2011





Prepared For:
Thurston County Planning Department

THURSTON COUNTY
WASHINGTON
SINCE 1852

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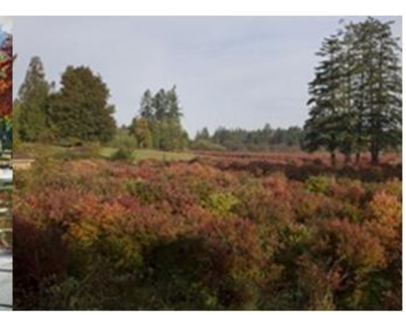
Photo Sources: Thurston County Website



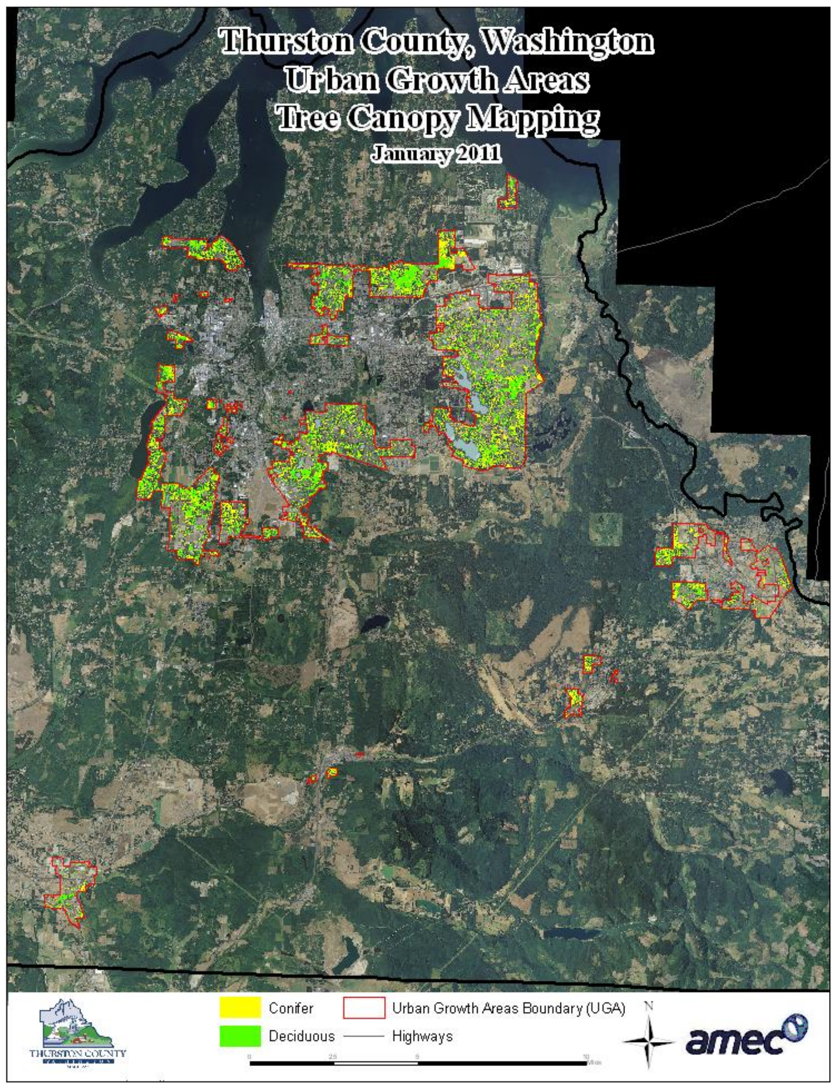


Introduction

Urban trees are a valuable natural and cultural resource providing multiple benefits, including increased property values, air and water pollutant removal, stormwater runoff mitigation, carbon storage and sequestration, species habitat, and energy savings. Geographic Information Systems (GIS) and remote sensing technologies offer powerful analysis and decision support tools for managing urban natural resources. In 2010, the Thurston County Planning Department submitted a grant application to the Washington Department of Natural Resources (WA DNR) for $10,000 for an urban forest data development mapping project. Once funded by WA DNR, the project was conducted by AMEC Earth & Environmental, Inc. after a Request for Proposal (RFP) process.

The objective of this project was to map urban tree canopy (UTC) within the unincorporated Urban Growth Areas (UGA) of Thurston County, Washington, an area of approximately 38.3 square miles. See Figure 1 at right. Along with other environmental inventories, the GIS-based tree canopy results provide a natural resources baseline for planning, development and urban forestry programs and an opportunity for further analysis towards goal setting, preservation and educating the public about the many benefits of trees. Project deliverables included 2-foot resolution 4-band multispectral imagery, ESRI GIS-based tree canopy polygon data, a sub-classification of coniferous tree canopy, an interactive GeoPDF map for non-GIS users and this summary report which describes the data and imagery requirements, tree canopy classification methods, results, data quality and accuracy, and recommendations for future use of the data related to urban forest management and preservation strategies. The project began in October 2010 and was completed in January 2011.

Figure 1. Thurston County boundary (black outline) and Urban Growth Boundary (red outline) and 2009 Imagery



Acknowledgments

Thurston County would like to acknowledge and thank the USDA Forest Service Urban & Community Forestry Program and the Washington Department of Natural Resources for their financial and technical assistance in the development and direction of this important project.

Data Requirements and Specifications

Figure 2a and 2b. Natural color and color-infrared 2-foot photography

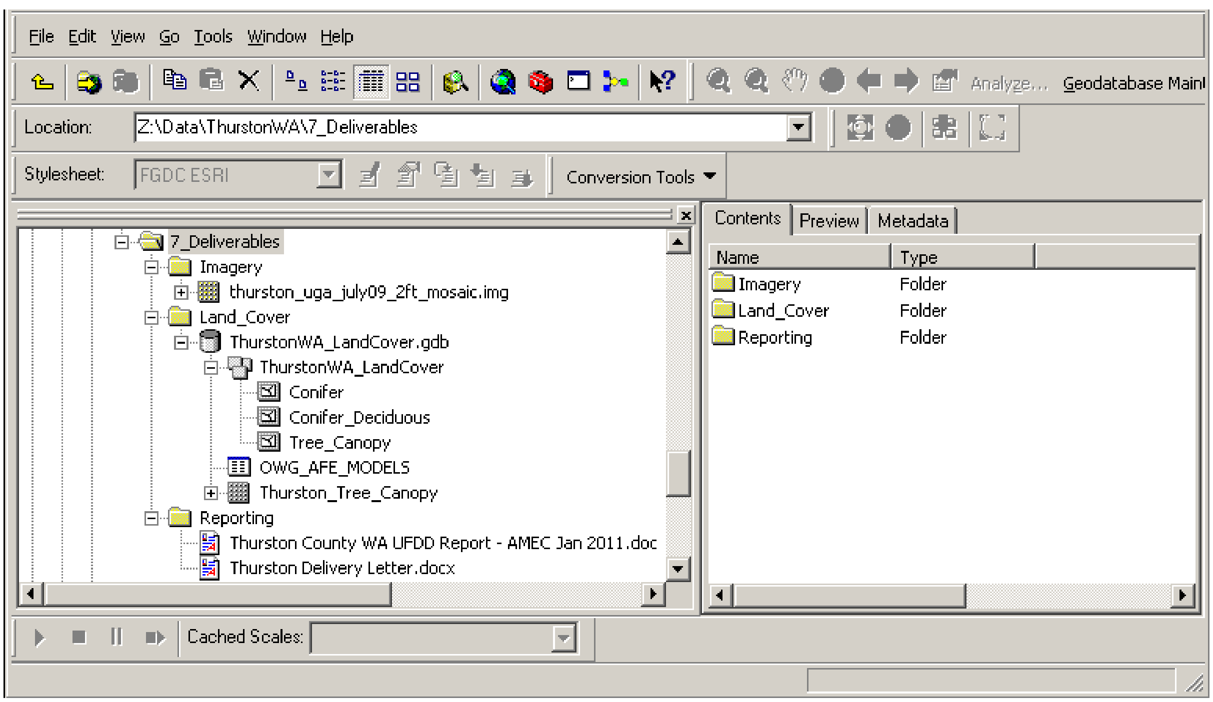
This project required a GIS-based project boundary and the use of high-resolution, multispectral leaf-on (summer) imagery to classify tree canopy. Multispectral imagery and the near-infrared spectral band specifically are useful in remote sensing of vegetation types. The County provided AMEC with an ESRI shapefile of the unincorporated UGA's and 6" resolution color-infrared (CIR) orthophotography acquired in July 2009. This imagery met the requirements as noted in the American Society for Photogrammetry and Remote Sensing Accuracy Standards for Class 1 mapping requirements at a scale of 1:1,200 with a 0.15 meter pixel resolution. The 16-bit, 4-band multispectral imagery consisted of blue, green, red and near-infrared spectral bands, included hundreds of tiles, and the file size at 6" resolution for the areas required was 142 gigabytes. Given the large size of the imagery and the nature of the desired tree canopy mapping, the full-resolution imagery was not needed nor would it be feasible in the remote sensing classification. The imagery was resampled (i.e., down-sampled) to 2-foot resolution, which is described further below. An example at right is provided showing natural color and false color imagery in an area where development has been designed to allow tree canopy cover in parking lots. Note that in the color-infrared image, vegetation appears in varying shades of red based on chlorophyll content and level of vigor.

It should be noted that two other imagery sources were discussed at the onset of this project but not used. In 2009, 1-meter imagery was collected statewide in Washington through the USDA Farm Services Agency's (FSA) National Agricultural Imagery Program (NAIP). While the imagery would not require resampling like the County's existing imagery, it did not offer any other benefits, would likely have worse horizontal (positional) accuracy and was not freely available as 4-band imagery. Additionally, LiDAR data was available which provides detailed aerial-based elevation information useful for efficient and accurate land cover classification including separation of trees versus shrubs; however it was acquired in 2002 and would be outdated in some areas, leading to inaccuracies rather than improving accuracy and reducing processing effort.

Specifications of Geospatial Deliverables

The fully attributed tree canopy polygon layer and the coniferous classification were delivered in ESRI file geodatabase format and raster ERDAS .img file format containing correct geocoding and georeferencing information. The data layers seamlessly integrate into Thurston County's existing imagery and GIS data. Consistent with the County's current GIS data, these products were delivered in NAD83 HARN State Plane Coordinate System, Washington South FIPS 4602 in units of feet. A "Sub-Feature" field was added to the tree canopy vector file indicating whether trees are coniferous or deciduous. Trees under 40 square feet were classified as "N/A" for their sub-feature. The resampled 2-foot aerial imagery was delivered as a single mosaic and in tiles for each UGA in .img format. Horizontal accuracy of the products was dependent on the imagery used, which as mentioned above met the requirements of this project. The delivery structure is illustrated in this ArcCatalog graphic:

Figure 3. Screenshot of the data delivery structure



Technical Approach and Methodology

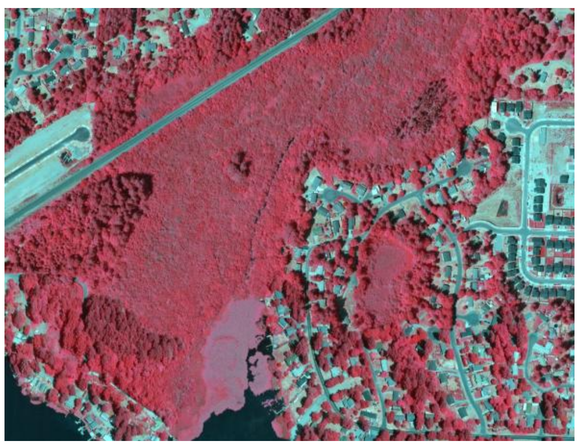
This section of the report provides documentation for how the imagery was resampled, how it was classified to map the extent of tree canopy, how that dataset was manually reviewed and assessed for accuracy, and how coniferous versus deciduous trees were classified.

Imagery Preparation

The tiled aerial imagery required two main preparation processes prior to the remote sensing classification: resampling and generation of a mosaic from the individual image tiles. To reduce the file size of the 4-band 2009 aerial imagery for suitability for the object-based image analysis (OBIA) classification, the imagery was resampled (down-sampled) from its original 6-inch resolution to a degraded 2-foot resolution. At this scale and these units, this means that groups of 16 pixels in a 4x4 pattern were averaged to a single pixel. This is important to allow for a stable and efficient remote sensing classification process which is described in more detail below. AMEC developed and utilized a custom tool that batch processes ESRI's standard resampling function from ArcGIS so that all image tiles within a folder will be resampled and renamed with the click of a button, significantly reducing labor time. Next, a single mosaic image was generated from the individual 2-foot resolution image tiles and clipped to the project area boundaries using the mosaic and subset functions within ERDAS Imagine. The imagery was then ready for tree canopy classification. An example of the imagery at 6″ resolution and 2-foot resolution is provided below in Figure 4.

Figure 4. Resampling of the 4-band imagery: color-infrared, 6″ resolution (left) vs. 2-foot (right)

Remote Sensing Tree Canopy Analysis



For the purposes of this project, the County and AMEC chose not to include shrub and briar vegetation in the tree canopy dataset. Figure 5 at right shows an area largely covered by shrub vegetation that would overestimate the amount of tree cover if included in the classification. Once the definition of tree canopy was agreed upon, AMEC analyzed the 2009 4-band imagery using Feature Analyst software v.5.0 and a technique

Figure 5. Shrub versus trees/forest vegetation

known as geographic object-based image analysis (OBIA) to develop a tree canopy land cover dataset that would support the needs of this project and other applications. According to Overwatch Systems, Inc., the developers of Feature Analyst, "the process uses spectral and spatial remote sensing analysis through a suite of machine learning algorithms such as Nearest Neighbor, Neural Networks, Decision Trees, Genetic Ensemble Feature Selection (patent pending) and others are used to efficiently extract user-defined features by 'learning' how to classify the object-specific geographic features specified by the user." Machine learning algorithms that exploit the feature attributes of size, shape, color, texture, pattern, shadow, and spatial association were used to efficiently extract tree and forest features. Polygon training samples were digitized throughout the project area representing different size and types of trees to train the software to classify groups of pixels as trees and forest. Incorrect results were re-trained using hierarchical learning methods that iteratively improve the classification. A separate shrub classification was also developed as a mask that eliminated much of the confusion between the two land cover types. The OBIA approach provided a highly accurate, automated and cost-effective method for feature extraction. At right is an example of the workflow and pattern-recognition input representation used in this process. This innovative method is essential for accurate extraction of features in complex scenes such as urban landscapes.

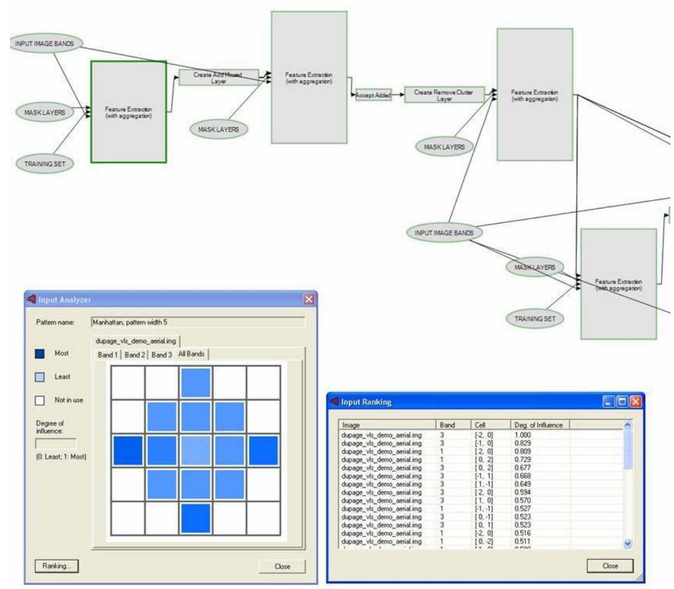


Figure 6. Example OBIA workflow in Feature Analyst software

Data Quality and Quality Assurance / Quality Control

The tree canopy classification was refined with an initial, manual quality assurance / quality control (QA/QC) process at 1:4,000 scale to remove incorrect features mapped during automation or add obvious missed features. This interim product was then shared with the County for review and feedback was provided regarding where and how the data could be best improved upon. AMEC then applied one last round of automated techniques and a visual review at 1:1,500 scale in order to finalize the tree canopy (Figure 7 below). AMEC then performed an accuracy assessment technique where 50 random, auto-generated points were placed within the final tree canopy layer and tallied. 48 of the 50 points were found to be tree canopy and 2 points were misclassified as other vegetation indicating 96% overall accuracy. An area based accuracy assessment where random polygons are drawn and compared to the automated classification was not deemed necessary given the initial accuracy check.

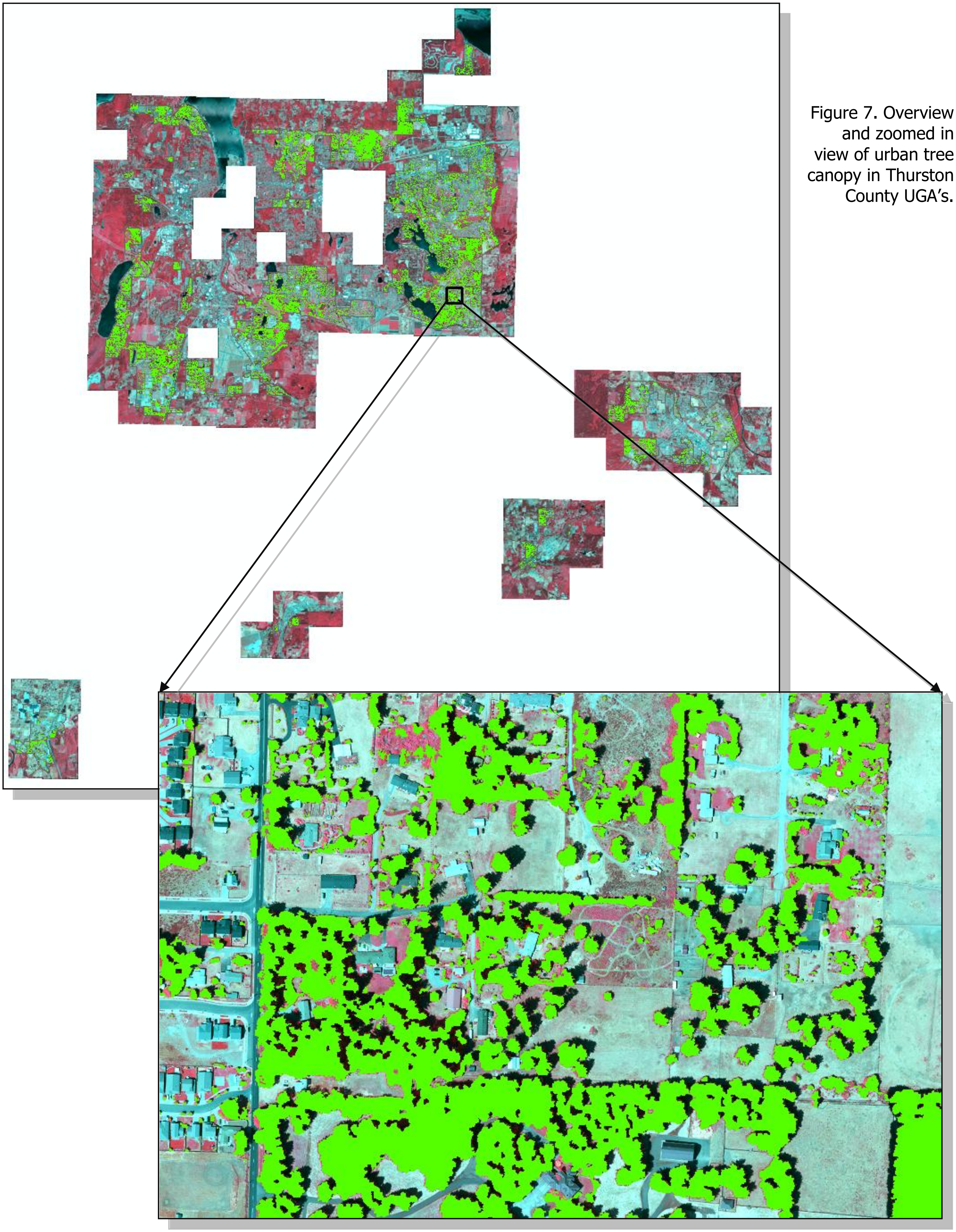
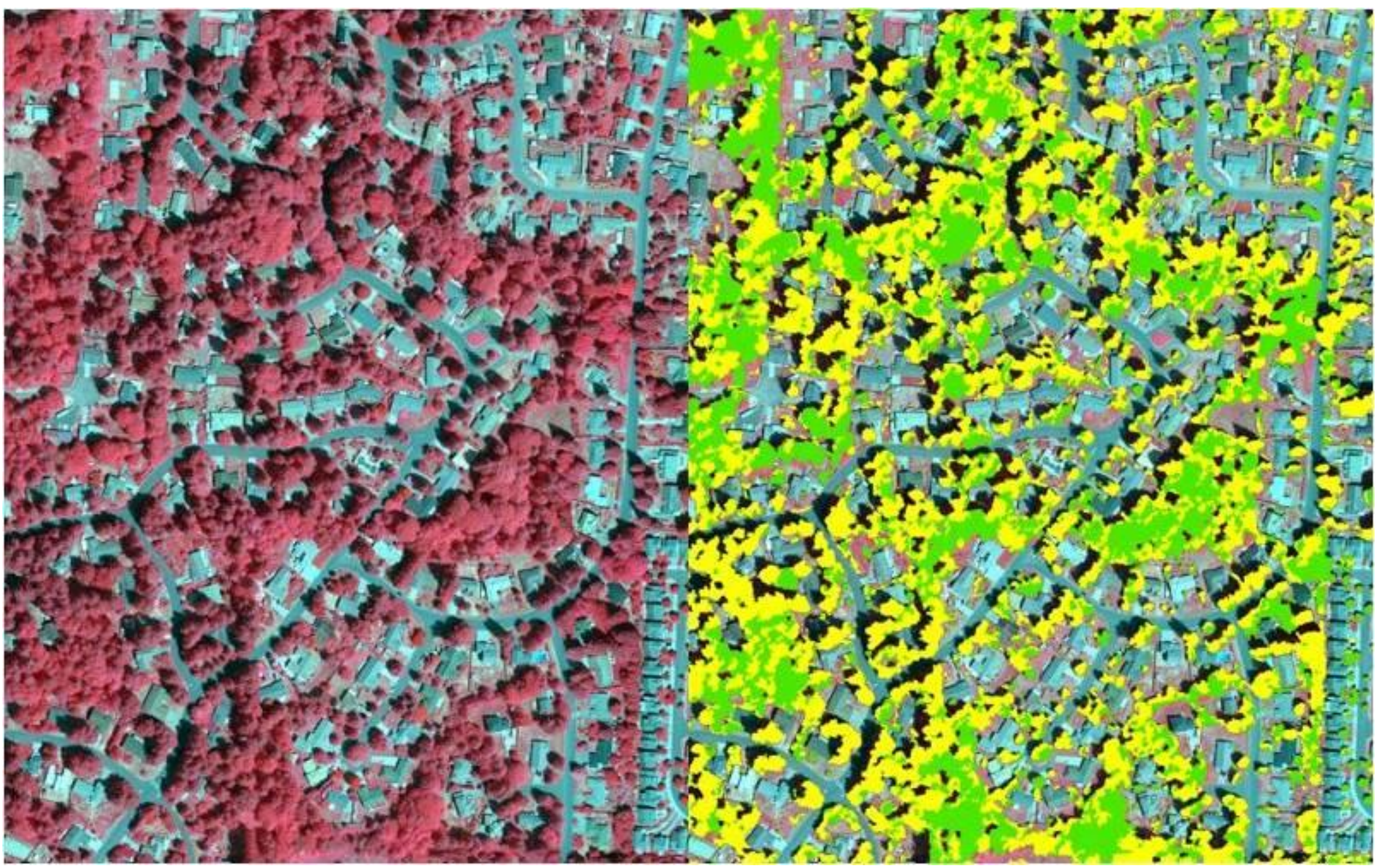


Figure 7. Overview and zoomed in view of urban tree canopy in Thurston County UGA's.

Deciduous versus Coniferous Tree Canopy Classification

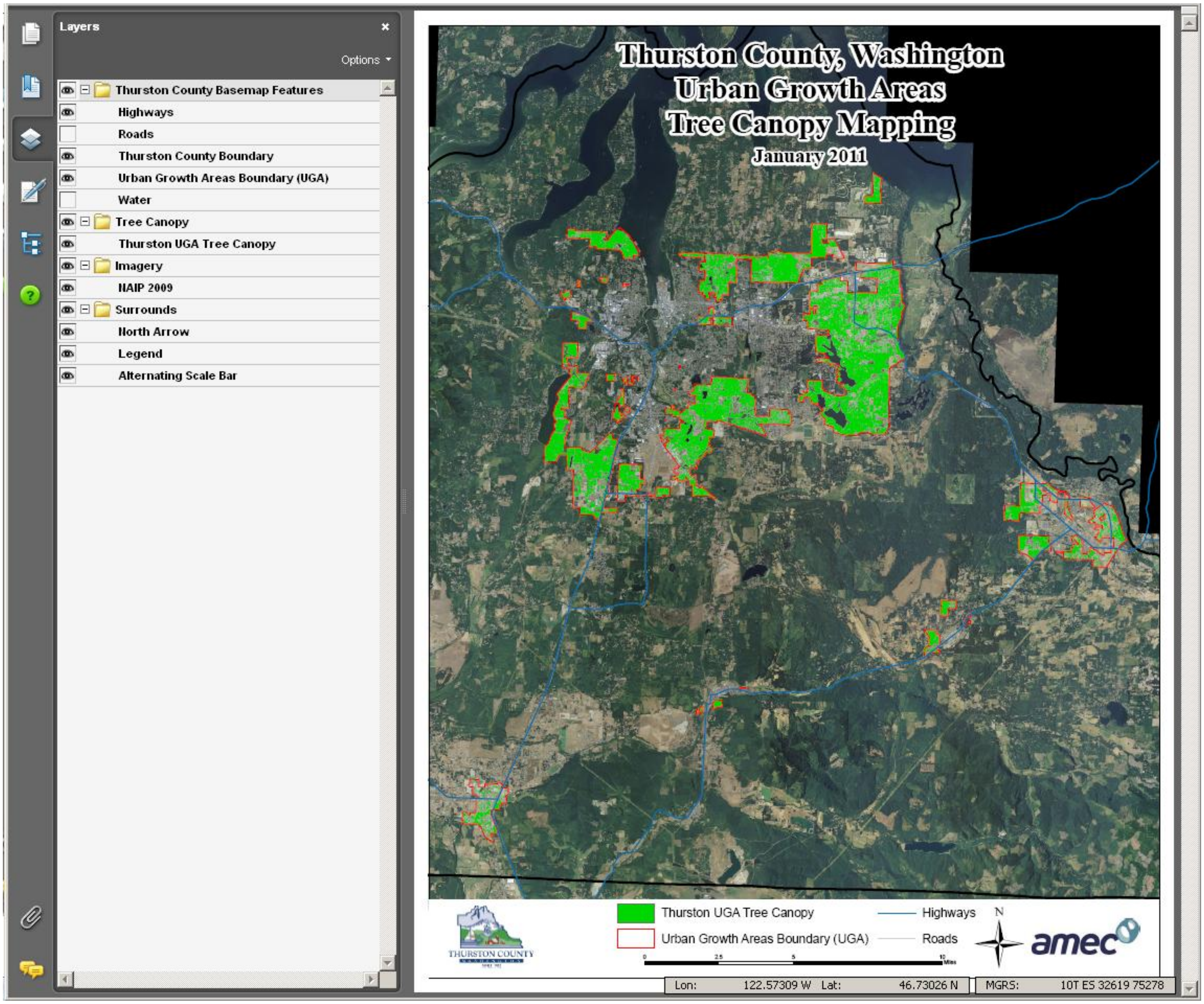
Using the final tree canopy data layer as a mask, coniferous tree canopy was then specifically classified using Feature Analyst. Sources of data for both the training samples for the initial classification and for the verification of the accuracy included support from Thurston County staff, Google Street View and the 6-inch resolution imagery. This technique leverages both the spectral qualities of coniferous versus deciduous trees as well as the textural and contextual (shape) differences in the tree crowns. Three iterations were performed in order to find the best balance of training samples and classification accuracy and some limited time was spent manually correcting obvious errors that may be due to varying atmospheric conditions of the imagery which produced incorrect results. A separate accuracy assessment of this classification was not required however visual reviews indicate the accuracy to be well above 80%. Additionally, while the contract specification did not require mapping coniferous trees beyond the forest stand- or forest group-level, individual conifers were accurately classified in many cases. A geoprocessing model was used to merge the conifer data layer with the original tree canopy layer including the addition of a "Sub-Feature" field that was added to discriminate between coniferous and deciduous canopy. An "N/A" class was also added for trees less than 40 square feet, which was determined in cooperation with the County after visual reviews of the accuracy at such a fine scale. See example below in Figure 8.

Figure 8. Illustration of tree canopy sub-classified by conifer (yellow) versus deciduous (green)



The final tree canopy layer was also delivered in an interactive PDF document that enables non-GIS users the ability to view and zoom in on the tree canopy data layers as well as turn each layer on and off in the PDF.   Only the free version of Adobe Reader is required to view the mapping results. Adobe's "Analysis - Object Data" tool can be used to identify GIS attributes. Note that the imagery used in the land cover analysis was not used due to file size and instead the 2009 National Agricultural Imagery Program aerial photography was used, which was collected at a similar time period (summer 2009), has 1-meter resolution and was significantly smaller in file size due to the MrSID compressed image format. A screenshot of the PDF is shown below in Figure 9.

Figure 9. Delivering spatial data in a PDF for non-GIS users of the tree canopy information delivered in this project.



Opportunities and Recommendations

Out of 24,512 acres in the UGA, 7,913 acres were mapped as tree canopy for an average urban tree canopy cover of 32.3% which provides a benchmark to monitor the impact of future development and land conservation policies. The tree canopy data obtained in this project can and should be further analyzed in a number of ways by a variety of stakeholders in Thurston County to improve strategic decision making regarding urban forest protection, preservation, policy development, tree planting and management. Below are recommendations on usage of the data as well as more broad suggestions for the County to consider.

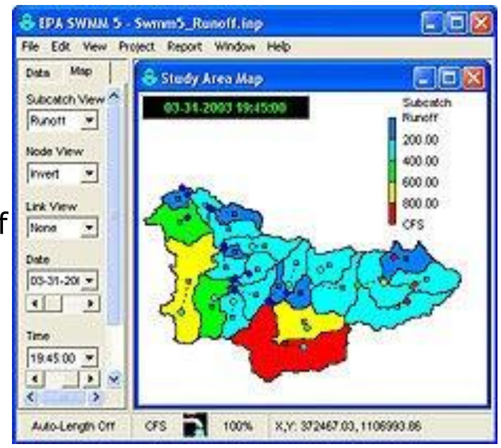
Using and Expanding Upon the Tree Canopy Data

- Suggested GIS Analysis of the UTC data
  - Calculate the percent canopy cover by land use categories including public vs. private ownership, by individual parcel boundary, by watershed and within riparian buffers. This provides a starting point for targeting increases in UTC at scales that are meaningful for planning and management purposes.
  - Assess canopy cover percentages in comparison to tree protection ordinances and age of development
  - Prioritize tree planting areas based on:
    - Walkable and social areas
    - Riparian corridors
    - Parking lots for water quality and shade benefits
    - Near populated areas and buildings for energy efficiency savings
    - High traffic congestion areas for noise reduction benefits
    - Streets, highways and other easements for improved noise reduction and air pollution removal
    - Areas with low UTC and high impervious surface area for watershed-related improvement projects.

  - Prioritize areas for preservation based on existing zoning codes, land use / land cover, sensitive habitat and water quality protection
  - Develop a tree "groves" sub-feature type of trees defined as interconnected areas of tree canopy greater than 0.5 acres in size.
- The tree canopy layer can be used as a mask when classifying other land cover types such as grass/open space, shrub vegetation, impervious surfaces, water and soil. This information can be used for a variety of stormwater modeling and management applications and used to benchmark greater land use / land cover conditions.

- Modeling Ecosystem Services – there are a number of software tools and models available for quantifying the benefits that tree canopy provides which should be applied to justify urban forest protection, policy and management, including but not limited to:
    - CITYgreen software from American Forests, which is a GIS-based model and used to calculate the ecosystem services and value of the urban forest in dollars and resource units. The reports will use the existing tree canopy cover to quantify air pollution removal capacity, carbon storage and sequestration (lbs./yr.), stormwater runoff (volume mitigated) and water quality (percent change in contaminant loading). Modeling can be done citywide, by watershed or by land use types for current conditions as well as future conditions scenarios. These 'replacement scenarios' can model the urban forest value at varying canopy cover percentages to demonstrate the estimated benefit of greater urban tree cover and progressive land use planning. Limitations of CITYgreen: it does not model benefits related to energy savings or aesthetic values, does not include any species-specific inputs, and the stormwater model (TR-55) does not include the level of rigor as in other models.
    - i-Tree suite of tools from the USDA Forest Service (http://itreetools.org/):
        - i-Tree Vue allows one to make use of freely available national land cover data (NLCD) maps to assess land cover and some of the ecosystem services provided by your current urban forest.
        - i-Tree Hydro is a stand-alone application designed to simulate the effects of changes in tree and impervious cover characteristics within a defined watershed on stream flow and water quality. It was designed specifically to handle urban vegetation effects so urban natural resource managers and urban planners can quantify the impacts of changes in tree and impervious cover on local hydrology to aid in management and planning decisions. AMEC will be using Hydro in Cincinnati, Ohio when it is released in version 4.0 of i-Tree in February 2011 and will be better able to describe its strengths and differences then.
        - i-Tree Eco is a software application designed to use field data from complete inventories or randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities. Baseline data can be used for making effective resource management decisions, develop policy and set priorities.
    - Community Tree Guides from the USDA Forest Service which provide average cost and benefit data for representative small, medium, large and coniferous trees on public and private property in 5-year increments to 40 years of age.
    - The Western Washington Continuous Simulation Hydrology Model (WWHM) from the State of Washington Department of Ecology is based on Hydrological Simulation Program – Fortran (HSPF) models and can be used to simulate the effects of urban forests on stormwater and water quality
    - US Environmental Protection Agency (EPA) Models:
        - SUSTAIN: The System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) is a decision support system to facilitate

selection and placement of Best Management Practices (BMPs) and Low Impact Development (LID) techniques at strategic locations in urban watersheds. It was developed to assist stormwater management professionals in developing implementation plans for flow and pollution control to protect source waters and meet water quality goals.
- BASINS is a multi-purpose environmental analysis system that integrates a geographical information system (GIS), national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package. Included within its open-source MapWindow GIS interface, are a Data Download Tool, project builder, watershed delineation routines, and data analysis and model output visualization tools. Plug-in interfaces are included for such well-known watershed and water quality models as HSPF, SWMM5, WASP7, and SWAT 2005.



- The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. Every 5 to 10 years, the County can investigate where and why tree canopy was lost and gained over time by land use type by performing this assessment using previous imagery or future data.

➢ Tree canopy improvements could be targeted in tangent with green infrastructure initiatives to mitigate stormwater issues and to shade and beautify retail centers to increase local business revenues.

Other Suggested Actions

Thurston County should consider setting an Urban Tree Canopy goal countywide or within UGA's. From a high-level perspective, this may include but is not limited to the following actions:

➢ Perform a cost/benefit and scenario analysis to determine the environmental, economic, and social benefits of increased tree cover as well as the costs associated with such an initiative.
➢ Assess the potential for public/private partnerships, local non-profit capacity, incentive/education programs, and adequacy of tree preservation ordinances and development codes in relation to the UTC goal.
➢ Conduct an urban forest "report card" assessment that would grade the County on tree cover, tree health, tree planting, tree awareness, and tree protection.
➢ This UTC assessment should be performed again in 5 to 8 years to monitor development and effectiveness of programs, policies, codes and ordinances.
➢ In determination of the actual percent UTC goal, we would recommend the following:
    - Map the County's "Possible UTC", or the areas of grass, open space, and parking lots available for tree planting, as an additional metric at various scales and by land use types

- Generate and utilize a "UTC Calculator" spreadsheet tool that enables a user to see the impact of tree planting on a countywide UTC goal or UTC goals within specific land use types.
- Identification of properties that realistically have less ability to increase tree cover (industrial, agricultural, etc) both biophysically and economically and can be excluded for a more detailed analysis of what's possible in residential, open space, and commercial properties. This would include consideration of the age of land use or individual parcels as it relates to young vs. mature tree cover.

There are many benefits of tree canopy assessment projects, including low cost, rapid turnaround, integration with existing GIS resources and resulting datasets that meet multiple agency and department needs. A UTC project will not replace the more detailed information collected through a traditional street tree inventory as specific species are not identified and no attempt is made to qualify the existing canopy in terms of its sustainable and diverse species. Nonetheless, it is an effective method for establishing canopy cover goals, estimating overall ecosystem services, and assessing the urban forest with results that are easily communicated with project stakeholders and the community at large.

About AMEC Earth & Environmental, Inc.

AMEC Earth & Environmental (AMEC) is a leading full-service environmental engineering firm in North America, providing environmental and geotechnical engineering and scientific consulting services. AMEC is a focused supplier of high-value consultancy, engineering, and project management services to the world's environmental, energy, power and process industries. We are one of the world's leading environmental and engineering consulting organizations. Our full service capabilities cover a wide range of disciplines, including environmental engineering and science, geotechnical engineering, water resources including green infrastructure and low impact development (LID) design and policy, materials testing and engineering, surveying, information management (GIS, remote sensing, database/application development) and program/project management.

Appendix

Figure 10. Google Earth Historical Imagery (1993 black & white and 2009 natural color imagery) showing forest loss due to development in Thurston County, WA