North Bend, WA Viewshed Analysis

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GEOG 569 GIS workshop
North Bend Viewshed Analysis
July 2019

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Presentation Link: https://sites.google.com/uw.edu/northbendviewshed/home

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Executive Summary

The Pacific NorthWest is renowned for its natural beauty and outdoor recreation opportunities. The city of North Bend embodies these values in real life, small town atmosphere with voluminous views of the surrounding mountains. In an effort to protect the character and natural beauty, a building height restriction of a maximum of 35ft has been in place via city building codes.

In recent years, the city of North Bend has experienced substantial growth concurrent with general growth in the region. However growth in North Bend has increased rent in the downtown region, resulting in more single family homes outside of downtown and general sprawl from the downtown core. In an effort to density downtown and increase available affordable housing and office space in the downtown area, three locations are proposed for multi-story, multi-dwelling buildings.

Three masters of GIS students analyzed the impact of potential buildings downtown views of Mt Si utilizing GIS and 3D analytical technology. The analysis includes three downtown vantage points and four mountain points. The mountain points are situated on the 1500 ft contour (approximately the elevation of Little Si). This analysis considered two scenarios: existing buildings at their current heights and existing buildings at the maximum zoned height (35 ft). For each scenario potential buildings were modeled in the 3D scene with generic footprints and heights of 35 ft and again at 50 ft.

The analysis found that none of the views from the vantage points along North Bend Way are impacted by the potential new buildings. The riverfront vantage point is impacted by one of the potential buildings. At the height of 35 ft, the view from the river front vantage point is ¾ obstructed. At a height of 50 ft, the view of Mt Si is completely obstructed.

In conclusion, the increase in building height from 35 to 50 feet or more has an insignificant impact of the view obstruction from the river front Vantage Point. Remaining areas of downtown North bend will not be impacted by the increased height of these potential buildings. Our group recommends pursuing the potential building projects as with architectural drawings around the height of 50 ft.

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Introduction

North Bend Washington is a city on the rise with a focus on growth and tourism aligning with their small town values and pride. The mission statement for the city reads: "The mission of the City of North Bend is to create a highly livable community by working in partnership with its citizens to blend and balance the following principles: high levels of police, fire, and emergency medical services; healthy infrastructure; quality public services; all to support a strong local economy and the rural character of the community." The city and people of North Bend value their reputation as outdoorsy with a focus on recreation and the amazing views of the mountains surrounding the city. Tourism has always been a significant part of North Bend's economy and that only continues to increase today between the outdoor adventurers and Twin Peaks fan resurgence.

The city's brand statement is "we are the highly livable small town that is creating the premiere outdoor adventure destination in the Puget Sound region." North Bend has seen accelerated growth in the recent past due to the economic growth of the region in general. Most of this growth for North Bend came in the form of high priced single family homes while multi family and commercial growth stagnated. An increased cost of living and lack of new jobs due to lack of office space were the outcomes of the one-sided growth seen in North Bend. To attract the businesses and people that North Bend seeks they wish to develop a denser downtown core with more diverse housing and commercial options while maintaining their core values.

The basis of this project is to analyze potential development sites aimed at increasing density and to bring more affordable housing and office space to the city's downtown core. For these projects to have a positive economic impact while being financially viable requires them to be built at a height above current zoning laws. These zoning laws are in place to protect the iconic views of the surrounding mountains, most notably Mount Si. Three sites in downtown North Bend have been earmarked for possible development and will be the focus of the three dimensional analysis. Using GIS software this project aims to visualize what impact new development above the current zoning height restrictions will have on the surrounding views of the mountains. Using key viewpoints around the downtown area will allow the three dimensional deliverables to provide a varied look from around town to determine impacts of possible future growth on North Bend's famous views.

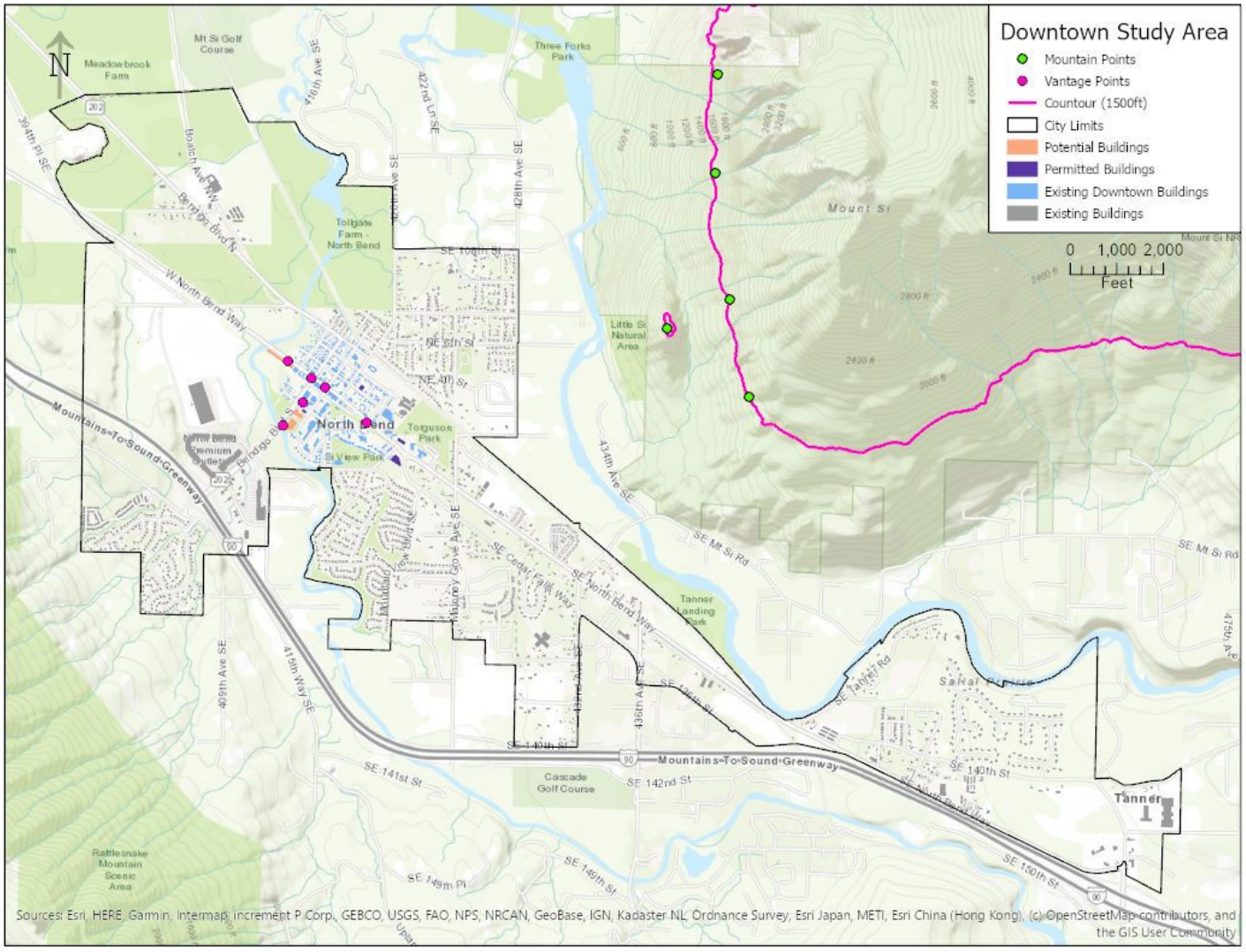

Figure 1. Overview of North Bend Study Area.

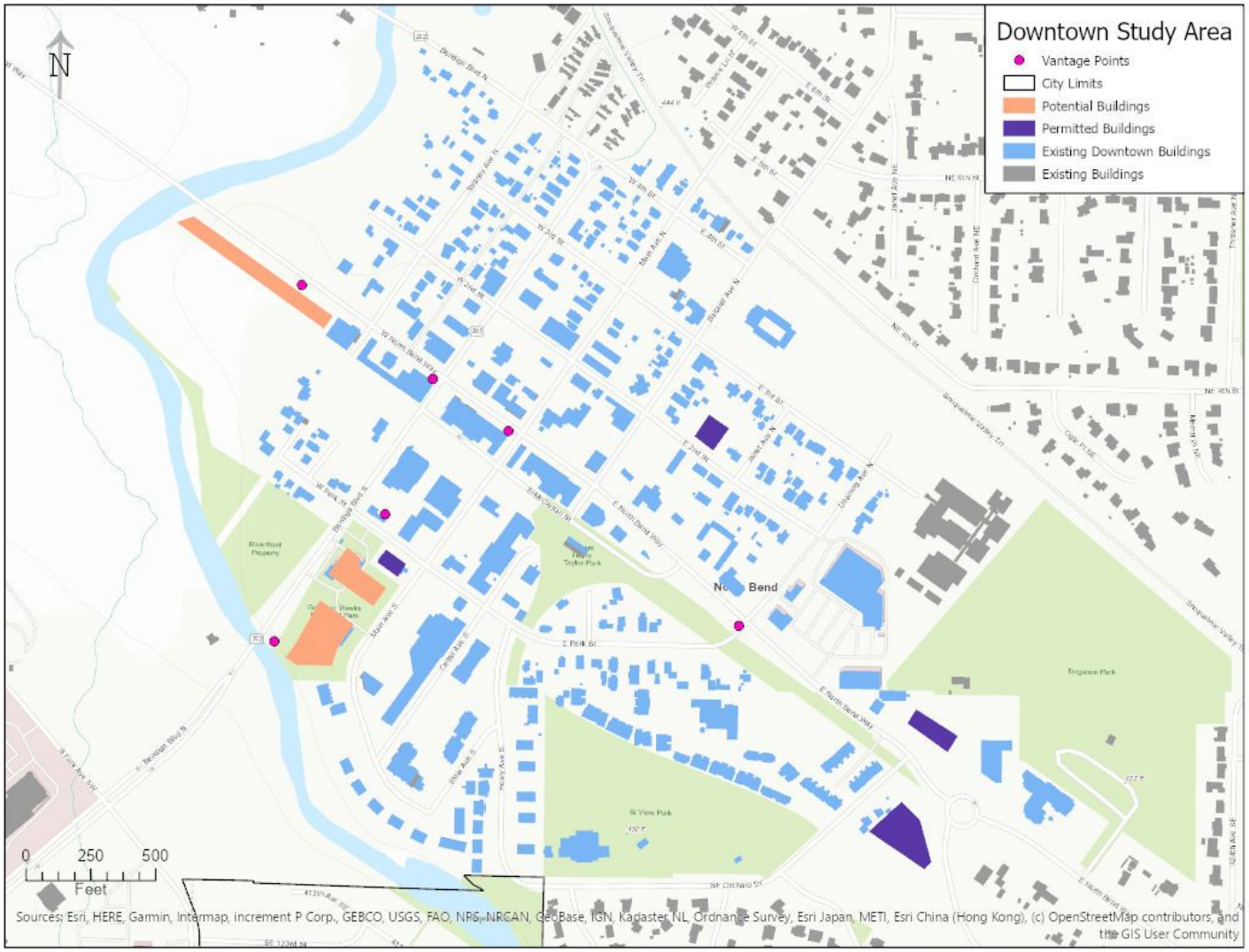

Figure 2. Downtown North Bend Study Area

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Methodology

This project was completed using ESRI ArcPro software, utilizing two dimensional maps and three dimensional local scenes. The workflow diagram below depicts the general method and processes utilized for this project.

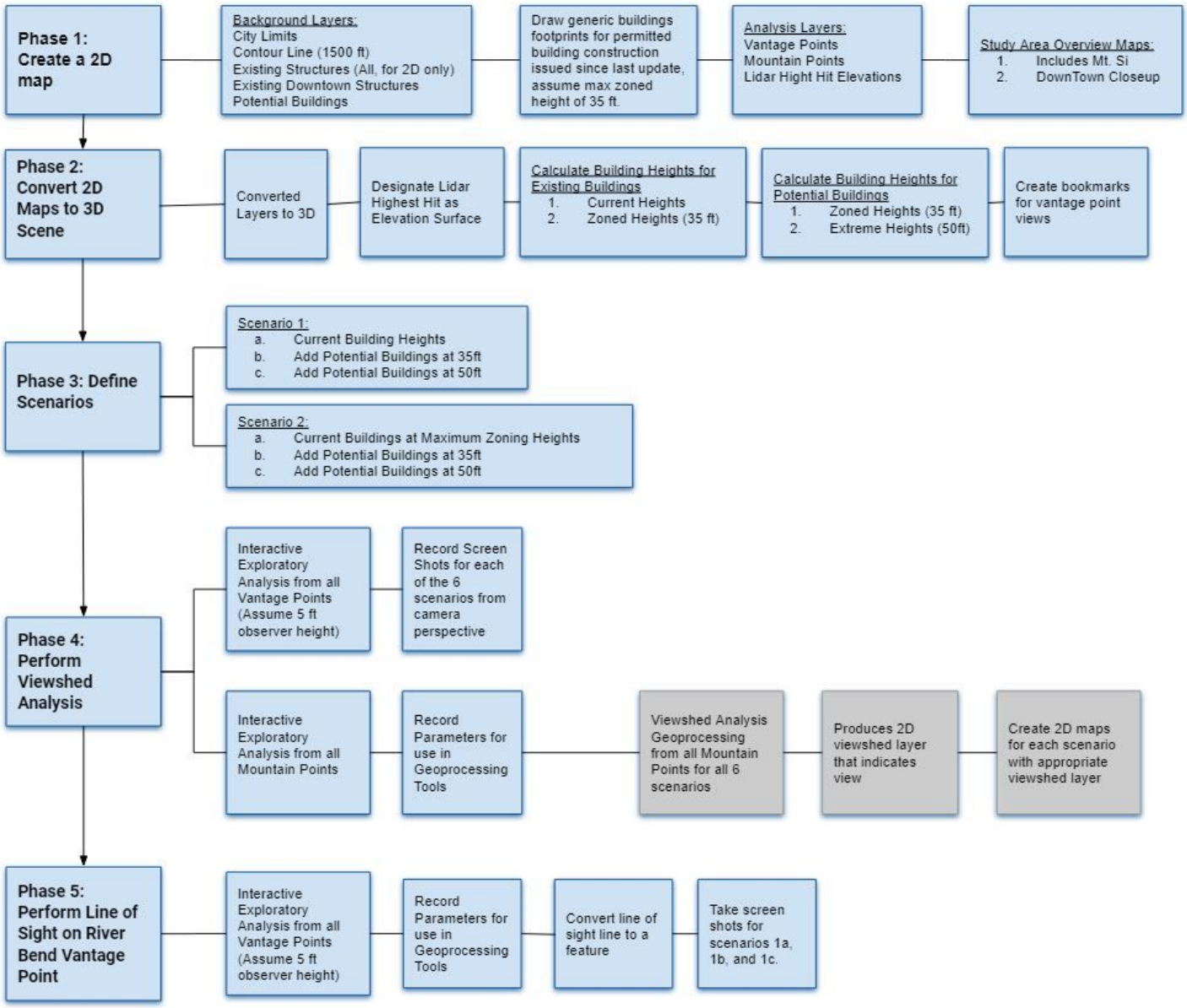

Figure 3. Project workflow diagram. Blue blocks were completed, grey blocks could not be completed due to lack of time and computing resources.

A geodatabase was developed for this project with pertinent datasets for the purposes of representation and calculations. Data was sourced from two major sources: the project sponsor (North Bend City data or project specific files), and the Puget Sound Lidar Consortium. Additional data sets were created/derived specifically for this project. The table below describes datasets utilized, data sources and purpose in this project.

Spatial Object Type	File Name	Source	Data Year	Brief Description	Purpose	Pertinent Attributes
Polygon	Analysis Boundary	Project Sponsor	2019	Area for viewshed analysis	project boundary	
Polygon	City Limits	Project Sponsor	unknown	North Bend city limits provided by project sponsor	reference	
Line	Contour 1500ft	Project Sponsor	2019	segment of the 1500ft topographic contour line of Mt Si and Little Si facing town	reference for mountain view as view of 1500ft and higher	
Grid	Elevation 2017 Bare Earth	clipped to Lidar Analysis Boundary from http://pugetsoundlidar.ess.washington.edu/lidardata/metadata/pslc2016/King_County/	2017	2017 Lidar data rasters downloaded from PSLC and clipped to Lidar Analysis boundary	utilized for 3D visualizations & viewshed analysis	elevation
Grid	Elevation 2017 Difference	Calculated	2017	bare earth elevation subtracted from highest hit elevation, to calculate the height of buildings and trees off the ground.	utilized for 3D visualizations & assigning heights to trees and buildings	elevation
Grid	Elevation 2017 Highest Hits	clipped to Lidar Analysis Boundary from http://pugetsoundlidar.ess.washington.edu/lidardata/metadata/pslc2016/King_County/	2017	2019 Lidar data rasters downloaded from PSLC and clipped to Lidar Analysis boundary	utilized for 3D visualizations & viewshed analysis	elevation

Polygon	**Existing Structures**	**Created**	**2019**	**combination of Structure_201607 and StructureNew, buildings heights were calculated**	**will be utilized 3D visualizations & analysis**	**Height - current (ft) Height - zonned Height - extreme**
Point	**Mountain Points**	**Created**	**2019**	**Point locations along 1500ft contour line**	**3D point locations for viewshed and line of site visibility**	
Polygon	**Parcels Study**	**Project Sponsor**	**2016**	**subset of North Bend parcels with zoning information**	**will be utilized to add buildings for any non-baseline scenarios**	
Polygon	**Permitted Structures**	**Created**	**2019**	**structures permitted for construction**	**3D polygon for viewshed and line of site visibility analysis**	
Polygon	**Potential New Structures**	**Created**	**2019**	**potential new structure locations and specs**	**3D polygon for viewshed and line of site visibility analysis**	
Point	**Proposed Housing Locations**	**Project Sponsor**	**2019**	**Three potential locations for affordable housing locations, height attributes were added**	**will be utilized for impact analysis of adding 5 story buildings**	**Height - current Height - zonned Height - extreme**
Polygon	**Structure 201607**	**Project Sponsor**	**2016**	**Building database**	**will be utilized 3D visualizations & analysis**	**Z_Current (ft)**
Point	**Structure New**	**Project Sponsor**	**2019**	**New building permits added since 2016**	**update structure dataset**	**raised structures heights (zone)**
Point	**Vantage**	**Created**	**2019**	**point locations in**	**3D point**	**locations**

	Points			**downtown region**	**locations for viewshed and line of site visibility**	**most desirable to maintain visibility of Mt. Si**
N/A	**Vantage Point Parameters**	**Created**	**2019**	**azimuth, angles, and vertices offset parameters**	**features for 3D viewshed analysis geoprocessing tool**	
Grid	**Vantage Point Viewshed**	**Created**	**2019**	**Visibility raster output**	**2D raster to drape 3D terrain**	**visibility and obstruction areas**

Table 1: Geodatabase scheme table.

Deriving Building Heights

Publicly available lidar data was downloaded from the Puget Sound Lidar Consortium as the base elevation data for this project. Lidar datasets typically contain two elevation surfaces: bare earth and highest hit. As seen in the figure below, the highest hit elevation surface follows the tops of trees and tops of buildings, while the bare earth elevation surface follows the actual ground surface.

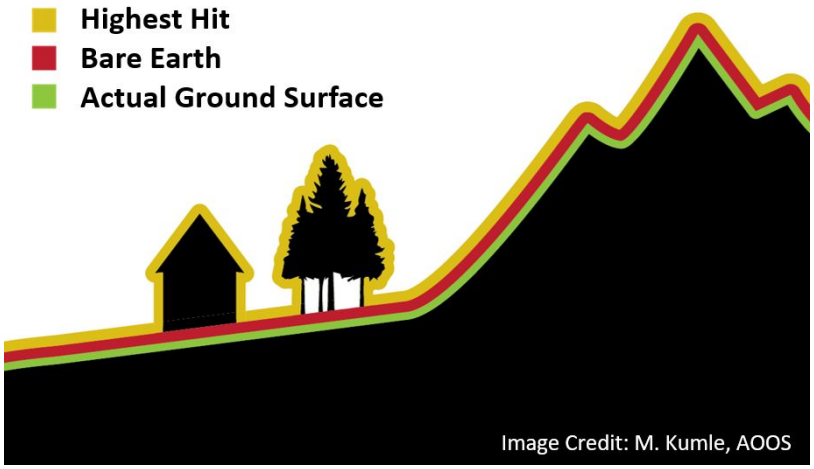

Figure 4. Depiction of highest hit and bare earth lidar elevation surfaces.

For the 3D scene, building heights were derived from an average difference between the lidar highest hit and bare earth elevations from within the city provided building footprints. The City of North Bend last update to the buildings footprint GIS data layer was in 2016 and a few building projects have since been built or approved since the dataset was created. For these structures, a

standard building footprint was assumed and drawn on land parcels identified by point locations by the project sponsor.
Heights for the new construction structures were assumed from standard zoning regulations. All buildings are represented as having flat roofs. For buildings in the 2016 city dataset average heights were derived from the lidar highest hit data layer.

However, through this method, a significant number of buildings had a derived height of less than 14 feet or more than 35 feet. Over estimation of roof heights could be caused by either tree canopy adjacent to or hanging over rooftops. Underestimation of heights could be caused by a small fraction of the building footprint overlaying with a lidar gridcell that is predominantly ground surface. Without city resources to conduct a quality control of building heights and real-life verifications, assumptions were made to correct for errors. It was assumed that minimum building height was 14 feet; any structure with derived height of less than 14 ft was corrected to 14 ft. It was assumed that all buildings are within city code and not taller than 35 ft; any building with a derived height greater than 35 ft was correct to 35 ft.

Due to lack of data attributes & metadata from the city of North Bend files, building heights are calculated from Lidar data and have not been verified by real life quality control. Additionally, without more detailed attributes, like building materials and construction type, a visualization rule package could not be implemented and photo-realistic scene could not be created. Thus, our 3D scenes are purely cartographic representations which do not reflect details such as the varying heights roof pitches.

Deriving Tree Heights

This project made an attempt at deriving tree heights from highest hit lidar elevations, however, there was not sufficient time to complete this task. The project sponsor did provide a point file of city owned tree locations. While tree heights for city owned trees could be derived relatively easily, these trees represent only a tiny fraction of trees located in downtown North Bend. It is possible to derive point tree locations with heights from the publicly available lidar data, but that analysis was too time consuming for the scope of this project and is not included in the scope of this project. As an alternative, our group utilized the lidar first return data, which includes the tops of trees and buildings.

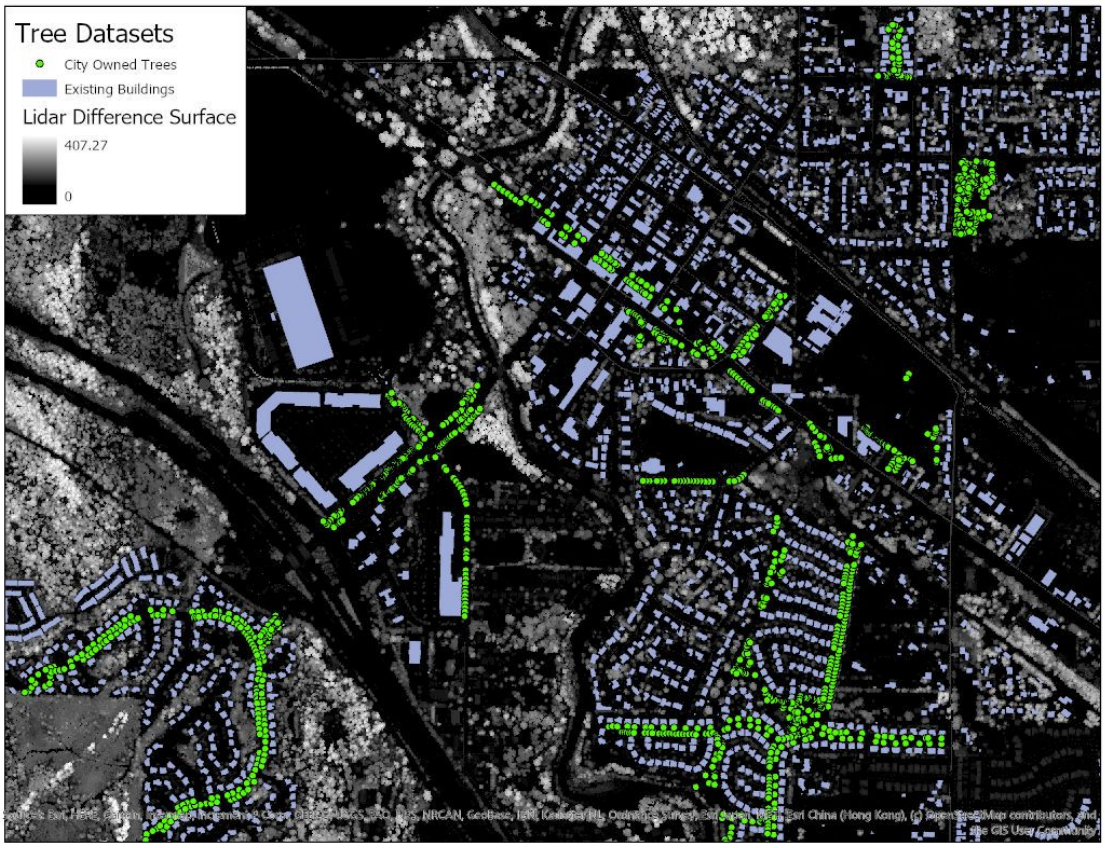

Figure 5. Lidar Tree Height Map

Discoveries & Discussion

After the 3D scene was constructed, an exploration of tools and results was conducted. Explorations included utilizing multiple points in an interactive viewshed environment, reversing the view from the mountaintop down into town and line of sight analysis. The viewshed analysis tool allowed the ability to work from these different vantage points with inputs to define observer parameters from said viewpoints in town and on the sightline from Mount Si. Conversion of these parameters into the feature class allows us to see where sightlines have been obstructed in the viewshed based on the building heights extruded in the three dimensional scene. Based on our viewpoints we altered tilt, heading, distance, and angle to develop a readable table for the geoprocessing tools viewshed analysis and line of site for 3D analyst tools. The following figures visualize the process and outputs for the analysis in three dimensions based on our extruded building heights derived from lidar data.

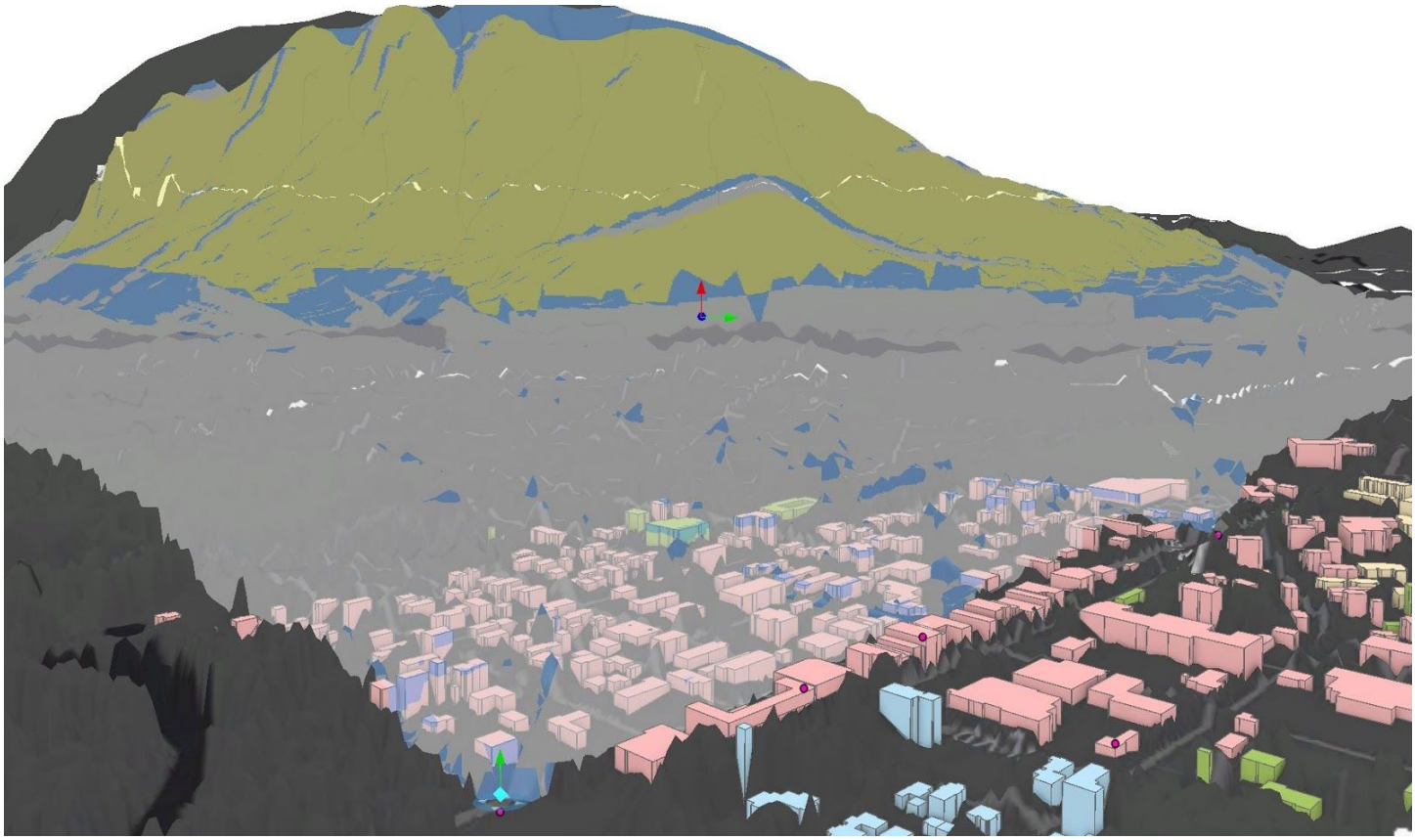

Figure 6. Exploratory viewshed analysis using the four vantage points along North Bend Way. Grey area cannot be seen from any vantage point, blue can be seen from one vantage point, while green can be seen from multiple vantage points.

Viewshed Visibility

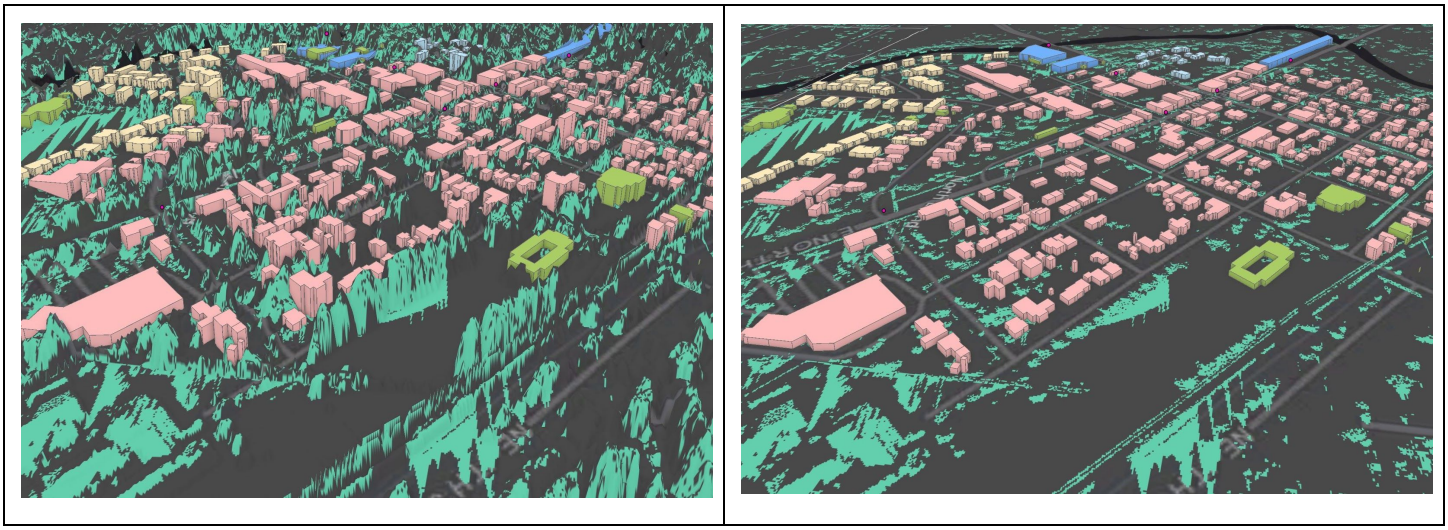

Figure 7. Visibility analysis from the mountain points into downtown. Lidar Highest Hit Surface Elevation (left) & Esri 3D Ground Terrain (right) illustrates the visibility (teal) and obstruction (grey) from mountain point locations towards downtown vantage point locations.

Line of Site Visibility

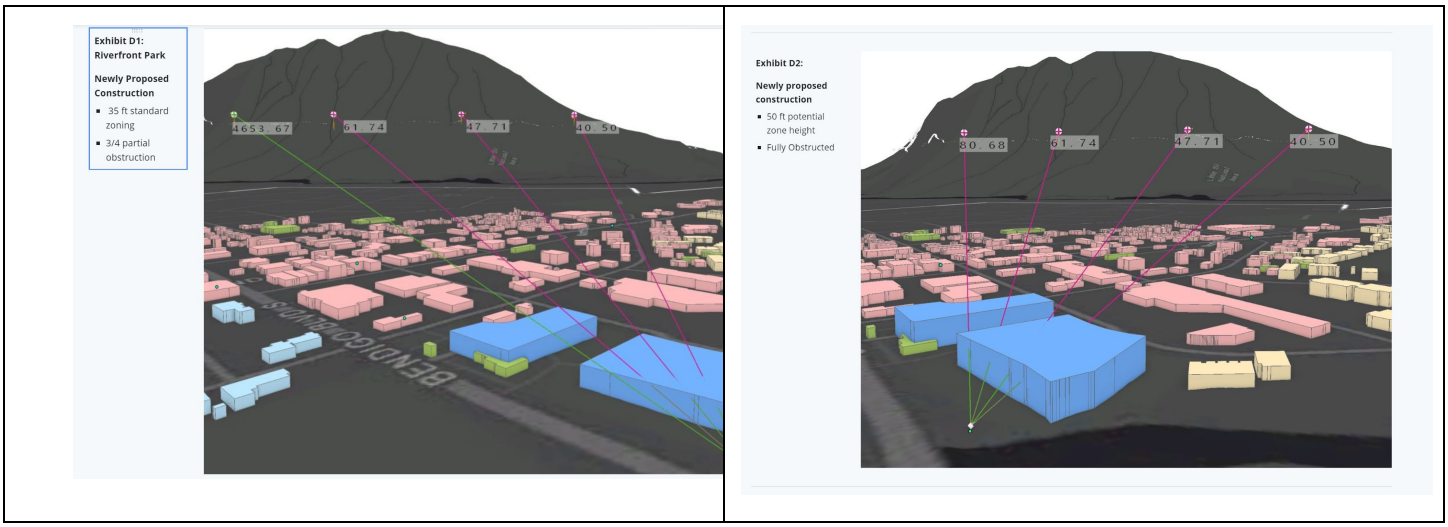

Figure 8. Line of site visibility analysis from the Riverfront Park vantage point to points along the 1500 ft contour line. Observation distance in meters with a vertical offset of 2 meters. The left panel illustrates potential new structure heights at max zone of 35ft with ¾ obstruction. The right panel illustrates potential new standards max of 50ft fully obstructed views.

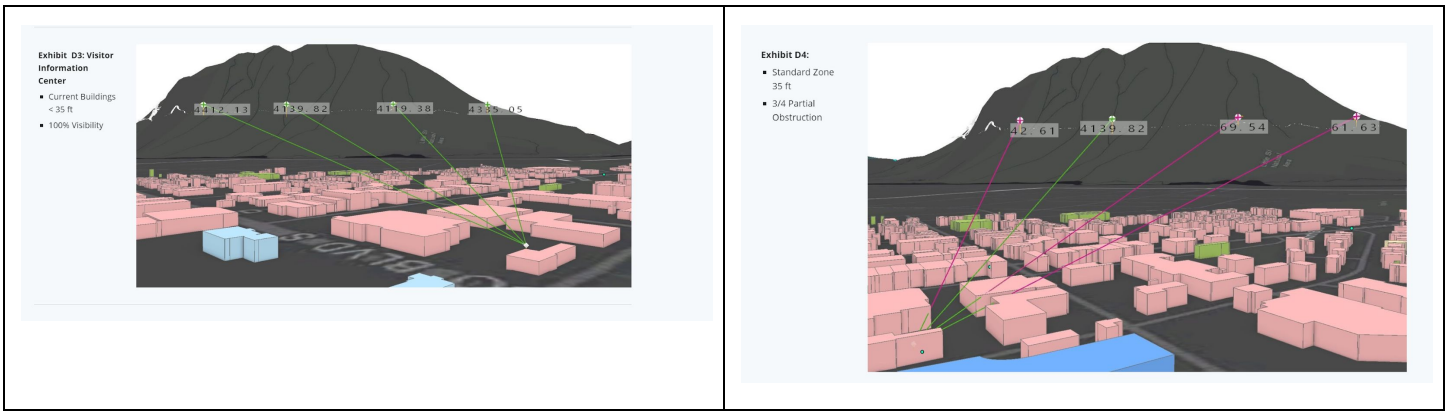

Figure 9. Line of Site visibility Analysis from visitor center vantage point to 1500 ft contour line. Observation distance in meters with a vertical offset of 2 meters. The image on the left Illustrates line of site visibility from the visitor center with existing structures; no obstruction. The image on the right illustrates existing structures with max zone heights; ¾ partial obstruction of Mt Si.

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Scenarios Results

Two basic scenarios, each with three iterations were formally compared. All Scenario 1 iterations use existing buildings at current heights to analyze the view of Mt Si from the downtown vantage points. All scenario 2 iterations use existing buildings at maximum zoned height of 35 ft. In each Scenario, iteration is the baseline scenario, scenario b includes the addition of potential buildings at 35 ft height, and scenario c increases the height of potential buildings to 50 ft.

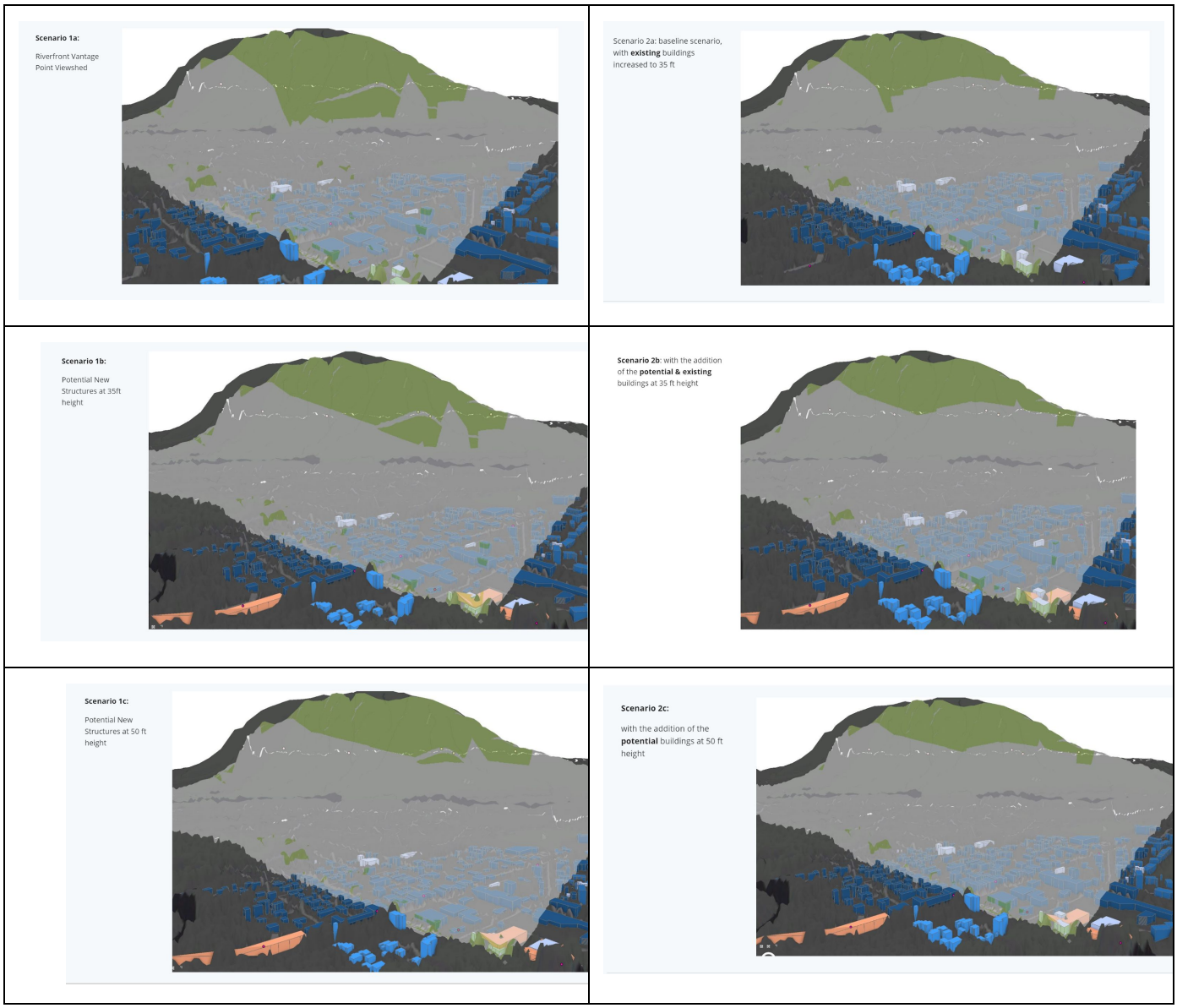

Figure 10. Scenario Results. Three versions of two scenarios were evaluated for mountain views from the Riverfront vantage point. The left three images depict scenario 1 iterations, while the right three depict scenario 2 iterations. Green shade represents areas visible from the viewpoint where grey shade represents areas blocked from view. All blue buildings are currently existing and potential buildings are shown in a salmon color.

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Challenges

Challenges faced over the course of this project were varied in scope from hardware to software and data sources. Working in three dimensional format proved to be our longest term challenge that never was completely resolved. More robust hardware for three dimensional rendering would be highly helpful to eliminate this challenge and help to smooth out processing issues. With a better hardware system the rendering of three dimensional graphics would be quicker and smoother, allowing for more time to be spent working on analysis and other areas of the project. Another issue related to three dimensional work was the viewshed analysis itself; performing this function with real world data was vastly different from doing an ESRI tutorial. The ESRI tutorial was a great introduction to the subject, but it didn't include every step necessary for real world data that might not be as perfect as data provided in a tutorial. With frequent updates to ArcGIS Pro, we also saw the tutorial became outdated quickly in the processing steps, as some things had changed with each update as compared to the tutorial.

Lidar data was another area that proved to be a major challenge over the course of our project. Working with the lidar data to extrude trees versus the buildings of North Bend was a challenge that wasn't fully resolved, but the team was able to work around and provide a full set of deliverables as planned without compromising any results. The tree point file we were using only included city owned trees but we quickly realized the lidar data was picking up much more trees around the city that we had no information on. When rendering this in three dimensions it became challenging and eventually necessary to ignore the trees completely to focus on the buildings that we had much more information for. With more time and resources it would be possible to derive these trees along with buildings to provide a more well rounded view of the project scope and analysis. In lue of modeling trees, our analysis relied on the highest hit lidar data to capture the tree obstructions.

Conclusion & Recommendations

In conclusion, increasing the potential building heights from 35 ft to 50 ft reduces the views of Mt Si from the riverfront vantage point from 75% obstruction to 100% obstruction. None of the North Bend Way viewpoints are obstructed by the potential new buildings. Within the North Bend downtown core, many trees are taller than existing buildings and obstruct more of the view than the buildings.

Recommendations

1. To further enhance the connection between people and nature and overall vitality of life within the region consider green stormwater infrastructure analysis utilizing Esri Green Infrastructure Data with the following data sets: Intact Habitat Cores ; WA Green Info Fragments; and WA Green Info Cost Surface to study the connectivity between habitat, green spaces, and people within the community.
2. Pursue architectural drawing of potential buildings around a height of 50 ft height; utilize x, y, & z to optimal potential
3. Future parcels development and revitalization of existing building:
    a. Potentially redevelop the visitors center (to be closed in september 2019); embracing a potential new zonal height of 35-50ft providing a raised look-out point for tourists.. Observable 35ft vertices with a 360 view of Mt Si and Rattlesnake Ridge

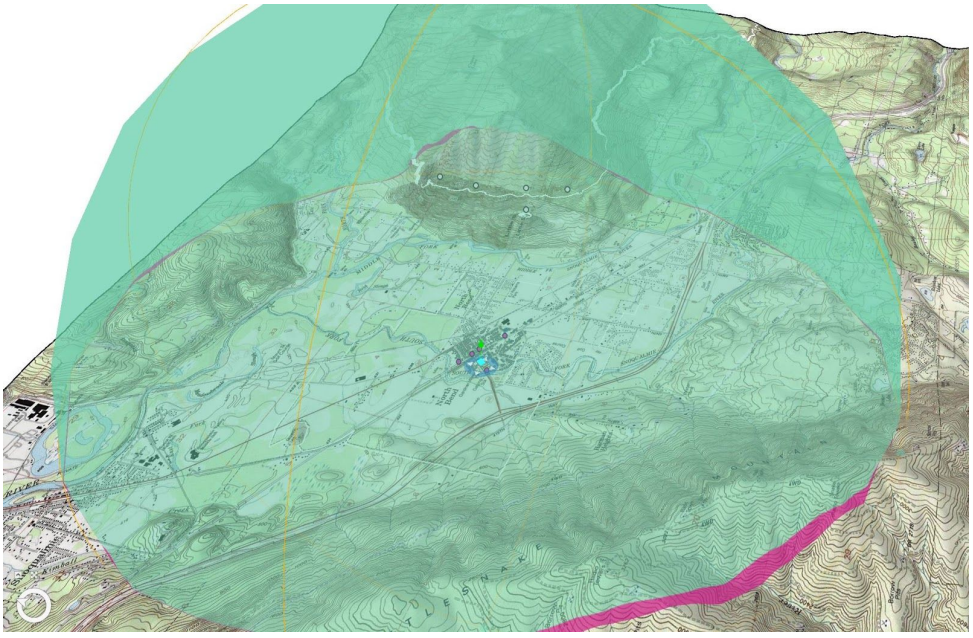

Figure 11. Potential visitor center views. 360 degree possible view from the height of 35ft at the location of the visitors center depicted in the teal sphere. Views include Mt. Si and Rattlesnake Ridge.

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Appendices

Appendix 1: Business Case Estimations

Introduction

Along with our mapping deliverables have estimated the costs and benefits associated with the GIS work being done and the technology being used. The following information outlines a business case of associated costs and benefits (qualitative and quantitative) for our work in completing this GIS project.

Benefits

Benefits are divided into four categories: quantifiable efficiencies that improve current practice, quantifiable expanded or added capabilities, quantifiable but unpredictable events that could take advantage of geographic information.

Type 1 Benefits: Quantifiable efficiencies in current practice, or improvements to existing practices

A. Quicker decision making by city council to approve/disapprove specific affordable housing projects.
    - Estimated benefit $5,250
    - 7 members of city council, assumed pay of $75 dollars per hour
    - Assume this saves 10 hours over one year of time
    - 75 * 7 *10 = $5,250

Type 2 Benefits: Quantifiable expanded or added capabilities to be more effective with work activities

A. No type 2 benefits were quantified for the purposes associated with the GIS cost/benefit analysis

Type 3 Benefits: Quantifiable, unpredictable events that can take advantage of geographic information

A. Type 3A: movie/film/tv show opportunities, being able to quantify views in the city, may bring in filming opportunities which would bring in tax revenue and further increase tourism.
    - For example, the town of Forks, Washington, had increased tourism after the books and movies Twilight from 10,000 to 70,000 people per year. Increased tourism is a boost to local businesses which bring in taxes for the city. (Faust, 2010)
    - In 2018, sales tax made up $2.4 M of the city's $7.3 M revenue
    - If a movie or TV show tripled the amount of visitors and amount of retail, then that would be nearly a $5 M revenue increase.
B. Type 3B: In the case of a natural disaster, such as an earthquake or a volcanic explosion, knowing the heights of buildings may have benefit to rescue workers and rebuilding

efforts. Recently, the USGS reported that the South Whidbey Island Fault, which is capable of producing a 7.4M earthquake, may extend all the way to North Bend. (Snoqualmie Valley Record, 2008)

- For a $50M emergency response (Hughes, 2018), if knowing the building heights saved 2%, that's $1M.
- Assume likelihood of earthquake is every 50 years. $1M/50 = $20,000

Benefits Summary Table	
Type 1A: Time savings in city council deliberations by having viewshed analysis	$5,250
Type 3A: Movies/TV shows increase tourism and thus retail sales tax	$5,000,000
Type 3B: Improved Emergency Response Effort	$20,000
Total:	$5,025,250

Table 2. Benefits Summary Table

Type 4: Intangible benefits related to intangible advantages.

A. Maintain views of Mt Si while adding to the downtown vibrancy of North Bend
   - A multi-faceted viewshed analysis focusing on the downtown core, its existing building footprints, and future building height scenarios to explore where mountain views are now and where they could be with the construction of new buildings.

B. Intangible benefits associated with walkability (Litman, 2018)
   - Improved accessibility for people who are transport disadvantaged
   - Increased neighborhood interaction and community cohesion
   - Improved opportunities to preserve cultural resources (e.g., historic buildings)
   - Increased parking efficiency (parking facilities can serve more destinations)
   - Openspace preservation
   - Reduced energy consumption and pollution emissions
   - Improved aesthetics
   - Health benefits to the population

C. With mixed use affordable housing downtown, there will be an increase in available jobs
   - Further development will follow proposed development
   - More affordable housing brings down the cost of living in the city (Affordable Housing Online, Rent Cafe, Best Places)
     i. Cost of Living index for North Bend is 174, compared to 100 nationally
     ii. Median home cost in North Bend is $578,300
     iii. Median rental price in North bend is $2,305
     iv. Median affordable rental price in North Bend is $1,199

Costs

Costs in this document are estimated costs as they would pertain to a consulting firm or other private/non-profit group performing the work. Workload is estimated at one GIS Analyst working full time on the project for a duration of three weeks.

Deliverables include digital data and five printed posters for city council meeting.

See tables below for specific costs associated with the project.

Capital Costs

Capital Cost Category	**Item Descriptions**	**Cost per Unit**	**Unit Count**	**Total**
Database	*server estimated at $5,200 with a lifespan of 5 years	$20 /week	3	$60
Hardware	*desktop computer capable of 3D processing estimated at $5,200 with a lifespan of 5 years	$20 /week	3	$60
Software	*ESRI licence per year estimated at $6,000 for Advanced licence with all extensions	$115 /week	3	$345
Implementation	*included in other categories	-	-	-
			Total	$465

Table 3. Capital Costs

Operating Costs

Operating Cost Category	**Item Descriptions**	**Cost per Unit**	**Unit Count**	**Total**
Personnel	GIS Analyst *Assumed pay rate of $60 per hour	$60 /hr	120	$7,200
Overhead	*assumed 100% of employee pay rate for employee burdened cost (health insurance, liability insurance, overhead, utilities, etc.)	$60	120	$7,200

Maintenance Fees	*included in the burdened personnel category under burdened cost	-	-	-
Utilities	*assumed 25% of employee pay rate	$15	120	$1,800
supplies	Printed posters for city council meeting *consider this to be expendable materials, typically paper, printing, posters, etc.	$85	5	425
Other				
			Total	$16,625

Table 4. Operating Costs

Combined Costs

Capital Costs	$465
Operating Costs	$16,625
Grand Cost Total	$17,090

Table 5. Combined Costs

Benefit-Cost Analysis

Cost-Benefit Summary Table	
Total Costs	$17,090
Total Benefits	$6,340,755
Net Sum	$6,323,665

Table 6. Cost-Benefit Summary Table

Appendix 2: References

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