# Environmental Mapping Incorporating LiDAR, Satellite Imagery, and Existing GIS Data

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## Abstract:

The objectives of Environmental Mapping in Snohomish County are to assist in property development/permitting, improve regulatory review, and provide for land capacity analysis. The location of streams and steep slopes on individual parcels is a desirable component. The estimate for a detailed ground survey mapping these features exceeds thirteen million dollars and is possible only with an extended timeframe. Alternatives utilizing remote sensing technology in conjunction with GIS are developed to model reality at considerably less cost. Data compiled from remote sensing sources are compared to existing data, and new modified data layers are created. All aspects of the project incorporate ArcGIS software from the analysis of the LiDAR DEM with ArcHydro to a website application developed in ArcIMS. This project is not possible without these valuable tools.

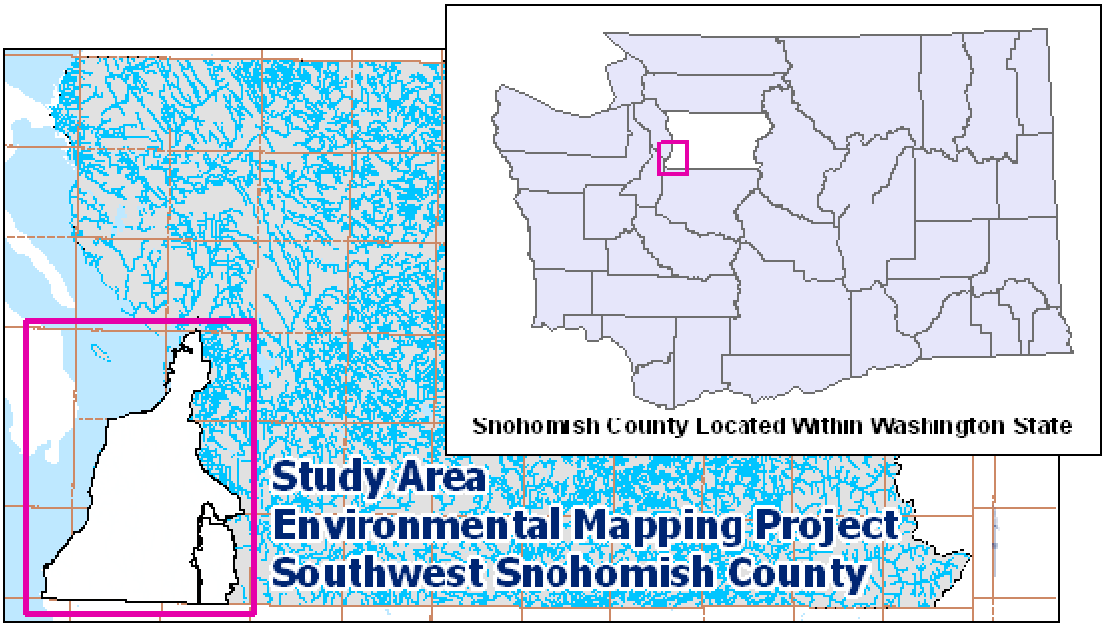
## Introduction

This environmental mapping project came about to assist the citizens of Snohomish County in the development of their property. The location of landscape features such as streams and steep slopes greater than or equal to 33 percent on individual parcels affects the permitting and development process. The most accurate way to find a precise location/classification of these features is to conduct detailed ground surveys. The original estimate for such a project was 13.2 million dollars and only possible with an extended timeframe. Consequently, alternatives were suggested utilizing remote sensing technology to develop a system of models to approximate reality.

A primary component of the following methods is the use of high resolution satellite imagery and airborne based Light Detection and Ranging (LiDAR) imagery. These imaging techniques allow relatively accurate mapping of landscape features such as valleys, slopes, vegetation, and water. Similar data are currently available through existing mapped data sources but only at smaller, more regional scales from 1:24,000 to 1:250,000. Computerized analysis of the data is used to model the location and extent of these landscape features.

### Project Study Area

The study area for this project is bounded by the Urban Growth Area (UGA) for Southwest Snohomish County derived from the Snohomish County GMA Comprehensive Plan, December 2005. The Little Bear Creek watershed lies to the East on the edge of this UGA boundary and is also included in the analysis. After evaluation of the Southwest County analyses the same techniques may be applied to the remainder of the County.




Project Study Area – Southwest Snohomish County, Washington, USA

All new data are projected on State Plane Washington_North_FIPS_4602_Feet coordinates with a horizontal datum of NAD83 to be commensurate with all County data.

## Remote Sensing Data Sources

### Satellite Imagery

The project uses the best available high resolution satellite imagery data from the Digitalglobe Quickbird2 satellite. The imagery area of approximately 221 square miles of Southwest Snohomish County was collected in March and May 2005. The Quickbird2 scenes available at these times are the most cloud free. The imagery data consists of a panchromatic band with 60cm (2ft) ground resolution and the four multispectral bands with 2.4m (8.1ft) ground resolution, including a near infrared bandwidth (760-900nm). The imagery is provided in 11 bit formatted to 16 bit digitization allowing for up to 2048 levels of gray scale. All imagery is orthophotorectified using the digital elevation models derived from the two sets of LiDAR data.

DigitalGlobe Inc. Quickbird Satellite Images of approximately 221 Square Miles of South/Central Snohomish County, panchromatic (1 band, 60 cm) and multispectral (4 bands, 2.4 m) imagery (not pan-sharpened), with second generation orthorectification

- Satellite Imagery: QuickBird imagery from the scenes and dates mentioned above.
- Bit Depth: 11-bit converted to16-bit
- File Format: GeoTiff 1.0
- Spatial Resolution: 60cm for panchromatic band, 2.4m for multispectral bands (original sensor spatial resolutions).
- Projection: State Plane Washington_North_FIPS_4601_Feet
- Datum: NAD83
- License Type: Civil Government Products
- Resampling Kernel: 4x4 Cubic Convolution
- Contrast Enhancement: DRA off/ No Color Correction

Quickbird Image Catalog ID Numbers:

1010010004146F01
1010010004146F02
101001000434F202

These images were delivered orthorectified to Snohomish County Orthophotography.

## Snohomish County Aerial Orthophotography

Specifications for Snohomish County 2002 and 2003 Digital Orthophotos:
Snohomish County 2002 Orthophotos

- 1-foot pixel resolution
- Color rectified aerial photos of Southwest Snohomish County
- Date Flown: June 11, 2002 – June 13, 2002
- Sun Angle: 35 to 50 degrees
- Nominal photo scale: 1:17,000
- Horizontal accuracy: +/- 5ft
- Camera focal length: 6in

Snohomish County 2003 Orthohphotos

- 1-foot pixel resolution
- Color rectified aerial photos of North and Eastern Snohomish County
- Date Flown: Sept 13, 2003 (Westerly ¾ of County) and Sept 24, 2003 (Easterly ¼ of County)
- Sun Angle 38 to 40 degrees
- Nominal photo scale: 1:17,000
- Horizontal accuracy: +/- 5ft
- Camera focal length: 6in

## LiDAR Imagery

The Light Detection and Ranging (LiDAR) data used for the project comes from two sources.
The first source was acquired by King County for a local sewage treatment construction project and covers a significant portion of Southwest Snohomish Count.
It was acquired in 2003 with a horizontal accuracy estimate RSME (Root Mean Square Error) of 1.8m (5.9ft) and a vertical accuracy estimate from 58.8cm to 117.9cm (2ft to 3ft).

The second LiDAR source was provided through contract by Snohomish County and collected in April/May 2006 with a horizontal accuracy of 30cm (1ft) and a vertical accuracy of 15cm (0.5ft). At this time additional LiDAR data to complete western Snohomish County was acquired for an area of approximately 249 square miles. This data was ordered by Snohomish County specifically for use in the Environmental Mapping Project and subsequent citizen application.

- Laser Wavelength - 1.064um
- Pulse Rate – 40kHz
- Typical Flying Height 1000m
- Swath Width - 350 m
- Swath Overlap – 50%
- Typical Resultant Point Density – 2pts/Sq. m
- Camera focal length: 6in

## LiDAR Derived Digital Elevation Models (DEM)

The DEMl for the new LiDAR data arrived as Arc export Grids and Hillshade files. Complete mosaics were then assembled from these files.

The LiDAR data is processed in two different batches, one each for the King County LiDAR data and for the newly acquired LiDAR. Although the accuracy of the latter is considerably greater, the metadata for both data sets supports sufficient accuracy for the purposes of this model building project. Due to the extreme density of these files the derivative DEMs were constructed using a 6ft by 6ft pixel size. The previous best available DEM was based upon the 10m USGS grid.

## GIS Data and Other Reference Sources

The following sources are used by Public Works-Surface Water Management (SWM) and Planning and Development Services (PDS) GIS staff to evaluate newly generated LiDAR streams. These reference sources are listed in order of their preference for use in the procedures outlined in the next section.

### Subdivisions, Plat Plans, and Critical Area Site Plans (CASP)

A Critical Area Site Plan is used to designate and record native growth protection areas and other environmental restrictions (e.g., wetlands and streams) for subdivisions, plat plans, and residential or commercial development. A PDS Land Use Division Biologist verifies the location of all native growth protection areas (NGPAs), and insures that these areas designated for permanent protection are accurately identified on binding site development plans (subdivisions or plats) and residential/commercial site plans. These reviews are not located by GPS.

Spatial Accuracy of Data – Although plats are surveyed and drawn in assumed or real world coordinates, they are submitted to the County in paper format. Making these plats accessible in GIS is a time consuming process that requires scanning of the plat. The original scanning is conducted by the County Auditor as part of recording process. The raster TIFF images of plats are available from the recorded auditor's files. Using ARCGIS georeferencing software from ArcMap, analysts georeference each individual plat to state plane coordinates. These are then referenced to their corresponding points from the Assessor's Parcel Database. The georeferencing typically uses four identifiable points from the plat.

Drainage inventory information from plats is not available in digital form, however, the Assessor's parcel layer does have all subdivision lines, parcels, common areas, and native growth protection areas associated with plats.

Regulatory Steam Types – PDS Land Use Division Biologists also verify the stream type and wetland classification. This verification is used to determine downstream stream type which may extend beyond an individual parcel boundary.

### SWM Drainage Inventory

As part of the Snohomish County Drainage Needs Report Project (December 2002), SWM conducted a GPS inventory of constructed and natural drainage features within unincorporated urban areas of the County.

Spatial Accuracy of Data – As part of the Drainage Needs Report Project, SWM uses survey grade real time GPS units to locate and attribute catch basin and drainage features in the field. These GPS units have a horizontal accuracy of ± 2 cm in.1ft) and a vertical accuracy of ± 2cm-5cm (.8in to 2in). In some areas, GPS units with sub-meter accuracy were used.

The spatial accuracy of the SWM drainage inventory data is high. GPS inventory staff follows set procedures for collecting inventory data and cross sections on naturally occurring defined stream channels. All DEM created hydrology is adjusted to route through drainage inventory culverts where a stream crosses a road.

Regulatory Steam Types – Although SWM staff inventoried and collected cross sections on a number of naturally occurring streams, staff did not type the streams.

### WADOT Culvert Inventory

Spatial Accuracy of Data – The Washington State Department of Transportation (WADOT) uses GPS units to inventory culvert locations, culvert approaches, and catch basins throughout Washington State. These GPS units are accurate to ± 2 meters. WADOT inventory provides information on culverts on state highway right-of-way that are inaccessible to SWM inventory staff. As a result, the WADOT Culvert Inventory is used to help supplement spatial location of streams when they cross state highways.

### Adopt-a-Stream Foundation South County Culvert Inventory

Spatial Accuracy of Data – The Adopt-A-Stream Staff (AASF) uses GPS units to inventory culvert locations throughout their study areas. These GPS units are also accurate to ± 2 meters (6.5ft). AASF is able to access culverts on private property that the SWM inventory staff can not access. As a result, the AASF South County Culvert Inventory is used to supplement spatial location of streams in areas where there is no GPS inventory from Snohomish County.

Regulatory Steam Types – The AASF staff collects information of fish usage and fish passage information to help in supporting stream type.

### Snohomish County Stream and Wetland Inventory

Beginning in 1985 and continuing through 1990, Snohomish County conducted a stream and wetland inventory in the western portion of the County. Uncontrolled aerial photography, National Wetland Inventory maps, Soil Conservation Service maps, and Washington Streams and Salmon Utilization data were used to identify stream corridors and probable wetlands. Field biologists walked streams and examined wetland vegetation to confirm that the wetlands were correctly identified on the maps.

Spatial Accuracy of Data – The Snohomish County Stream and Wetland Inventory was mapped using 1984 aerial photography of the County as a base. The scale of the annotated photography was 1:4800, although, it was never converted to orthophotography. These surveys were later georeferenced in ArcInfo by 2003. Even though stream and wetland locations are considered approximate, the streams correlate well with DEM generated hydrology.

Regulatory Steam Types – The County used a different stream typing system at the time of preparing the Stream and Wetland Inventory maps. The original tabular field sheets often contain specific information on fish usage or other information that can be used to confirm stream typing under the current system.

### Personal Communications with SWM or PDS Staff

Existing SWM and PDS staffs (e.g., stewards, planners, biologists, and habitat specialists) have first hand knowledge of specific stream reaches and may have field knowledge of fish usage, fish passage, and can corroborate existing stream type or help identify stream type on DEM generated streams.

## Stream Model

### Objectives

1. To improve the spatial accuracy of existing Snohomish County Hydrography data.
2. To model potential locations of previously unknown streams.
3. To provide for this new stream data to be compared at an increased level of detail (higher resolution) to other County geographic features (parcel boundaries) and make these available to the citizens of the County.

### Process

The hydrologic analysis is developed using the digital elevation models from the two LiDAR data sets in combination with ESRI ArcGIS software. The Public Works-Surface Water Management (SWM) division uses the software extension called ArcHydro as a set of tools that work within the ArcGIS software environment and act as a data model for water resources. The ArcHydro Data Model consists of five main components, drainage, hydrography, network, channel, and time series, which describe different components of natural water systems. The focus, for this project, is on the drainage component of the model which delineates hydrology based on an analysis of land surface topography derived from the LiDAR.

In order to generate the hydrology from any LiDAR dataset, a series of sequential steps, outlined by the ArcHydro toolset, are used. Each step contains functions that automate the process of delineating drainage areas and stream networks, and builds upon the output from the previous step. The key user input, defined by the intricate nature of the project area of interest, is the stream definition threshold.

The stream definition threshold defines the threshold drainage area that flows into a specific stream or watercourse. This determines the extent of the resulting stream network. A stream definition threshold that is too large does not adequately depict all possible watercourses. A stream definition threshold that is too small depicts many small tributaries that may be supported by the topography but are not realistic ground networks.

A literature review indicates there is no definitive rule for determining this stream definition threshold input. In part, this is due to the high level of variability that is encountered in topographic relief. To ensure that all potential watercourses are captured, a series of varying stream definition thresholds are generated for the model. Stream definition thresholds tested include; 0.005 $km^2$ (1.2 acres), 0.0075 $km^2$ (1.8 acres), 0.009 $km^2$ (2.22 acres), 0.034 $km^2$ (8.4 acres), 0.05 $km^2$ (12.4 acres), and 0.1 $km^2$ (24.7 acres). Previously, the Washington State stream model incorporated a stream definition threshold of 0.21 $km^2$ or 52 acres.

A comparison of the resulting hydrology data using the various stream definition thresholds with existing county hydrology data is made to determine the most reasonable threshold. Based on this assessment 8.4 acres has been chosen as the most likely stream definition threshold. The goal is to capture existing county hydrology as well as any potentially realistic tributaries that have not been previously mapped.

The digital elevation model, the basis for this analysis, has limitations especially in areas that have become urbanized and there is a reduction in natural topography. In addition to the automatic generation of a hydrology layer by ArcHydro, there is a need to manually edit some stream networks in areas of low relief. Additional interpretation is also needed, as in some cases where a roadbed with a culvert may alter the natural topography and hence the natural drainage network.

## Procedures

In Southwest Snohomish County urbanization results in altered topography through development. The reduced relief (i.e. raised roadbeds, graded areas, etc.) introduces error in the modeled hydrology. In order to realize more accurate data, all stream arcs generated are verified and edited according to the following guidelines.

1. A stream definition threshold is selected and ArcHydro generates new hydrologic features from the digital elevation model. In this case eight steps of the ArcHydro Model are incorporated to process for drainage lines.
2. All generated stream arcs are evaluated against pre-existing sources and datasets that could verify the existence of a stream. (see below) A hierarchy of evaluation is established for verifying these stream arcs.
3. To increase spatial accuracy, all verified stream arcs are aligned to corresponding survey quality (GPS) Surface Water Management (SWM) Drainage Inventory points such as stream thalweg points or culvert locations.

4. Any stream arc that cannot be verified against the proxy data, but is deemed to be potentially significant based upon the LiDAR data, is flagged and marked to be field checked. It is also left un-typed/unclassified.
5. Any stream arc that cannot be verified using the proxy data and/or is not deemed significant based upon the LiDAR data is then deleted.
6. All stream arcs are visually generalized and smoothed in ArcGIS to improve cartographic depiction and reduce pixel edge effects resulting from the original LiDAR raster data.
7. All significant stream arcs are typed according to the pre-existing County hydrology data, or County permit data from the Critical Area Site Plan database. Where previously unmapped streams are evident the typing occurs only when ground based data is available.

Several existing data sources, including ground based sources, are compared to the remotely sensed data and evaluated in turn. The above mentioned hierarchy of evaluation (guideline #2) is illustrated here in descending order of importance.

For DETERMINATION OF STREAM EXISTENCE:
1. The LiDAR Derived Digital Elevation Model (DEM) plus ArcHydro software determines the location of the valley bottom and hence the existence of a potential stream.
2. Any stream located from a georeferenced surveyed subdivision or plat plan is then compared and confirms existence of the LiDAR stream data.
3. Stream data obtained from SWM drainage needs reports (with GIS) of December 2002 is used next to verify streams.
4. Any additional information from the Washington Department of Transportation (WDOT), Adopt-A-Stream Foundation (AASF), or Snohomish County Stream and Wetlands Inventory next offers corroborating evidence, however, spatial accuracy is considered approximate. No cases were found where WDOT or AASF data indicated the presence of streams that were not found in 1-3 above.
5. The geography acquired from the LiDAR imagery is visually compared to County 2002-2003 orthophotography and to the high resolution satellite imagery.

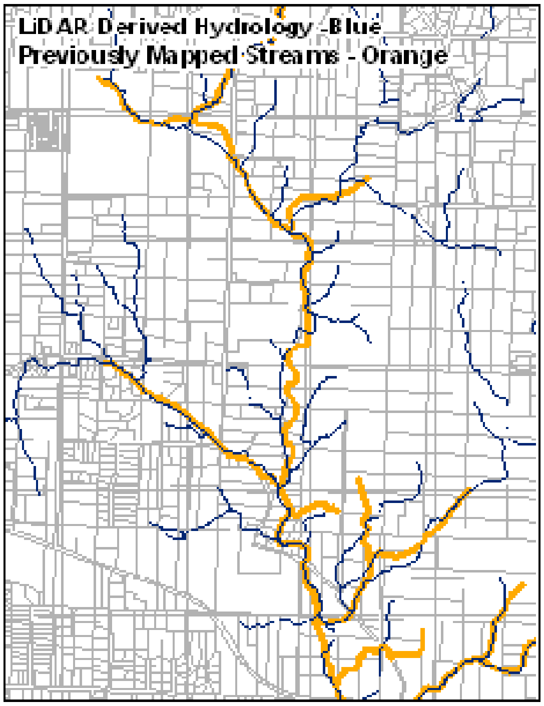
For SPATIAL ACCURACY
1. The LiDAR DEM plus ArcHydro software determines the location of the valley bottom and hence the potentially correct stream channel location.
2. Global Positioning System (GPS) Points obtained from SWM drainage inventory are now used to modify the spatial accuracy .The accuracy of these points is +/- 2cm to 5cm (0.8in to 2.0in.

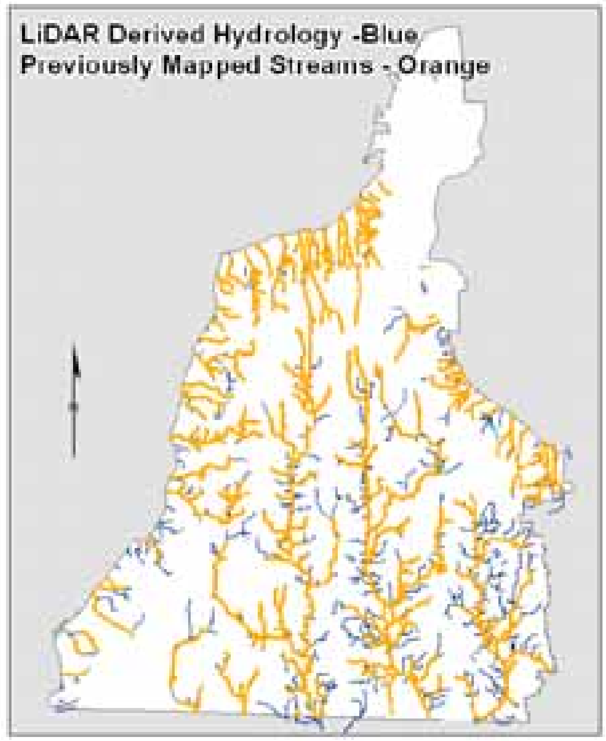
For STREAM TYPING:
1. Any stream typed from a georeferenced surveyed subdivision, plat plan, or residential critical area site plan determines the typing of that stream as derived from the LiDAR data.
2. Typing from the previous Snohomish County Hydrography typing, if not included in #1 above, is then applied to the LiDAR streams
3. SWM, WDOT, and AASF inventories then apply if not contradicted by the above datasets.

Snohomish County Stream and Wetland Inventory and/or personal communication with SWM or PDS staff may also offer corroborating evidence.

Stream types are compiled in both the previous system of stream typing and the newly adopted stream typing system. Stream types are transferred from the previous Snohomish County Water Courses Data Set in the following manner.

| PREVIOUS STREAM TYPING | RECENTLY ADOPTED NEW STREAM TYPING |
| --- | --- |
| Type 1 streams | = Type S - Shorelines of State Importance-Fish Bearing |
| Type 2 and 3 streams | = Type F - Fish Bearing |
| Type 4 streams | = Type Np - Perennial Non-fish |
| Type 5 streams | = Type Ns - Seasonal Non-fish |
| Type 9 streams | = Type U - Undefined |




A comparison of the previously mapped streams with the newly modeled hydrography

## Data Documentation

As the stream data layer is compiled attributes are added to the data that outline the source, types, and reliability. The sources mentioned above are outlined in the feature class metadata and data dictionary for this layer.

### Stream Layer Attributes

| Attribute Field | Description |
|---|---|
| SOURCE1 | Primary Supporting Data Source. |
| SOURCE2 | Secondary Supporting Data Source. |
| SOURCE3 | Tertiary Supporting Data Source. |
| SOURCE4 | Additonal Supporting Data Source. |
| SOURCE5 | Additional Supporting Data Source. |
| COMMENT | How the stream segment was modified. |
| TYPE | DNR Stream Typing. |
| W_TYPE | Possible New Stream Typing. |
| PARCELID | ID of Parcel if a CASP or Plat was used as a data source. |
| NEEDSFLDCH | Marked yes, if the stream segment needs ground truthing. |
| NAME | Name of Stream. |
| LENGTH | Length of stream segment (ft). |

Of note, is the inclusion of attributes for the previous stream types and newly adopted new stream types (yet to be adopted or not adopted).

# Slopes Greater Than or Equal to 33 Percent Model

## Objectives

1. To improve the spatial accuracy of the existing Snohomish County slopes data.
2. To model any potential slopes greater than or equal to 33% that may have been previously unknown.
3. To provide for more precise location of slopes greater than or equal to 33% in relation to other geographic features (parcel boundaries) and make these available to the citizens of the County.

## Process

Slope data for Snohomish County currently exists for slopes greater than or equal to 33%. However, this slope data was generated from the USGS ten meter digital elevation model (DEM). This has served well, but for smaller areas of slope or areas of relative low relief a higher resolution, denser DEM is needed. Also, there is little precision in the location of the slope boundary.

With the acquisition of LiDAR data and the subsequent development of digital elevation models that are at least an order of magnitude denser, the creation of slope data becomes more refined and more definitive.

ESRI software ArcInfo 9.1 workstation is used to analyze the LiDAR DEMs and develop the slope dataset. Slopes are generated from an Arc Macro Language (AML) program using the two sets of LiDAR imagery digital elevation models. (These two data sets are described in this document under LiDAR Imagery.) The two newly generated slope data sets are processed and stored separately because of the differences in accuracy of the original LiDAR. They are converted to polygons and assembled into an intermediate data layer. They are processed to remove slopes within Rights of Way and slopes with less than ten foot vertical rise.

## Procedures

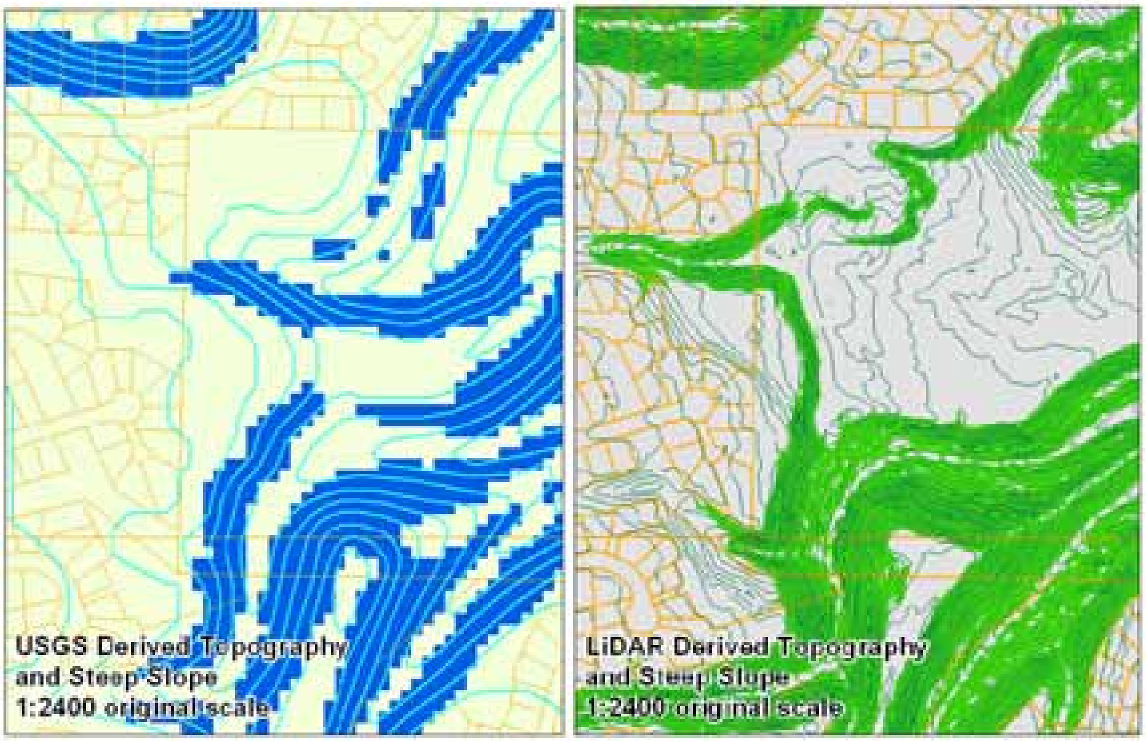
The development of slope data using ArcInfo software is relatively straight forward. Using ArcGIS it becomes even more so. The ArcInfo method is chosen simply because a program had been developed previously and was ready. ArcGIS software will likely be used for additional iterations. The following steps outline this procedure:

Department of Information Services analyzes the LiDAR imagery and produces a derivative GIS digital elevation model (DEM) for the two sets of data. The data itself is much more data dense than the final layer which is based on a 6ft by 6ft pixel size. Once this GIS GRID is produced ArcInfo is able to carry out further analysis as follows:

1. This data is analyzed by Planning and Development Services (PDS) using the Grid module in ArcInfo 9.1 workstation. The slope percentage is calculated for each raster cell and only those with a slope of 33% or greater are used to generate the layer..
2. The raster cells that remain are then grouped by connectivity.
3. The height of the slopes is then calculated and slopes with a rise of less than 10ft are selected within the AML program and then removed. The 10ft rise is the minimum regulatory height for consideration in the permitting process.
4. The raster data are then converted to polygons
5. Next the rights of way (ROW) data from the County ILR parcel data set are used to remove the slopes within in the ROW area. The ArcInfo 'erase command' is incorporated within the AML. To achieve this.

The result is a polygon layer that appears jagged with edges that form a stair step pattern. No attempt to remove this edge effect is made. Generalization of this boundary was considered, however, no improvement in accuracy can be achieved. This may be considered at a later date to improve cartographic depiction for the end application.

The initial derived DEM Grid for the new LiDAR data set did not abut or overlap the King County data in a few places. Consequently, these places did not facilitate connectivity (2 above). An overlap of 200ft has been ordered from the vendor and will be incorporated into the model upon arrival.



A comparison of the 10 meter USGS DEM derived data and data from the recently acquired LiDAR DEM

### Data Documentation
The opportunity for additional slope categories is now available. Several test data sets to produce a broad spectrum of slope data are being developed. It is expected that a variety of uses can take advantage of the data set.. However, for this iteration, only the classification of greater than or equal to 33 percent slope is created.

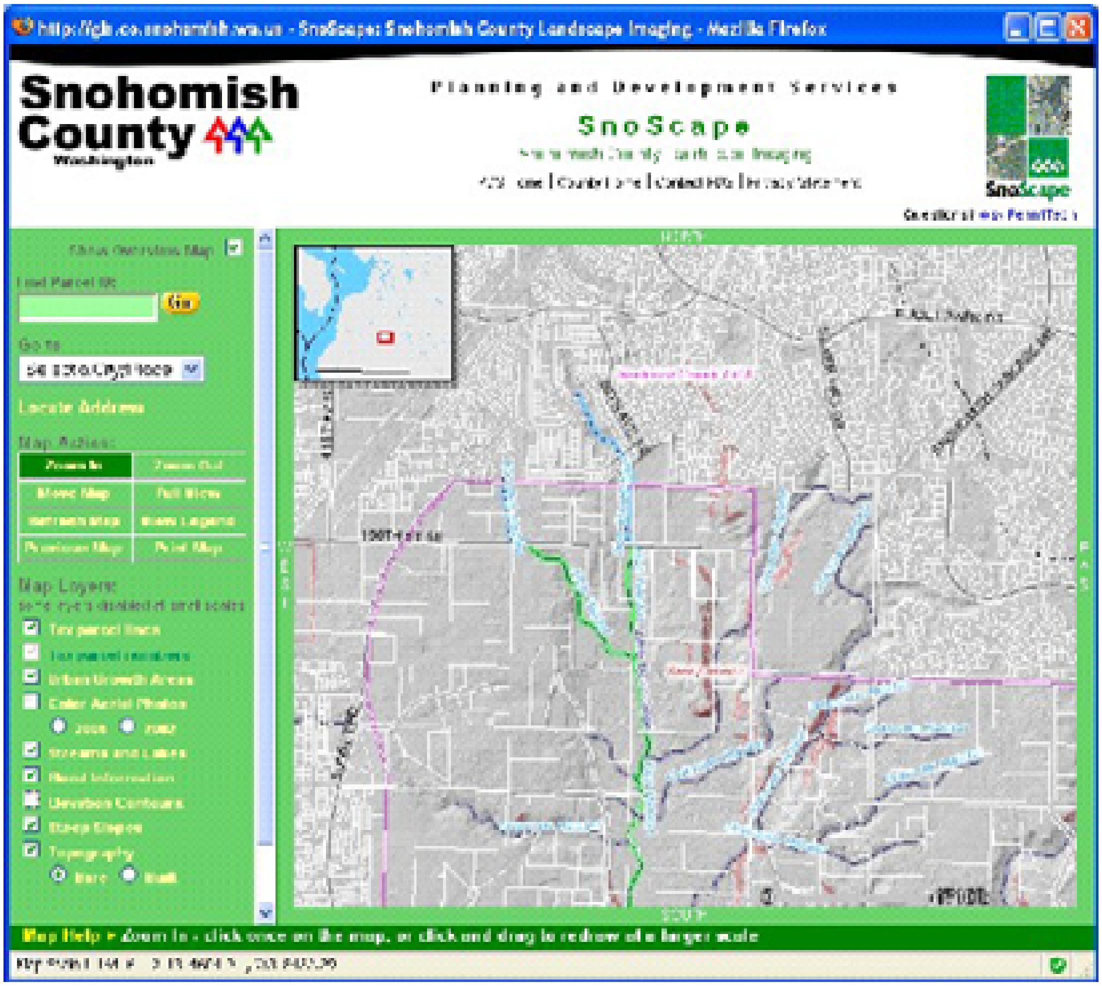
### Slope Layer attributes

| Attribute Name | Description |
|---|---|
| OBJECTID | Object identifier |
| GRID_CODE | field used in previous calculation |
| ZONE_ | field used in previous calculation |
| SLPHT_FT | average slope height of polygon |
| Shape | type of data (polygon) |
| SHAPE.area | area of polygon in square feet |
| SHAPE.len | perimeter length of polygon |

# Citizen Website Application

**SnoScape: Snohomish County Landscape Imaging**

http://gis.co.snohomish.wa.us/maps/snoscape/index.htm




### Objectives

1. Make available to the citizens of Snohomish County the best possible models of the types and locations of key landscape features and display them in relation to parcel boundaries.

2. Provide for citizen review of possible areas of concern in property development, such as areas on or near their property, and enable informed decision making.

3. Make permitting process more efficient by using web to confer with citizens.

### Approach and Process

The county permitting and land use specialists use a variety of data sources, maps, and computer applications to review landscape characteristics and to make permitting and land use decisions. Some of these data sets and maps are relatively new; some are older. They have different levels of detail and different levels of accuracy.

Data created from the environmental mapping project will be a new resource for permitting and land use specialists, developers, and citizens. Providing access to the data via the Internet has the advantages:

- Easy map navigation
- Ability to view landscape data at large and small scales
- Single-source of information for all users
- Internet connections are common and readily available to the general public

SnoScape is the fifth ArcIMS-based application to be released by Snohomish County. Maps of property information, permits and zoning, registered sex offender locations, and groundwater data can be accessed online.

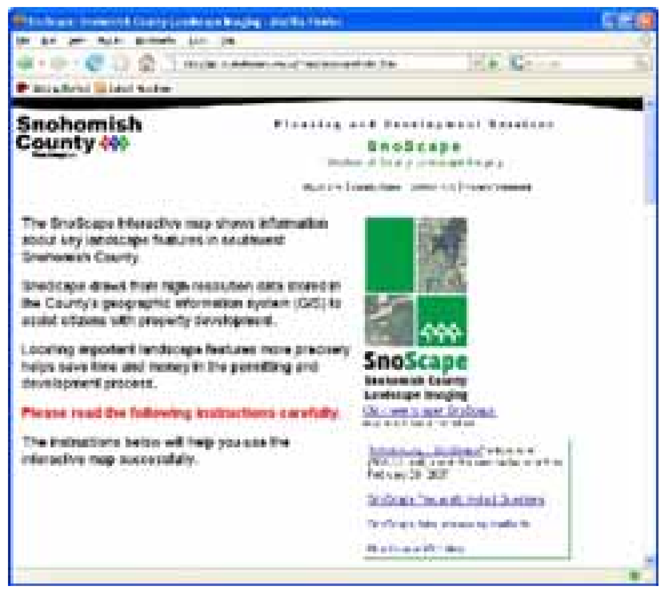
SnoScape interactive map uses much of the same configuration as previously developed applications, including scale-dependent display, navigation system, interactive tools, and address location. By re-using code and focusing efforts on new data and functionality, the overall time and cost to release SnoScape was less than it would have been otherwise. In addition to lower costs, users can obtain information more easily since the application has a familiar look-and-feel.

GIS data layers used in prior maps include:

- Assessor parcel boundaries/row
- Assessor parcel numbers
- Flood Hazard information
- Lakes and other water bodies
- Map notation, grids, scales, etc.
- Additional place names as scale increases
- Aerial photo viewer

The new data layers in SnoScape are:

- Stream Locations and Typing
- Slopes Greater then 33 Percent
- Topography represented as five foot contours
- 2006 aerial orthophotography
- Shaded relief (bare-earth and built environment)




Launch page with links to documentation and instructions

New data layers may be included in other applications, however, SnoScape is developed specifically to assist citizens with the location of landscape features which may affect the development of their property. Also, because the scope of the application (and some data) is limited to a portion of Southwest Snohomish County and limited to these specific landscape features (streams, slopes, and topography) the decision was made to develop the application separately from other County web applications.

## Application Development

Snohomish County has developed several interactive maps using ArcIMS technology. The applications are currently running on two Hewlett-Packard DL380 servers with dual 2.4 GHz CPU, Windows 2000 Server OS, running IIS and Tomcat, drawing GIS data from another box running ArcSDE SQLServer geodatabase.

Working from an existing application framework enabled a prototype to be developed within a week or two, incorporating new graphics, names, links, using ArcIMS and descriptions. Project participants were able to view the data in the web browser at an early stage, and demonstrate specific features to the County Executive, County Council and other project sponsors.

GIS data and application files were developed and stored on test servers having similar specifications as the production environment. Testing and evaluation was done by all members of the project team using internal web links to the test application.

**Data Development**

GIS data development was done by GIS Analysts in Public Works, Planning and Development Services, and Information Services, processing source information into workable GIS data sets. Some data sets needed additional processing to be used on the web, mostly due to large file sizes causing slow responses from the ArcIMS application.

For example, five-foot contours generated from the DEM in ArcGIS were extremely dense and required smoothing to display on the map within a reasonable time. By generalizing vertices at 5 feet, contour data was reduced from 145Mb to 60Mb in size, without losing the essential contour trend line. Drawing speed subsequently increased from 8 seconds to 1 second.

Furthermore, 5-ft. contours obscured most other map features when viewing areas larger than a few parcels. To increase response time and improve cartographic display, SnoScape displays contours at a 20’ interval above 1:2,400 scales, using a subset derived from the 5’ contour data. Data derivatives such as this are best created and refreshed using fully-automated processing.

GIS data developed for SnoScape is fully attributed with technical information, but did not originally have descriptive attributes with user-friendly values. ArcIMS has the ability to place text labels dynamically on the map using feature attributes. Labeling is an effective way to identify features on the interactive map, so an attribute (named ‘LABEL’) was added to the database to identify basic features such as ‘Steep Slopes’ polygons and ‘Fish Habitat’ streams.

Data used in final production were copied from the project work space to production servers accessible to the World Wide Web.

**Marketing**

SnoScape was introduced to the citizens of Snohomish County at an early morning meeting of the County Executive and local developers. A tri-fold brochure was produced to describe the application and identify the web address. Press releases prompted an article in the local newspaper, and the County home page featured the site’s release for the first week.

Over 100 external users (citizens, developers, etc.) accessed the site on the first day, and nearly 100 County staff accessed the site via internal networks. On average, SnoScape was producing a map every 10 seconds during its debut.

## Conclusions and Future Considerations

The use of remote sensing, and LiDAR in particular, has provided for significant cost savings to Snohomish County. The original estimates for a ground based survey of hydrography and slopes for our study area were for $13.2 million. The budget for this project was not to exceed $500 thousand which included the collection of LiDAR for a significant portion of the County. The City of Everett also partnered with the County for this LiDAR acquisition. The management, analysis, interpretation, review, and development were all achieved by Snohomish County staff from three departments, Public Works, Planning, and Information Services This project was truly a team effort.

Apart from actual ground surveys of individual parcels or projects, the data previously available for both streams and slopes via citizen web site application and/or hard copy maps were based upon USGS 1:24000 topography (20ft contours vs. the 5ft contours derived from the LiDAR). The location accuracy of the new data is considerably improved. In total 142 new stream miles were modeled. In part, this is due to better stream meander location. However, many of these new stream miles have been verified as actual streams (previously unmapped). New slopes greater than or equal to 33 percent had a net increase of 1690 acres which also accounts for a removal of 707 acres. These new streams and slopes may affect 4881 parcels. It is to be remembered that for final development, the landscape models produced using these methods are still subject to evaluation and/or validation by on site field staff.

Additional data layers being considered for modeling and inclusion are:

- Wetlands and Water Bodies
- Critical Aquifer Recharge Areas
- Fish and Wildlife Habitat Conservation Areas
- Geologically Hazardous Areas
- Emergency Management Related Areas

As new data is acquired and analyzed, it is anticipated that these same methods will be used to extend the model to the remainder of Snohomish County.

The data models developed are non-regulatory and are intended for information purposes only. However, this analysis can help citizens and permit staff to determine if any additional review may be needed to consider a property for development. In the early evaluative stages of the permitting process, previously unmapped features may appear in this model thus alerting a citizen to increased complications for land development. If a citizen has knowledge early in the process he or she will be better equipped to make decisions and choose options. The County will also be able to provide better service. The scope and time frame for this project precluded the incorporation of additional data layers. Additionally, there is a considerable library of historical information in existence that can be added to this data as time and resources allow. As unmapped sources are identified and corroborated the reliability of the model builds in stature. Protocols are now being developed for the ongoing updates and additions from field staff as they conduct new field reviews.

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