DRAFT MEMORANDUM

Date: November 7, 2014
To: Structure Survey Technical Committee
From: Watershed Science & Engineering (WSE)
Cc: Bob Montgomery, Anchor QEA
Re: Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species - Description of Structures Database/Methodology for Finished Floor Estimation

Introduction

To help map and quantify flood hazards in the Chehalis River basin, a database of structures in the floodplain was created. As used herein the term "floodplain" is defined as the 500-year floodplain (plus a 200-foot buffer) along the main stem Chehalis River as determined from analysis of previous Watershed Science & Engineering (WSE) hydraulic modeling for the Chehalis River Basin Flood Authority (WSE 2012). The resulting structure database is a Geographic Information System (GIS) layer containing spatial data (roofline delineation of each structure) and relevant information (e.g., land-use classification, finished floor elevation, assessed value, etc.) for each structure in the floodplain. This information will be used to determine where the greatest flood risks are in the basin and where to focus flood damage reduction strategies.

Background Data

The following sources of information were used in the development of the structure survey database:

- Lewis County Tax Assessor Data (February 2014)
- Thurston County Tax Assessor Data (September 2013)
- Grays Harbor County Tax Assessor Data (September 2013)
- Light Detection and Ranging (LiDAR) Data (various sources, data collected 2009 - 2012)
- Aerial photos (NAIP 2011)
- Lewis County roofline delineation data (December 2013)
- Google Earth and Google Street View

The data listed above (with the exception of Google data) were imported into a GIS database using ESRI ArcGIS version 10.1. These data were then added to and manipulated as described in the following paragraphs to create the finished structure survey database.

Delineating Structure Outlines

All visible structures in the Chehalis River floodplain were delineated in GIS. Rooflines of structures in Grays Harbor and Thurston Counties were hand-delineated by WSE using National Agriculture Imagery Program (NAIP) aerial photographs from 2011 as well as more recent (2013) aerial photographs available in Google Earth. Care was taken to use the most current high resolution aerials available at all locations to ensure that all current structures were included. Lewis County had previously contracted with a consultant to collect roof outlines of all structures in that County, therefore WSE did not hand delineate any structures in Lewis County, but rather obtained a GIS shapefile of structures from the County and simply selected all structures that were in the Chehalis River floodplain. The Lewis County structures were then merged with the WSE delineated structures for Thurston and Grays Harbor Counties; a total of 9,087 structures were thus delineated.

Creating the Database

GIS shapefiles include a table of attributes that are associated with the spatial data. The database created for this study includes all of the attributes for each parcel as taken from the Grays Harbor, Thurston, and Lewis County tax assessor databases. These attributes include information about each parcel's ownership, land use, condition, acreage, land value, and structure improvement value among other data. All attributes from the parcel databases were assigned to each structure on the parcel (the improvement value was subsequently subdivided amongst the structures on each parcel as described in the following paragraphs).

Each structure delineated in GIS was then viewed using Google Street View and the NAIP aerial photographs. Based on this visual examination, structures were classified as "valuable" (for example schools, residences, businesses, etc.) or "not valuable" (for example garages, sheds, park shelters, carports, etc.). This information was added as an attribute in the database. A total of 5,512 structures (of the 9,087 identified) were classified as valuable.

Finished Floor Estimation

To help quantify the number of structures inundated by flood events, and to what extent they are inundated, an estimate of the elevation of the lowest finished floor of all valuable structures in the floodplain was needed. These were obtained using a combination of methods including: topographic survey, estimation using remote sensing techniques, and estimation using average height above ground. Each of these methods is described herein.

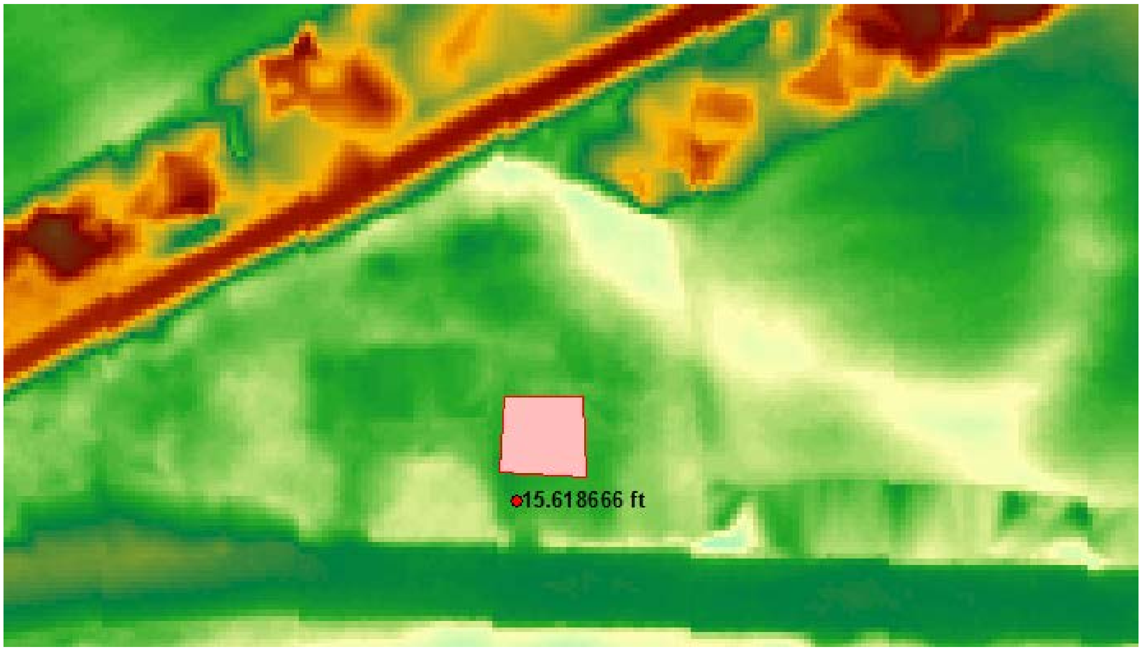
Field survey is the most accurate method for determining finished floor elevations. However, field surveying every valuable structure within the floodplain was not feasible given time and budget constraints of this project. Therefore field survey was used primarily to validate an alternative data collection technique. A total of approximately 130 residential structures in the Centralia area were field surveyed by WH Pacific and used to test the remote sensing methodology described herein. Field survey was also used to obtain highly accurate finished floor elevation estimates for approximately 50 of the highest valued structures in the floodplain.

As noted previously, field surveying every valuable structure within the floodplain was not practical. Therefore, an alternative method was developed that used available LiDAR data and free, online imaging available through Google Street View. The first step in this method consisted of estimating a "finished floor height above ground" by zooming in on a structure, identifying the number of steps (if there were any) leading to the front door, and using this information to determine an approximate height of the finished floor relative to the ground near where the estimate was made. In general, each step leading up to the front door of a structure was assumed to have a height of 7 inches and thus the height of the finished floor was computed as 7 times the number of steps. If a door threshold was visible, 1 to 2 inches were added to the finished floor height estimate. Other observations were used to refine these estimates based on the estimator's judgment such as if no steps were seen but there the foundation of the building was visible or if there were apparent differences in the sizes of steps. For example, if one or more of the steps leading up to a front door was significantly smaller than the rest, the estimate was adjusted to account for this. Figure 1 shows the Google Street View for a house for which the finished floor was estimated using this method. The house in Figure 1 has a finished floor height above ground of 37 inches ([7 inches x 5 steps] + 2 inches for the door threshold = 37 inches or 3.08 feet).

Figure 1
Street view of a house in Grays Harbor County as clipped from Google Street View

Once a finished, floor height estimate was made for a structure, an associated point was created within a new GIS shapefile. The point was placed as close to the location where the height estimate was made using a combination of aerial imagery and LiDAR. The ground elevation at each of these points was then determined from the LiDAR data set and added to the finished floor height to obtain an estimate of the finished floor elevation of the structure. Figure 2 shows the roofline delineation for the house in Figure 1 and the point where the ground elevation was taken from the LiDAR. The label near the point gives the LiDAR elevation. This house thus has an estimated finished floor elevation of 15.62 feet + 3.08 feet = 18.7 feet.

Figure 2
Roofline Delineation for the House in Figure 1 and Location at Which the Ground Elevation was Estimated from the LiDAR (shown as the background in this figure)



Before applying the Google Street View methodology to the entire floodplain, it was implemented in two small areas within Centralia. Finished floor elevations were estimated for a total of 164 structures using the Google Street View methodology. Afterwards, the finished floors for a random sampling of 81 of these structures were field surveyed. The differences (errors) between the field-surveyed and the estimated finished floor elevations were computed and statistics were calculated. The mean and standard deviation of the errors are 0.02 foot and 0.50 foot respectively. This means, using this methodology, approximately 68% of the estimated finished floor elevations would be within one half foot of the actual finished floor elevation and 95% of the estimated data would be within one foot of the actual value. The maximum and minimum differences seen in the data are +1.6 feet and -1.6 feet respectively. These statistics encouraged the implementation of this methodology for the entire floodplain. Table 1 shows the results of the statistical analysis of the differences between the field-surveyed and the estimated finished floor elevations.

Table 1
Analysis of Differences (field survey versus remote sensing)

DESCRIPTION	VALUE		NOTE
Mean	0.02	foot	
Standard Deviation	0.50	foot	
Maximum	1.59	feet	
Minimum	-1.64	feet	
Mean ± 1 Standard Deviation	-0.48	0.51	68.3% chance of being within this range
Mean ± 2 Standard Deviations	-0.97	1.01	95.5% chance of being within this range
Mean ± 3 Standard Deviations	-1.47	1.50	99.1% chance of being within this range

Finished floor elevations could only be estimated using this approach for structures that were visible in Google Street View. Many structures were obstructed by vegetation or fencing, sat too far away from the road to see clearly, or were simply not within the extents of the Google Street View imagery. In total, finished floor estimates were made for 2,704 structures using this approach and finished floors were field surveyed for 178 structures meaning that finished floor estimates were still needed for 2,630 structures.

To obtain the additional finished floor elevation estimates, an approximate method was used. All structures for which finished floor estimates were obtained by field survey and/or remote sensing were grouped into four categories: residential, mobile home, agricultural, and commercial based on the assessor's data. Generally, any structure that did not fall into the first three categories was included in the commercial category. This includes schools, government buildings, park facilities, wastewater treatment facilities and other similar structures. For each category the average height above ground of all estimated finished floors was then computed. Table 2 shows the results of this analysis. As seen in Table 2, the average height above ground for residential structures was 1.75 feet while the average height to the finished floor of commercial structures was 0.8 feet. The number of structures in each category is shown in Table 2. Also shown are the maximum and minimum heights and the median height above the LiDAR surface.

For each structure that could not be analyzed using the Google Street View approach, the finished floor elevation was estimated by adding the average height above ground by structure type to the average estimated ground elevation of the structure outline, as determined from the LiDAR data. This resulted in estimated finished floors for the remaining 2,630 structures. It is not possible to say how accurate the estimated finished floors obtained in this manner are but they are clearly less certain than those obtained by either field survey (the most accurate method) or the Google Street View approach. In general, we expect that most finished floor estimates made in this manner are within 1 to 2 feet of the actual finished floor elevation.

Table 2
Analysis of Finished Floor Heights by Structure Type (feet)

DESCRIPTION	RES	MOB	AGR	COMM	Total
Number of Structures	2062	81	67	672	2882
Average	1.75	2.04	1.36	0.84	1.52
Median	1.56	2.05	1.30	0.56	1.36
Maximum	11.49	3.77	4.54	7.94	11.49
Minimum	-1.28	-0.05	-1.04	-7.52	-7.52

Structure Value Estimation

One of the fields included in the tax assessor data is the value of improvements on each parcel (e.g., the total value of all structures on the parcel). For the current project, it is important to know the value of each individual structure rather than simply the total value of all structures on the parcel. This is because in some cases some of the structures on a parcel may be affected by flooding and others will not. To estimate the value of each structure in the database, the following approach was used:

1) The number of "valuable" structures on each parcel, as identified in the Google Street View analysis, was determined using GIS.

2) The total improvement value from the assessor's data for the parcel was then divided by the number of valuable structures on the parcel.

3) A new field titled “Value per structure” was added to the database, and the value determined in Step 2 was input into this field.

4) Non valuable structures denoted in the Google Street View analysis were assigned a value of $0 (thus keeping the total value of improvements the same as in the assessor’s database).

Final Products

The final products of the structure survey analysis include a final structure shapefile in ESRI GIS format and an Excel spreadsheet containing the GIS data and post processed summaries of the data. The GIS shapefile contains polygons representing all of the structures delineated in the Chehalis River floodplain (more than 9,000 in all). Each structure has a set of GIS attributes associated with it. Some of these attributes were obtained from the from the County assessors’ databases (e.g. ACREAGE, OWNER, ADDRESS, CONDITION, etc.); others were determined using GIS tools (PERIMETER, AREA, COUNTY, etc.), while others were determined separately in Excel and imported into GIS (e.g., the finished floor elevation for non-surveyed structures or the estimated cost of floodproofing). Water surface elevations and ground elevations at each structure were determined using a GIS tool that computes statistics for line features that overlap gridded values. For these computations, the gridded LiDAR surface and gridded water surface elevations were overlain with the GIS shapefile of structure outlines. Therefore, the minimum ground elevation, average ground elevation, and average water surface elevations represent these values along the perimeter of the structure.

The final GIS structures shapefile is titled “Chehalis_Structures_2014.” Some of the attributes of this shapefile have been described previously (e.g., finished floor elevation, structure value). The remaining attributes are summarized in Table 3. All elevation fields in the database are in feet referenced to the NAVD88 vertical datum. Attributes taken from the County assessors’ databases (e.g., LU CODE, TAXCODE, SUBAREA, etc.) are not included in Table 3. Descriptions for these attributes can be obtained from the appropriate County Assessor’s office. For purposes of this project the assessor’s data was simply joined to the final structures layer using a GIS tool. The fields were not modified, but were used as the basis for other attribute fields such as VALUE and PARCELNO.

Table 3
Description of Attribute Fields of Final GIS Structures Layer

ATTRIBUTE	DESCRIPTION
ID	Unique ID assigned to every structure. Used for GIS analyses
FF_EST_FT	Google Earth Estimated finished floor elevation. A value of -5555 indicates no estimate (non-valuable structure) and -9999 indicates no estimate (valuable structure)
FF_SURV_FT	Surveyed finished floor elevation, if available. Value of -6666 indicates no survey data available
FF_FINL_FT[1]	Final finished floor elevation estimate used for analysis
GROUND_MIN	Minimum ground surface elevation at the structure as extracted from LiDAR
GROUND_AVG	Average ground surface elevation around the perimeter of the structure as extracted from LiDAR
VALUABLE	Designation indicating if structure is valuable or not (see description above)
COUNTY	Location of structure (e.g. Grays Harbor, Thurston, or Lewis County)
PARCELNO	Parcel number obtained from the appropriate County assessor database

ATTRIBUTE	DESCRIPTION
VALUE[1]	Building or improvement value on the parcel
NO_STRUCT	Number of valuable structures on the parcel
VALUE_PER	Value per structure determined as described above
TYPE	Property type: residential, mobile home, agricultural, or commercial
WSEL_PL_05 – WSEL_PL_93	Water surface elevations corresponding to specific HEC-RAS plans. PL indicates that the plan is contained in the HEC-RAS project file Chehalis.prj
WSEL_PLAN8	Water surface elevation for the initial baseline 100-year event. This WSEL gridded surface was later updated using a refined mapping process. WSEL_PLAN8 was retained as it was the basis for calculating other data that were reported by the consultant team during the project.
PL8_MIN_FF	The WSEL for the original 100-year event minus the estimated finished floor elevation
WSEL_CL_01 – WSEL_CL_53	Water surface elevations corresponding to specific HEC-RAS plans. CL indicates that the plan is contained in the project file Climate.prj (with inflows scaled for climate change)
WSEL_SP_11	Water surface elevations for a HEC-RAS model run. SP indicates that the plan number is associated with the SmallPrj project file.
DEPTH_BASE	The depth of flooding for the baseline 100-year event
DEPTH_SP	The depth of flooding for the 100-year event with all small projects
AREA	Computed roofline area of each structure (square feet)
PERIMETER	Computed perimeter of each structure (feet)

Note: 1. Value information and estimated finished floor elevations were refined for select structures near the Chehalis airport.

The final Excel spreadsheet of structure survey data is titled “Structures_Chehalis_Floodplain_2014_Final.xlsx.” The Excel file contains exported attributes from the GIS structure shapefile. These data were then post processed to compute values such as:

1) The depth of water at each structure (WSEL_PLxx minus GROUND_MIN or GROUND_AVE).
2) The structure VALUE of all structures in the floodplain corresponding to each HEC-RAS model run.
3) The cost of floodproofing flooded structures (broken down by residential, commercial, and agricultural property type).
4) The number of structures flooded to depths of 0-1, 1-2, 2-3, 3-4, 4-5, and greater than 5 feet for each HEC-RAS run.

The Excel file also includes tabs with tabular or graphical summaries of some of the results that were reported in various technical workshops or public meetings. The file also includes a statistical analysis tab that has a template for generating additional comparisons between any two model runs including the number of structures changed from wet to dry or dry to wet and the change in flood depth at each structure. These data were supplied to WSDOT to support other aspects of the Chehalis Basin Strategy project.

Summary

A structure survey database and corresponding GIS layer of structures was developed for the Chehalis River basin. The GIS layer contains spatial data (roofline delineation of each structure) and relevant information (e.g., land-use classification, finished floor elevation, assessed value, etc.) for each structure in the floodplain. The database also contains an estimate of the value of each structure determined as described above. In addition to the GIS data a corresponding Excel spreadsheet has been developed to facilitate post processing of the data and summarization of the results. The structure survey information has been used in other analyses in the Chehalis Basin Strategy project to evaluate flood risks and determine the benefit of flood damage reduction strategies.