Greetings Hydrolink Subscribers!

Welcome to this special edition of the AASHTO Hydrolink with a focus on Light Detection and Ranging (LiDAR) and its use for Hydraulic Engineering. Use of LiDAR data in Hydraulic Engineering is becoming more common with the need for better surface models used in hydraulic modelling. Two-dimensional modelling driven by the FHWA Every Day Counts program rely on detailed surface models to yield more accurate representations of results, which requires extensive ground surveying which may be collected with LiDAR technology from various platforms such as airborne, terrestrial, or mobile in an efficient manner.

In simple terms, LiDAR is a remote sensing technology that uses pulsed laser light energy and its captured reflection(s) to measure distance. The speed of light is a known physical constant, which is used to measure the distance to an object by measuring the timing of the reflected laser (ie: distance= ½ (speed of light x time)). The utility of LiDAR was expanded when it was combined with other technologies such as the Global Positioning System (GPS) and Inertial Measurement Units (IMU’s), which allow the measurements to be spatially georeferenced into Geographic Information Systems (GIS) or Computer Aided Design and Drafting (CADD) software.

Statewide LiDAR data coverage is a reality to some States as the utility of the collected data is realized by many agencies and departments, including the DOTs. In other States, LiDAR data is available on a project basis due to its ability to collect large areas of data quickly. The AASHTO Technical Committee on Hydrology and Hydraulics (TCHH) recognizes the impact of LiDAR data on hydraulic modelling and offers this special edition of the Hydrolink.

Just a reminder that the TCHH wants to hear from you. We want to know what's working and what's not, research needs, and other hydraulic related concerns you might have. We are in the early stages of an AASHTO Drainage Manual update. The goal is to break the manual up into more manageable volumes to better facilitate future updates with the most recent peer-reviewed research. We welcome your input on current knowledge gaps, oversights, and errors in the manual.

In closing, I would like to recognize and thank Andrea Hendrickson for her continued service to the TCHH. As the longest-serving member, she has been the calming voice behind the scenes, the facilitator of this publication, and a dedicated public servant. Thank you, Andrea!

-Steve
Steven.sisson@delaware.gov
The recent release of FHWA’s *Two-Dimensional Hydraulic Modeling for Highways in the River Environment Reference Document (See Reference 2)* will provide practitioners with answers to many common questions about the development of two-dimensional (2D) hydraulic models. This article highlights portions of Chapter 4 of the Reference Document, specifically providing a base understanding of the various collection methods, data formats, recommended model extents and methods to communicate with surveyors for development of a successful hydraulic model. The terrain data used to create the model geometry has the greatest impact on the quality of the hydraulic model and typically requires the most resources to obtain sufficient representation of a project reach. A study by the Federal Emergency Management Agency, the National Oceanic and Atmospheric Administration, and other federal agencies found that “Topographic data are the most important factor in determining water surface elevation, base flood elevation, and the extent of flooding and, thus, the accuracy of flood maps in riverine areas.” (NRC 2009)

All hydraulic models, whether 1D, 2D or 3D, require terrain mapping that provides the sufficient resolution to properly represent both the ground features and hydraulic characteristics needed for a given analysis. The resolution, amount, and type of data necessary to create hydraulic models will vary depending on the model application and the type of data being collected. The recommended terrain data for transportation-related hydraulic models are bulleted below and discussed in further detail in the subsequent sections and in Chapter 4 in the Reference Document.

- **Topographic data** -- Typically lidar or photogrammetric data, covering the entire model domain.
- **Bathymetric data** – Channel cross sections at notable changes in channel geometry and slope, or higher resolution below water data collected with single beam or multi-beam sonar transducer.
- **Supplemental survey data** – Terrain under a bridge, culvert dimensions and invert elevations, bridge deck details, bridge low chord elevations, pier and abutment locations and alignment, and other topographic detail not captured in the topographic data.
- **Data from surveys and engineering drawings** – Supplemental information on bridge and culvert geometry (i.e., pier width and shape).

**TERRAIN DATA COLLECTION METHODS AND DATA FORMATS**

As noted above, a typical terrain dataset for a 2D hydraulic model includes a combination of lidar, photogrammetry, bathymetry, and supplemental site survey data. A variety of collection methods exist for obtaining topographic and bathymetric data; each has benefits and limitations that practitioners should understand. A list of conventional data collection methods, with ideal uses and limitations, is provided in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Method</th>
<th>Ideal Use</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic</td>
<td>Traditional</td>
<td>wide area (county, municipality, watershed, etc.) and long corridors</td>
<td>cannot penetrate some dense vegetation types, cannot penetrate water</td>
</tr>
<tr>
<td>Aerial Lidar</td>
<td>Geiger mode</td>
<td></td>
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<td></td>
<td>Flash</td>
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<tr>
<td></td>
<td>Photon</td>
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<td></td>
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<td></td>
<td>UAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photogrammetry</td>
<td>Traditional</td>
<td>sites and narrow corridors</td>
<td>lower surface definition and limited by dense vegetation</td>
</tr>
</tbody>
</table>

Table 1. Common terrain data collection methods
Terrain data is the most important dataset for 2D modeling as the terrain has the most influence on the movement of water in open channel flow. The various terrain features that influence hydraulics are commonly referred to as hydraulic controls. Typical hydraulic controls could include the channel banks, grade control structures, high ground in the floodplain, roadway embankments, and transportation infrastructure like bridges and culverts (Figure 1). If hydraulic controls are not well represented in the terrain and mesh geometry, the model cannot accurately represent the hydraulic characteristics at the project location.

Knowing what features act as hydraulic controls is a skill modelers fine-tune after years of experience. Terrain features controlling hydraulics at low discharges may not have any impact at high discharges. Similarly, features controlling hydraulics for larger discharges may have no impact for lower discharges. For example, a stream rehabilitation study with a small channel and floodplain may require more detailed representation of features such as a small rock outcropping or minor changes in bank to bank width because they impact hydraulics at a scale that is important to the rehabilitation plan. In contrast, a floodplain study on a river system with a wide floodplain will likely not require as much detail of the channel and minor terrain features to determine water surface elevations as a model with more detailed terrain data.

To efficiently develop a terrain surface, multiple types of the collection methods provided in Table 1 can be used. It is typically not feasible to collect data over large areas using ground-based survey methods, in or out of the water. For these reasons, topographic data is often a
combination of lidar, photogrammetry and ground survey. In many states lidar is available to the public and can be used to supplement photogrammetry or ground-based terrain data. Lidar is great collection method for large areas, such as floodplains and should always be checked for accuracy, especially in highly vegetated areas. Most lidar does not penetrate the water, therefore collecting bathymetry using other methods is still required. The most common method of collecting bathymetric data on non-wadable waterways is with sonar, attached to a boat, and combined with a GPS or robotic total station to provide the location of the sonar device. A recent trend in sonar bathymetry collection utilizes remote controlled systems. Julie Heilman with Washington Department of Transportation discussed one such system in *Hydrolink Issue 17*. These systems are usually equipped with multibeam sonar and cost around $20,000-$30,000, providing widely applicable and relatively inexpensive bathymetry collection options.

**SELECTING MODEL EXTENTS**

Determining the extent of terrain to survey is crucial for producing an accurate representation of a project reach for 2D hydraulic model development. A common question many modelers ask is, “How much survey data do I really need?” Typically, this question is asked in the context of balancing project costs with the feasibility of obtaining the best available data. Generally, the survey area should fully encompass the potential width of area inundated during the flow(s) of interest, and the model limits should be located far enough upstream and downstream from the area of interest to avoid or minimize any errors that may be associated with assumptions at the boundary conditions (i.e., flow distribution at the upstream boundary and normal depth estimates at the downstream boundary). A useful estimate for initially determining the extent of terrain data is to place the upstream and downstream boundaries at least two floodplain widths upstream and downstream of the area of interest. However, the modeler should consider extending the study domain downstream to an area where the water surface can be estimated with higher confidence, such as at an existing stream gage, natural channel constriction, weirs, or other control features where the water surface can be accurately estimated. It is good practice to conduct a sensitivity analysis of boundary conditions to ensure that variations in water surface elevations do not change model results around the area interest.

**SURVEY DATA REQUEST**

An accurate survey of existing terrain is crucial for producing a correct representation of a project reach for 2D model development. Appendix B of the *Two-Dimensional Hydraulic Modeling for Highways in the River Environment Reference Document* includes a discussion of the unique hydraulic control features that should be evaluated by the modeler and the importance of effective communication between the modeler and survey crew so that survey can be collected efficiently. To aid in the communication, Appendix B also includes a convenient example survey request form that can be adopted for any hydraulic modeling project. By understanding site features and project goals, a modeler can identify important terrain features and allow the surveyors to determine the most efficient way to collect the requested data. Ideally, the modeler can conduct a site visit prior to submitting a survey request; however if this is not possible, it is recommended the modeler meet the survey crew on-site to ensure all necessary data is collected. This allows the modeler and the survey crew to discuss survey extents and identify hydraulic control features that should be included in the survey.

To represent common channel hydraulic controls, channel geometry, surveyed breaklines, and points should be collected along the thalweg, bank bottom, bank top, and any additional locations where there is a change in grade. Figure 2 shows an example of the minimum number of channel features that should be collected.
To appropriately assess the sufficiency of the terrain data, modelers need to understand the application of the model, the range of discharges to be analyzed, the area of interest, and the limitations of terrain data collection methods used. If additional data collection is not feasible, then the modeler should understand the potential limitations of the model and communicate those limitations to stakeholders. FHWA’s recent release of *Two-Dimensional Hydraulic Modeling for Highways in the River Environment Reference Document* provides 2D modelers with an easily accessible resource to better understand the various collection methods, data formats, and necessary attributes for building a successful 2D model.

**REFERENCES**

Robinson, et. al. 2019, Two-Dimensional Hydraulic Modeling for Highways in the River Environment -Reference Document, FHWA-HIF-19-061  Editor’s Note: It is anticipated that this document will be posted on the FHWA website very soon. Contact Scott Hogan scott.hogan@dot.gov about the availability.

**Lessons Learned from Initial 2D Hydraulic Modeling**

As a participant in FHWA’s Every Day Counts program for Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE), the Michigan Department of Transportation (MDOT) has been evaluating the use of 2D hydraulic modeling as part of its everyday business practice. In 2017, the Department initially participated in EDC-4 by enrolling in NHI training for SMS training and looking for initial pilot evaluation projects. Concurrently, the State of Michigan was in the process of collecting statewide aerial LiDAR which rapidly fueled the opportunity for several test sites for evaluation.

In 2018, the department committed to participating in EDC-5 (CHANGE 2.0) and evaluated approximately 6 – 8 sites for 2D Modeling using SRH-2D through SMS. Efforts were focused on particular sites with either decent aerial LiDAR coverage and/or decent stream bathymetry. Upon completion of these sites, the models were sent to FHWA’s Hydraulic Resource staff for review and commenting.

MDOT is in the process of designing for the replacement of twin corrugated metal culverts that convey the Carp River under M-35 in Michigan’s Upper Peninsula. The culverts have shown signs of deterioration, and a relatively large scour hole downstream of the culverts indicate a lack of hydraulic conveyance. As part of the evaluation for replacement, the MDOT Hydraulic Unit evaluated multiple options for replacement, including a precast pre-stressed 48 feet span clamshell type box culvert. To aid in this evaluation, a 2D hydraulic model was developed using aerial LiDAR and traditional ground survey for stream bathymetry with some channel stamping.
The aerial LiDAR for this project was downloaded from USGS’s National Elevation Map, as part of the 3D Elevation Program (3DEP). The State of Michigan has been uploading their statewide aerial LiDAR pickup through the MiSAIL Program into the USGS database. As of August of 2019, most of Michigan has accepted data and/or has been flown for LiDAR pickup, as shown in Figure 3. The LiDAR data from this project was published in January of 2018, with flight dates between May 2015 and May 2016.

Figure 3 – Status of Michigan DTMB’s MiSAIL QL2 Collection

Upon completion, the SMS model for M-35 over the Carp River was sent for review to FHWA’s Hydraulic Resource group. The reviewers requested access to the aerial LiDAR data, as they thought that the vegetation had not been filtered out. The scatter data surface had shown surface irregularities of +/- 1 foot, as shown in Figure 5. These surface irregularities were better viewed by skewing the vertical elevations. After reviewing the LiDAR data, the reviewers confirmed that the vegetation had been filtered out of the data.

Figure 4 – Carp River looking upstream from M-35
The location of interest is in an area of heavy vegetation and scrub brush in the floodplains. Subsequent to FHWA review, several other sites across Michigan with heavy vegetation in the floodplains have shown inconsistencies in the vertical elevation data. There are a couple of theories as to why there are inconsistencies in the elevation data:

1. The altitude at which the aerial data was flown may lead to errors.
2. The filtering software may not be powerful enough to filter out all the vegetation data.

Future efforts will be made to produce better data. Additional software may be evaluated for filtering prior to importing into SMS. MDOT is also evaluating purchasing an aerial drone with LiDAR capabilities, as part of a separate EDC-5 program. The unmanned aerial system is initially planned to use a camera for photogrammetric modeling and will add LiDAR next year.

Along with improved aerial LiDAR, MDOT will also be investigating the use of mobile LiDAR integrated with multi-beam bathymetry boats to collect streambed bathymetry with topographic pickup along the streambanks. The efforts are in hope of improving input data for advanced hydraulic modeling.

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**Not All Point Clouds are Created Equal**

Kyle Ince, Ohio Department of Transportation

Point clouds have been around for decades, but until recently, extracting useful information was left to specialized software and personnel. This is not the case anymore with the near exponential growth of computing power, readily available public datasets, and the advent of “black box” set it and forget it software. The “average” user can now create actionable designs and analysis at the click of a button. This leads to common misconceptions that all point clouds are created equal in terms of accuracy, level of detail, and repeatability just to name a few.
To understand these misconceptions, it is important to be familiar with how point clouds are generated and the systems used to collect them. Point clouds can be generated using either an active or a passive sensor. Active sensors emit their own energy to illuminate the subject and measure the reflected energy with receivers on the unit. A typical example of an active sensor is a flash camera or a LiDAR unit (Light Detection and Ranging) or more commonly known as a laser scanner. Conversely, a passive system uses ambient energy to collect data on the subject in question. An example of a passive sensor would be a flash-less camera (your eyes can be considered a passive sensor too!).

The idiom “a chain is only as strong as its weakest link” is a great metaphor to depict the accuracy of both active and passive sensors. These systems are made up of a few main components but for simplicity sake they can be defined into two categories. The first category is the receiver/detector/processing computer (an active system adds an energy source as well) which will gather precise timing, scanning, and raw data storage to the system. The second category is the navigation system which can be comprised of a GNSS (Global Navigation Satellite System) receiver and an Inertial Measurement Unit (IMU). Each component of the system can introduce error into a final product if not properly accounted for using calibrations and error modeling techniques.

Active sensors (LiDAR specifically) lend themselves to large area data collections and make up most of the publicly available datasets. The remainder of this article will focus on aerial LiDAR and a general point cloud creation workflow.

Figures 6 and 7 are LiDAR images of The Ohio State University Stadium (Shoe). The left image is an Intensity image (strength of the return) and the right image is colorized based on elevation.

REQUESTING A DATASET

Whether the dataset is requested for a specific purpose or is “canned” data, the user will need to outline the information that is trying to be extracted from the point cloud. Common examples of this, include curb and drainage details. In a standard aerial dataset, it is almost impossible to continually collect data at the flow line of a curb. Since points are collected in a “random” fashion, some laser pulses will hit the top of the curb, face of the curb, and the flow line. When these points are triangulated into a terrain model (Triangulated Irregular Network) the curb details are lost. Supplemental conventional surveys are needed to add this level of detail back into the model. Without this addition, inlets can be designed and built to an incorrect elevation causing costly change orders and schedule delays.
MISSION PLANNING
An often-overlooked process, mission planning plays a critical part in the success of a project. Some factors in the planning stage include collection efficiency, adjustment geometry (crossing flight-lines), point density and spacing, control locations (more on this topic later), and airspace restrictions. A lesser known but critical factor is subject visibility. This example plagues most of the country and across all disciplines. LiDAR can only capture data on subjects the laser pulse reflects off and if that subject is a creek inside a heavily vegetated area, critical details (or no data at all) will be missing if flown during leaf on conditions. This leads to planning missions during leaf off conditions (Ohio has that luxury) to maximize the amount of laser pulse penetration and beam returns. This process may not be feasible for some extremely large public data collections or regions with no leaf off conditions.

GROUND CONTROL
Now that a dataset has been requested and a mission has been planned, the ground control (also called ground truth) needs to be established. Depending on state regulations this step is typically managed by a land surveyor. Ground control/truthing sets apart different levels of point cloud data in terms of relative and network accuracy. It is important to note that relative accuracy describes how well the point cloud fits within itself, while network accuracy depicts how well the entire point cloud fits within the reference datum. When reading through an accuracy report or metadata of a dataset, those numbers are generally defined as network accuracy. To assess network accuracy, horizontal and vertical control points are established to test and adjust the dataset to known points during the processing phase.

FLIGHT OPERATIONS
As the pilots go through their checklist, it is easy to get excited for the rush of takeoff and the unparalleled views during the day’s flights. The rush goes away quickly after the wheels have left the ground and it’s time to get down to business. Aerial data collection is a carefully choreographed dance of constant communication, tedious piloting, and monotonous monitoring of computer screens. Each passing minute stores gigabytes of data that will need processing and polishing to become the mind-boggling point clouds we’ve become accustomed to.

POST FLIGHT PROCESSING
This is where the rubber meets the tarmac, after a well-executed mission it is back to the office to download the spoils of the bumpy teeth rattling flight. Post processing and data analysis are the most important aspects in creation of a usable accurate point cloud. Since these steps vary greatly depending on the brand/software being used, a general workflow consists of processing the navigation solution, extracting a preliminary point cloud, reference frame transformations, applying calibration and flight line analysis, editing and classification, and ground truthing with QA/QC (Quality Assurance/ Quality Control) to match accuracy standards.

NAVIGATION SOLUTION
The navigation solution defines the path the sensor took and the attitude of the aircraft (roll, pitch, and yaw) during the mission. These parameters are paramount to creating a kinematically generated point cloud. A GNSS receiver coupled with an IMU will generate a trajectory with a timestamp to show when and where the laser was firing. Since this data is processed after the flight (RTK or Real Time Kinematics will complete these during flight) several other inputs are needed to finalize the solution. One of the additional inputs is GNSS base station data. This can come in the form of a base manually set up by a survey crew during the flight or from a Continuously Operating Reference Station (CORS).

REFERENCE FRAME TRANSFORMATIONS, CALIBRATION APPLICATION
Pairing the trajectory, the raw outputs from the LiDAR unit, and a calibration file (to account for system errors) a preliminary point cloud can be created. This file typically has a world coordinate system applied and will need to be transformed into the user’s reference frame of choice. These transformations can introduce errors into the dataset and generally require specialized software to transform them appropriately.
EDITING/CLASSIFICATION
Point clouds can be overwhelming and difficult to interpret when they are first opened in a 3D visualizer. One thing that helps connect all those dots is point cloud classifications. This step classifies each point into a “category” or “layer” for easier viewing or analysis. Some examples of classifications are ground, vegetation/miscellaneous, bridge, etc. There are numerous algorithms available to automatically classify point clouds, but no algorithm is perfect, it still takes a human eye to interpret difficult areas (for example those pesky picnic tables and trampolines) and take the point cloud to the next level.

QA/QC AND ACCURACY STANDARDS
Now that a beautiful classified point cloud has been created, how well does it model the real world? This is where accuracy standards come into play. One excellent national standard is the ASPRS Positional Accuracy Standards for Digital Geospatial Data. These standards set the industry benchmark for how to report digital geospatial data in a clear, concise, and accurate manner. Using the ground control set prior to flight operations, a sample population of the point cloud is compared to known points. Using statistical modeling, a confidence rating can be determined of how well the point cloud reflects the real world per land classification (non-vegetated, vegetated, etc.). The axiom “buyer beware” holds true when reviewing point cloud accuracies (or any accuracy claims in general). It is very easy to lie with statistics to make a dataset seem more accurate. An example of this manipulation is reporting accuracies to one standard deviation or sigma. A dataset that is reported to test to an accuracy of 0.5’ at one standard deviation says that 68% (assuming a normal distribution) of the points fall within that tolerance (what about the other 32%!?). Whereas, if that same point cloud was reported using 2 standard deviations it should be reported to test to an accuracy of 1.0’ at a 95% confidence rate, which more accurately describes the point cloud across the entire project area.

As with any task or project it is imperative to use the right tool for the job. Point clouds, as easily accessible as they are, have a usable shelf life and are only a representation of the area at the time of collection. It is important to use professional judgement and caution when using datasets outside their intended collection purpose.

Statewide Mobile LiDAR Project Yields Valuable Asset Data for Minnesota Department of Transportation

Trisha Stefanski, Minnesota Department of Transportation

The Minnesota Department of Transportation had done several contracts for small Light Detection and Ranging (LiDAR) data collects before, but the statewide asset collection project solicited in 2016 was different in scale and complexity. The scope of the Request for Proposal included inventory and assessment of all traffic barrier end treatments within 15,000 centerline miles of roadway, with an optional Task 3 that included locating and attributing 15 asset classes and clearance data on MnDOT owned roadways as well.

The contract was awarded to Continental Mapping and data collection began in February of 2017 with mobile lidar the collection method of choice. Continental Mapping utilized Maverick scanners to acquire submeter accuracy lidar data and 360° street-level imagery and several suites of software for asset extraction. The $4.7M project was scanned in roughly 9 months and the asset extraction completed in 2018.
The asset inventory, assessment, and clearance data that was collected through the project is rich in value and has helped steer MnDOT’s safety asset maintenance initiatives. The data continues to be reconciled with existing data, reviewed by key experts, and imported into MnDOT TAMS (Transportation Asset Management System) Enterprise Asset Management Software.

Catch basins, attributed with the inlet type, roadway type, collection date, and unique ID, are one of the collected assets currently being integrated and imported into TAMS. The catch basin locations were collected in sub-meter accuracy where the assets were unobstructed in the lidar point cloud and imagery.

The catch basin asset inventory data is valuable for planning and scoping future systematic budget needs and construction project budgets. When Maintenance and Construction work impacts a catch basin, the work will be recorded in TAMS and linked to the impacted asset to facilitate accurate life cycle and maintenance tracking. Analysis of the costs, labor hours, and materials for different asset types, ages, and locations will help MnDOT better understand deterioration rates and lower life cycle costs.

### Table 2 – Number of Assets Identified

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<th>Asset Type</th>
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<tr>
<td>Cable Anchor</td>
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<td>Cable Barrier</td>
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### Project Background:

WSDOT recently assessed a new stream crossing for Glacier Creek on State Route (SR) 542 near Mile Post (MP) 33.3 in Whatcom County as part of the Chronic Environmental Deficiency (CED) program. Glacier Creek is a steep, mountainous river that descends about 10,000 ft in only 14 River Miles from the top of Mount Baker to the SR 542 crossing (elevation 902 feet). Within the vicinity of the highway, this river is a highly unstable braided stream (2.5% average slope) that occupies an alluvial fan, extremely coarse (cobble, boulder), and has a mean annual precipitation of 110 inches. Just upstream of the highway, Glacier Creek is experiencing net aggradation in response to an undersized bridge (78 ft span within a 1,000 ft channel migration zone (CMZ)) and a 1,700 ft levee extending upstream from SR 542 and bisecting the CMZ. The watershed is rugged and heavily forested.

The SR 542 crossing over Glacier Creek has a long history of channel instability, road emergency repairs, flood control projects, and several bridge replacements. Built on alluvial fan sediments, significant portions of the highway experience recurring bank erosion and flooding from Glacier Creek and its side channels, which result in highway closures and emergency maintenance actions.

For the geomorphic reach assessment and 2D hydraulic modeling, WSDOT hired a consultant to create a topobathymetry DEM from an Unmanned Aerial Vehicle (UAV) LiDAR and sonar bathymetry due to extremely challenging field conditions and expense to acquire high resolution topographic data using ground survey.

### Survey Equipment:

UAV LiDAR has many advantages over ground AND airplane (manned) survey by offering the following:

- Quick, cheap, highly accurate data collection;
- Higher sample density of surface data;
- Capability of penetrating dense forest for elevation data;
- No geometry distortions;
• Ability to integrate elevation data with other data sources;
• Minimum human dependence; and
• Ability to map inaccessible and featureless areas.

Legal considerations for UAV and equipment failure were the primary challenges for flying drone at Glacier Creek. Local residents cannot be captured on film without permission, so as a general rule the UAV is not flown over houses. The drone must be kept in visual sight 100% of the time, which required more set-ups to negotiate channel meanders and trees. There are also FFA rules for how high to fly the drone, which could conflict with exceeding the instrument range. Without legal challenges, the flight could have been made in one pass.

The following equipment was used to conduct the UAV survey:

• UAV for Photogrammetry
• LiDAR sensor technology
• Camera
• Drone mapping photogrammetry software

SONAR BATHYMETRY

The vertical accuracy of the topographic data acquired from sonar is 1% of channel depth with measureable channel depths from 20 cm to 30 m. Because the density and volume of data collection exceeds ground survey, sonar bathymetry is well suited to developing grids for 2D hydraulic models and cross sections for 1D hydraulic models. Higher granularity of hydraulic models should yield more accurate results. Data resolution from sonar bathymetry exceeds many model requirements, which allows future use of historic data sets as hydraulic models evolve to incorporate larger data sets.

In order to get the most out of combining UAV LiDAR and sonar bathymetry, it’s important to fly drone and float sonar on the same day because the WSE is known for both, and makes the mosaic as accurate as possible. The second best option is to overlap UAV with sonar data collection by floating sonar during lower flow levels than when UAV is flown. Three data lines were collected on Glacier Creek with rafts: one on each side of the river, then a third down the middle. The sonar data collection was performed at the same time as the DEM for best accuracy. Floating sonar bathymetry at Glacier Creek presented several challenges. Impassable woody debris at 7 locations were safety issues (strainers) and necessitated portaging equipment for each run (3 total). The longest portage was 50 yards but was usually less than 10 m. Shallow depths and steep gradients created data collection challenges. The consultant anticipated that approximately 10% of the measurements collected would be valid. Post-collection processing yielded more than 50% of valid measurements, which exceeded expectations. (Invalid measurements were excluded from the data set prior to compilation with the LiDAR point cloud.)

The following equipment was to conduct the sonar bathymetry survey:

• Teledyne RiverPro Acoustic Doppler Profilers (ADP) (Sontek M9, RDI Riverpro) with fully integrated Hemisphere
• Vector V102 GPS compass units deployed from catamaran rafts to measure water depth, flow velocities and vectors of flow direction
• Proprietary data collection software for river mapping (River Analyzer) written by Teledyne in collaboration with Freshwater Map
• Sonic camera

Bathometric data was used in 2D models to evaluate water depths and velocities of existing conditions, proposed conditions, and future conditions for design events. Figure 9 are the bathymetric measurements taken for SR 542 at Glacier Creek and Figure 10 is an example of one of the 2D modeling scenarios that was evaluated during design.
Figure 9 – Bathometric Measurements for SR 542 over Glacier Creek

Figure 10 - Existing Conditions with 100-Year Water Depth
Welcome New TCHH Members

Erik Carlson, P.E.
Michigan Department of Transportation

Erik Carlson has worked for the Michigan Department of Transportation (MDOT) for over 15 years (all within the Hydraulic Unit), and as supervisor of the Hydraulic Unit for nearly 2 years. During his time in the unit, he has worked on hydraulic modeling and scour/or calculations for nearly 100 bridge replacements, multiple large culvert replacements and/or rehabilitation projects, storm sewer evaluations, and attenuation designs. He has been a participant on multiple policy forming committees within MDOT. He has helped establish the criteria files for MDOT’s GEOPAK Drainage and is currently assisting with the implementation of SUDA. He also has been a participant on AASHTO Domestic Scans.

Erik graduated from Michigan State University in 2002 with a B.S. in Civil Engineering. He is currently a guest lecturer/instructor teaching Hydrology & Hydraulic modeling for the Senior Capstone Design at Michigan State University. He is married to an emergency room nurse, with two small kids. When he’s not working, chasing kids, or doing home improvement projects, he’s activity following the Green Bay Packers.

John Hobelman, P.E.
Road Squad Leader
Kansas Department of Transportation

John Hobelman joined the Kansas Department of Transportation (KDOT) in May of 2016 as a Road Squad Leader. He assists and organizes the squad to complete projects on schedule and provide coordination with other sections and bureaus. He is responsible for maintaining the Drainage Manual for the Bureau of Road Design. He also reviews highway access permit applications for compliance with current drainage criteria. He monitors research projects relating to drainage on behalf of the agency.

Prior to joining KDOT John worked 32 years in the private consulting sector. Most transportation related projects have a hydrology and hydraulic design component, so he has been exposed to a variety of water related issues. Projects have ranged from rural and urban roadways, municipal and residential street projects, sanitary sewer projects, site development, and bridge replacement projects. As a part of these projects he has designed detention storage, outlet scour protection, hydraulic jumps in pipes and channels, sizing riprap for channel protection, inverted siphon, and erosion control. John received his Master’s degree in civil engineering (MCE), from Kansas University in 2000, where he completed classes in the area of Wetland Hydrology, Surface Hydrology, and Free Surface Flow.

John has been involved in Engineers Without Borders, where he helped raise money for water supply improvements in Guatemala. To raise the money he helped at events where the public would build and purchase rain barrels and solar dehydrators.
In his spare time, John enjoys traveling anywhere outdoors. He has visited sand dunes, swamps, rain forests and mountains, but his favorite place to go are the Flint Hills of Kansas. They have a subtle beauty and peacefulness. The native stone walls shown in the photo remind him of the hard work it took to build a life on the prairie.

**Lu Saechao, P.E.**  
**Oregon Department of Transportation**

Lu Saechao has over 13 years of design, construction and engineering experience in hydraulics, hydrology and transportation engineering. He spent the first 12 years of his career with the Washington State Department of Transportation (WSDOT) in various roles, most notably as a hydraulic engineer with WSDOT’s HQ Hydraulics office. In that role, Lu supported the State Hydraulic Engineer on river engineering, bridge hydraulics, culverts, bank stabilization, stream restoration, woody material design, floodplain design, fish passage, scour analysis, storm drain systems, and roadway drainage.

In June of 2018 Lu joined the Oregon Department of Transportation (ODOT) as the department’s Senior Hydraulics Engineer in ODOT’s HQ office. In this role, he is responsible for maintaining ODOT’s statewide policies on stormwater and hydraulics, including the Hydraulic Design Manual, hydraulic computer software, standards and specifications, training, consultant work review, drainage facility asset management and research or special initiatives with universities and other state/federal agencies. He is currently working with colleagues to update ODOT’s MS4 permit regarding post-construction stormwater management policy and implementation.

Lu graduated from Oregon State University with a Bachelor of Science in Civil Engineering in 2006 and is a licensed professional engineer in the States of Oregon and Washington. He enjoys the great outdoors and loves to hike and camp the Pacific Northwest. Lu and his wife have two young children that keep them on their toes.
Channel Stability Workshop Scheduled in Oregon

Oregon DOT is hosting a 2 day workshop on Design Tools for Channel Stability at Stream Crossings. This workshop trains participants to assess stream response potential and compute analytical channel designs to balance water and sediment using the capacity supply ratio (CSR) spreadsheet tool as published in Guidance for Design Hydrology for Stream Restoration and Channel Stability (NCHRP Research Report 853, 2017). This workshop was previously hosted by Maryland and Minnesota in 2019. The Oregon workshop is planned for May 2020 in Portland. For more information or to express interest in attending contact Lu Saechao at lu.saechao@odot.state.or.us.