PATTERSON CREEK FISH PASSAGE FEASIBILITY AND CONCEPTUAL DESIGN STUDY

Feasibility and Conceptual Design Report October 18, 2015

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INTRODUCTION

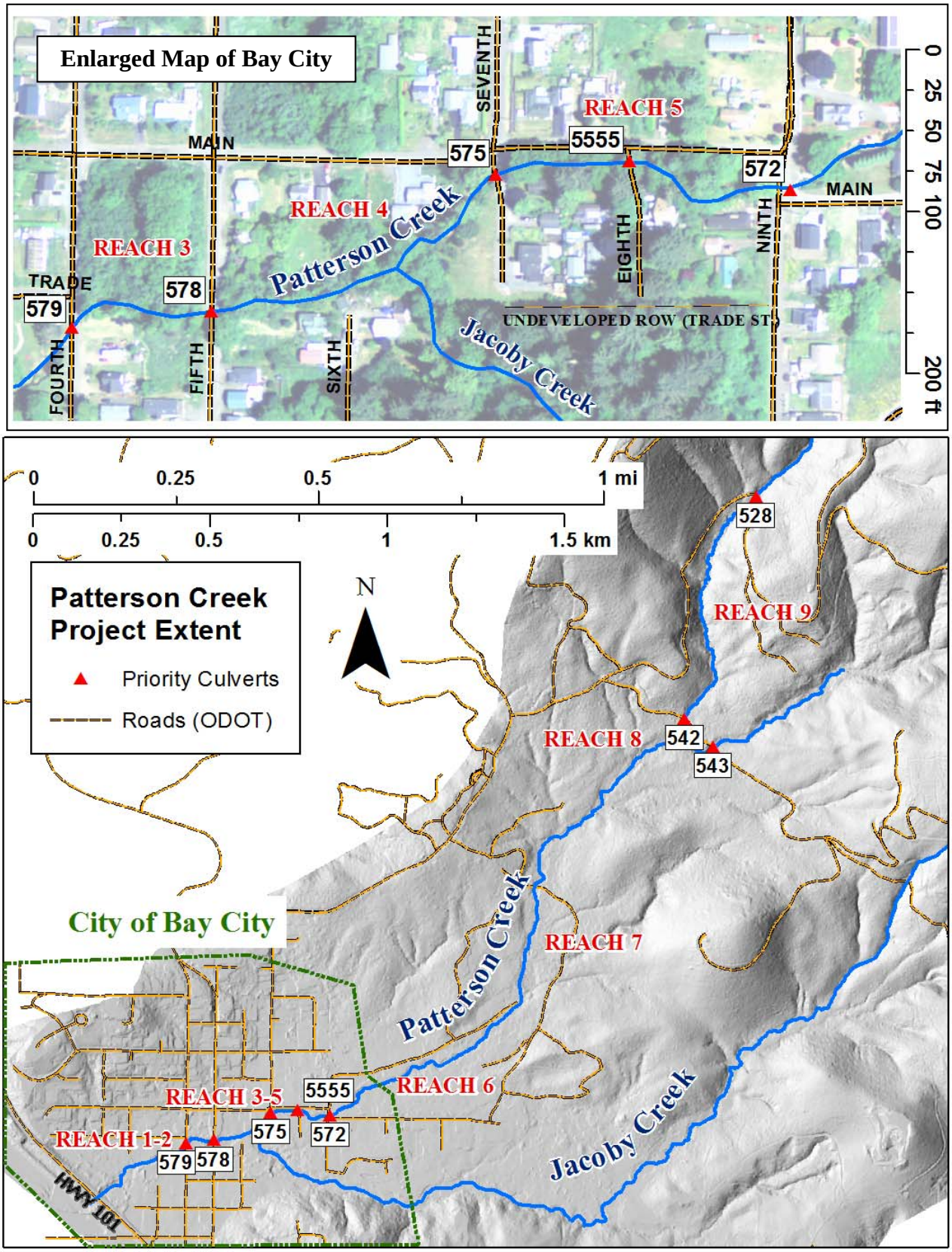
The objectives of the Patterson Creek Fish Passage Feasibility and Conceptual Design Study were to gather the necessary technical information needed to assess eight existing culverts; and to develop conceptual design documents for feasible, cost effective replacement structures that would allow fish passage through Bay City and into the upper watershed. Four specific goals were identified at the outset:

- **Meet or exceed State and Federal requirements for fish passage**. At all crossings, the design selected replaces undersized culverts with structures that are 1.5 times the active channel width. Some structures require re-alignment of the channel to match surrounding channel elevations and to remove fish passage barriers. In particular, designs address the modified (deepened and straightened) channel between crossings 575 and 572, requiring extensive streambed modifications to assure long term channel stability.
- **Minimize maintenance costs and risks to existing infrastructure.** High flow events, sediment transport, and proximity of private property to Patterson Creek all pose inherent risks. Information gathered over the course of the project identified several complicating factors and design constraints. The most significant challenges are sewer lines crossing Patterson Creek throughout Bay City. Patterson Creek is in close proximity to private and public property, utilities, and critical transportation infrastructure throughout Bay City. This phase of design explored feasibility of improving fish passage barriers without increasing flood risk to private and public property. The proposed conceptual designs also address replacement of failed infrastructure that has exceeded service life.
- **Minimizing delays and costs associated with temporary bypass and access**. Designs for crossings 572 (9th Street) and 542/543 (ODF road) were most affected by this consideration. Straightforward solutions were proposed by stakeholders for the forest road crossings. At crossing 572 (9th Street), the preferred alternative suggests a two stage construction plan to prevent long term road closure. One option considered development of a right-of-way as an alternative to replacement of three culverts, but further work is needed by stakeholders to explore these options.
- **Provide additional materials for presentations and other forms of outreach, to educate and solicit public support**. Throughout the design process, input was solicited from public and stakeholders to identify critical design considerations. Initial feedback from residents helped validate survey observations and model results used for hydraulic calculations. Existing infrastructure was flagged as a major design constraint for replacing culverts in Bay City (particularly sewer mains and laterals). The complexity of this project will require ongoing collaborative decision-making to achieve feasible solutions during Phase 2 design.

This report outlines the Phase 1 feasibility study of improving fish passage on Patterson Creek through Bay City and into the upper watershed. This study included document review, ground surveys, opportunities and constraints analysis, and stakeholder meetings. The report also summarizes conceptual designs proposed for replacement of the eight priority structures identified by Tillamook Estuaries Partnership. Replacement of these structures will significantly increase access to habitat for anadromous fish populations in Tillamook Bay. The design process considered the context of the entire Patterson Creek watershed, emphasizing stream connectivity and physical and biological processes as essential considerations for achieving success. In addition to structural designs, fish passage, and cost estimates, this report outlines critical infrastructure improvements that are overdue. Feasible opportunities to improve habitat and mitigate flood risk are identified for Bay City.

In completing Phase 1, this report also details specific unresolved design considerations to be revisited in Phase 2 for project implementation. During the feasibility analysis, there were discoveries of complications beyond the scope of Phase 1. Bay City sewer lines are exposed in Patterson Creek and at risk of failure. At several crossings, sewer lines cross Patterson Creek at the optimal elevation required for improving fish passage. Phase 2 designs will include alternative analysis to evaluate options for addressing this constraint. As an alternative to culvert replacement, developing a city road Right-of-Way may allow removal of several structures, but would fundamentally change the nature of the local neighborhood. These design challenges will also need to be addressed in Phase 2 design work.

MAP OF PROJECT AREA



REVIEW OF EXISTING DOCUMENTATION

Lower Columbia Engineering (LCE) staff received documents and digital resources from City of Bay City (CoBC) Public Works office, Oregon Department of Fish and Wildlife (ODFW), and Oregon Department of Forestry (ODF) Tillamook office. These included:

- ODF- Property ownership/jurisdiction, streams, and roads GIS layers
- ODFW- Memorandum certifying active channel widths (2014)
- Bay City Downtown Watermain Improvement Project (2003)
- Bay City Sanitary Sewer System (1970)
- City of Bay City Storm Water Master Plan (2003)
- City of Bay City Water Distribution Map (2006)
- Culvert Assessment Forms (Included in Phase 1 RFP, 2014)
- TEP In-Stream Enhancement Assessment (2015)
- TEP Riparian Enhancement Assessment (2015)

CoBC drawings and documents were received in paper form. These documents were digitized and made available to CoBC and TEP staff. LCE staff also collected and reviewed GIS data from state and local resources, including lidar data (Oregon Dept. of Geology and Mineral Industries - DOGAMI), state roads layer (Oregon Dept. of Transportation), tax lot layer (Tillamook County Assessor's office), and national 10 meter digital elevation model (US Geological Survey). These layers are compiled into a GIS database which is part of the final project deliverables (from LCE to Tillamook Estuaries Partnership).

Lidar “Highest hit” and “Bare earth” rasters were used to derive hillshade, contours, vegetation/structure heights, slopes, and to manually correct stream delineations. Lidar elevations provided a first estimate of stream channel elevation, and are shown on charts used in this report. Survey data (collected using NAD83 (2011) and NGS 2012b geoid) was adjusted to match lidar elevations by least square regression to known control points collected during each survey session. Sample elevations were used to compare with all existing records, including sewer manholes, known benchmarks, water mains, and culvert elevations.

FIELD SURVEYS- METHODS AND RESULTS

Surveying was conducted by LCE staff from January to April 2015 to corroborate existing documentation, extend stream profile measurements, and measure structures at each crossing.

An initial reconnaissance survey of crossings within Bay City was conducted on January 23, 2015. Culverts at Crossings 579 (4th Street), 578 (5th Street), 575 (7th Street), 5555 (8th Street), and 572 (9th Street) were photographed, structural dimensions measured, and water depths taken (for flow calculations). A GPS surveying unit (TOPCON Hiper II) was employed to collect location and elevation measurements of roads, utilities in proximity of crossings, survey benchmarks, and all culverts (Fig. 1). In RTK (real time kinematic) mode, the GPS survey unit is capable of reporting coordinates within 1cm (<0.5") relative horizontal location and 1.5cm (0.5") relative vertical location. A combination of known point measurements, static GPS calculations, and post processing were used to establish absolute locations in the UTM and the Oregon State Plane coordinate systems. GPS data was used to establish control points for total station surveys and stream profiles, to validate lidar data, and to reconcile field surveys with existing documentation.

Figure 1: Locating culverts with GPS-RTK survey unit. Survey staff use a combination of methods including tapes and level rods.

Crossings 542 and 543 (ODF road/Pacific Power access road) were surveyed on February 13, 2015. The GPS-RTK unit was used to measure road location and width, culvert elevation and orientation, and stream thalweg for at least 10 channel widths both upstream and downstream at both crossings. Obstructed sky view prevented the use of the GPS unit to survey Crossing 528 (uppermost crossing, Patterson Creek Road).

A continuous stream survey was conducted on Patterson Creek within Bay City on March 4, 2015. The survey extended from 470 feet downstream of Crossing 579 (4th Street) to 240 feet above Crossing 572 (Ninth

St.) for a total of 2300'. Survey methods were adapted from the EMAPS *Field Operations Manual for Wadeable Streams* (EPA 620/R-06/003, Oct. 2006). Measurements of water depth at the thalweg, wetted width, active channel width, and bank height ratio were collected (Figure 2). Additionally, a hand held optical level and ruled level rod were used to determine a continuous elevation profile of the streambed. Streaming GPS and photographs were used to augment field notes, and timestamps allowed the stream survey data to be combined with other elevation surveys to create a continuous elevation model of Patterson Creek through Bay City (Figure 3).

Figure 2: Stream survey of bed elevation and profile

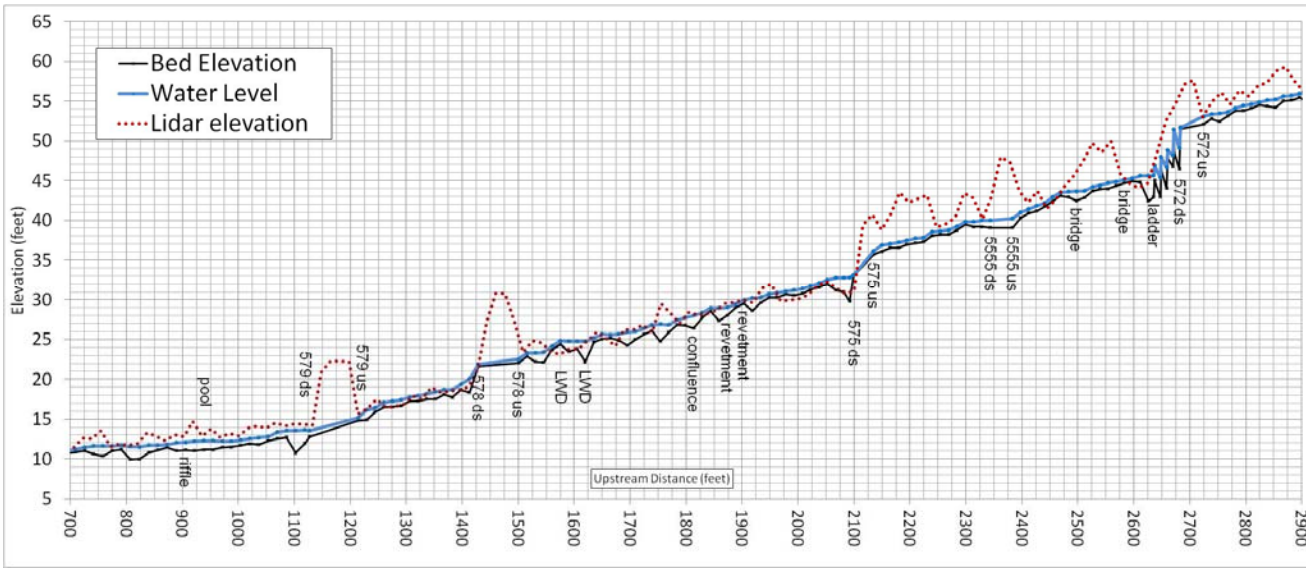


Figure 3: Stream survey data plotted with elevations extracted along Patterson Creek from lidar DEM

Crossing 528, the uppermost culvert included in the project, was surveyed using a total station on March 19, 2015. Due to the additional complexity of the Crossing at 9th Street, a total station survey was also conducted for the fish ladder and culvert at crossing 572 on April 26, 2015. For both of these surveys, the stream thalweg, banks, road surface and prism, and surrounding topography was measured. Utilities and control points were also located at Crossing 572. Temporary survey benchmarks were placed at all locations; however several of these were damaged during the course of the summer and are no longer reliable for surveying purposes.

Additional surveying was conducted during each of the survey dates to locate and find elevations of features and boundaries pertinent to the design process. One set of design options considered the development of a currently unused city road Right-Of-Way (ROW) between 7th and 9th Streets, one block south of Main Street. A summary of findings was presented in the Design Alternatives Memo (Attachment C). These findings are also discussed below.

FLOW ANALYSIS AND FLOOD RISK ASSESSMENT

RETURN INTERVAL DISCHARGE CALCULATIONS

Stream discharge statistics (recurrence interval of instantaneous peak flow) were compared from two sources to determine the magnitude of flood discharges for reaches within Bay City. The automated StreamStats tool (USGS) utilizes empirical regression equations that estimate land cover characteristics and drainage area from the National 10m DEM. These discharge estimates were queried from the USGS's web-based tool for Patterson Creek above and below the confluence with Jacoby Creek. These values were compared to discharges estimated using the Rational Method (HLB and Assoc., CBC Storm Water Plan, 2003). For the design reaches, the rational method predicted stream flow within 10% of the Streamstats result. Differences were tabulated, and a conservative estimate was obtained by areal estimates (Figure 4). Streamstats estimates were also found for upper Patterson Creek and tributary (near Crossings 542 and 543), although Streamstats indicated that some input values (watershed area) were almost outside valid limits for the regression equation. These flow estimates were included in the Opportunities and Constraints Report (Attachment B). Streamstats estimates for

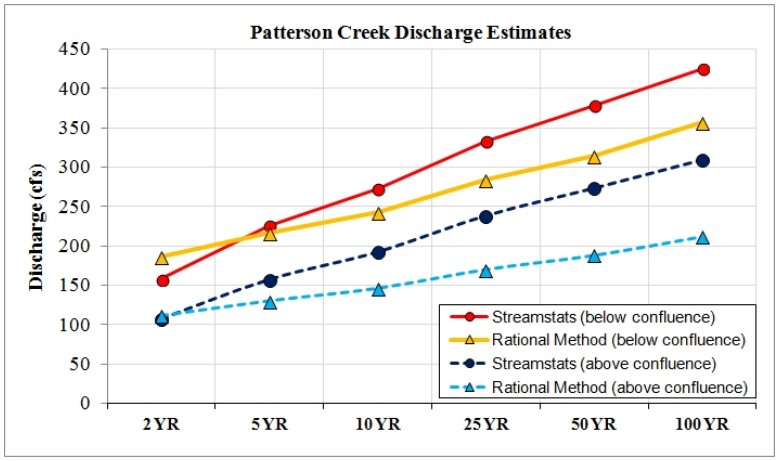


Figure 4: Example of adjusted discharge calculations, compared to estimates from Streamstats and rational method. Confidence intervals given by regression equations (±30%) are shown dotted.

Crossing 528 were obtained but not used (basin area smaller than valid range for regression equation).

HYDRAULIC FLOW MODEL: HEC-RAS METHODS AND RESULTS

Instantaneous stream flow values were used to build a hydraulic model in HEC-RAS (version 4.1, USACE) for the Bay City reaches of Patterson Creek (the entire surveyed length). Channel geometry, flow obstructions, culvert sizes and alignments, and roughness were obtained from field survey data, and implemented in the model using the GeoRAS Toolbox (Figure 5). Flow obstruction and overflow areas were extrapolated from the lidar DEM and NAIP aerial imagery. The surface DEM for the model was adapted from a grid based sampling of lidar data, which was adjusted at the location of the stream channel to match surveyed streambed elevations. This adjusted DEM was ground filtered and smoothed to create a continuous topographic surface approximating the actual channel, stream banks, and flood plain areas.

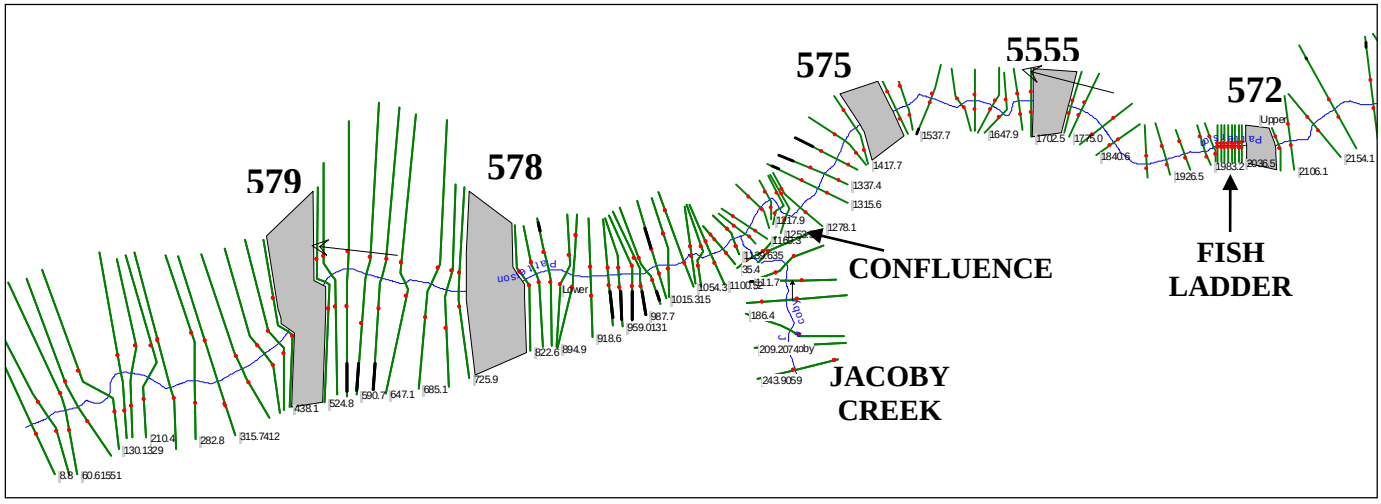


Figure 5: Geometry of flow areas and structures in HEC RAS model, obtained from survey data using GeoRAS Toolbox.

Flow conditions were entered using a known water surface elevation at top and bottom of each reach, and discharge values were adapted from 5 nodes based on observed sources of inflow and on basin delineations from the CoBC Stormwater Master Plan. The model was calibrated by adjusting channel roughness, followed by inlet and outlet coefficients for all culverts. The final calibration agreed with survey measurement throughout the channel, with minor departures from observed conditions between Crossings 578 and 575 (Figure 6). Flow in this reach is influenced by large woody debris, field observations indicate that flow obstruction occurs here and may

be a source of inefficient drainage. Better model performance may be possible with additional detailed survey information and elaboration of the complicated flow behavior in locations Reach 4 (woody debris) and Reach 5 (fish ladder and multiple channel behavior at confluence). This additional model development was not completed for Phase 1.

Despite the calibrated model's acceptable performance under low flow conditions, the model did not perform well under high flow conditions. High flow events (2, 10, 50, and 100 year recurrence intervals) were run in the model, based on adjusted Streamstats discharge estimates (see previous section above). The model showed overtopping events for Crossings 575 and 572 during the 10 year event, and 572 showed overtopping during a 2

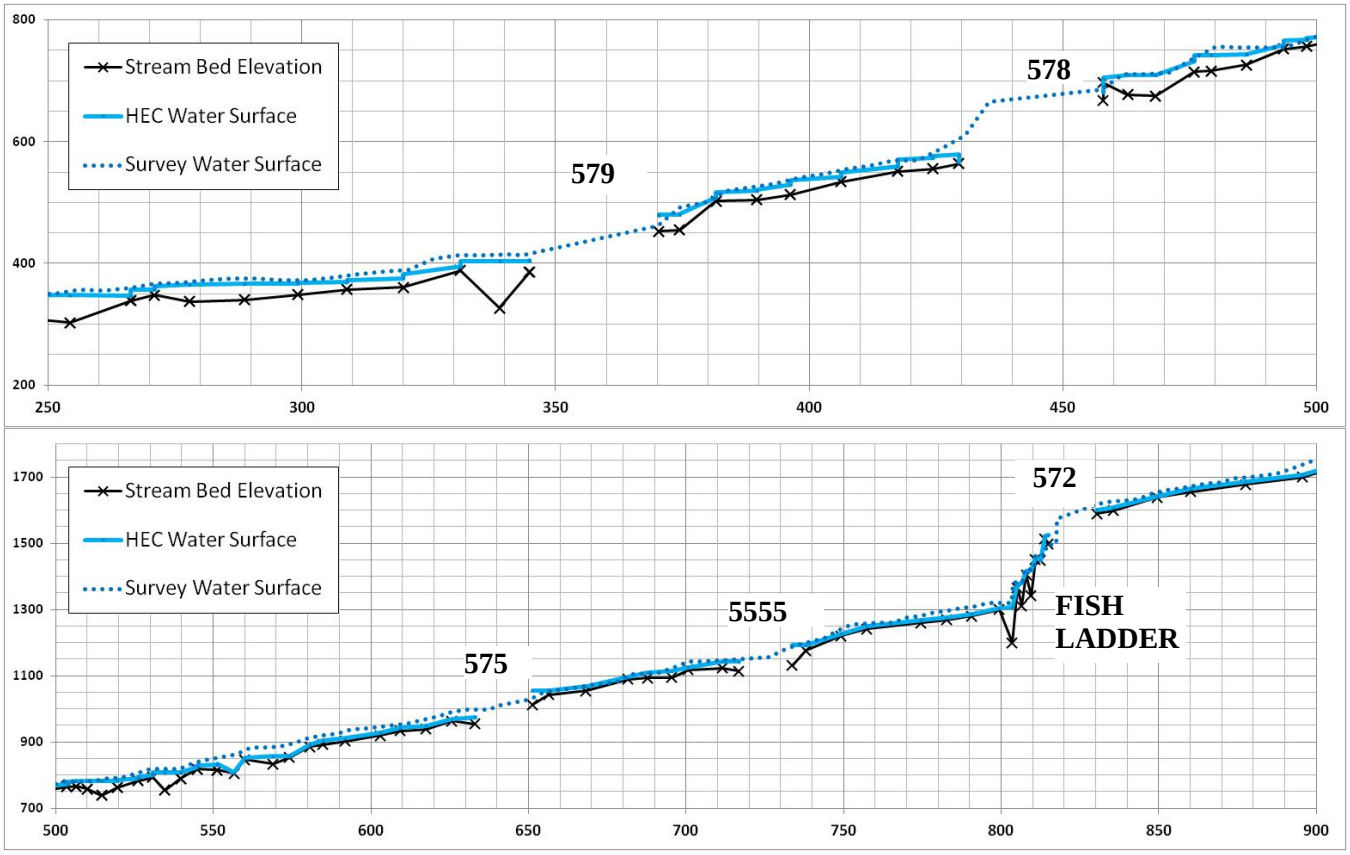


Figure 6: Calibration of HEC-RAS model, using low flow water depths (from field survey) as boundary conditions.

year event. Long term residents suggested that the flooding occurred on a 10 year interval at Crossing 572, which indicates that the model may be overestimating flooding duration and extent during the 2Y return interval (and greater) events. Observations made by local residents were not consistent, but it seems likely that the model

results are not accurate at the fish ladder in particular. To evaluate the capacity of the model to capture high flow events, input parameters were adjusted beyond reasonable assumptions about hydraulic behavior. Culvert coefficients, channel roughness, slopes, and other parameters were all changed up to and beyond physically realistic values; nonetheless, the model did not yield significantly different output. Further improvements to model will require additional surveying to accurately represent channel parameters. Flow behavior around the fish ladder and the undersized culverts at Crossings 572 and 575 in particular did not behave as expected and need more explicit measurements of channel and bank geometry. The hydraulic model was not developed further for Phase 1 designs; further model development is suggested to address flood risk mitigation in Phase 2 designs.

FLOODPLAIN ELEVATION MODEL

Given that the results from the hydraulic model did not provide a complete picture of flood behaviors required for the design, LCE staff developed an elevation model to map flood risk in the riparian area of Patterson Creek (150' buffer). In addition to undersized structures, artificial breaks in the stream slope (perched structures) are the major fish passage barriers at crossings, requiring vertical adjustments throughout Bay City. These vertical adjustments could not be determined independently for three reasons. All crossings in Bay City are within a short reach of each other, and the hydraulic influence of each overlaps. Patterson Creek is in a close lateral and vertical proximity to both private residences and transportation and utility infrastructure. Finally, the channel of Patterson Creek was historically straightened and deepened, reducing in-channel flood capacity and restricting lateral migration. Multiple private residences and other structures are located in the treatment reaches. In addition, it was found that sewer lines located in Crossings 575, 5555, and 572 are at the stream elevations that are optimal for fish passage. These design constraints were addressed by use of an "altimetric" elevation model which generates maps of relative elevation in the riparian areas. These maps assume simplified flow behavior, divide the riparian buffer area into short

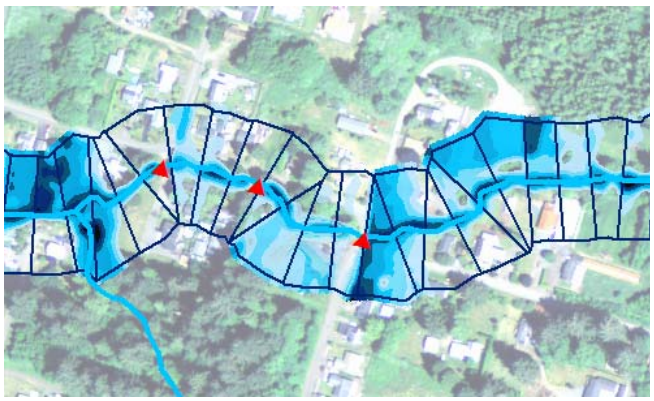


Figure 7: Polygons delineating "local stream elevation" used in determining "height above base flow" for flood extent estimate.

reaches (75' in the flow direction, 300' width), and assign a base elevation to each reach (the lowest stream elevation in that reach). Blue colored areas indicate the height in reference to this base elevation (Figure 7).

It should be emphasized that this is an elevation model, not a flow model, and should not be taken as a prediction of flooding likelihood or flow depth estimates under any particular set of conditions. The maps generated were used to give an approximation of the locations and areas requiring consideration when changing streambed elevations. The model allowed strategic distribution of the vertical adjustments required to allow fish passage in Bay City. The resulting preferred alternative (below) includes recommendations to relocate Patterson Creek laterally below the fish ladder, and suggests areas where bank reinforcement may be required. These recommendations for treatments between the structures will be developed further in Phase 2 designs. A complete description of the modelling method can be found in Attachment C (Technical Memorandum, May 15, 2015).

EXISTING CONDITIONS- PROJECT CULVERTS, INFRASTRUCTURE, AND CONNECTING REACHES

Design considerations for the existing culverts to be replaced can be divided into three groups. Using the reach designations from the *Assessment of Potential In-Stream Enhancement Opportunities* (TEP, 2015) Reaches 2 through 4 include Crossings 579 and 578 (4th and 5th Streets). These two culverts are similar in size and structural requirements, lying below the confluence with Jacoby Creek and supporting 20' width roads. These two HL-93 crossings must meet ODOT standards to accommodate highway loads (alternate routes for Highway 101). The existing elevations are near the required final stream (invert) elevations, although 578 is perched at the outlet.

Crossings 575, 5555 and 572 are all smaller crossings, requiring less flow capacity (smaller active channel width). However, these three crossings are severely constrained by elevation controls imposed by sewer lines and structures within the riparian corridor. Phase 2 designs

Figure 8: Reach designations from TEP Instream Assessment

will need to resolve the challenges for replacing Crossings 575, 5555, and 572 raised by this study.

Crossings 542, 543, and 528 required standard replacement designs; designs presented here fulfill fish passage, cost effectiveness, and structural requirements; decisions on structures used at these crossings are provisional and will be finalized by staff at Oregon Department of Forestry (Tillamook). The primary constraint on replacing the upper culverts is limiting time of closure during construction and to allow continuous access for Pacific Power over Crossings 543 and 542. The uppermost culvert at 528 has a moderate amount of fill to remove and replace, and cost estimates included transport and disposal costs related to fill.

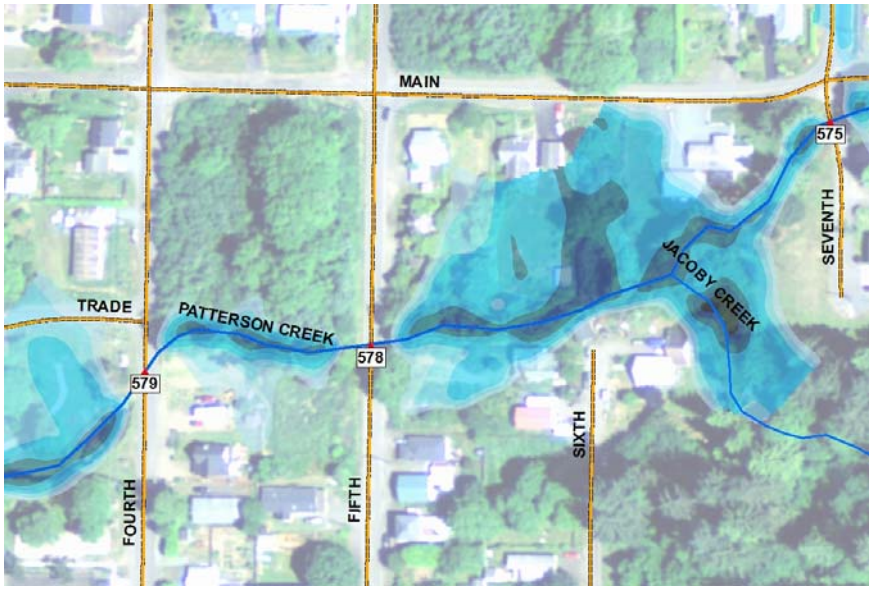


Figure 9: Reach 2-4. Altimetric model showing existing conditions. Field survey staff noted the area between Crossing 578 and confluence with Jacoby Creek is likely to flood adjacent to channel. This reach currently has multiple revetments and stream bank protections to prevent erosion. See Figures 10-12

REACH 2-4

Slope of the creek in this reach is 1% or less. The confluence with Jacoby Creek is located at the upstream end of Reach 4. Between 4th and 5th Streets, building lots have been condemned as unbuildable; however at least one buildable lot south of Patterson Creek is listed for sale. East of Crossing 578, residential structures are located directly adjacent to the creek on both north and south banks. Revetments and bank reinforcement have been built in several places near the confluence with Jacoby Creek. Between the


Figure 10: Large woody debris (several large conifer and hardwood logs) located between Crossing 578 and confluence of Patterson and Jacoby Creek

confluence and Crossing 578, large conifer logs and other woody debris have accumulated, and enough accumulated bedload to affect drainage. Notching in logs and revetments are evidence that constrained flow may be causing flooding and erosion upstream.

Figure 11: This reach currently has multiple revetments and stream bank protections to prevent erosion both above and below confluence with Jacoby Creek.

Figure 12: Several residential structures are located within one active channel width of the average high water line of Patterson Creek in Reach 4.

CROSSING 579 (ATTACHMENT D, EXISTING CONDITION DRAWING 1000-02)

Patterson Creek crosses 4th Street via a 6' diameter corrugated metal pipe with mitered ends (91.5' length invert to invert) at a 60 degree skew to 4th Street. Concrete wing walls downstream are in poor condition, with a large concrete block (broken splash apron or wall abutment) located in the downstream pool. The upstream wing walls are completely overgrown, but appear to be badly eroded and possibly failed on north side. This culvert was flagged for replacement in the CoBC 2003 Storm Water Master Plan.

Figure 13: Crossing 579 (4th St.), looking upstream.

A 6" PVC water main crosses on the west edge of the road, and sewer main "I" terminates at south side, approximately 15' feet south of the culvert. The extreme skew and proximity of the sewer main were determining factors in the selection of a replacement structure.

CROSSING 578 (ATTACHMENT D, EXISTING CONDITION DRAWING 1000-04)

Figure 14: Concrete box culvert Crossing 578 (5th St.)

The box culvert at 5th Street is the first significant fish passage barrier on Patterson Creek. The outlet invert of the culvert is perched 2.5', and is a total barrier to juvenile salmonids. The shallow water depth in the concrete bottom culvert is a partial barrier to upstream migration by adult fish. The existing structure is a 6' x 8' x 72' concrete box culvert. The primary sewer conveyance from the north side of Bay City, a 10" sewer line (Main A), passes exposed through the culvert with approximately 4.75' of clearance beneath the cast iron pipe (see Figure 27). 8" PVC and 6" steel water mains cross on the east side of 5th street, and a hydrant is located north of the crossing. It was decided by project partners that upward adjustment of the stream channel elevation to eliminate the downstream perch is not feasible. The primary reason for this would be increased flooding risk at two buildable properties on the south side of Patterson Creek downstream of the crossing. Additionally, the exposed sewer main inside the box culvert is located at the top of the structure, by lowering the replacement structure it is possible to protect this pipe within the fill above a replacement culvert. Lots on the north side of Patterson Creek downstream are not buildable (DEQ assessment, see Tillamook Co. Assessor records) and may provide opportunities for habitat improvement and flood storage capacity.

REACH 4-6

Figure 15: Residential development extends to the average high flow water level in Reach 5, limiting the potential to aggrade the channel as an approach to removing the fish passage barrier at the existing fish ladder, upstream approximately 200 feet.

Above the confluence with Jacoby Creek, Patterson Creek has been extensively modified to facilitate residential development close to the banks of both Patterson Creek and Jacoby Creek. The Patterson Creek channel has been straightened and deepened where it parallels Main Street (see Cross sections in Attachment C, Alternatives Analysis Figures, page 10). A deep scour pool and the perched, undersized culvert at 575 is a fish passage barrier to both adults and juveniles at most flow levels. The reach below the fish ladder is also deeply incised (in places nearly a 10' bank height and a 16' active channel width). Between 8th and 9th Streets, two private bridges cross the creek, and a foundation for a residence is built within the active channel width (Figure 15). Designs to improve fish passage in the area of the existing fish ladder require aggrading the channel, but are constrained by the height of adjacent low lying residential properties on the south side of Patterson Creek (Figure 15). The altimetric model was used to identify the maximum

Figure 16: Existing conditions between 7th and 9th Streets, with altimetric elevations shown in blue. Structures located on the south side of Patterson Creek between 8th and 9th Streets are the most limiting constraints on vertical adjustments, coinciding with low lying areas south of Main Street. Residential developments east of 9th Street and south of Main Street (between Patterson and Jacoby Creek) are built on what was historically riparian floodplain.

aggradation possible without significantly increasing flood risk to surrounding properties. Additional modelling will be required in Phase 2 to further explore this aspect of the design.

Sewer laterals F-4 and F-5 cross at 7th and 8th Streets and each are located within 4' of the current stream elevation. As-built drawings indicate that sewer pipes are in contact with existing culverts at these locations. Sewer Main F follows Main Street and 9th Street. Where it crosses Patterson Creek at Crossing 572, the sewer main is approximately 2.8 feet below the culvert pipe. Both 575 and 5555 access 2-3 residential properties; Crossing 572 is the only existing access to approximately 25 residences. Bay City has Right-Of-Way between 7th and 9th Streets at the south end of these streets (aligned with Trade Street). This Right-Of-Way was perfunctorily evaluated as an alternative access route for any of 7th, 8th or 9th Streets, which would allow removal rather than replacement of the culverts, or to serve as temporary access during construction of 572. This evaluation indicated that many large spruce trees would need to be removed, and also noted that this area is currently used as ad hoc public space with walking paths. Additional exploration of this possibility was deferred prior to further community and Bay City staff input regarding future development plans. See Attachment C, Design Alternatives

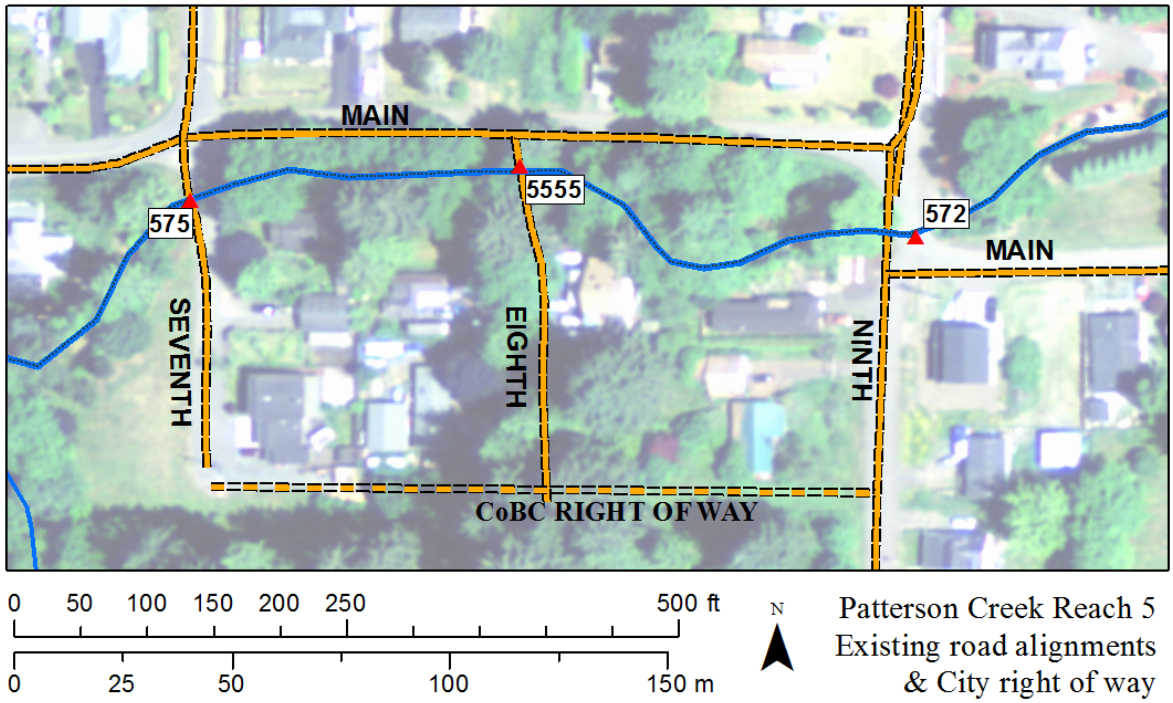


Figure 17: Road alignments in Reach 5. Sewer lateral F4 is located below 7th Street (south of Main), Sewer lateral F5 is located below 8th Street (south of Main), and Sewer main F follows 9th Street and continues eastward underneath Main Street. CoBC Right-Of-Way is undeveloped- there are several large spruce trees and the area is extensively used by the public & adjacent landowners.

Figures, pages 12-14.

CROSSING 575 (ATTACHMENT D, EXISTING CONDITION DRAWING 1000-06)

The 48” corrugated metal pipe is 36’ in length at 7% pipe slope. It is undersized, is corroded along the entire length, and the pipe has completely failed at the outlet due to corrosion (Figure 19). The outlet is perched 1’ from the low flow water surface (16" to rock bed), with a 3’ deep scour pool. The steep slope, undersized and failed culvert pipe, and perch all prevent fish passage. Residents note that very few fish are seen past this point on Patterson Creek, and that significant numbers were seen in upstream pools in past decades.

A 16” corrugated plastic pipe outlet is located in the north face of the crossing fill, approximately 1' higher than Crossing 575, and connects across Main Street to a drainage ditch. A water service line is located in the crossing and connects to an 8” PVC main under Main St. The 8” sewer lateral F4 is shown in the sanitary sewer plans to be located directly below the existing culvert pipe.

Figure 18: Crossing 575 (7th St.). The plastic culvert fed by the 7th Street drainage ditch can be seen on the left bank of the crossing fill. Downstream scour pool is 3' at deepest point.

Figure 19: Outlet of Crossing 575, showing complete pipe failure. Scour has eroded below the pipe, which now projects above the pool below. Total perch height is 12" from water surface to outlet of pipe.

CROSSING 5555 (ATTACHMENT D, EXISTING CONDITION DRAWING 1000-08)

Crossing 5555 provides access to 2-3 residences at 8th Street. The culvert is a 5' diameter, 40' long corrugated metal pipe. The pipe is undersized, and is partly embedded (approximately 12") at zero slope. Both ends are projecting and show damage from wear or during installation or maintenance. The stream thalweg is approximately 9 feet below the surrounding road surfaces, and becomes more deeply incised in the reach immediately upstream. A water service line is located in the crossing and connects to an 8" PVC main under Main St. The 8" sewer lateral F5 appears in plans to be resting directly in contact with the top of the culvert pipe. An overhead power line crosses Patterson Creek, with a power pole approximately 6' from the crossing at the northwest corner.

Figure 20: Crossing 5555 (8th St.)

CROSSING 572 (ATTACHMENT D, EXISTING CONDITION DRAWINGS 1000-10 & 1000-11)

The fish ladder and culvert are a total fish passage barrier in their current condition. The four cell ladder is in poor repair, with failed weir boards in at least two cells. The bottom three cells have accumulated gravel and fine sediment nearly to the depth of the weir boards at each cell outlet. At the outlet of the fish ladder, the bottom weir is perched 2' above the water surface of the scour pool. The depth of the outlet pool below the fish ladder is greater than 3' (at low flow); the depth is controlled by a downstream cobble riffle. Several residents indicated that fish historically collected below this crossing to pass upstream, but have not been seen in recent years

Above the fish ladder, the 49" wide x 33" high corrugated metal pipe arch is 42' in length and at 4% slope. The outlet is perched 2.3' above the water level in the highest cell. It is completely impassable to any fish which

may reach the top cell due to the perch, high velocities within the pipe, and/or shallow depth at all flow conditions. The inlet of the pipe is constrained by vegetation, and Bay City Publics Works staff indicated that maintenance at this culvert was required to prevent plugging with debris. Residents noted in later interviews that Patterson Creek overtops 9th street during a ten year recurrence interval flood event, even if the culvert is free of debris or obstructions. Residents also indicate that bedload has accumulated upstream since the construction of the fish ladder.

Sewer main F is located 2.8' underneath the culvert pipe. Man holes at either end of this crossing receive additional sewer laterals (F3 and F6), which constrain sewer elevations without extensive redesign (see discussion regarding *Bay City Infrastructure* below).

Figure 21: Outlet of fish ladder below Crossing 572 (9th St.)

Figure 22: Crossing 572 (9th St.)

UPPER WATERSHED CROSSINGS

CROSSING 542 (ATTACH. D, EXISTING CONDITION DRAWING 1000-13)

The main tributary of Patterson Creek passes through a 36" corrugated metal pipe, 36' long, which is in moderate condition. The culvert is undersized and perched 2.5' at downstream end, creating a total barrier to both adult and juvenile passage. Maintence is required to prevent blockage by trapped debris and sediment (ODF staff). Another small culvert and drainage ditch at the northwest side of the crossing may require additonal site grading.

Figure 23: Crossing 542 (ODF/PP access Rd)

CROSSING 543 (ATTACH. D, EXISTING CONDITION DRAWING 1000-15)

This crossing bridges a tributary of Patterson Creek, which is of equal size and drainage area to the main channel. The 42" diameter, 40' long corrugated metal pipe is undersized and perched 5' above the outlet pool, creating a total barrier to both adult and juvenile passage. This culvert also retains bedload and is a source of ongoing maintenance costs. Significant accumulation of bedload upstream is evident in the lidar profile and was also marked in the field survey.

Figure 24: Crossing 543 (ODF/PP access Rd)

CROSSING 528 (ATTACHMENT D, EXISTING CONDITION DRAWING 1000-17)

The 36" corrugated metal pipe is 72' long, with 18-20' fill height. Patterson Creek Road makes an 80' radius turn, with 15% road uphill slope south of crossing; this geometry makes replacement of the culvert with a bridge cost-prohibitive. The existing pipe is perched 3' above the scour pool at the outlet, and is undersized based on the active channel width in adjacent reaches. The pipe slope is 5.5%; slope of Patterson Creek is 12% upstream and is 7% downstream. Conveyance of bed load is reduced due to the undersized pipe and shallow pipe slope.

The replacement structure will need to account for depth of fill over the culvert; fill removal and construction will require staging sites and additional time for shoring and bank stabilization (Figure 25). The replacement structure and fill will match the existing turn radius, load rating, and slope, per ODF road standards.

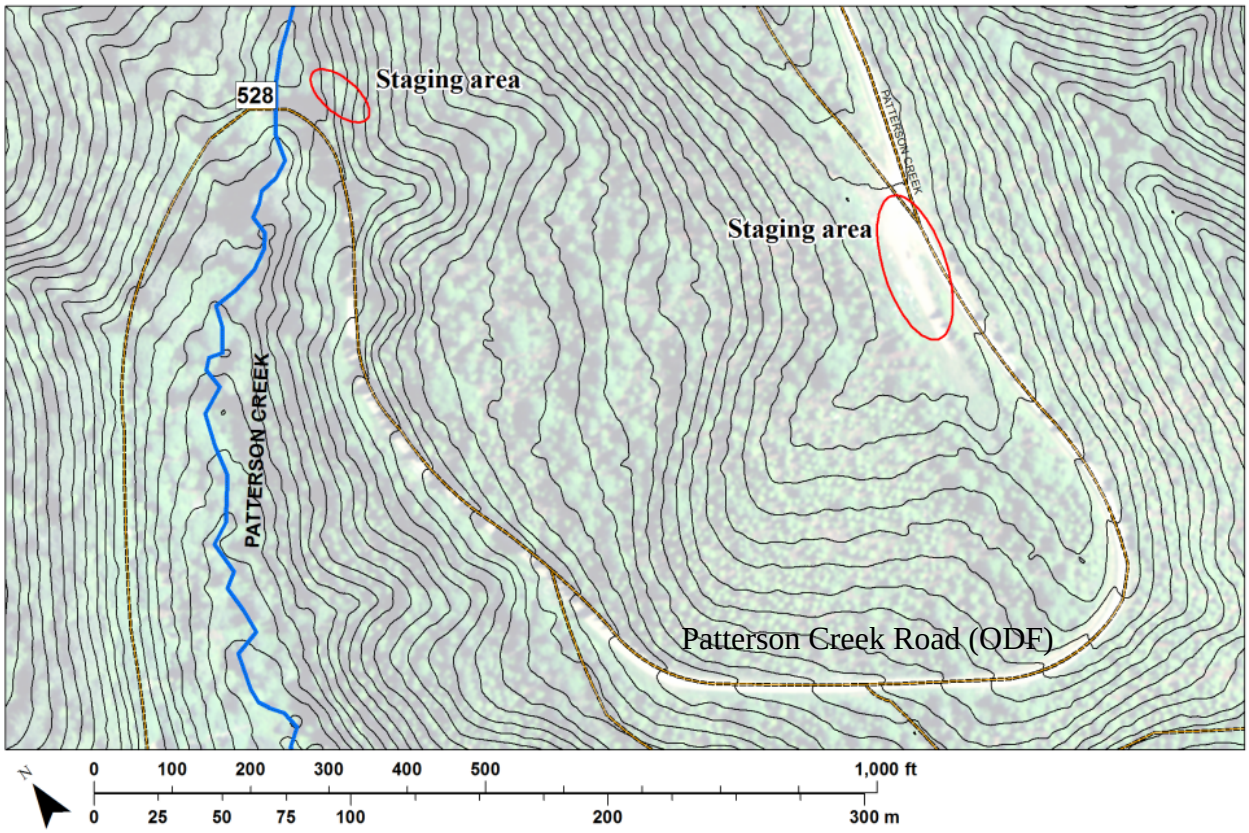


Figure 25: Patterson Creek Road at Crossing 528. Potential staging areas for fill to be used during construction. Eastern site is larger, located 0.4 miles away from Crossing 528.

BAY CITY INFRASTRUCTURE - SEWER SYSTEM AND RIGHT OF WAY

During Phase 1 feasibility study, it became evident that the Bay City sanitary sewer system is a source of risk and design challenges for improving stream function at several locations. The most obvious problem identified is the exposed sewer main that crosses Patterson Creek approximately 600 feet downstream of Crossing 579 (equivalent to 2nd St.) and just below the City Park (Figure 26). Several options to re-route this sewer main were presented to the project partners (Attachment C, Design Alternatives- Figures), and City of Bay City elected to pursue a solution for this independently of this study.

Figure 26: Exposed sewer main crossing Patterson Creek (Reach 1)

At Crossing 578, there is an exposed sewer main inside the existing culvert (Figure 27). The proposed replacement culvert design retains the sewer main at the current elevation, and the replacement structure passes underneath (i.e., the sewer main will be buried in the fill- see Conceptual Design Drawings).

Figure 27: Exposed sewer main inside Crossng 578. Visible near top of box culvert

The sewer main and laterals along Main Street pose more serious constraints on the replacement of structures at Crossings 575, 5555, and 572. The proposed stream profile in Reaches 4-6 was established following fish passage guidelines, matching the estimated elevation profile without creating jump heights exceeding 6". This realignment adjusts the elevation of the streambed at each of these three structure downward. In each case, this would result in exposure or other conflicts with sewer pipes. For the following discussion, please refer to *Bay*

City Sanitary Sewer Plans, page 28 to find elevations and sewer alignments. Potential alternatives proposed

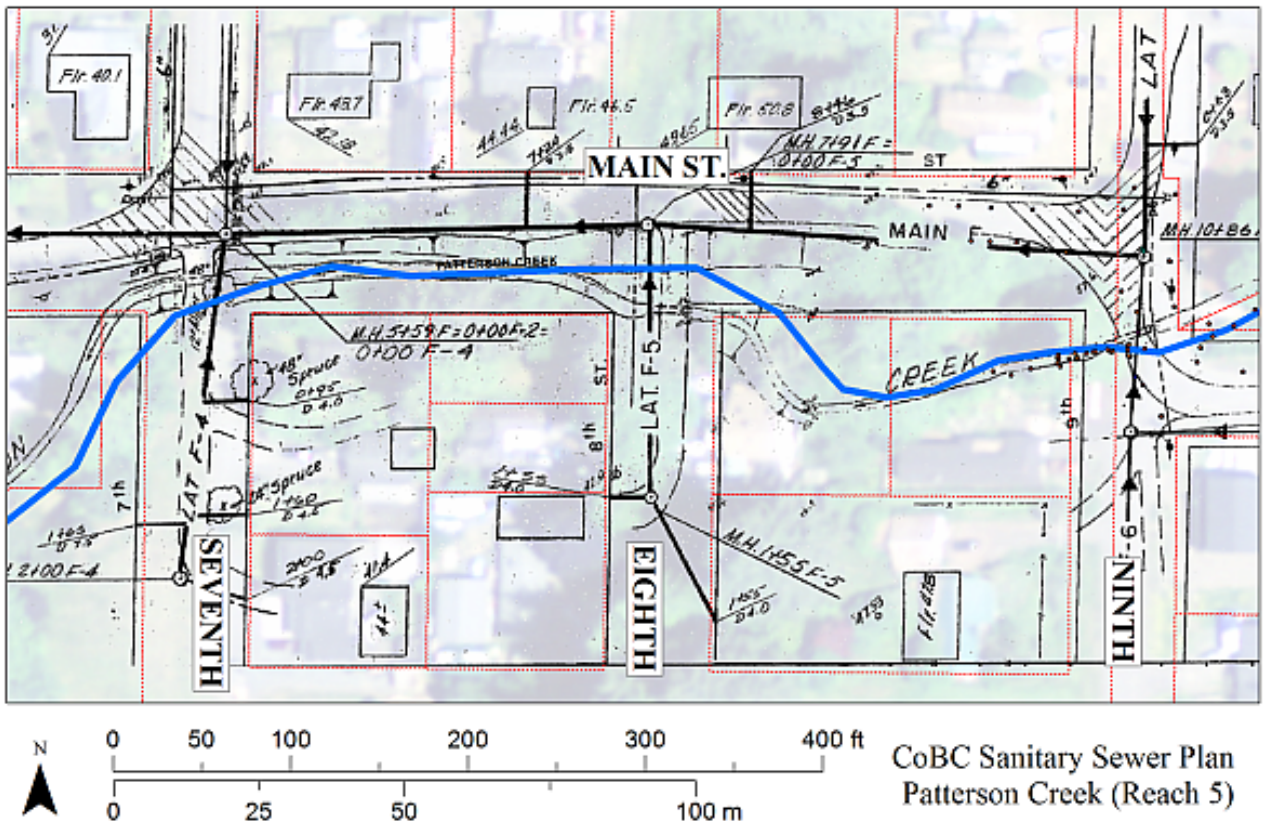


Figure 28: Bay City sanitary sewer plan in the proximity of Reach 5, showing Main F and laterals F4 and F5.

below have not been presented to nor verified by Bay City Public Works or city engineers, and were considered only for purposes of the feasibility study. Any potential solution will require additional analysis and verification of sewer design.

At 7th Street, the existing culvert is above sewer lateral F4 (see Figure 28 and Attachment D - Existing Conditions Drawings). Eliminating the perch at this culvert brings the streambed near or below the sewer lateral. The outlet of F4 cannot be lowered without modifying the manhole (F5+59) and lowering Main F below this manhole. One alternate solution would be to move some or all of the length of Lateral F4 vertically upwards, which would allow the sewer to be buried in the fill above the replacement structure. It is not clear from existing as-built drawings if there is adequate clearance for this approach.

At 8th Street, the existing culvert pipe is located directly underneath sewer lateral F5. Replacement of the culvert at 5555 with an open bottom structure would leave sewer Lateral F5 exposed at its existing elevation (see Attachment D, Existing Conditions and Proposed Conceptual Design Drawings). The connection of Lateral F5 to Main F (under Main St.) prevents moving the lateral downward below the new stream channel, but the lateral could be moved upwards. It is assumed with the proposed design (a modular bridge) that the lateral would be moved upwards and attached to the new bridge. This solution suggested the proposed bridge design, and would require an exposed sewer line attached to the replacement structure.

At 9th Street, sewer Main F is at the proposed elevation of the streambed (see Attachment D, Proposed Conceptual Design drawings). The elevation of this sewer main is constrained by the existing inlet and outlet of Main F, as well as laterals at both ends (Figure 29). A solution has not been proposed for this crossing. Re-routing sewer Main F via the city Right-Of-Way was explored, but this solution requires additional design considerations and input from stakeholders. Resolving this challenge was beyond the scope of the Phase 1

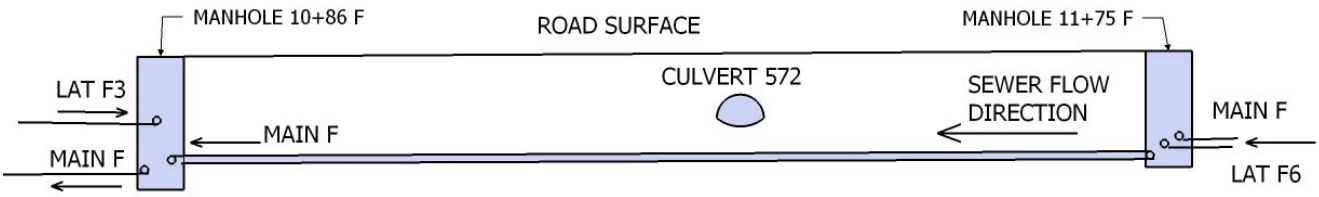


Figure 29: Simplified existing condition elevation diagram of Bay City sanitary sewer at Crossing 572, showing elevations of inlet and outlets controlling Main F. The preferred elevation for Patterson Creek (allowing fish passage past 572) is at the current elevation of sewer Main F. Outlets of Main F and Lateral F6 (at right) prevent upward movement of Main F. Downward movement of Main F is prevented by current outlet elevation of downstream manhole.)

feasibility study.

The sewer main and laterals at 7th, 8th and 9th Streets will need to be re-aligned to allow replacement of the culverts. This may involve a number of possible solutions, including routing the sewer main via the city Right-Of-Way on Trade Street; developing Trade Street and abandoning any of the three crossings from Main Street; some combination of replacing the existing structures and developing Trade Street. Solutions for these design challenges should be among the first tasks addressed in Phase 2 designs.

PROPOSED DESIGNS FOR REPLACEMENT STRUCTURES

PATTERSON CREEK - VERTICAL PROFILE

A continuous stream elevation profile was generated that removed all artificial vertical jumps greater than 6 inches. Linear regression (over 150' intervals) was used to find the average stream slope. Adjustments made at structures were extended upstream and downstream using an average channel slope of 2.5% (Figure 30). This method approximates potential stream power and bedload mobility. Site-specific grade control designs should be specified in Phase 2- the vertical profile indicates the extent and locations of required engineered structures. In addition to rebuilding 75' of roughened channel below Crossing 572, 2-3 additional grade control/energy dissipation structures (rock weirs and/or large in-stream wood structures) will be required between Crossings 572 and 5555 to maintain a stable channel.

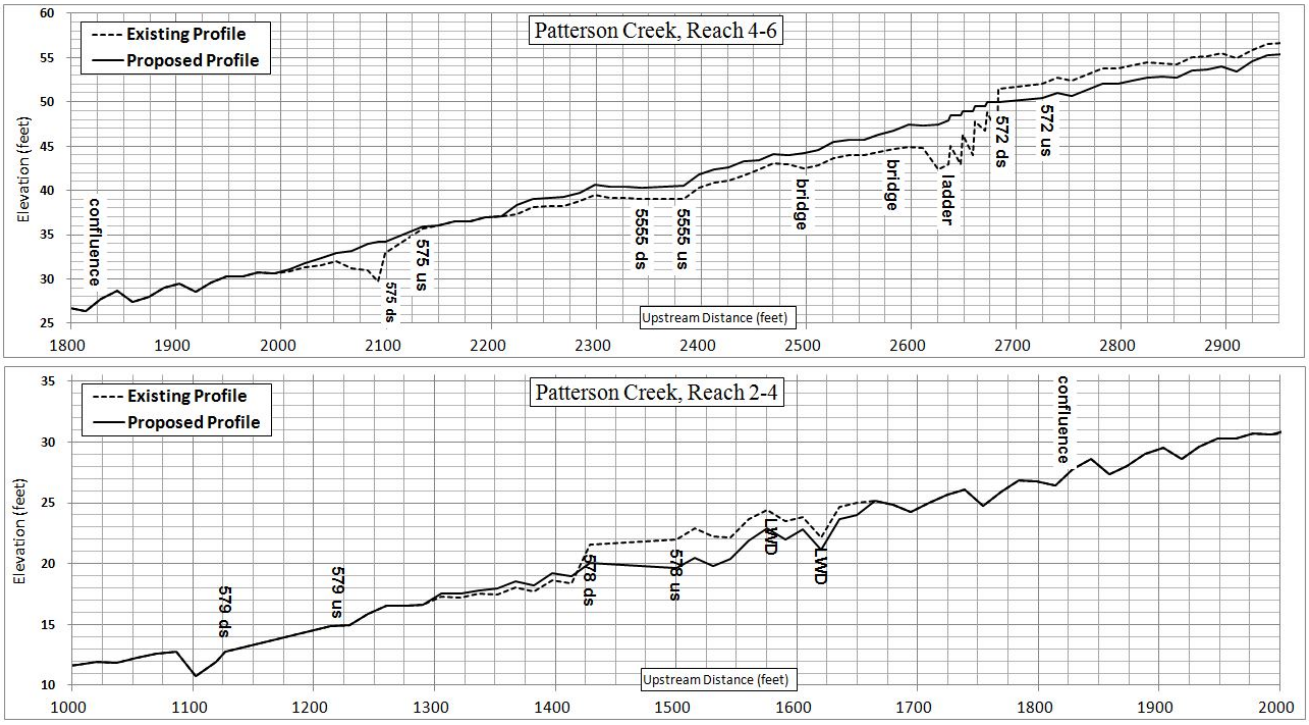


Figure 30: Proposed elevation profile, based on removing fish passage barriers

LATERAL ADJUSTMENTS AND BANK STABILIZATION

The vertical profile was used to generate an altimetric map (Figure 31), which highlights two areas requiring additional design. The area north of the confluence with Jacoby Creek, which was flagged during field surveys (structures in riparian, revetments, flood risk) includes a city Right-Of-Way (6th Street). This low lying area is directly upstream of the large conifer logs described in the field survey (Figure 10). Project partners elected to lower the elevation of the replacement structure for Crossing 578, and the existing large wood will be helpful in maintaining a stable channel in this reach. The right of way (shown in green) is a potential site for off-channel improvements that can serve multiple benefits. Suggested improvements include replacement of revetments with increased setbacks, stable bank construction, and off channel habitat pools which double as flood storage

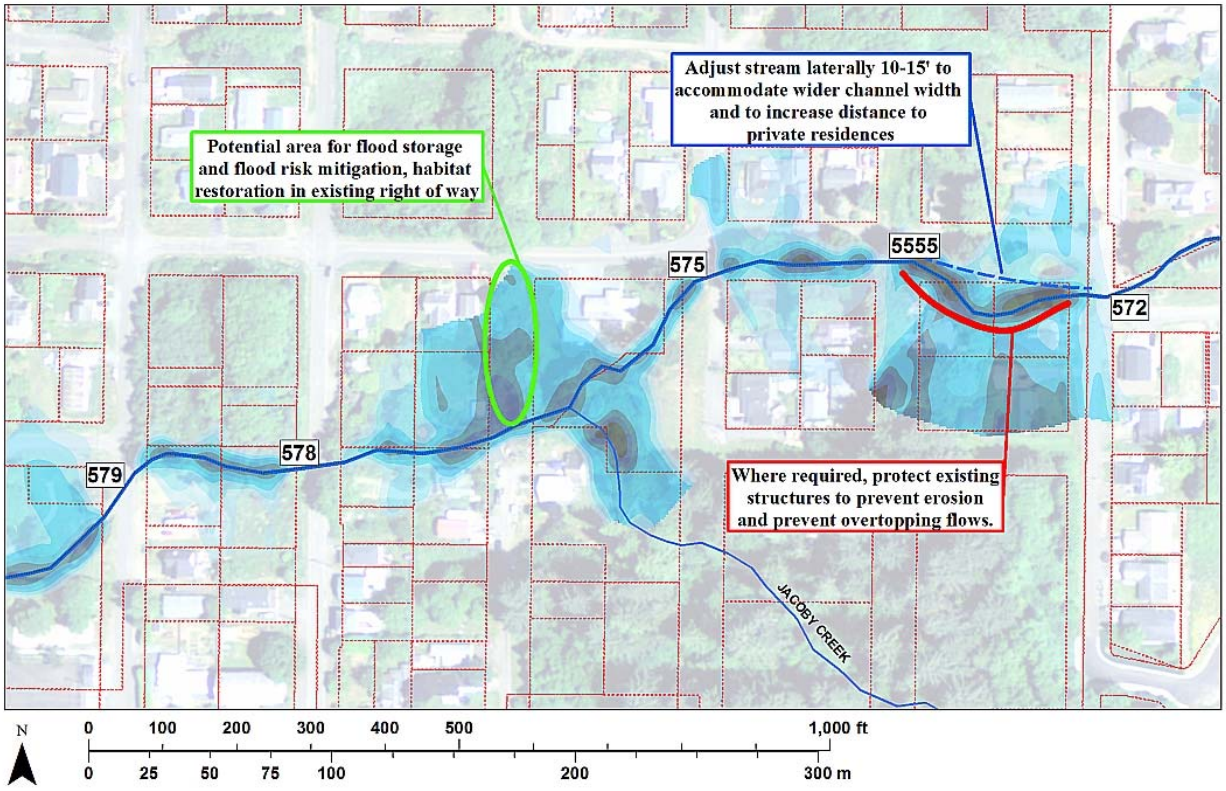


Figure 31: Proposed stream re-alignments, showing altimetric elevation model for proposed elevations and suggested habitat improvements and flood mitigation measures.

capacity.

The elevation profile was selected to minimize exposure of adjacent residential properties to flood risk. In the conceptual designs, extensive stream bed modifications are proposed for the reach above and below the existing fish ladder, with smaller adjustments required downstream of both Crossing 575 and Crossing 578. The project managers met with upstream residents, who expressed support for deepening the channel above Crossing 572. Longtime residents observed that removing accumulated bedload and lowering the channel in Reach 6 would return Patterson Creek to its historic condition. This modification is represented by the reduction of areas show in blue to the east of Crossing 572.

The residential properties south of Patterson Creek, downstream from Crossing 572 continue to show areas that may be prone to flooding, as discussed above in existing conditions. Alternatives that increased the elevation by more than 2' were deselected in the final proposal to minimize any additional flood risk in this reach. The wider, restored channel at the existing fish ladder should be constructed to 1.5 times the active channel width on the north side of the existing channel (shown with dashed line in Figure 31). This is suggested to eliminate erosion of the structures built on the south bank. Additional stream bank protection may be required at the footings of structures discussed above. A geotechnical engineer should be consulted in Phase 2 to address erosion risk at the existing structures located inside the active channel width.

PROPOSED STRUCTURES

CROSSING 579 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-03)

The most challenging constraint for this crossing is the current 60 degree skew to 4th Street. The proposed design reduces the skew by realigning the creek 13.5' feet northward at the outlet. Reducing skew and increasing channel width as proposed at the outlet of Crossing 579 is feasible as both sides of Patterson Creek are within the city park. Based on the *Assessment of Potential Riparian Enhancement Opportunities (TEP, 2015),* the proposed design assumes that the outlet of the new structure will incorporate construction of a wider natural channel with shallower side slopes, some bank stabilization beyond the wing walls, and extensive low-density planting and

bank restoration. These design features are compatible with the current uses in the city park, and may provide opportunities for education and outreach about the entire Patterson Creek restoration project. Additional considerations for the proposed design included: proximity of sewer Main I to the south side of the existing culvert, which terminates at a manhole on the south side of the proposed structure and highway bypass requirements.

The proposed structure is an 8' high by 28' wide skewed (40 deg.) open bottom concrete box culvert. The clear (structural) span of the culvert cells are 35 feet; the active channel width is 18.2', the skew width of 28' is 1.5 times the ACW. The structure is 75' in length. The skew structure minimizes the exposed structure ends. Based on availability, a straight box culvert may be used (with a longer structure length and more exposure past side slopes). Wing walls are required at inlet and outlet. The design slope of the constructed bed matches upstream reaches (2%). The constructed streambed will extend downstream to the head of the existing scour pool, which will be reinforced with a rock weir to prevent erosion at the box culvert's foundations. A low flow channel will be constructed from the existing scour pool through the entire structure to facilitate fish passage at low flow levels.

CROSSING 578 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-05)

The proposed design was based on the decision by project partners to adjust the existing streambed downward to eliminate the outlet perch. This resolved two design constraints by relocating the flow area underneath the exposed sewer main (see discussion above); this also created no additional flood risk in the upstream reach (to the confluence with Jacoby Creek).

The proposed structure is an 8' high by 28' wide open bottom concrete box culvert, 1.5 times the active channel width (18.5'). The structure is 66 feet in length. Wing walls are required at inlet and outlet. The design slope (2.3%) exceeds the surrounding stream slope by 1%, which is equivalent to a 6” rise over the length of the proposed structure. The constructed streambed will extend to the base of the existing outlet, which will be reinforced with a rock weir to prevent erosion at the box culvert's foundations. Due to significant accumulation of bedload at the large woody debris in Reach 4, additional rock weirs are suggested upstream of the structure to

reduce potential for head cutting. A low flow channel will be constructed from the elevation of the existing outlet invert through the entire structure to facilitate fish passage at low flow levels.

CROSSING 575 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-07)

In addition to the deep scour pool and perch of the existing crossing, the 200' reach centered on Crossing 575 is the steepest section of Patterson Creek within Bay City. The open bottom structure in the proposed design is deeply embedded and controls lateral migration of the creek, which is tightly constrained by Main Street and private residences on each bank.

The proposed structure is a 103" high by 25' wide open bottom multi-plate (steel) arch. Active channel width at the crossing is 16.2'. The proposed structure is 50' in length, 14' longer than the existing culvert. The extra length accommodates increasing the turn radius and building stable side slopes to the road surface. Additionally, if 7th Street is designated by Bay City as access for the city Right-Of-Way at Trade St., the road width may be required to increase. The proposed design can support a road width of 24' with minimum required structural fill height. If this width is not required, it is possible to reduce the length of the structure accordingly.

The proposed design and stream elevation plots indicate the elevation to which the channel will be increased, requiring filling of the eroded scour pool (existing condition) at the existing outlet. The steep channel slope in this reach will require a roughened channel and will also require rock weirs to dissipate energy downstream of the proposed structure. A step pool sequence may be possible utilizing rock weirs, but should not be necessary. Final designs will include calculations for rock sizing, energy dissipation structures, and rock weir placement. One unresolved design consideration remains: sewer Lateral F4 is located just below the proposed streambed elevation. Vertical realignment of this lateral may be possible, although the overall plan for sewer main and laterals in this reach will need to be considered prior to final designs (see discussion above).

CROSSING 5555 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-09)

Design alternatives initially considered removal of this crossing in lieu of re-routing access to the Right-Of-Way on Trade Street. Additional complications of utilizing the Right-Of-Way and realigning the sewer laterals

were beyond the scope of Phase 1 designs, and the proposed replacement structure is provided as one feasible solution. This crossing is located within the reach where stream elevation is aggraded (see Vertical Profile, Figure 30). Replacement (or removal) of this structure will include the first of several grade control rock weirs extending upstream to Crossing 572. The cumulative elevation gained by these rock weirs allow the construction of a stable roughened channel in the place of the fish ladder at Crossing 572. Modifications to the channel will extend throughout the reach from Crossing 5555 to Crossing 572.

The proposed replacement structure at Crossing 5555 is a 16' wide by 30' long modular steel bridge. The clear width between the bridge footings is 24', 1.5 times the 16' active channel width at the crossing. The design elevation of the existing road was increased by one foot to maintain clearance in the flow path while aggrading the channel 12" in the vicinity of Crossing 5555 (see discussion above). The current structure is also partly embedded and undersized.

One unresolved design consideration remains: sewer Lateral F5 is located just above the existing culvert pipe, and is shown exposed in the proposed stream profile. As-built drawings of the sewer show that this lateral could be adjusted upward, although the overall plan for sewer main and laterals in this reach will need to be considered prior to final designs (see discussion above). Moving the sewer lateral closer to the surface will require replacement with sewer line approved for shallow burial and attachment to the bridge.

CROSSING 572 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-12)

The proposed design was based on adjustments of the streambed downward from the culvert elevation, filling the scour pool downstream, and constructing a continuous roughened channel in place of the existing fish ladder. Concerns about flooding in adjacent low lying properties precluded additional increase to the bed elevation downstream, and upstream landowners are amenable to lowering the stream elevation above Crossing 572 (see discussion above). During the design process, project partners identified that this crossing may be subsidizing maintenance costs in downstream reaches by storing large volumes of bedload. A more extensive plan for managing bedload should be considered in Phase 2 designs.

The proposed structure is an 8' high by 24' wide concrete box culvert, 1.5 times the active channel width (14.7'). The structure is 48 feet in length. Wing walls are required at inlet and outlet. The design slope of the constructed bed is greater than upstream reaches (3.3% versus 2.5% upstream) to accommodate the existing break in slopes at the fish ladder. The roughened channel will extend downstream to the base of the existing outlet pool below the fish ladder, approximately 100' in length. Rock weirs and energy dissipating step pool sequence will be designed to facilitate fish passage and to prevent erosion at the box culvert's foundations. Additional rock weirs shall be constructed upstream of the structure to stabilize the stream slope at the design elevations. A low flow channel will be constructed from the elevation of the existing outlet invert through the entire structure to facilitate fish passage at low flow levels.

The existing channel below the fish ladder is deeply incised and has actively eroding banks over 8' high on the south side of Patterson Creek. The constructed channel will be developed towards the north side of Patterson Creek and into the Main Street Right-Of-Way (see discussion above). Erosion mitigation may be required on the south bank of Patterson Creek, pending geotechnical assessment.

UPPER CULVERT CROSSINGS (ODF MANAGEMENT)

Proposed designs for replacement structures are subject to revision according to ODF standards and current road construction practices, and may be changed to reflect ODF preferences at a later date.

CROSSING 542 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-14)

The design selected for the crossing prioritized reliability and speed of installation as the road cannot be closed during construction without providing temporary access (Pacific Power emergency access to distribution lines). Although Crossings 543 and 542 cannot be closed, temporary bypass can be provided at minimal cost by providing fill rock and a temporary diversion pipe. An excavator is to be available (with an operator on call) during the entire construction process to facilitate access at all times.

The proposed replacement structure is a 20' wide by 60' long modular steel bridge. The active channel width at the crossing is 11'; below the footings, 2:1 side slopes extend down to an unobstructed channel 1.5 times the

ACW. The design elevation and slope of the existing road matches the current road. The road alignment and width match the existing road. The steep channel slope in this reach (7%) will require a roughened channel or rock weirs to dissipate energy in the new channel and to prevent erosion below the footings. A step pool sequence may be possible utilizing rock weirs.

CROSSING 543 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-16)

As above, the design specifies that the road cannot be closed during construction. The proposed replacement structure is a 20' wide by 60' long modular steel bridge. The active channel width at the crossing is 11' (tributary is same size as Patterson Creek); below the footings, stable side slopes extend down to an unobstructed channel 1.5 times the ACW. The design elevation and slope of the existing road matches the current road. The road alignment and width match the existing road; the 20' bridge width accommodate the slight turn radius of the road alignment. The steep channel slope in this reach (7%) will require a roughened channel or rock weirs to dissipate energy in the new channel and to prevent erosion below the footings. A step pool sequence may be possible utilizing rock weirs.

CROSSING 528 (ATTACHMENT D, PROPOSED DESIGN DRAWING 1000-18)

The primary design consideration for replacement of this culvert is the height of the fill above the culvert. Existing conditions discussion (above) indicated two possible sites for staging fill material during construction. Based on stability and required shoring during construction, structural fill, disposal, and trucking estimates may vary considerably from the cost estimate provided. The turn radius, fill height, and road slope all precluded the selection of a bridge.

The proposed structure is an 87" high by 14' wide open bottom multi-plate (steel) arch. Active channel width at the crossing is 9'. The proposed structure is 84' in length, 12' longer than the existing culvert. The extra length accommodates stable side slopes to the road surface. The replacement structure is designed at 9% slope; downstream slopes are 7% and slopes increase to 12% upstream of the culvert.

COST ESTIMATE SUMMARY FOR PROPOSED STRUCTURES

Tillamook Estuaries Partnership
Patterson Creek Fish Passage Feasibility and Conceptual Design Study
Engineer's Construction Cost Estimate - Overall Summary

Item Description	Units	Qty.	Unit Cost	Cost
Final Design/Engineering (Culvert Replacements)	(item)	1	$80,000.00	$80,000.00
Engineering of Utility Adjustments	(item)	1	$40,000.00	$40,000.00
Potential Additional restoration activities				
In stream habitat structures	(item)	8	$10,000.00	$80,000.00
Riparian planting and restoration	(lin. ft)	2000	$25.00	$50,000.00
Bank stabilization	(lin. ft)	100	$500.00	$50,000.00
Public Outreach	(item)	1	$25,000.00	$25,000.00
Crossing 579 (Fourth St.)				**$358,969.00**
Structure				$240,000.00
Other				$118,969.00
Crossing 578 (Fifth St.)				**$386,505.00**
Structure				$220,000.00
Other				$166,505.00
Crossing 575 (Seventh St.)				**$136,668.00**
Structure				$40,000.00
Other				$96,668.00
Crossing 5555 (Eighth St.)				**$128,394.00**
Structure				$50,000.00
Other				$78,394.00
Crossing 572 (Ninth St.) & Fish ladder				**$357,168.00**
Structure				$160,000.00
Other				$197,168.00
Crossing 542				**$117,516.00**
Structure				$60,000.00
Other				$57,516.00
Crossing 543				**$117,516.00**
Structure				$60,000.00
Other				$57,516.00
Crossing 528				**$144,039.00**
Structure				$42,000.00
Other				$102,039.00
Estimated Total				**2,071,775**

REFERENCES AND SUPPORTING DOCUMENTATION

Bay City Downtown Water Main Improvement Project, 2003. HLB and Associates, Inc.

Bay City Sanitary Sewer System, 1970. W.F. Perley and Assoc. (extensively edited by CBC Publics Works staff)

City of Bay City Storm Water Master Plan, 2003. HLB and Associates, Inc.

City of Bay City Water Distribution Map, 2006. HLB and Associates, Inc.

DOGAMI Aerial Lidar data (LDQ 45123 E7 and E8), Oregon Dept. of Geology and Mineral Industries (DOGAMI) Lidar Consortium, Accessed September 2014. Data collected 2008-2009.

Patterson Creek Culverts Replacement Project: Assessment of Potential In-Stream Enhancement Opportunities, 2015. Tillamook Estuaries Partnership.

Patterson Creek Culverts Replacement Project: Assessment of Potential Riparian Enhancement Opportunities, 2015. Tillamook Estuaries Partnership.

ATTACHMENTS

DOCUMENTS

Attachment A. Active Channel Width letter from ODFW

Attachment B. Opportunities and Constraints Report, LCE

Attachment C. Design Alternatives Memo, LCE

Attachment D. Project Drawings (Existing Conditions and Proposed Conceptual Designs)

Attachment E. Detailed Cost Estimates for Proposed Structures

DIGITAL FILES

- HEC RAS files (compressed folder)
- GIS geodatabase and ArcMap layer files