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**To: Jonathan Slaney, P.Eng.**
**River Engineer, The City of Calgary**

**Subject: Bow River 10th St Gravel Bar Project: Literature and Data Review**

This Literature and Data Review prepared by O2, Matrix, and Applied Ecohydraulics summarizes the main researched literature supporting the project's landscape architecture and engineering design.

**Site Inventory, Site Analysis and Preliminary Landscape Design**

The following reports inform the landscape site analysis and preliminary design:

- Rood, S. (2020). Louise Island in the Bow River at Calgary - Mitigation of a Growing Flood Hazard and Prospective Environmental Impacts from the Urban Surf Beach and River Waves Project. Chinook Environmental Resources, University of Lethbridge.
- Surf Anywhere. (2019). River Waves & Urban Beach Initial Design Report at Calgary Alberta.
- Klohn Crippen Berger (KCB). (2017). Calgary Rivers Morphology and Fish Habitat Study. City of Calgary, Alberta.
- Yu, Q., Rennie, C.D., Slaney, J.M., and Parsapour-Moghaddam, P. (2022). Impact Evaluation of Instream Bar Management Using Morphodynamic Modelling. Journal of Environmental Management. 318. DOI: https://doi.org/10.1016/j.jenvman.2022.115564
- Alberta Riparian Health Management Society (ARHMS). (2020). Riparian Health Inventory Summary Report Bow River, north (left) bank.

The reports by Klohn Crippen Berger (2017), Steward Rood (2020), Yu *et al*. (2022) and the Alberta Riparian Habitat Management Society (2020) provide the cultural, physical, and biological background to inform the development of a context-sensitive landscape design. They influence the proposed landscape programming, physical character, and main construction materials.

KCB (2017) and Rood (2020) shed light on the site's morphological history and illustrate how the river was used as a channel for logging, gravel mining and hydropower generation.

They are a source of inspiration for a new landscape design programmed with educational and ecological enhancement features to teach visitors about the history of the site and the new efforts to mitigate the environmental effects of its industrial past.

We propose a landscape with utilitarian and structurally sound construction materials rooted in the site's cultural and natural history. Ecological enhancements are based on the vegetation inventory developed by KCB (2017), Rood (2020) and ARHMS (2020). Balsam poplar, shrub chokecherry, water birch, and Manitoba maple are identified in the literature and are the main components of the proposed planting design.

Yu *et al*. (2022) contribute information on gravel bar formation and function that informs the design and construction materials for the proposed landform. Yu *et al.* (2022) explain the critical role that riparian vegetation plays in sustaining aquatic and terrestrial habitats as well as the structural stability of the gravel bar. Based on their research, the river is characterized by gravel-size bed sediment, channel meandering and a distinct instream bar formation. Consequently, we propose a design based on gravel/river-rock/riprap, vegetation, and wood to seamlessly integrate with the meandering, morphological form/geometry of the riverbed and riverbank.

The landscape design aims to integrate the South Slopes, the Wave Deck, the Wave, the Louise Bar, the Landing, and the North Channel as a continuous and seamlessly morphological landscape form. This multi-layer approach integrates the flood and erosion control design with new areas for terrestrial and aquatic habitats and recreational amenities. This approach is influenced by the methods proposed by KCB (2017), Rood (2020), Yu *et al.* (2022) and Surf Anywhere (2019). Their designs holistically integrate flood mitigation, erosion control, wildlife habitat and recreational amenities. They consider shaping the riverbed and riparian slopes to create preferential water-flow pathways that reduce the risk of flooding and create microhabitat features. The concept design by Surf Anywhere (2019) focuses specifically on the Wave Deck site. It provides detailed information on the programming, access and circulation, and operational requirements for the Wave and Wave Deck.

**Hydrotechnical and Geomorphology Literature and Available Information Review**

This literature and available information review was used to support the river engineering and wave teams for engineering analysis and design. The river engineering team required a comprehensive understanding of historical land use, work to date in the area, nearby infrastructure, river geomorphology, past floods. This team focused on information pertinent to general engineering considerations and design practices to ensure appropriate engineering constraints and criteria were applied to the project. The wave team used these information and data sources in a similar manner with a focus on sediment transport, channel stability, and seasonal hydrology. This team focused on pertinent information related to wave operation and performance, which will occur below the safe boating advisory. The following key reports and information were used to inform the project:

1. City of Calgary Louise bridge drawings and historical inspections:
    - 1920 drawing showing the previous steel girder bridge and current bridge, which was completed in 1921.

- 1967 drawing showing an inspection of the south pier.
- 1987 drawings showing the rehabilitation of the south pier of the Louise bridge. Class 3 riprap was placed around the south pier, extending 2 to 3 m away from the pier and with a thickness of about 1.5 m. A new concrete footing was installed under the pier with the bottom of footing at 1041.3 m elevation. The class 3 riprap was placed to 1m below the footing (to 1040.3 m).
- 2019 underwater inspection report of the bridge piers. The report noted about 1 m of scour has occurred at the upstream nose of the south pier but that there is no undermining at the south pier.

2. Historical aerial and ground based imagery (City of Calgary, various dates; Glenbow Archives, various dates): provide historical context on the morphological and anthropogenic changes the Bow River experienced in the project area from the 1920s to present. Historical ground-based photos and a timeline of key events are presented on Figure A. Georeferenced historical aerial imagery of the Bow River in the project area is available from The City for select years from 1924 to 2022. This imagery shows the river changes during that time and provides evidence for certain river features still present in the project location (e.g., wooden piles from the diverter channel for the Calgary Power hydroelectric plant and sawmill, and remnant concrete from previous bridges).

3. Borehole / Geotechnical data (provided by The City, various dates): Allowed for the mapping of the lithology layers in the project area. This data will be used to estimate the volume of each type of river substrate (e.g., gravels and clay) that will be moved during construction. It will also be considered while interpreting the physical modelling results (i.e., if large amounts of scour are observed in locations with a clay bedding layer, the physical model may be adjusted to reflect the more resilient substrate conditions.

4. Hydraulics of Repelling Groynes and their Application to the Bow River After the June 2013 Flood (Oosting et al., 2015): Provides an assessment on the efficacy of repelling groynes (i.e., those pointed upstream and sloped downwards from the bank towards the river) and provides a selected design approach that is recommended for the City of Calgary based on observed and modelled hydraulic characteristics.

5. Implications of Ice on the Morphology of the Bow River (NHC 2016): Provides an extensive overview of the winter hydraulic and ice regimes of the Bow River, including the formation, lodging, and breakup processes of ice, and how these impact mobilization of bed material. This study will inform the detailed design of the project, and specifically how to ensure project components are resistant to damage from ice and do not increase the severity of ice jams through the project area.

6. Calgary Rivers Morphology and Fish Habitat Study (Klohn Crippen 2017): this study was extensive and among other things documented the substrate size of the Louise bar: $D_{50}$ = ~100 mm at the surface and $D_{50}$ = ~50 mm subsurface, and provided historical context of the Bow River (albeit at a higher level for the project area than Rood 2020). This report also provided a conceptual design for reshaping the 10th street gravel bar, discussed the mechanisms of fluvial shear stresses and their effect on stable channel geometry, and indicated that while bank strength related to vegetation (i.e., shear resistance) dominates the hydraulic geometry equations for small streams, bank vegetation has virtually no effect on the stable (regime) width of large streams. This same paper provided definitions for small and large streams based on the mean hydraulic depth and the rooting depth for dominant riparian species.

7. The City of Calgary's River Morphology Risk Mitigation Program (Slaney et al., 2019): This study assessed the cost to benefit ratio of addressing four different morphologic risks to infrastructure, including valley wall failures, avulsions, erosion, and sedimentation. The study determined that the best option in terms of resources used is usually intervening at areas that experience sedimentation (i.e., gravel bars). These sedimentation areas usually experience riparian colonization that reduces flood conveyance (by increasing channel roughness). This study provides a solid basis for the method of flood impact mitigation chosen for this project (i.e., removing the large vegetation and reducing the size of the Louise bar to improve flood conveyance).

8. Bow River hydrology assessment (Golder 2020): flood hydrology from the 1:2-year to the 1:1,000-year flood are available and used for modelling.

9. Paper on mitigation of flood hazard and environmental impacts from the Louise gravel bar and recreational wave (Rood 2020): this paper provides river history at the site (including the historical presence of a 4 m high hydroelectric dam within the project boundaries), provides an assessment of potential project impacts, and concludes that a gravel bar will consistently form at the Louise bar location.

10. Post-flood bathymetry (City of Calgary, 2020): The combined LiDAR/bathymetry data was utilized in the 1D and 2D physical modelling, and for developing the digital elevation model for physical modelling.

11. Impact evaluation of instream bar management using morphodynamic modelling (Yu et al 2022): This paper modeled and compared three scenarios for the Louise bar: (1) do nothing, (2) complete bar removal, and (3) bar reshaping to match the conceptual design for the Louise bar. The study concluded that bar reshaping was the most stable bed form for the project area, and that reshaping the bar would lower the

1:100-year flood peak water level by about 0.07 m compared to the "do nothing" condition.

12. City of Calgary Flood Damages Report (Draft; CoC 2022): Modelled a theoretical future scenario where the gravel bar increases in height and the south channel infills. This resulted in an up to 0.54 m increase to the 1:100-year water level, and an increase in damages by $86 million. It is unclear if this modelling assumed the Manning n increased due to vegetation or stayed the same.

13. City's 2D model results for this project (2023): used to determine the flow split in the wave channel (1/3 of the flow) and the main branch of the river (2/3 of the flow) is appropriate for operation of the wave. Results of the 2D model were used to refine the location of the upstream tip of the dividing island to provide the desired flow split.

14. Previous experience by The City restoring aquatic side channel habitat along the Bow River (e.g., at Quarry Park, Bowmont West, Elbow Island Park, and the Inglewood Bird Sanctuary) and by Matrix (e.g., at the North Channel near St. George's Island and at Jack Tennant Memorial Bridge in Cochrane).

15. Previous and extensive in-house experience and knowledge of the Bow River's flow history, geomorphology, and proven construction/isolation methods.

**Aquatics Desktop Assessment and Literature Review**

Matrix completed a desktop assessment to inform the various aquatics field surveys and assessments completed for the project. Standard database searches were completed through Alberta Environment and Protected Areas (EPA) and Fisheries and Oceans Canada (DFO). The desktop review component and associated data sources will be discussed in detail in the fish and fish habitat assessment report and are not further discussed herein.

Perhaps more relevant to the design of the project infrastructure (i.e., the island and recreational wave) are the potential effects of the wave structure on fish movement. The following papers and studies informed the potential effects of the wave structure on fish movement:

1. The movement behaviours of salmonids and other species was reviewed by:

    a. Gowan, et al., 1994: Restricted Movement in Resident Stream Salmonids: A Paradigm Lost?

2. The day and night movements of trout in response to light intensity, prey availability, and water temperature (i.e., diel movement) were reviewed by:

   a. Naman, et al., 2022: Diel Patterns of Foraging and Microhabitat Use by Sympatric Rainbow Trout and Bull Trout: Implications for Adaptive Differentiation and Instream Flow Assessment.

3. The movements of salmonid species with a focus on Brown, Rainbow, and Cutthroat Trout were reviewed by:

   a. Northcote 1992: Migration and Residency in Stream Salmonids - Some Ecological Considerations and Evolutionary Consquences.
   b. Young, et al., 1997: Constrasting movement and activity of large Brown Trout and Rainbow Trout in Silver Creek Idaho
   c. Hilderbrand & Kershner, 2000: Movement patterns of stream resident Cutthroat Trout in Beaver Creek Idaho-Utah
   d. Schmetterling & Adams, 2004: Summer movement within the fish community of a small montane stream
   e. Diana, et al., 2004: Movement patterns of large Brown Trout in the mainstream Au Sable River, Michigan
   f. Heggeners, et al., 2007: Movement by wild Brown Trout in a boreal river: response to habitat and flow contrasts
   g. Railsback, et al., 2005: Test for the Theory for Diel Variation in Salmonid Feeding Activity and Habitat Use
4. The classification of movement and migration in relation to the transit of fish from one location to another was provided by:

   a. Thurow, 2016: Life histories of potamodromous fishes. In: P. Morais & F. Daverat, eds. Introduction to Fish Migration.

**Results of the Fish Movement Literature Review**

The wave and associated infrastructure installed in the wave channel have the potential to disrupt fish movement in the wave channel. This effects pathway has been discussed at a high level throughout the design process, with the general expectation that fish will be able to move through the north channel if fish movement is impeded in the wave channel. However, it cannot be assumed that if fish encounter a movement impediment in the wave channel, that they will turn around, swim downstream and find an alternative route through the north channel. Once the preliminary design is completed, velocities at the wave structure will be input into the Fish Swim Performance Tool to determine whether velocities will present a barrier to fish movement in the wave channel under different flow stages. The following key observations were made as part of the fish movement and literature review:

1. The terms "migration" and "movement" have been used interchangeably in relation to the transit of fish from one location to another. However, the two terms are not synonymous. Migration is a specialized type of movement that occurs at large temporal and spatial scales where fish from one habitat to another outside

of their home range (Thurow, 2016). Movement is defined as changing of locations or positions to seek essential resources such as food or cover to protect themselves from predators and typically occurs within the home range of the individual (Thurow, 2016). **Effects of wave structure and facilities on fish are considered in the context of fish movement rather than migration.**

2. Although both stationary (i.e., high fidelity to home range[1]) and mobile (i.e., moving beyond home range) categories of movement behaviours are present among salmonids (and other fish species) (Gowan, et al., 1994), most individuals fall into the stationary category. Most individuals are stationary most of the time but move short distances to other habitat within their home range (Heggeners, et al., 2007). Most of such movement occurs at dawn or dusk.

3. Structures or facilities are unlikely to adversely affect fish movement if operated at times when fish activity is likely to be lowest (i.e., during daylight ours and avoiding dawn or dusk or night).

[1] Home range is defined as an area regularly utilized for feeding and shelter.