

TROUT FISHERY PUBLICATION REVIEWS

A Review of the City of Calgary Fish Habitat Compensation Program 2024 Update

The Report's Review:

The City of Calgary Fish Habitat Compensation Program (FHCP) is unique in so far as the sites selected for the fish compensation initiative are spread across the entire City of Calgary Bow River and the Elbow River watersheds. In addition, the sites are located above and below the Western Irrigation District Weir–Harvie Passage (HP) and the Bonnybrook Wastewater Treatment Plant (BWTP) which have historically had an impact on fish movement and aquatic food sources, respectively.

- **The Quarry Park Side Channel Project** (Figure 1) is located below both HP and BWTP and is representative of a more abundant fish population that the Bow River is renowned for.
- **Bowmont West Side Channel Project** (Figure 2) is located above the BWTP and HP. The site is located close to the Bearspaw Reservoir outflow and is subject to water management discharge practices close to the reservoir's outflow.
- **The Elbow Island Gravel Bar Enhancement Project** (Figure 3) is above both BWTP and HP and is located in a city-managed river flow source and primary brown trout spawning area.

Historically the Western Irrigation District Weir presented a barrier to the free movement of fish across the City reach of the Bow River, but the development of the Harvie Passage Low Water Channel that was opened in 2011 and upgraded in 2018 eliminated this restraint. Over the past 20 years, BWTP practices have improved whereby less phosphate and other residues are discharged into the river. Both these improvements have an impact on the fish population dynamics now and into the future.

Brown Trout, Rainbow Trout, and to a lesser degree Mountain Whitefish are the principal sport fishing targets in the Bow River. The City reach of the Bow River and the Elbow River are considered prime fall spawning sites for brown trout. But little is known of the rainbow trout spawning activity in the spring. The FHCP offers valuable insight into the fish population dynamics within the City of Calgary. It also demonstrates that the hard armament of vulnerable riverbanks under flood conditions can be compensated by back-channel enhancement initiatives and long-term site maintenance.

This review is limited to fish and habitat dynamics. An expanded review of the references in this document will allow for further investigation by those individuals who wish to broaden their knowledge base. The discussion within the publication gives direction that should be considered in the interpretation of fish population dynamics and what research is needed to fill in the gaps.

It is not the intention of this review to present an opinion but rather to highlight the pertinent information that relates to the Bow River sport fishery.

Introduction:

Following the 2013 flood, The City of Calgary undertook several projects to repair and reinforce riverbanks along the Bow and Elbow Rivers. These projects helped protect critical City infrastructure but had adverse effects on fish and sensitive fish habitats.

With support from both The Government of Alberta (AEP) and Fisheries & Oceans Canada, (DFO) the City developed a plan to offset the loss of fish habitat and restore these vital habitat areas. Three projects are in various stages of completion to offset the habitat loss:

- Phase 1 - **Quarry Park Side Channel Project** - 2017⁽¹⁾
- Phase 2 - **Bowmont West Side Channel Project** - 2018⁽²⁾
- Phase 3 - **Elbow Island Side Channel Project** - 2020⁽³⁾

The program was developed in consultation with AEP and DFO to monitor gains made in fish habitat and increased productivity of key indicator species that represent the fishery management objectives of the region: brown trout, rainbow trout, and mountain whitefish. Local consulting engineers, Klohn Crippen Berger (KCB) were contracted to

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manage the monitoring program. The five-year monitoring program for Phases 1 and 2 is now complete. Phase 3 will reach its fifth year of monitoring in 2025 and a Year 5 Report will be available at that time.

The **Inglewood Bird Sanctuary Reconnect Project** was added in – 2022. Details can be found at the following link: <https://engage.calgary.ca/ibs>

1. Habitat Suitability Mapping and Modeling

An evaluation of change in habitat suitability was a key method used to assess progressive development and performance of the offset habitat relative to design expectations using a novel Habitat Suitability Index (HSI) model.

2. Biological Indicator Sampling

Biological data was collected through targeted sampling to provide the support that aquatic organisms and fish are using the new habitat. In addition to sampling fish populations, benthic invertebrates, periphytons, and macrophytes species were assessed.

3. Fall Spawning Survey

A fall spawning survey was conducted in November to assess sessional habitat use. The occurrence of redd counts for fall-spawning brown trout was assessed late in the fall before the onset of winter to optimize the redd counts that indicate the suitability of the habitat for spawning activities.

4. Water Flows and Quality – Summer and Winter

Physical and chemical parameters were monitored to support the suitability of the new habitat within each project. Water depth, velocity, temperatures, oxygen content, pH, electrical conductivity, and oxidation-reduction potential were measured during summer and winter flow conditions.

Results:

The City of Calgary supplied the Quarry Park Bowmont West, and Elbow Island - Monitoring Results to Calgary River Users Alliance (CRUA) for a review of the potential use of the data to support future Bow River fish habitat enhancement and population research initiatives.

1. Habitat Suitability Mapping and Modeling

Quarry Park – Although the projected increase in suitable habitat was not achieved in the first year of the project at 33% less than the project design. An increase of 42% in suitable habitat was achieved by Year 5, and only 4% less the projected in the design. The growth of overhanging vegetation as a source of cover had increased substantially, increasing the habitat value attributed to several species-life stages, as well as increasing the overall integrity and resiliency of the aquatic ecosystem. Increased incidence of instream vegetation had also contributed to increased habitat value for a wide range of species-life stages. The Habitat Suitability (HSI) for the fish was represented by the resulting Weighted Habitat Unit (WHU) value. Table 4.2 shows improvements in suitable fish habitat for all sportfish species, with Brown Trout being the highest at 16.2%.

Table 4.2 Quarry Park Year 5 Change in Habitat Value by Species and Life Stage

		Life Stage			
		Fry	Juvenile	Adult	Spawning
Brown Trout	Change in WHU by Species	34,709			
	% Change within Project Areas	16.2%			
	Change in WHU by Life Stage	7,363	10,335	10,215	6,795
	% of Change in WHU by Life Stage	21.2%	29.8%	29.4%	19.6%
	Relative % Difference from Predicted	-6.3%	-21.6%	-27.3%	204.2%
Rainbow Trout	Change in WHU by Species	23,407			
	% Change within Project Areas	11.7%			
	Change in WHU by Life Stage	7,462	5,822	6,383	3,739
	% of Change in WHU by Life Stage	31.9%	24.9%	27.3%	16.0%
	Relative % Difference from Predicted	-5.7%	-10.7%	50.8%	33.1%
Mountain Whitefish	Change in WHU by Species	22,403			
	% Change within Project Areas	8.7%			
	Change in WHU by Life Stage	6,798	6,384	5,259	3,962
	% of Change in WHU by Life Stage	30.3%	28.5%	23.5%	17.7%
	Relative % Difference from Predicted	-30.2%	-21.7%	-4.2%	88.5%

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Bowmont West – The projected increase in suitable habitat was exceeded by 60% in Year 5 of the project. This substantial increase is attributed to differences between the interpretation of the design hydraulics and what was constructed. Other contributions to the increase may well be enhanced excavation and an increase in bank cover and overhanging vegetation. Table 4.2 shows improvements in suitable fish habitat for all sportfish species, with Brown Trout being the highest at 34.5%. Rainbow Trout and Mountain Whitefish had lower WHU value scores of 16.1% and 12.1% respectively.

Table 4.2 Bowmont West Project Effects by Species and Life Stage

		Life Stage			
		Fry	Juvenile	Adult	Spawning
Brown Trout	Change in WHU by Species	56,590			
	% Change within Project Areas	34.5%			
	% Change in Bow WHU	0.5%			
	Change in WHU by Life Stage	8,881	14,221	13,141	20,347
	% of Change in WHU by Life Stage	15.7%	25.1%	23.2%	36.0%
	% Change in Bow WHU	0.4%	0.4%	0.4%	1.4%
Rainbow Trout	Relative % Difference from Predicted	46.7%	44.5%	30.3%	408.1%
	Change in WHU by Species	29,272			
	% Change within Project Areas	16.1%			
	% Change in Bow WHU	0.3%			
	Change in WHU by Life Stage	9,011	1,524	5,438	13,299
	% of Change in WHU by Life Stage	30.8%	5.2%	18.6%	45.4%
Mountain Whitefish	% Change in Bow WHU	0.4%	0.1%	0.1%	0.9%
	Relative % Difference from Predicted	53.2%	127.8%	62.2%	150.9%
	Change in WHU by Species	30,731			
	% Change within Project Areas	12.1%			
	% Change in Bow WHU	0.2%			
	Change in WHU by Life Stage	7,946	6,744	8,546	7,495
	% of Change in WHU by Life Stage	25.9%	21.9%	27.8%	24.4%
	% Change in Bow WHU	0.2%	0.2%	0.3%	0.2%
	Relative % Difference from Predicted	11.9%	64.9%	78.0%	300.0%

Elbow Island – An initial site assessment was undertaken in Years 1-2 of the project that showed a large net improvement in fish habitat. The projected increase in suitable habitat was exceeded by 19% with spawning Brown Trout and Mountain Whitefish receiving the highest value at 118% and 123% respectively. This substantial increase is probably due to the inaccuracy of the methodology, but also an underestimation of the contribution of the natural environment before site excavation. Table 4.2 shows improvements in suitable fish habitat for all sportfish species, with Brown Trout being the highest at 39%. Rainbow Trout and Mountain Whitefish had lower WHU values scores of 26% and 10% respectively. A detailed assessment will be repeated in Year 5 of the project.

Table 4.2 Elbow Island Project Effects by Species and Life Stage

		Life Stage			
		Fry	Juvenile	Adult	Spawning
Brown Trout	Change in WHU by Species	20,773			
	% Change within Project Areas	39.3%			
	Change in WHU by Life Stage	6,142	5,352	5,042	4,237
	% of Change in WHU by Life Stage	29.6%	25.8%	24.3%	20.4%
	% Change from Predicted	44.7%	-1.1%	2.5%	118.1%
	Change in WHU by Species	12,466			
Rainbow Trout	% Change within Project Areas	25.5%			
	Change in WHU by Life Stage	6,814	2,117	1,507	2,028
	% of Change in WHU by Life Stage	54.7%	17.0%	12.1%	16.3%
	% Change from Predicted	60.3%	-25.5%	-41.1%	58.2%
	Change in WHU by Species	26,380			
	% Change within Project Areas	10.3%			
Mountain Whitefish	Change in WHU by Life Stage	6,999	5,507	7,681	6,193
	% of Change in WHU by Life Stage	26.5%	20.9%	29.1%	23.5%
	% Change from Predicted	-4.2%	18.5%	15.6%	123.0%

2. Biological Indicator Sampling

Quarry Park –Year 5 fish population sampling in the summer showed a higher population of Brown Trout and Longnose Dace. Fish capture results are shown in Table 4.3. Fish capture efficiency was impeded by water depth and velocity in some portions of the side channel. Adult trout may likely have been present in deep water habitats and evaded capture. Although Mountain Whitefish have been observed in the channel, the lack of capture may be related to variations in seasonal habitat and potential sampling bias. Rainbow Trout were not captured in Year 1 and only 3 were caught in Year 5, despite having similar habitat preferences to Brown Trout fry.

Table 4.3 Fish Capture Results from Quarry Park Side Channel (August 16, 2022)

Species	Scientific Name	Minimum Fork Length (mm)	Maximum Fork Length(mm)	Count	CPUE (fish/100 seconds)
Brown trout	<i>Salmo trutta</i>	49	172	87	2.38
Longnose dace	<i>Rhinichthys cataractae</i>	17	56	75	2.06
Longnose sucker	<i>Castostomus catostomus</i>	57	173	22	0.60
Rainbow trout	<i>Oncorhynchus mykiss</i>	56	58	3	0.08
White sucker	<i>Castostomus commersoni</i>	42	127	35	0.96
Total				222	6.08

Table 4.4 Fish Capture Results from Bowmont West Channel 1 – Single Pass (July 13, 2023)

Species	Scientific Name	Minimum Fork Length (mm)	Maximum Fork Length(mm)	Count	CPUE (fish/100 seconds)
Fathead Minnow	<i>Pimephales promelas</i>	45	56	2	0.11
Longnose Sucker	<i>Castostomus catostomus</i>	71	88	4	0.22
Longnose Dace	<i>Rhinichthys cataractae</i>	41	91	40	2.23
White Sucker	<i>Castostomus commersoni</i>	54	66	3	0.17
Rainbow Trout	<i>Oncorhynchus mykiss</i>	30	54	8	0.45
Brown Trout	<i>Salmo trutta</i>	49	136	19	1.06
Total				76	4.24

Table 4.5 Fish Capture Results from Bowmont West Channel 2 (July 13, 2023)

Species	Scientific Name	Minimum Fork Length (mm)	Maximum Fork Length(mm)	Count	CPUE (fish/100 seconds)
Longnose sucker	<i>Castostomus catostomus</i>	85	465	4	0.25
White sucker	<i>Castostomus commersoni</i>	234	380	4	0.25
Mountain whitefish	<i>Prosopium williamsi</i>	58	295	17	1.08
Total				25	1.58

Table 4.6 Fish Capture Results from Bowmont West Channel 2 Margins (July 13, 2023)

Species	Scientific Name	Minimum Fork Length (mm)	Maximum Fork Length(mm)	Count	CPUE (fish/100 seconds)
Rainbow trout	<i>Oncorhynchus mykiss</i>	29	49	17	2.80
Brown trout	<i>Salmo trutta</i>	56	56	1	0.17
Total				18	2.97

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Elbow Island - Fish population sampling reported in Table 4.3 for the summer of Year 1 showed a higher population of Longnose Dace followed by Brown Trout. Rainbow Trout were not captured in Year 1, despite having similar habitat preferences to Brown Trout fry. All of the Brown Trout were considered to be young-of-year which supports the value of the Elbow River as a fish nursery for that species.

Benthic Invertebrate Surveys - A qualitative assessment of benthic invertebrate species and periphytic algae development at all three project sites suggests a sufficient aquatic food base to support the fishery.

Table 4.3 Fish Capture Results (August 4, 2021)

Species	Scientific Name	Minimum Fork (or Total*) Length (mm)	Maximum Fork (or Total*) Length (mm)	Count	CPUE (fish/100 seconds)
Brown trout	<i>Salmo trutta</i>	51	92	49	1.17
Burbot	<i>Lota lota</i>	83*	83*	1	0.02
Lake chub	<i>Cosmepus plumbeus</i>	42	94	4	0.10
Longnose dace	<i>Rhinichthys cataractae</i>	23	66	180	4.31
Prussian carp	<i>Carrasius gibelio</i>	106	106	1	0.02
Trout perch	<i>Percopsis omiscomaycus</i>	61	64	3	0.07
White sucker	<i>Catostomus commersoni</i>	41	127	27	0.65
Total				265	6.37

3. Fall Spawning Survey

Quarry Park - The spawning surveys recorded 26 Brown Trout redds in Year 1 across the full length of the channel. This increased to 30 brown trout redds in Year 4, and 53 redds in Year 5.

Bowmont West - A relatively high total number of 80 Brown Trout redds were recorded in Year 1 across channels 2 and 2A. At the time of the assessment Channel 1 was blocked at the entrance rendering the flow to a trickle and no redds were observed. In Year 4 and Year 5 respectively, 49 redds and 93 redds were observed in Channel 2. Channel 1 and 2A were devoid of redd activity. The fluctuations in spawning activity between years were considered to be within acceptable variations.

Elbow Island - In Year 1 a total of 33 Brown Trout redds were recorded throughout the length of the side channel.

4. Water Flows and Quality – Summer and Winter

Quarry Park

Summer - In Year 1 the mean summer discharge rate was 4.5cms which represents approximately 5% of the estimated flows in the Bow River. In Year 4 the mean discharge measured was 1.6cms which represents approximately 2% of the estimated discharge within the Bow River at the time of the assessment. Data indicates that the side channel is performing according to the design criteria, and would be maintained within the side channel even in extremely low-flow conditions.

Winter - The Year 5 winter assessments of flows of 0.6cms demonstrated that deep run and pool areas continued to provide suitable winter refuge areas despite the cold temperatures. There was no evidence of ice cover freezing to the substrate across the full channel width at any location and flow would be maintained throughout the length of the channel even under extremely cold winter conditions.

Bowmont West

Summer - The Year 1 Channel-1 summer discharge rate was 0.7cms which represents less than 1% of the estimated flows in the Bow River. Although Channel 2 was not monitored during this time, previous flow estimates indicated approximately 19% of the Bow River flow went through Channel 2. The Year 5 Channel-1 mean summer discharge rate was 0.2cms which represents less than 1% of the estimated flows in the Bow River. Channel 2 summer discharge rate was 15.2cms or 18% of the estimated flows in the Bow River during this time.

Winter - In Year 1 Channel 1 was frozen over, with isolated deeper pools having flowing water. Channel 2 was free-flowing with some ice shelves built up on the edge of the channel making it ideal for the preservation of brown trout eggs over the winter months. The Year 5 assessment of flows was conducted in March 2023 when the Bow River flow was at 43cms. The Channel 1 flow was calculated at .4cms or 1% of the Bow River flow. Sufficient flows were evident where redds had been present in the previous fall. This data supports the design of the Bowmont West site for enhanced fish habitat. Although Channel 1 with a lower flow will need periodic maintenance to reach its full potential, Channel 2 more than compensates, and improves fish habitat in this reach of the Bow River

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Elbow Island

Summer – The Year 1 mean summer discharge rate was 0.91 cms which represents approximately 16% of the estimated flows of 7cms in the Elbow River.

Winter – The Year 1 mean winter discharge rate was 0.4 to 0.5cms with a lower flow in the Elbow River. Ice covered the entire river and project channel during the winter but there was still sufficient flow under the ice shelf to support the incubation of Brown Trout egg incubation from the fall spawning activities, and adequate to support fish survival.

Dissolved Oxygen – Dissolved Oxygen concentrations were more than 10 mg/L at all sites and at the time of year. The minimum threshold level of 5.0 mg/L was never reached.

Evaluation of Projects by the Consulting Engineers

A detailed "Evaluation and Discussion" for each year of the three projects was prepared by Klohn Crippen Berger, the consulting engineers, who documented the monitoring of the projects and prepared an evaluation of the outcome of habitat enrichment and fish populations in the newly created side channels. A summary of the consultant's evaluation follows:

Quarry Park – Year 5 Assessment:

The habitat values generated through the implementation of the project were 33% less than predicted in Year 1. By Year 5 instream and bankside vegetation had increased to approximately equal the predicted value (-4%). The fish sampling in the summer shows an abundance of juvenile Longnose Dace and Brown Trout which supports that the channel is suitable as a nursery. Redd surveys for Brown Trout in the fall support the use of the channel for spawning activity. Benthic invertebrate and periphytic algae development suggest adequate food for fish. Water discharge measurement and quality assessment indicate that flows are adequate and of sufficient quality even during the extremely cold winter months. The monitoring data suggests that the habit that has been created is suitable, is being used by fish, and the design criteria have been met.

Bowmont West – Year 5 Assessment:

The habitat values generated through the implementation of the project were assessed to be 60% greater than what was predicted. The difference between what was predicted and what was observed can be attributed to higher-than-predicted flows as well as higher-rated habitat creation than predicted. Overhanging vegetation contributes significantly to the assessment values. Overhanging vegetation contributes significantly to the assessment values. The fish sampling in the summer shows an abundance of Mountain Whitefish and to a lesser degree Rainbow Trout and Brown Trout. Redd surveys for Brown Trout in the fall increased over the five-year assessment. Benthic invertebrate and periphytic algae development suggest adequate food for fish. Except for Channel 1, the water discharge measurement and quality assessment indicate that flows are adequate and of sufficient quality even during the extremely cold winter months. The monitoring data suggests that the habit that has been created is highly desirable, is being used by fish, and the design criteria have been met.

Elbow Island – Year 1-2 Assessment:

The habitat values generated through the implementation of the project were 19% greater in Year 1. The difference between what was predicted and what was observed can be attributed to improvements in overhanging vegetation and structural bank cover. The fish sampling in the summer shows an abundance of fry and juvenile Longnose Dace, while Brown Trout fry was also in abundance. Redd surveys in the fall support the importance of the Elbow River as an important migratory spawning location for Bow River Brown Trout. Benthic invertebrate and periphytic algae development suggest adequate food for fish. Water discharge measurement and quality assessment indicate that flows are adequate and of sufficient quality to support the overwintering of fish and the incubation of deposited eggs. The monitoring data suggests that the habit that has been created is suitable, is being used by fish, and the design criteria have been met. It is expected that the Year 5 monitoring of the project will support the Year 1-2 assessment.

Reviewer's Evaluation of the Project

Brown trout, rainbow trout, and to a lesser degree rocky mountain whitefish are the principal sport fishing targets in the Bow River. The City reach of the Bow River and the Elbow River are considered prime fall spawning sites for

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brown trout. Little is known of the rainbow trout spawning activity in the spring, although redds and fish have been observed in the main stem and tributaries of the Bow River. Fishing reports do indicate that fishing effort and success are considerably lower than upstream of the BWTP and HP. Hopefully, the recent Alberta Environment & Protected Areas fish population evaluation will shed more light on exactly what the difference could be.

The City of Calgary Fish Compensation Program reports from the Year 5 offset monitoring program for Quarry Park and Bowmont West support that habitat enhancement initiatives will improve suitable fish habitat for predominantly juvenile fish populations and to some degree, improve habitat for more mature resident populations of fish. What is also clear is that if suitable habitat is available brown trout will spawn there. This has been documented at both sites. Improvements in vegetation planting at Quarry Park have shown improvements in the suitability of the habitat of this site at the five-year data monitoring stage which will also improve the aim the channel's integrity.

What is unclear is the impact of improved side-channel habitat on the improvement of cross-river fish populations. Fish will gravitate to the most suitable habitat available, and for juvenile fish, suitable habitat protection from predators. For mature fish, the food sources are most likely the driving force for residence. Therefore, improved access to the upper City reach of the Bow River through Harvie Passage (HP) appears to support a thriving brown trout spawning population, but will they reside in the same area is unknown. Certainly, further investigation is needed to answer this question.

The Bow River water management policy has changed in recent years to enhance flood protection for the City of Calgary. Although historical management practices have assisted in sustaining a world-class trout fishery, the modified water management operations during the spring runoff may well have altered the fishery and fish habitat. The report, "The Impact of Water Management on the Bow River Fish Population"⁽⁴⁾ details the changes that have taken place in water management policy since the Bow River Basin flood of 2013. The modified operations of the Ghost Hydroelectric Power Plant changed from hydropeaking to a free-flowing water management practice from mid-April to the first week of July has impacted the sport fishery during the same time. Higher and more variable flows together with increased turbidity have impacted angler catch rates during what is considered the most productive fishing season. Conversely, higher, and more natural flows in the spring will scour the riverbed which should enhance the aquatic habitat and balance the river's ecology.

Moving forward, the City of Calgary's commitment to enhanced riparian habitat with the Inglewood Bird Sanctuary Reconnect Project is good to see. Other sites, such as the Calgary Zoo side channel (Figure 4), the Douglasdale side channel (Figure 5), and the Pine Creek Wastewater Treatment Plant side channels (Figure 6) offer unique opportunities to offset instream hard armament bank protection with further improvements in riparian habitat and the potential enhancement to the sport fishery that contribute significantly to the local economy.

All three of the proposed sites were impacted by the 2013 flood. The gravel base at each site has been built up as a result of the high flows during the flood that reduced the suitability for recruitment of fish. At the same time, boat access to both the Douglasdale and Pine Creek Channels has been severely limited. Reestablishing year-round flow to these channels offers a two-fold benefit of enhanced fish habitat coupled with increased sportfishing opportunities in these reaches of the Bow River. There is a certainty that there are other City of Calgary reaches of the Bow River that would benefit from improved river flows. Our suggestion is for the City of Calgary to consult with the local fishing community to ascertain which sites could contribute the most to the fishery.

Peter Crowe-Swords
March 24, 2024

References:

1. Fish Habitat Offsetting Program – Phase 1: Quarry Park Offset Monitoring Year 5 Reports. December 2022
Klone Crippen Berger – For the City of Calgary
2. Fish Habitat Offsetting Program – Phase 2: Bowmont West Offset Monitoring Year 5 Report. December 2023.
Klone Crippen Berger – For the City of Calgary.
3. Fish Habitat Offsetting Program – Phase 3: Elbow Island Offset Monitoring Year 3 Report. December 2023.
Klone Crippen Berger – For the City of Calgary.
4. The Impact of Water Management on the Bow River Fish Population, Bow River Trout Foundation. 2019. [Report](#)

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Figures:

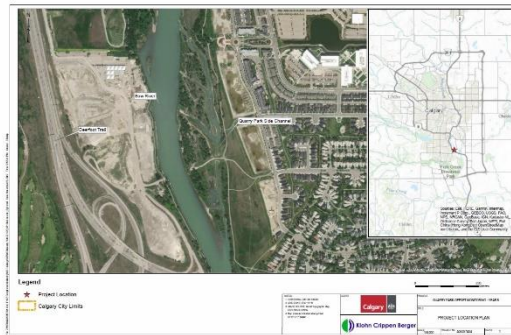


Figure 1: Quarry Park Fish Habitat Compensation Site

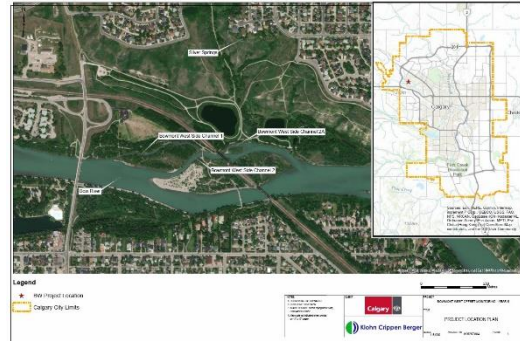


Figure 2: Bowmont West Fish Habitat Compensation Site



Figure 3: Elbow Island Fish Habitat Compensation Site



Figure 4: Calgary Zoo Side Channel Site Proposal



Figure 4: Douglasdale Side Channel Proposal

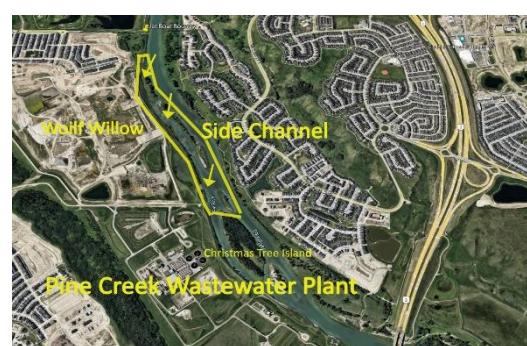


Figure 6: Pine Creek Wastewater Channel Proposal