Whitewater Park Design Principles:
An Integrated Approach for Multiple User Groups

by

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ABSTRACT

WHITEWATER PARK DESIGN PRINCIPLES:
AN INTEGRATED APPROACH FOR MULTIPLE USER GROUPS

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Professor Sean Kelly

Existing whitewater courses have several design issues relating to their ability to balance expert, novice recreational, and commercial use. The goal of this study is to establish a better understanding of whitewater park design that incorporates the needs of multiple user groups in one integrated approach. Through elite interviewing whitewater park design was investigated and the data was analyzed identifying seven design principles and thirty seven detailed design recommendations. These design principles and recommendations were applied to create a preliminary conceptual design of a whitewater park. The design recommendations and conceptual design were evaluated by a professional whitewater course designer. The evaluation revealed that adaptability is an important principle in whitewater park design and that design recommendations must be flexible to allow for client input and site constraints. This research expands our knowledge of multifunctional design of whitewater parks that resolves user conflicts and important functional relationships.

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Chapter One: Introduction

1.1 Study Overview

"We make this run a few more times, and on each pass, another of my raft mates flies out. There are paddles strewn throughout the water and maybe an errant shoe. It looks like the aftermath of an aquatic Viking battle. As we head to shore, Scott takes a casualty count, pointing at empty seats white mouthing, *One…two…three*, before smiling. Not bad for fake white water" (Walters, 2007).

Whitewater parks are venues that have been partially or wholly augmented to facilitate whitewater recreation. There are over 60 operating whitewater parks world wide. The most recent construction is in London, designed specifically for the summer 2012 Olympic Games. Some of these parks are on artificially enhanced active river channels but many others are entirely artificial which includes pumping all of the required water to run the facility.

There are many economic and social benefits to the development of urban centred whitewater parks (Cordell, Bergstrom, Gregory, & Karish, 1990). These parks can provide the means for professional paddling training/competition, provide the facilities necessary to host international competitions, promote active recreation, attract tourists, and provide economic returns. The success of these parks, in part, lies in their ability to serve the needs and desires of multiple different user groups. However, existing whitewater courses have several design issues relating to their ability to balance expert, novice recreational, and commercial use.

This study focuses on an investigation of urban whitewater park design in order to determine who the different user groups are and what their needs are. By examining

these needs and desires, a set of design principles and recommendations is developed to help inform future whitewater park design. A conceptual design of a whitewater park is developed as a practical application and graphic representation of the design principles and recommendations. Finally, the design recommendations and conceptual design are evaluated by a professional whitewater course designer.

1.2 The Problem

Existing whitewater courses in both Canada and abroad have several design and operational problems relating to their ability to serve the needs of multiple user groups. Specifically, whitewater courses are limited in their ability to balance professional, recreational and commercial paddler challenge, enjoyment, and appeal. Furthermore, these design problems result in whitewater courses which are expensive to operate or simply unsustainable and can pose serious safety risks to the various users. This problem is compounded by the fact that there are no publicly-available sets of design principles for creating whitewater parks which appeal to multiple users. Finally, there is a lack of whitewater courses in Canada which are appropriate for professional paddling. There are only two courses, one located in Pemberton British Columbia and the other in Minden Ontario. Considering that countries such as the United States, France, and the United Kingdoms all have over 10 whitewater parks, Canada is falling behind and missing a great opportunity to provide whitewater facilities which promote professional sport and encourage tourism and active outdoor recreation.

1.3 Goals and Objectives

There are two main goals of this study. The first is to establish a better understanding of whitewater park design that incorporates the needs of multiple user groups in one integrated designed facility. Secondly, the goal is to determine if subsequent study is warranted.

Several objectives were created to help achieve these two goals. The first objective is simply to study whitewater. This includes a review of fluid dynamics, typical river features, whitewater classification, whitewater recreation, and the economic benefits of whitewater recreation. The second objective is to identify and examine existing whitewater parks in Canada and abroad. This includes identifying and comparing the different design considerations and general layout of each park. The third objective is to identify key whitewater park user groups. Once these user groups are identified, an attempt is made to determine their needs when it comes to whitewater park use. The fourth objective is to develop design principles and design recommendations for whitewater parks which combine and integrate the needs of the previously determined key user groups. Next, the objective is to develop a preliminary conceptual whitewater park design at an existing site as a practical application and visual representation of the design principles. The design principles, recommendations, and conceptual design are evaluated by a professional whitewater park designer. Finally, the future application of the design principles is considered.

1.4 Assumptions

This research makes a few assumptions. The first is that a single integrated designed whitewater facility can satisfy the needs of multiple users groups. The second assumption is that design considerations gained through the interviewing of elites will appeal to the broader paddling community.

Chapter Two: Literature Review

2.1 Introduction

> What is white water? It is a light boat in a fast rapid, a game of skill played against a river, a sport in which wit and subtlety outrank muscle. It is the passage of a wilderness stream; a weekend's paddling for its own sake, and the few intense minutes of effort and precision of a slalom race. The constant elements are skill in handling the boat and a close knowledge of the ways of moving water. (Urban, 1981)

The focus of this study was to provide a background foundational knowledge for the understanding of whitewater and its application in manufactured whitewater parks. An explanation of the different types of whitewater parks and a summary of the existing parks and their various design elements is provided. A thorough explanation of the various features present in moving water is offered to aid in the understanding of the features which make up a whitewater course. This explanation is followed by an account of basic mechanics of moving water. A description of the rating scale for moving water is provided to summarize the whitewater features and flow mechanics.

The final section of the review covers whitewater recreation. A comprehensive explanation of whitewater crafts is accompanied by an account of the various dangers associated with whitewater recreation. The key whitewater user groups are identified and described. Finally, a basic report on the economic benefits of whitewater recreation is provided. Refer to Appendix A for a listing of common whitewater terms.

2.2 Whitewater Parks

There are over 60 operating whitewater parks world wide. Whitewater parks are venues that have been partially or wholly augmented to facilitate whitewater recreation.

Whitewater parks can attract locals and tourists, provide a venue for paddling competitions, create a popular and accessible creek/river-side park, enhance the aquatic habitat of a river, restore riparian vegetation along the banks of the river, improve the aesthetics of the particular site, provide local economic stimulation, and improve general river safety through the removal of hazards ("Whitewater Parks: Considerations and Case Studies", 2007). Former U.S. whitewater slalom Olympian Kent Ford summarized whitewater parks this way: "I have seen these courses trigger a tremendous boost to paddle sports, as well as serve the community at large by providing a focal point for riverfront renewal" (Peters, 2000).

Whitewater parks come in two different forms. The first type of park is made up of artificially enhanced sections of an active river channel or in-stream modifications. These modifications can include dam modifications (modifies the rate of flow), and the addition of rocks and drop structures to create waves and holes. These traditional parks are valued for their recreational appeal and the positive economic impacts that they provide. These parks are typically free to use and provide economic stimulus through local businesses ("The national whitewater center", 2012). This form of whitewater park can be made with natural native materials and plantings and can be designed to mimic and restore natural aquatic and riparian zone habitats ("The national whitewater center", 2012). For example, the upper section of the Ocoee River in Tennessee, USA blends artificial rock faces with the natural features of the river to create one of the top whitewater slalom courses in the world (Gromer & Herbst, 1996).

The second form of park is more extensively constructed. These parks are totally artificial, creating whitewater in constructed concrete channels using pump-

stations to provide flowing water. This is typically the type of whitewater park used to host Olympic and World Championship paddling events ("The national whitewater center", 2012). While highly specialized for competitive paddlers and international competition standards, these parks are used by all skill level of paddlers from novice-advanced paddlers to commercial rafters. Table 2.1 summarizes design specifications for some of the main artificial whitewater parks from around the world.

CITY/STATE/YEAR	LENGTH (m)	GRADIENT (m)	DISCHARGE ($m^3.s^{-1}$)	WIDTH (m)	DEPTH (m)	SLOPE (%)
Augsburg, Germany, 1972	305.0	3.2	10.0	6-15		
Dickerson, USA, 1991	274.3		10.0	12.2		
Barcelona, Spai, 1992	340.0	6.5	10.0	5-17		
Atlanta, USA, 1996	600.0	12.0	40.0	30.0		
Sydney, Austrailia, 2000	320.0	5.5	14.0	8-14	0.8-1.2	
Athens, Greece, 2004	270.0	6.0	17.5		1.9	1-2
Zoetermeer, Netherlands, 2006	300.0	5.0	10.0	13-20	1.6	
Peking, China, 2008	280.0	5.9	17.5	10.0	1.2	2.1

Table 2.1 Summary of the World's Whitewater Courses (table adapted from (Čubanová & Rumann, 2009))

A table of existing whitewater parks is listed in Appendix B. The table was adapted from a listing of the United States Whitewater parks by American Whitewater, a national non-profit organization ("Whitewater Parks: Considerations and Case Studies", 2007). Additional information on whitewater park location and design details was developed from publicly available information including individual whitewater park websites. The table is not a complete inventory of all the existing whitewater courses but lists the majority of courses.

Of the 65 whitewater parks listed, 26% have a loop channel configuration. This configuration allows for a short ramp or conveyor system from the bottom of the whitewater section to the top. However, 43% of the listed whitewater parks are laid out in a linear configuration. These courses may be modified existing channels or totally manufactured. Of the 65 whitewater parks listed, the majority have a linear configuration.

The source of the water flow is another main distinguishing factor of these parks. 20% of the listed parks use pumped water. Water is physically pumped from a bottom pool to the top of the course. This is technically challenging from a construction stand point and makes the park more expensive to operate. However, this allows parks to be developed in areas that either do not have access to an adequate amount of water or are not steep enough to create the desired flow rate. 50% of the listed whitewater parks get their water source from flow diversion. These parks are potentially much cheaper to operate; however, the location of the park is more site specific.

2.3 River Features

Rivers are part of the natural hydrologic cycle in which water runoff from the landscape is transported downstream because of gravity. Because of this process rivers are very dynamic in nature. Rivers have several characteristics which determine their overall shape and type of whitewater. Features including bends, chutes, waves and holes, falls, surges, boils, and eddies are all present in rivers. The prevalence and strength/nature of these features determines the overall severity of the whitewater present in the channel.

2.3.1 River Bends

A sharp turn in a channel causes many changes in the current. The water flow takes the path of least resistance and flows into the outside bank drastically increasing the water velocity. Also, the water boils up along the outside bank. A strong eddy line or eddy fence extends from the inside of the curve with an eddy or gently swirling pool behind it.

2.3.2 Chutes

A chute or tongue is formed between emergent obstacles in the flow or when a channel narrows. This constricting accelerates the flow of water. However, once the channel widens again the accelerated flow hits a pool of slower moving water. This in turn creates a wave or hole.

2.3.3 Waves and Holes

Dr. Luna B. Leopold described the distinguishing hydraulic features of four different types of waves in his article "The Rapids and the Pools-Grand Canyon" published as part of a Geological Survey Paper ("Geological Survey (U.S.)", 1969). Figure 2.1 illustrates these four different wave features. The first form of wave is found below large rocks or outcrops which blocks and forces the water to flow over and around the obstruction. This action causes the water to speed up on the downstream side of the obstacle thereby causing a deep trough or 'hole/hydraulic' followed by a standing wave. The wave is characterised by water shooting upward to form the wave crest which continually breaks upstream.

The second type of wave is formed by the convergences of a deepwater channel or waterway. This narrowing forces the water to 'pile up' near the centre. This pile up creates a series of waves just downstream of the channel convergence. Referred to as tailwaves, constriction waves, or wave trains, the waves are preceded by a downstream 'v' which extends form the channel wall at the start of the convergence (Huser, 1975).

The third type of wave is formed by fast flowing shallow water over an uneven surface. Characterized by the creation of waves and riffles, the current is forced up and down over the irregularities of the bottom surface.

Finally, the fourth type of wave is created in deep, high velocity water. Another form of water convergence is formed when fast flowing water hits a section of water which is moving slower (often deep pools). This differential in current velocity causes waves to build up because of friction between surface (fast flowing) water and sub surface (slower flowing or still) water.

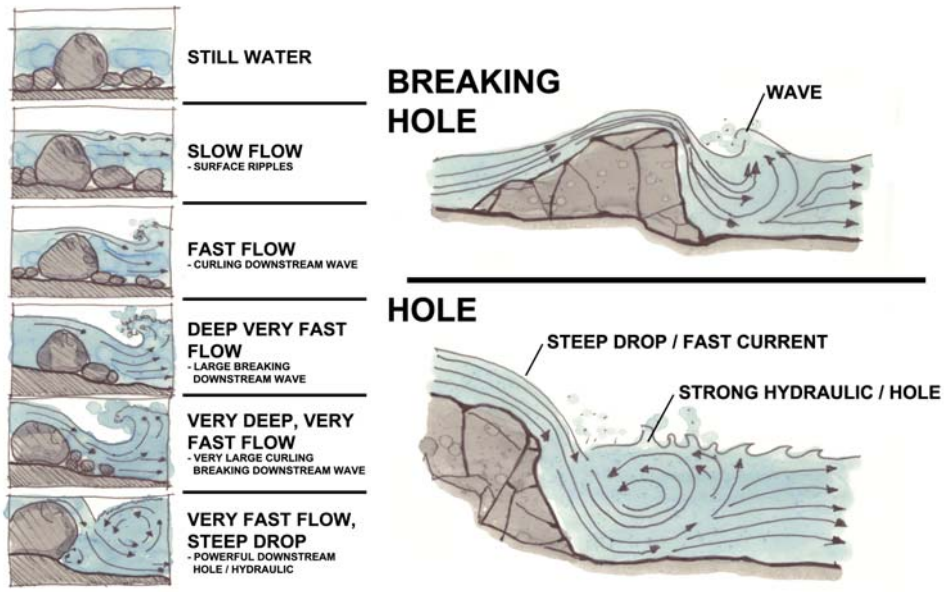

Figure 2.1 Hydraulic Features: Waves / Holes (adapted from (Mason, 1983; Strung, 1976))

2.3.4 Falls

Falls occur when there is a sudden vertical or near vertical drop in the riverbed resulting in very powerful holes at the base of the falls. The strength and retentiveness of the hole at the base of the falls is dependent on the steepness and height of a drop and the amount of water flowing over it. Figure 2.2 illustrates the direction of current encountered at the base of falls.

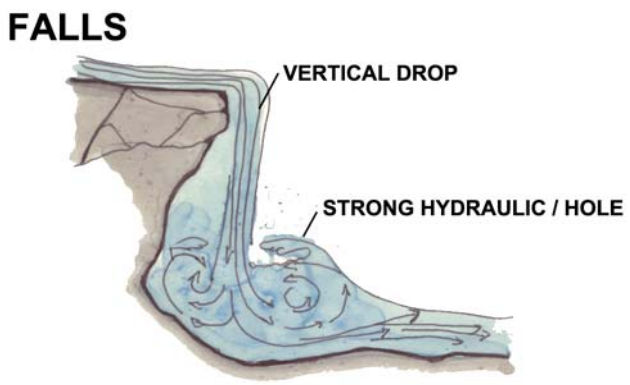

Figure 2.2 Falls (adapted from (Strung, 1976))

2.3.5 Surges

Surges are the gentle rising and falling of water current. Surges generally occur for two reasons. As illustrated in Figure 2.3, surges can be the result of gently flowing deep current over a submerged obstacle. The hydraulic that forms downstream of the obstacle gently pulses up and down. Surges can also result from fast current flowing through a narrow channel with steep or near vertical embankments (Strung, 1976).

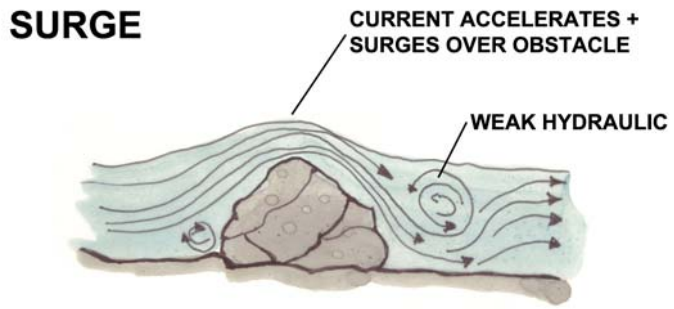

Figure 2.3 Typical surge (adapted from (Strung, 1976))

2.3.6 Boils

Boils result when water current is directed upwards from the bottom. When the current reaches the surface of the water the planes of flow part and create boils. Boils are often highly oxygenated resulting in lowered buoyancy for floating objects. Boils are often found along strong eddy lines and behind powerful hydraulics. Very strong boils can form downstream travelling whirlpools which can pull floating objects under (Franks, 1977).

2.3.7 Eddies

Eddies form when the flow of water is forced to move around an obstacle (Riviere, 1969). For example, when water is forced to flow around a midstream obstacle like a rock, an eddy is formed behind the rock. Water surges up directly in front of the obstacle and is forced to flow around each side of the obstacle. The water velocity increases and the level is higher than the pool of water directly behind the obstacle. Because of this different in water level, the current flows back toward the obstacle in an upstream direction to balance the differential in water level. Therefore, the river flows in

two directions. It flows slowly upstream in the eddy and swiftly downstream in the main current. The dividing line between these opposing flows is called the eddy line or eddy fence. The opposing flows create a downstream expanding band of turbulence between the flows.

Eddies can also form along the shoreline behind embankments which extend out into the channel. The size of the obstacle and the velocity of the flow determine the overall strength of the flow in the eddy and the level of turbulence on the eddy line (McNair, 1972). Figure 2.4 illustrates the two different types of eddies.

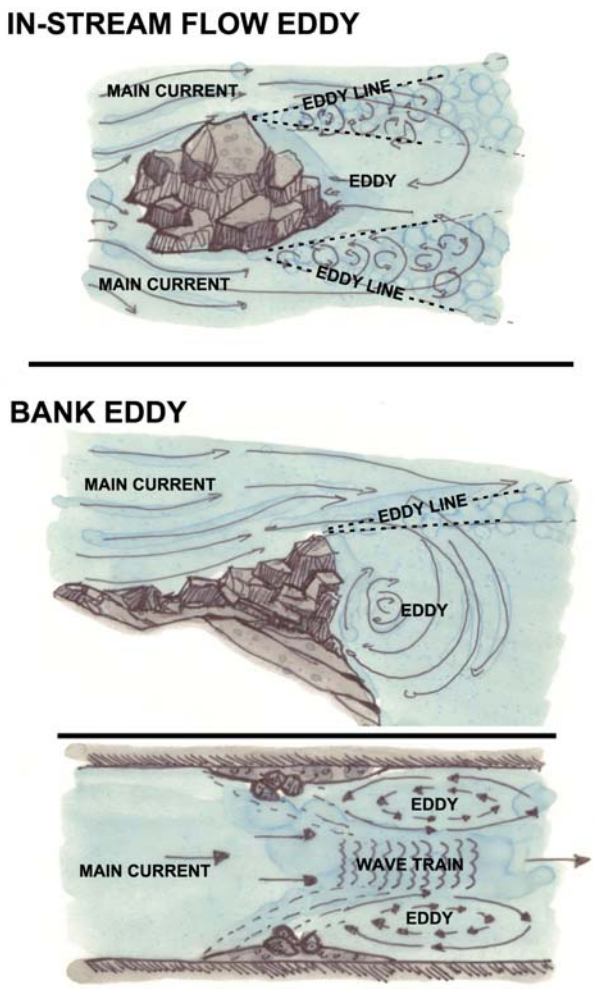

Figure 2.4 In stream and bank eddy (adapted from (Franks, 1977))

2.4 Basic Mechanics of Moving Water

The flow in a moving channel is varied and uneven and can change quickly with time and space (Shen, 1971). This varied flow occurs when the velocity changes in magnitude or direction and is often due to several characteristics of moving water including roughness, turbulence, and laminar flow (Morisawa, 1985).

2.4.1 Roughness

Rapids and moving water or 'roughness' can be characterized by the change from one flow regime to another (Morisawa, 1985). As is illustrated in, Figure 2.5 a hydraulic drop and hydraulic jump causes roughness in the water. A hydraulic drop caused by the change from a gentle slope to a steep slope increases the waters velocity and turbulence (Shen, 1971). Secondly, a hydraulic jump can be caused by the change from a sleep slope to a gentler one. This change in depth and velocity causes roughness in the water at the transition point. Also, a hydraulic jump can be created by an obstruction in the waterway which also causes roughness.

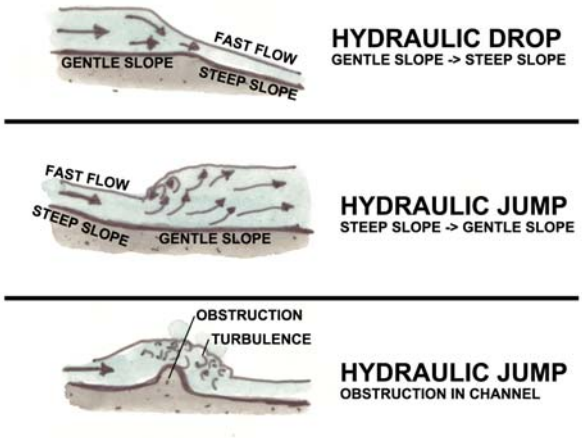

Figure 2.5 Section of Hydraulic Drop and Jump (adapted from (Morisawa, 1985))

Several factors contribute to channel roughness. The size and shape of materials or obstacles on the channel bed and banks contribute to roughness. When the ratio of the height of the materials to the thickness of the water layer is great roughness will be high causing turbulence in the sub layer of the water (Morisawa, 1985). Secondly, abrupt variations in the size and shape of the channel affect its roughness. This includes the channel's sinuosity or meandering nature. Finally, the Spacing of the material or obstacles on the channel bed or banks affects its roughness. If the material is spaced far apart then eddies or vortices caused by the obstacle will be dissipated in the space between. If the material is spaced close together then the water flows over the material leaving dead or relatively calm water between the obstacles. Finally, high roughness will result when the material is spaced so that the vortex created from one obstacle interferes with the flow over the next obstacle (Morisawa, 1985). Figure 2.6 illustrates this process.

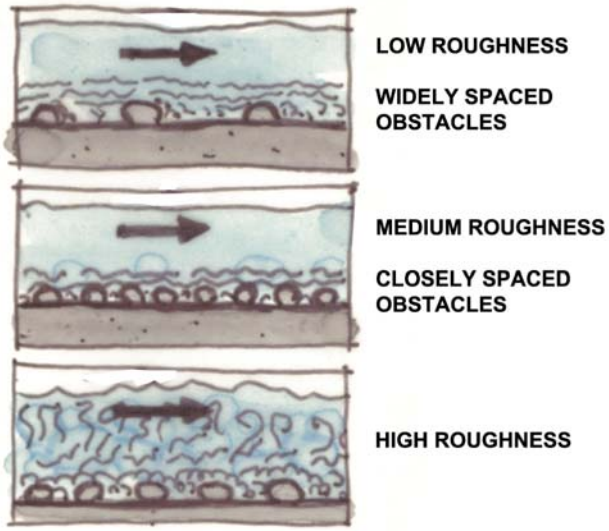

Figure 2.6 Section Depicting Effects of Material/Obstacle Spacing on Roughness (adapted from (Morisawa, 1985))

2.4.2 Turbulence

The Mechanics of moving water is greatly influenced by turbulence. Turbulence is made up of abrupt changes in flow velocity from eddies which causes overall fluctuations of the average flow velocity along a channel (Morisawa, 1985). Rhythmic/cyclic pulsations are one common type of turbulence. Obstructions in a channel which are commonly caused by separation of flow, abrupt expansions/ contractions of the banks of a channel or bends results in turbulence or roughness (Yalin, 1992). Irregular and unstable vortices and rollers form at the boundary layer but dissipate downstream. These vortices in the current can spiral upwards or downwards (Morisawa, 1985).

Helical flow is another common type of turbulence. Characterised as a circular current which resembles a spiral or coiled spring flow that corkscrews downstream, helical flow is caused by friction and drag and the convergence of opposite currents (Shen, 1971). For example, helical flow can be found along an eddy line or eddy fence. Figure 2.7 illustrates this process.

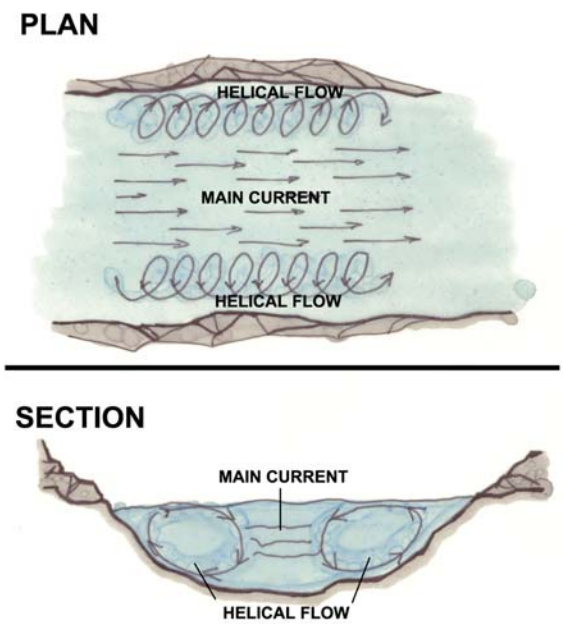

Figure 2.7 Helical flow (adapted from (Strung, 1976))

2.4.3 Laminar Flow

Friction or drag, which occurs in flowing water, causes a property of water called laminar flow (Strung, 1976). Laminar flow can be imagined as multiple sheets of water or shear planes stacked up on each other all moving downstream at slightly different speeds. As illustrated in Figure 2.8, because of friction with the bottom of a channel, the flow will be the slowest near the bottom. Also, friction exists at the surface of the water. Furthermore, each layer of water moving at different speeds will produce friction on the surrounding boundary layers. Therefore, the fastest flow will be between 5 and 15 percent of the rivers depth below the surface (Strung, 1976). Because of this property of moving water, a swimmer in the water will have most of their body exposed to the fast current and move downstream faster than a raft on the surface. Laminar flow is also

related to depth. Channels with receding banks will have significantly slower current at the sides than the current midstream (Strung, 1976).

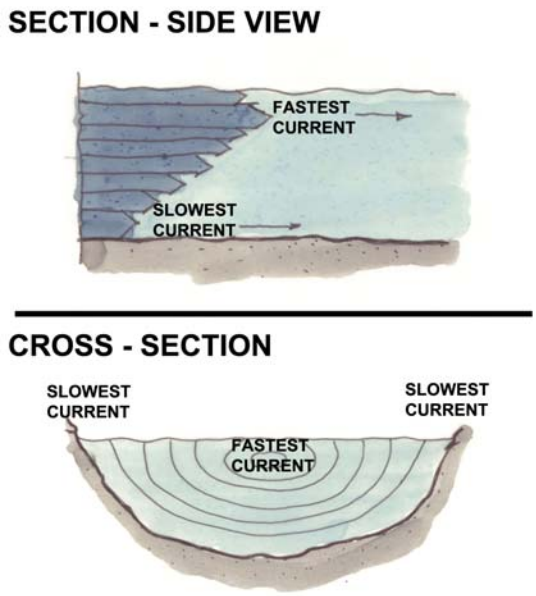

Figure 2.8 Laminar flow (adapted from (Strung, 1976))

The rate of laminar flow is limited. When the velocity of the flow increases, turbulence develops. This turbulence interferes with the shear planes and agitates the smooth flow of water and creates flow resistance as gravity propels the water downstream (Strung, 1976). Therefore, as the gradient increases so too does the potential energy of the water. However, increased flow velocity results in increased turbulence which in turn increases the flow resistance. Because energy cannot be created or destroyed, the potential energy of the moving water, which cannot be released through increased velocity, must be released elsewhere. That energy is released in the scouring action of moving water, transportation of suspended particles, and surface agitation or whitewater.

2.5 Whitewater Rating Scale

The actual volume of water moving along a channel can be measured fairly accurately in cubic metres or feet per second flow rate. However, the rate of flow is a measure of its energy but does not indicate the difficulty or severity of the rapids. The International Scale of River Difficulty is a universal scale used to rate the safety or severity of rapids. The classification system uses Roman numerals I through VI to rate the whitewater. However, the explanation of the scale differs slightly from place to place. Table 2.2 summarizes this rating scale as explained by Norman Strung and Peter wood (Strung, 1976; Wood, 1978).

I	Very easy difficulty. Slight gradient. Often wide and unobstructed channel with small waves and riffles. Little to no manoeuvring required. (Skill Level: Little/ None)
II	Easy difficulty. Rapids of moderate difficulty which are easily avoided. Regular waves rarely breaking over two feet in height. (Skill Level: Basic Paddling Skill)
III	Moderate difficulty. Many irregular waves up to three feet in height. Many rocks and eddies. Scouting is advisable on the first run. (Skill Level: Experienced paddling skills)
IV	High difficulty. Rapids are often long (several hundred feet) with violent and irregular waves up to five feet tall. Rapids are often host to large rocks and powerful holes/hydraulics. There are often many turns and drops in the river. Scouting is highly recommended. (Skill Level: Moderate-High Whitewater Experience)
V	Expert difficulty. Almost continuous violent rapids without letup. Rapids are often host to dangerous emergent obstacles, falls, drops, and powerful and dangerous holes/hydraulics. Irregular waves often over five feet with high flow and large gradient. Many dangers to watercraft and life. Mandatory scouting. (Skill Level: Advanced-Expert Whitewater Experience)
VI	Un-navigable or at the extreme limit of safe navigation. Extreme danger of damage or loss of equipment and serious injury or death. (Skill Level: Dare Devil Expert)

Table 2.2 Whitewater Rating Scale

2.6 Whitewater Recreation

The rapids and falls that break up most of Canada's rivers were once a barrier to early trade but are now a source of recreation to those with the appropriate skills. There are several different groups of people who whitewater recreate including professional competitive paddlers, commercial paddlers, and recreational paddlers. The crafts which they use to navigate whitewater vary from large inflatable rafts to small plastic kayaks. Regardless of the type of paddler or water craft used, whitewater recreation is inherently dangerous and requires careful consideration of ones skill to avoid injury. The following sections outline the various river crafts, dangers associated with whitewater, and the main groups of whitewater paddlers.

2.6.1 Whitewater Crafts

2.6.1.1 Rafts

As described by Norman Strung, "stability, capacity, company and a relative margin of safety are the qualities that make a rubber raft ideal for floating" (Strung, 1976). Rafts are designed in many shapes and sizes and are purpose built as stable platforms which can carry multiple paddlers or passengers. For this reason, rafts are ideal for commercial recreational use.

Because rafts float on the surface of the water, friction makes them travel downstream slower than the main subsurface flow. Also, rafts do not track well across the water. Instead, a raft will tend to skid across the water when there is a direction change. Imagine pushing someone in a chair across the ice in one direction and then attempt to change directions. The chair will do a sweeping turn as the original

momentum wants to keep it travelling in a straight line. For this reason, guiding rafts through small channels with multiple obstacles is a technical affair requiring skill and pre planning.

2.6.1.2 Kayaks

First thought to be developed by the Eskimo's, the kayak was made of skins (mostly sealskins) stretched over a frame of wood so as to cover the craft completely except for a small opening for the paddler (Wood, 1978). One of the main advantages of the kayak is that it can handle very rough water and even roll over without taking on much water.

The evolution of the modern kayak has resulted in a drastically different design in craft compared to its ancestor. Kayaks started to be used competitively during the early twentieth century and have continued to evolve in design and materials since. Kayaks can be made of wood, canvas, fibreglass, ABS (Acrolonitril Butadiene Styrene), Kevlar, and carbon fibre or composite materials. Table 2.3 describes general kayak terminology.

K1	One-person kayak. Single person craft in which the paddler sits with a skirt that attaches to the cockpit to keep the water out. Paddler uses a double bladed paddle. Designed and built in all shapes and sizes for purposes including: flat water recreation, sea kayaking, slalom, downriver racing, water polo, flat-water racing, touring, surfing (river and ocean), and downriver whitewater recreation.
K2	Two person kayak. Typically designed for flat-water or sea kayaking although some specialized 2 person kayaks are used for whitewater. Features two cockpits for two paddlers using double bladed paddles.

Table 2.3 Kayak Terminology

Kayaks can fall into four different categories of use: Flat-water or sea kayaking, surfing, downriver/creeking, and slalom. Flat-water or sea kayaks are typically longer and designed for one or two paddlers. These boats are built to be comfortable and

efficient for long distance paddling. Surfing kayaks are typically short or 'stubby' boats with a flattened hull with lots of rocker and high air volume. These boats are typically a tight fit but are designed to surf and carve on waves without the bow or tail nose-diving into the trough of the wave. Downriver or creeking kayaks are designed more for speed. Slightly longer than surfing kayaks, downriver/creeking kayaks have a pointier nose and tail. Creek boats have more volume and are slightly shorter than downriver kayaks. This enables them to be more manoeuvrable and buoyant in tight, steep, fast flowing creeks. Finally, Slalom kayaks are designed for manoeuvrability and speed. In order to slip more easily through the hanging slalom gates, slalom boats have become smaller over the years (Wood, 1978). Most commonly made of fibreglass, slalom kayaks are just over half a metre wide and three and a half metres long. Being made of fibreglass, slalom boats are less durable than other whitewater craft. Impacts with obstacles can wear down the fibreglass or crack it.

2.6.1.3 Canoes

The raft is a large and fairly stable platform designed to handle 'big water' and the kayak is more spry and temperamental performing well in technical water. The canoe, in comparison, is a more modest craft not typically designed for high class whitewater (Strung, 1976). As explained by a professional guide, "Canoes combine the best features of a raft and a kayak. They carry a lot, yet can themselves be carried…You can move across lakes and reservoirs and manoeuvre them down rapids, and when the water runs out, you can turn amphibian, pick up your boat, and carry it on your back turtle-fashion" (Wood, 1978).

The North American Canoe was first developed by the Native Americans who migrated into Canada at the end of the last glaciation period (Franks, 1977). These craft were used on Canada's vast waterways as a mode of water transport. The first description of a canoe by a European was made by Samuel de Champlain during his visit to Tadoussac in 1603. Champlain wrote:

> Their canoes are some eight or nine paces [aprox. 6.5 metres] long, and a pace or a pace and a half broad amidships, and grow sharper toward both ends. They are liable to overturn, if one knows not how to manage them rightly; for they are made of a bark of trees called birch-bark, strengthened within by little circles of wood strongly and neatly fashioned, and are so light than a man can carry one of them easily; and every canoe can carry the weight of a pipe [aprox. 450 kilograms]. When they wish to go overland to get to some river where they have business, they can carry them with them. (Champlain, 1971)

Although hundreds of years have passed since first described by Champlain, the design of the canoe has changed little. However, the materials and construction techniques have changed drastically. In the late nineteenth century European trading companies began to replace birch bark with canvas as a covering (Franks, 1977). Several years later, all wood canoes made of tightly fitted cedar or basswood strips reinforced by narrow interior shaped oak ribs was developed in Ontario.

Canoe design and build did not change much from the early years of the twentieth century until after the Second World War (Franks, 1977). At this point the aluminium canoe was developed by the Grumman Company as a product of wartime airplane production. The next canoe innovation was the fibreglass canoe. Glass fibres are woven into a cloth which is then bonded with polyester resin to form a flexible, weather resistant and very strong material. Most recently, canoes can also be made of ABS, Kevlar, and

carbon fibre or composite materials. Each material requires a different process to manufacture and varies in its complexity and expense. However, each material yields a very strong, durable and incredibly light canoe. Table 2.4 describes the modern terminology for river and lake paddling canoes.

C2 (open)	Two-person, open canoe. Traditional recreational canoes not specifically designed for whitewater.
C2	Two-person, covered canoe. Highly 'rockered', completely covered canoes in which paddlers kneel on the bottom of the craft. Designed for high manoeuvrability and stability in whitewater.
C1	One-person, covered canoe. Smaller versions of C2's, C1's are normally used in solo downriver and slalom racing in which the paddler kneels and uses a single-bladed canoe paddle. Designed for sprinting short distances.

Table 2.4 Canoe Terminology

2.6.2 Dangers of Whitewater Recreation

As with any active recreational sport, whitewater paddling has the potential for injury. Injuries either occur while one is still in their craft, or while one is swimming in the water. In a study of injuries occurred in whitewater kayaking, D. C. Fiore and J. D. found that of the 392 kayaking respondents included in the final analysis, 219 suffered 282 distinct injury events. Of these events, 87% occurred while the kayaker was still in their boat. 44% of the included respondents reported striking an object as the mechanism of injury while 25% reported traumatic stress and overuse as their injury. The most common types of injury were abrasion (25%), tendonitis (25%), contusion (22%), and dislocation (17%). At 96%, almost all of the injured reported a complete or good recovery (Fiore & H., 2001). Figure 2.9, developed by D. C. Fiore and J. D., depicts the breakdown of type of injuries by mechanism.

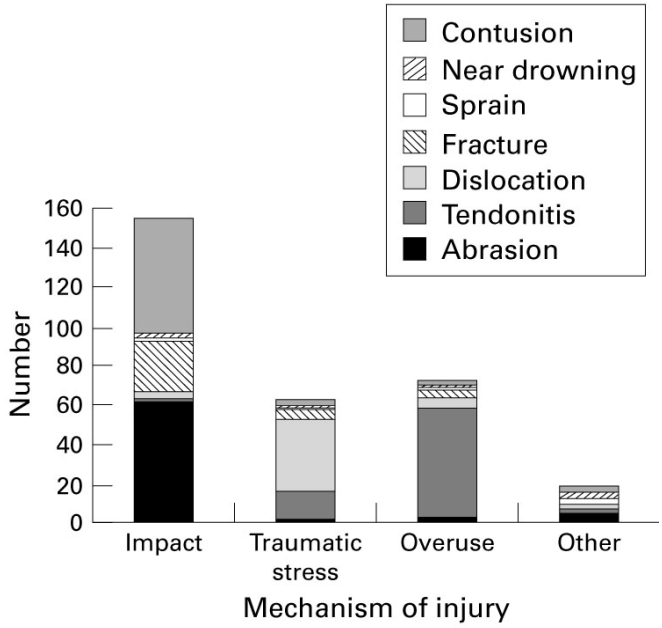

Figure 2.9 Injury Type by Mechanism (Fiore & H., 2001)

Aside from impact, traumatic stress, and overuse injuries, drowning and near drowning are a serious threat posed by whitewater recreation. Drowning can occur because of river water features or obstacles in the river. Very powerful holes/hydraulics can re-circulate a swimmer for an indefinite amount of time. The shape of the hole is important in assessing its retentiveness. A hole that is shaped like a 'u' or upstream viewed smile is less retentive than a hole shaped like an 'n' or upstream viewed frown. The 'smile' hole allows re-circulating water and anything caught floating in it to exit out both sides of the hole. However, the 'frown' hole pushes all the water to the apex or centre of the hole. This shape of hole is very retentive and can be quite dangerous. Figure 2.10 illustrates this description.

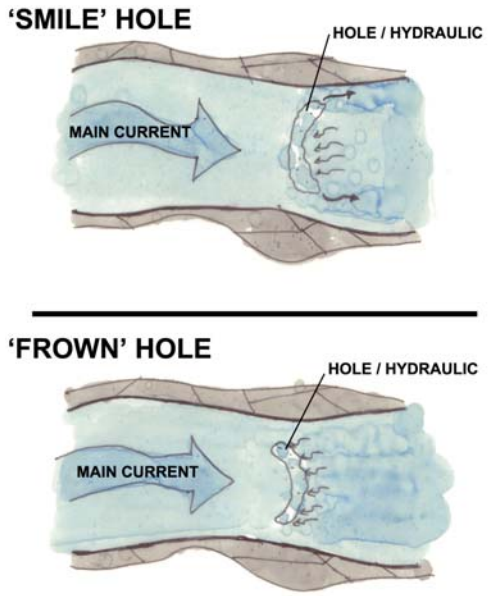

Figure 2.10 Plan Graphic of 'Smile' and 'Frown' Shaped Holes

Drowning or serious injury can also be caused by strainers. Strainers are formed when an object blocks the passage of larger objects but allows the flow of water to continue. Strainers can be formed by many different natural or man made objects such as: storm grates over tunnels, trees that have fallen into a river, semi-submerged bushes, wire fences, rebar, and other debris. These objects can be very dangerous because the force of the water will pin an object or body against the strainer and then push it down under water. Once caught against a strainer it is exceedingly difficult to climb over the top.

Finally, foot entrapment is another very serious and dangerous scenario in whitewater. Foot entrapment occurs when a swimmer gets their foot caught on an obstacle on the bottom of a channel with flowing water. Even in shallow moderately flowing current, a foot entrapment can be deadly. Once ones foot is caught on the

bottom, the current pushes the victim over. The current then holds the victim under. Because of the risk posed by foot entrapment, it is important for swimmers to avoid attempting to put their feet down until out of the current.

2.6.3 Key Whitewater Users

2.6.3.1 Professional: Whitewater Slalom

Whitewater slalom is a competitive sport in which the aim is to navigate down whitewater through a course of ordered hanging gates (a combination of downstream and upstream manoeuvres) in the fastest time.

The first known whitewater slalom competition which was modeled after ski slalom occurred in 1933 (*Canoe/Kayak slalom.*2009). The Internationale Repräsentantschaft für Kanusport (IRK), founded in 1924, was the first International Federation to govern canoeing. This was succeeded by the International Canoe Federation (ICF) after World War Two. Canoe and kayak racing were first introduced as Olympic medal sports at the 1936 Berlin Games. However, Canoe slalom did not make its debut until the 1972 Munich Games and was not competed again in the Olympic Games until the 1992 Barcelona Games.

There are typically 18-25 gates which make up a competitive slalom course (Hunter, Cochrane, & Sachlikils, 2008). The gates are coloured differently to distinguish between upstream gates and downstream gates. Upstream gates are typically placed near eddies. The paddler exits the main current, enters the eddy, turns around, paddles up stream through the gate, and exits the eddy to continue the course. Most slalom courses are designed to take 80 to 200 seconds to complete (Hunter et al., 2008). Figure 2.11

depicts a whitewater slalom course designed by architect Bligh Voller Nield in Penrith, New South Wales, Australia. The time taken to complete the course depends on the number of gates, difficulty of the rapids and the overall length of the course. In professional competitions, each paddler has two runs on the course. Depending on the event, the results are based on either the fastest run or the sum of the two runs. Time penalties are added if a competitors paddle, boat, or body touches the poles that make up a gate. Time penalties are also incurred if a competitor misses a gate, goes through the gate upside down, or goes through the gate in the wrong order.

Figure 2.11 Penrith Whitewater Slalom Course ("Whitewater", 2000)

2.6.3.2 Professional: Freestyle

Professional freestyle or rodeo paddling is an offshoot of slalom competitive paddling. Paddlers 'drop' into hydraulics or fast cresting waves to execute flips, twists and a variety of other kayak manoeuvres during 45 second runs. Similar to surfing and snowboarding, freestyle paddlers are judged on the variety and difficulty of their moves. Professional freestyle paddling is not an Olympic event. Instead the competitors themselves regulate the sport.

2.6.3.3 Commercial: Rafting/Paddling Schools

Whitewater rafting is an outdoor activity using an inflatable raft to navigate a stretch of whitewater. Although whitewater sports are inherently dangerous, rafting offers a low risk alternative to beginner whitewater enthusiasts. Commercial outfitters can offer whitewater rafting as a means to transport multiple guests down whitewater in a single craft with limited risks.

Paddling schools are another type of commercial whitewater operation. Ideal for those interested in navigating themselves down rapids, whitewater paddling schools provide students with instruction in whitewater paddling. Learning to paddle whitewater is much safer when done in a group situation under the watchful eye of a skilled instructor (Mason, 1983).

2.6.3.4 Recreation: River Runners/Playboating

Private whitewater recreation takes two main forms. The first is river running. Paddlers choose a water craft and simply paddle down the section of whitewater. The second form of whitewater recreation is playboating or "park-and-play." These paddlers choose to stay by a particular wave or hole and attempt to do manoeuvres while surfing in

the whitewater feature. There are also those that choose to do a bit of both. These paddlers may choose to run a section of rapids, stop and surf a wave, and then continue down the section. Whitewater paddling is a dynamic sport and paddlers are free to participate in whichever way they prefer.

2.7 Economic Benefits of Whitewater Recreation

As stated by Cordell et al., "protecting and managing rivers for outdoor recreation may provide a clean, economical viable means for enhancing local economic development, as well as for providing needed recreational opportunities to the nation" (Cordell et al., 1990). In the paper, "Economic Effects of River Recreation on Local Economies," Cordell et al. concluded that visits to recreational rivers may stimulate a considerable amount of economic activity in local regions ($2.57-$13.35 million gross output) (Cordell et al., 1990).

The economic benefits of whitewater parks can be determined on a case by case basis. There is a distinct difference in return depending on the type of course. Courses on active river channels or modified in-stream flow generate less economic returns than artificial courses. This is due to the fact that one type of course is free to use whereas the other is not. Marca Hagenstad et al., in a report on the beneficial value of the Clear Creek Whitewater Park, concluded that the whitewater park (modified in-stream flow park) generated considerable economic benefits to the kayakers using the course, other interested parties, and the community as a whole. The researchers found that the total annual economic benefit of the Whitewater Park amounted to between $1.4 and $2.0 million (Hagenstad, Henderson, Raucher, & Whitcomb, 2000). On the other hand, S2O

Designs, a top whitewater park design and engineering company, explained that completely artificial parks, “represent an up-to 20% rate-of-return on investment and can pay themselves off in as little as 6-7 years” (“The national whitewater center”, 2012).

2.8 Conclusion

The literature review outlines the various elements of whitewater in order to provide a foundational knowledge for the understanding of whitewater and its application in manufactured whitewater parks. The review focussed on an explanation of the different types of whitewater parks, the various features and basic mechanics of moving water, and a description of the moving water rating scale. Whitewater recreation including an explanation of whitewater crafts, the various dangers associated with whitewater recreation, the key whitewater user groups, and a review of the economic benefits of whitewater recreation was provided.

Three key whitewater park user groups were identified. These user groups included professional/competitive, commercial, and recreational paddlers. Varying types of watercrafts are used by these groups including inflatable rafts, kayaks, and canoes. A study of existing whitewater parks in Canada and abroad revealed that of the sixty five existing parks identified many different design considerations and general layout options exist. The majority of the existing parks (43%) have a linear channel layout and 50% of the parks were supplied with moving water through flow diversion.

Chapter Three: Methods

3.1 Research Strategy: Theoretical Approach

The overall research strategy involves an interpretive qualitative study towards an understanding of whitewater park design and user group needs in which the researchers own biases as participant in the research must be recognised and accommodated. Given limited previous research on this topic, a flexible process is needed in order to gain a rich variety of descriptive information on whitewater course design and function (Robson, 2011). Furthermore, qualitative research is necessary because the results can be taken as true reports of the research subject's views and experiences (Hakim, 1987).

The strategy of inquiry used in this study can be classified as interpretive constructionist research. As such, the focus is on understanding the current trends in whitewater course design, learning what people make of existing competitive courses, how people interpret the whitewater courses they have encountered, and how they assign value to whitewater recreation/competition (Rubin, 2012).

As an interpretive strategy the research follows a reflexive or abduction approach, a strategy that is between inductive and deductive research (Deming, 2011). As such, the research moves back and forth between the two perspectives allowing for modifications to theoretical propositions, revisions to the understanding of the evidence, and the exploration of new ways of understanding. "Deduction proves that something must be; induction shows that something actually is operative; abduction merely suggests that something may be" (Deming, 2011).

As a constructionist mode of inquiry, knowledge is actively constructed rather than found through the interactions between the investigator and the research subject

(Deming, 2011). In this way, the investigator is actively engaged in making sense of the data and becomes a social actor within the research. This study requires the active involvement of the researcher because of the belief that people interpret their own understanding of the external world and it is not possible for the researcher to eliminate all biases (Rubin, 2012).

The interpretive strategy used in this research is ethnography. Ethnography can be described as an approach based upon observation and is often descriptive in nature (Deming, 2011). In this research, the approach ultimately requires the active engagement between the research and researcher. This active interpretation takes place in the form of in-depth semi structured elite interviewing.

3.2 Research Design

To establish a better understanding of whitewater park design that incorporates the needs of multiple user groups in one integrated designed facility this study combines information gained from literature review and elite interviewing. Interviews are conducted to gain direct access to a subjects experiences (Silverman, 2010). This research is analyzed to generate design principles for creating integrated whitewater parks. These principles are then used to develop a preliminary conceptual design for an integrated whitewater park at a site chosen through specific criteria. Finally, the design and the principles that helped develop it are evaluated by a whitewater course designer. Figure 3.1 depicts the methodology procedure followed.

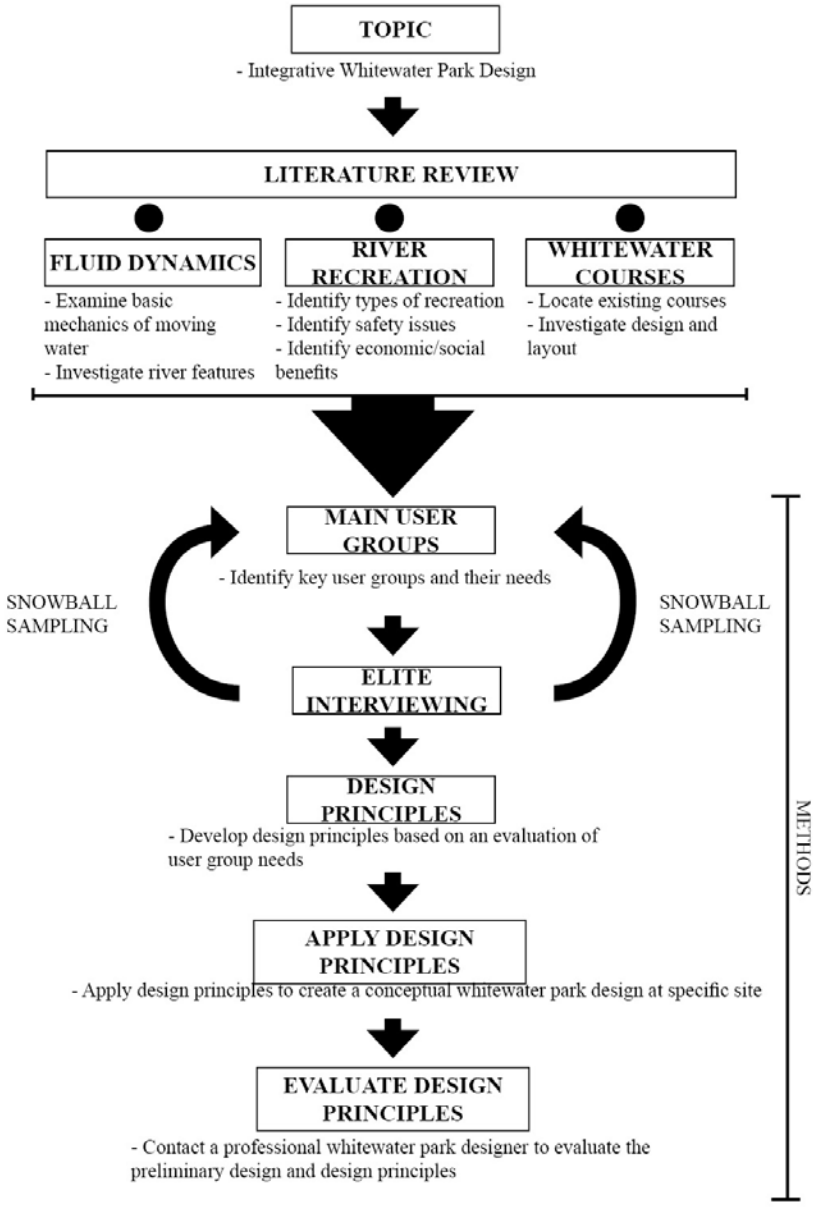

Figure 3.1 Methodology Procedure

3.2.1 Overall Design

A reflexive interpretive research strategy is used to explore whitewater park design and the various user groups. This research design strategy is appropriate because people and their interactions with whitewater is a significant focus of this research.

Furthermore, because it is not immediately obvious why and how people interact with whitewater, the researcher must actively engage in making sense of the data. As such, this study involves elite interviewing of a few subjects with a rather informal pattern of questioning in which the interviewee is allowed to set the pace (Silverman, 2010).

In-depth semi structured or 'conversational' style elite interviewing is conducted to gain first-hand expert information from informants at the 'top' of their professional field. Exploratory in nature, these interviews are conducted to encourage respondents to speak in their own words thus helping to produce a rich depth of information (Babbie, 2004). The goal is to receive and record detailed information of the user group's interactions with whitewater including experiences, stories, and examples. A prepared set of questions is used for the interview, but mainly as a guide. Furthermore, the questions are not fixed allowing the order and wording to be changed on the spot. The initial interview questions are developed through the literature review and the researchers past knowledge.

The interview data is analyzed resulting in design principles for the development of integrative designed whitewater facilities which serve the needs of multiple user groups. These principles are used to create a preliminary conceptual graphic demonstration of a whitewater course at a specific site. Finally, this design principles and preliminary design is evaluated by a professional in the field of whitewater course design through the use of a questionnaire. This professional is selected based on research conducted during the literature review and by the recommendations of the elite informants.

3.2.2 Sampling Approach

This research follows a theoretical sampling approach (Deming, 2011). Specifically, elite informants are identified from three main whitewater park user groups who are well informed on the topic. The initial elite informants are selected from the contacts the researcher has previously made in the paddling industry. Further elite informants are identified through snowball sampling. In other words, respondents are asked for the names of other people who may be well informed on the topic. These potential respondents are contacted and the process continues. The most appropriate elite informants are selected and contacted, but ultimately only those who are willing to speak to the researcher are interviewed.

3.2.3 Data Collection

Selected elite informants are asked to volunteer for participation in an in-depth semi structured interview. In order to conduct a successful interview and ensure that a rich variety of unbiased information is gained, the following criteria were followed:

1. Perform a pilot interview to test the recording instruments and clarity of the initial questions.
2. Conduct interviews at a respondent's place of employment (Bailey, 2007).
3. Attempt to maintain a balance between the respondent speaking about topics that interest them and topics that are pertinent to the research (Rubin, 2012).
4. Allow the respondents to talk at a pace of their own, avoid interrupting, and avoid asking leading questions.
5. Limit the researchers own expectations on respondents.

6. Give the respondent open ended questions. This allows the interviewee to respond any way they choose including elaborating on a topic, raising new issues, or simply disagreeing with the question (Rubin, 2012).
7. Attempt to guide the discussion while allowing respondents the freedom to steer the conversation and speak personally and at length about the topic.
8. Ask questions that only relate to the respondents professional knowledge (Babbie, 2004).
9. Limit the number of main topics to maintain a conversational flow between topics (Rubin, 2012).
10. Try to adopt the role of "socially acceptable incompetent" in order to facilitate the process of being taught by the respondent (Lofland, 1971).
11. Limit the number of questions in order to complete the interview in less than an hour and a half.

3.2.4 Data Recording Methods

In order to help make the interview process unstructured and uninterrupted, the conversation is digitally recorded with the respondent's permission. Adobe Soundbooth, a computer recording program, is used to record the interviews. The software allows for several hours of uninterrupted recording and offers many editing options. These editing options are useful in coding and analyzing the data. To supplement the recording, detailed notes are taken during the interview. These notes highlight the researcher's initial thought and analysis. Immediately following the interview, while the exchange is

still fresh, time is spent investigating and reflecting on the assumptions the respondents were making and the context in which they were speaking/acting.

3.2.5 Ethics

All of the elite informants are affiliated with a professional organisation and the questions asked reflect the work that they do professionally. The respondents are asked for their permission to record the interview and use the answers in this research paper. The respondents are ensured that the recorded interviews are not used for any other purpose. The respondents are informed that the final paper will be publicly available and are asked their permission to include their names in the document. Finally, the respondents are ensured that the digitally recorded interviews will be erased upon submission of the completed report.

3.3 Data Analysis/Response Interpretation

An ad hoc meaning generation method is used in this study as the form of interview analysis. This form of analysis is used because of its flexibility. It is an unstructured use of different approaches for data analysis allowing for free interplay between the varied techniques (Kvale, 1996). The data is analyzed to determine the particular needs/desires of each user group.

3.3.1 Design Principles Development

Design principles describe fundamental ideas about the practice of good design. Furthermore, these principles serve as the ‘umbrella’ under which detailed design

recommendations can be organized. However, the various design principles and recommendations may overlap. Furthermore, the design principles are simply a means to organize and present recommendations for design. The organization structure is flexible and can be continually modified or refined.

The information gained from literature review and elite interviewing is used to develop a list of criteria for whitewater park design which integrates the needs and desires of the various user groups. The design recommendations made by the elite informants are analyzed and grouped together based on similar topics. These topics are refined to develop a list of design principles which incorporate all of the design recommendations.

3.3.2 Design Implementation

As part of the first stage of evaluation a site is chosen to demonstrate the application of the design principles. Several criteria were used to select the site. The site must be in close proximity to an urban centre. Specifically, the site must reside within 10 Km of an urban centre. The site must have a minimum 2.0% slope to be able to facilitate the creation of whitewater. A 2.0% slope is the approximate average of existing whitewater park slopes. The site must be situated within a close proximity to a source of water which can provide a minimum 10 m^3/s flow rate. This flow rate is the approximate average flow rate of existing whitewater parks. Finally, the site must have a minimum 300 metres (either lengthwise or circular) of available space for a whitewater course. This number is based off of the approximate average minimum existing whitewater park course length and width.

The conceptual design is intended as a practical application of the design principles. The design is not intended as a test of feasibility for developing a whitewater park at the chosen site. Instead, the design is used a visual representation of the design principles and recommendations to help refine the original design principles. Secondly, the design is used to test the assumption that one site can be designed in such a way as to appeal to and serve the needs of the three main user groups.

3.3.3 Design Evaluation

A summary of the design principles and the final demonstration design is submitted to a professional whitewater course designer. The course designer is selected based on several criteria. The course designer must be actively working for a company that designs multi-use whitewater courses internationally. The respective company must be recognized by the elite informants as being a leader in whitewater park design. An electronic questionnaire is provided for the evaluation. The questionnaire must provide close-ended or scalar questions because they require less work for the respondent to complete and are easier to analyze than open ended questions (Dillman, 2009). The questionnaire must provide a mix of nominal close-ended and ordinal close-ended questions in an unordered and ordered set of answer categories. The categories reflect the different design principle categories. Finally, the questionnaire must provide some optional open-ended questions to allow for additional respondent comments. The questionnaire is pre-tested by two volunteers prior to the submission to the evaluator. The goal of the pre-test is to ensure the clarity of the questions and understand the time required to complete the questionnaire.

Chapter Four: Results

4.1 Introduction

This study set out to investigate whitewater park design to identify the key user groups, assess their needs, and organise the results into a list of design principles and recommendations which could be applied to a preliminary whitewater park design.

Three key user groups were identified and four elite informants were selected to provide detailed design recommendations for each user group. Seven design principles and thirty seven detailed design recommendations were identified. Based on specific site selection criteria the Chaudière Falls was selected as the location for applying the design principles through a preliminary whitewater park design. The design principles/recommendations and preliminary design was evaluated by Scott Shipley, a professional whitewater park designer and engineer working for S2o Design.

4.2 Elite Informant Interviews

Four elite informant interviews were conducted to gain insight into professional, commercial, and recreational paddling needs for whitewater parks. The researcher used his personal contacts in the commercial whitewater industry to set up initial interviews. Additional elite informants were selected through snowball sampling. Elite informants were selected based on their potential expertise in their respected professional field and by the recommendations of the previously contacted elite informants.

4.2.1 Commercial Whitewater Operations

Dirk Van Wijk

Owner/Operator Owl Rafting/Madawaska Kanu Cenre,

Ottawa, ON

Dirk Van Wijk has been the part owner and operator of Owl Rafting (Ottawa River) and the Madawaska Kanu Centre (Madawaska River) for over twenty five years. Owl Rafting has been in operation since 1981 and specializes in combining white-water excursions on the Ottawa River with a 25 acre lakeside resort. It now employs over 50 people and has a seasonal clientele of over 8000. The Madawaska Kanu Centre has been in operation as Canada's first whitewater school for kayaks and canoes since 1972. Dirk Van Wijk runs the companies with his wife and partner Claudia Van Wijk.

Throughout his years of paddling experience Van Wijk has had several opportunities to paddle on both natural and artificial courses worldwide. However, Van Wijk mentioned that Canada has very few artificial courses. Furthermore, there are very few acceptable slalom courses in Canada. When asked about an example of a good artificial course in North America, Van Wijk mentioned the U.S. National Whitewater Centre in Charlotte North Caroline. Van Wijk explained that the course is successful because it incorporates multiple whitewater features and allows paddlers to attain back up the rapids. Also, the course had been designed as a double loop which has a specific slalom and recreation channel. The recreation channel is approximately 500 metres long. The slalom channel is about half that length.

Van Wijk explained that in order to be successful, whitewater courses need to be multi purposed. Specifically, the whitewater centers need to appeal to as many different

users as possible. When asked if the U.S. National Whitewater Centre accomplished this, Van Wijk replied that it was successful in some areas and not in others. Specifically, Van Wijk mentioned that the recreation channel was probably too difficult for beginner paddlers and not exciting enough for commercial rafters. As such, the channel does not get as much use as it could have.

Whitewater parks are often designed to have a loop layout. Van Wijk pointed out that there needs to be an easy way from the bottom back to the top of the course for commercial use. Specifically, for sustainable rafting, there needs to be some sort of a mechanical ramp back to the upper water level, or at least part way with a flat water paddle. Because of the short length of the course, commercial operations make several runs of the course. Van Wijk explained that it is not ideal to have commercial clients paddling for only a few minutes and then spend most of the time portaging to make multiple runs. Ideally, a fast, simple, and cheap system which moves people back to the top while still in their boats is ideal.

The layout of the sections in the course is important. Whitewater courses should start hard and end easy, or have a way of circumnavigating the two sections. If a paddler swims in the difficult section they wash out into the easy section. Also, this configuration allows a beginner paddler to put-in below the difficult section. If the layout was reversed, paddlers swimming in the beginner section would wash out into the more challenging section.

When it comes to wave features, freestyle paddlers want waves and holes while slalom paddlers want strong upstream eddies. Commercial paddlers, including paddling schools and rafting operations, do not need big holes but do want big waves. The trick is

to balance all of these features and locate them in the appropriate section to appeal to all user groups. Furthermore, these features need to be easily modified to be constantly improving the performance of the course.

Due to the high construction and operational costs a constant source of revenue is needed to keep these parks in operation. Van Wijk explained that commercial rafting is what often sustains these parks. For example, Van Wijk mentioned that the Penrith Whitewater Park is a very popular rafting destination. As such it has been quite successful in making a profit. Van Wijk explained that artificial whitewater courses make for excellent rafting. Clients can warm up on the easy or recreational channel and then go down the big stuff.

Artificial whitewater parks are very efficient with their use of water. Van Wijk explained that the Madawaska Kanu Centre runs quite well on 25cms (cubic metres of flow per secon) but narrow artificial courses could easily operate on 15cms. However, due to the winter months, the course would be inactive for part of the year. As such, Van Wijk mentioned that it would be important to cooperate with hydro to make use of the winter month's water supply and offset the cost of operating/maintaining the course.

In terms of general park features, Van Wijk mentioned that the whitewater park has to be aesthetically pleasing. Specifically, the park has to be a comfortable and nice place for people to watch the paddlers. The park should be designed to include viewing locations at major whitewater features. This allows spectators to engage in the activity in a passive way. Furthermore, the park has to be very accessible for both passive and active users. Van Wijk explained that bridges and multi-use paths are a good means of moving people around the park.

4.2.2 Professional Paddling

James Cartwright

Canoe Kayak Canada

Ottawa, ON

James Cartwright is a Canadian slalom canoer who has competed since the early 2000s. He has competed in three summer Olympics and finished ninth overall in the C-1 event at Athens in the 2004 Olympics. James Cartwright currently works for Canoe Kayak Canada.

Cartwright started by explaining that whitewater parks in Canada do not have a really good track record. Because of his vast experience with whitewater courses around the world, Cartwright had a lot of advice when it came to specific recommendations for whitewater park design. Cartwright explained that it is important to have a good whitewater warm-up area. This section could simply be an easy or recreational channel. To make it easier, this section should be less sloped, have larger eddies and have an overall wider channel width than the slalom section. This channel should be located either below or as a separate channel to the slalom course. If the recreation channel is located below, the main whitewater facilities should be located at the beginning of it. An advanced section or slalom course should have a 3-4 class difficulty.

Cartwright explained that slalom training courses are steep and are therefore difficult to attain back up the rapids. For this reason it is important to have a conveyor system which allows paddlers to do loops without getting out of their boat. This becomes important if one is paying for the paddling time. A conveyor system allows paddlers to

train in a more efficient way by not spending a lot of time travelling back to the top of the course for multiple runs.

As far as the course layout is concerned, Cartwright explained that he had never really seen a whitewater course designed to run on multiple channels work well. Specifically, Cartwright explained that in theory designing for multiple channels (like multiple runs on a ski hill) sound good. However, in practice it hasn't been successful, at least not enough to justify the added expense of creating it. Instead, Cartwright proposed that courses be designed to run on one channel where the saved resources can be put to better course design.

Cartwright explained that eddies are a very important feature in whitewater slalom courses. The goal is to have very strong, well defined eddies with a strong upstream flow. Cartwright explained that there are several features which help create an eddy. First, removable vertical structures placed in the whitewater will create defined eddies which can be modified. Second, near vertical walls on the side of the eddy will help create a strong upstream flow. Furthermore, by creating a vertical embankment it ensures that the eddy stays deep enough all the way to the edge. Cartwright explained that if the eddy is not deep enough, the boat will hit the bottom when paddlers make their turn in the eddy. This damages equipment and affects competition time. However, vertical walls make it difficult to get in and out of the water. Therefore, stepped vertical walls may be a good compromise. Also, having vertical walls throughout the course can lead to surging. Therefore, as a compromise, having slopped walls between eddies may reduce the amount of surging and make it easier for swimmers to exit the water.

Trying to incorporate waves into a course design will make for a better slalom course. Cartwright explained that this is something that course designers have not been able to produce reliably. The ideal wave is a fast, standing, cresting upstream wave. Essentially, the more "surfer" friendly the waves are the better they are for slalom. When it comes to freestyle, paddlers want a fast moving big wave that they can pop on and get air. That seems to be where the sport of freestyle paddling is going. However, care is needed in where play features are placed. Cartwright suggested that placing these features in the middle of the slalom course might create tension between the user groups. Finally, good eddy access on either side of the wave is important to allow for paddlers to queue up for wave time.

On the other hand, when it comes to holes one ore two are fine. However, there needs to be a good balance between waves and holes. When holes are created it is important that they are not too big and retentive. It is important that paddlers and swimmers can easily get out of the holes. Also, it is important that the holes do not extend to both sides of the channel. There should be an exit out each side of the hole. Finally, if holes are created on an angle they can be used to "Jet Ferry" paddlers across the channel. However, holes should not be created in the beginner or warm-up section.

Another thing to take into account is take out and access points along the river. Cartwright explained that this is important for slalom training. Specifically, slalom trainers either do full length runs of the course or repeat sections when doing technique training. A lot of existing courses do not have enough take out spots. Cartwright explained that a take out spot is really needed after all the major features.

When considering construction of the whitewater channel, Cartwright explained that the finishing materials are very important. Specifically, when it comes to the type of concrete or bed material, the smoother it is the better. A rough finishing material is very abrasive on boats, equipment, and people. Furthermore, if the water is silty then the finishing material will continue to scour away and expose the rough particulate.

As some general design recommendations, Cartwright concluded that the slalom section should be 5-6 metres wide. Also, if it is 300-400 metres long then it should have an elevation drop of 6-10 metres. Secondly, the course should be designed to have a good piece of flat water at the top and bottom of the course. The top pool of flat water is important to have before a competition start beam. Finally, keeping the course interesting and exciting is important. Cartwright suggested that avoiding repeating the same sequence of features and keeping the design as dynamic as possible will make for a better whitewater course.

4.2.3 Recreational/Professional Paddling

Doug Corkery

Ottawa River Runners, President

Ottawa, ON

Doug Corkery is the President of the Ottawa River Runners Whitewater Club Inc.(ORR). The ORR is an organization dedicated to promoting whitewater paddling and encouraging both recreational challenge and competitive excellence. The ORR and Doug Corkery are responsible for the original development of a small publicly funded whitewater course in Ottawa. The course was built in the outflow channel of the Fleet

Street Pumping Station. The Pumphouse facility provides class 2 whitewater just a few kilometres from the Parliament buildings in downtown Ottawa.

Corkery has worked hands on with the development of the Pumphouse course since its original development. This and his participation with both recreational and competitive paddling have given him a diverse perspective when it comes to whitewater facilities. Corkery explained that there are very few slalom courses in Canada. Although the Pumphouse is set up as a slalom training site Corkery admitted that site constraints, namely not enough elevation change and flow rate, has limited the effectiveness of the course. Corkery identified two other slalom courses in Canada as the Minden Wildwater Preserve and the Rutherford Whitewater Park. Of the two sites, Corkery highlighted the Rutherford course as having the most problems.

Corkery explained that the Rutherford course has not been successful because it did not appeal to a broad range of users. The Rutherford course was built to replace existing whitewater that was destroyed by the construction of a hydro project. Corkery pointed out that the course was designed to mimic the type of whitewater that was destroyed. Specifically, the course was designed to replace steep, fast flowing, and continuous "creeking" whitewater. This advanced level whitewater is not appealing to most recreational paddlers and was not appropriate for most slalom training. Essentially, the course was created as an elite site which only appeals to an expert group of paddlers.

Corkery explained further that the Park is plagued with several design and construction problems. First off, Corkery believes that the course is too long. At 500m it is intense whitewater and Corkery believes that a smaller section would have been more appropriate. Furthermore, the expenses saved by creating a shorter section could have

been used to improve the overall quality of the park. For example, Corkery explained that the channel was constructed of cheap concrete with a coarse aggregate base. Upon its opening, the surface was very rough. Because of the silty nature of the glacial water, sediment has continued to wear away leaving an even rougher surface. What has resulted is a channel surface which damages boats and equipment and poses a safety risk for swimmers. Corkery described the concrete surface as similar to coarse sandpaper.

Another major problem is the overall course layout. Corkery explained that the course needed to be built as stepped or pool-drop whitewater. As it is, Corkery described the course as a "horse race." By itself, this fact may have been overlooked. However, when combined with several dangerous water features this "horse race" is very intense and potentially dangerous. Specifically, Corkery explained that many of the steeper drops are accompanied with a very retentive hydraulic. Furthermore, this hydraulic or hole extends to both embankments of the channel. As such, there is no exit from the hole. Boats and swimmers re-circulate in the hole without being able to paddle or swim out the sides. This design issue poses serious safety concerns when coupled with the fact that the channel is very shallow and its surface resembles sandpaper.

Finally, Corkery explained that the Rutherford site is simply not very aesthetically pleasing. Corkery described the site as bleak and exposed with a lot of concrete. The design and materials used do not complement or respect the context of the surroundings. This becomes an issue when it comes to attracting tourists. Corkery explained that whitewater facilities need to be multi-use. With its dangerous design and poor aesthetics, the site does not attract commercial and novice recreational use.

Due to his experience designing and building the Pumphouse course, Corkery had several design recommendations. As a recommendation for general layout, Corkery suggested that a whitewater course combine a Slalom site or a section of advanced whitewater with an easier section below it. Corkery explained that this course configuration would allow recreation/freestyle paddling to operate at the same time as professional or competitive paddling with little conflict. However, safety is an important consideration and the beginner section should have a calm pool or "catch pool" at the bottom. This functions as a safety pool to collect swimmers and equipment. Furthermore, the whitewater should be deep enough so that swimmers and paddling equipment do not hit the bottom.

Corkery also made several specific design recommendations. Corkery explained that it is important to have features which can be easily modified. Expensive and time consuming physical modeling is needed to predict how features will impact the water flow. Even following a detailed modeling process, the creation of desired whitewater features is often a trial and error process. As such it is important to be able to modify features after construction.

As a challenging slalom site it is important to have defined eddies with strong upstream flow. Corkery explained that incorporating vertical obstructions and embankments will help create strong eddies. Vertical embankments help preserve the upstream velocity of the eddy water flow. A sloped embankment causes turbulence and slows the upstream flow. Vertical embankments also create a deep eddy. Corkery explained that Slalom paddlers now drop the back end of their boat to "catch" the strong upstream current. This new competitive technique requires sufficiently deep eddies with

vertical walls. However, vertical embankments may lead to water surging problems. Corkery suggested that a mix of vertical embankments adjacent to eddies with sloped embankments elsewhere would be a good compromise.

Corkery concluded by stating that whitewater courses need to be dynamic and exciting. Creating lots of eddies and multiple routes down are important. Corkery also explained that careful placement of eddies and angled waves can facilitate attainment back up the rapids. This allows paddlers to constantly find new ways of challenging themselves and increases the overall entertainment factor.

4.2.4 Recreational Paddling

Wayne Donison

Whitewater Ontario, Vice President

Port Perry, ON

Wayne Donison is the Vice President of Whitewater Ontario (WO). WO is a volunteer-driven organization which focuses on uniting, supporting, and sustaining the inclusive development of the whitewater paddling community and resources. WO owns and operates the Minden Wild Water preserve, one of only two Slalom courses in Canada. The Preserve is a modified section of whitewater located the Gull River. The preserve is located on 100 acres just outside the Town of Minden Ontario. The site offers whitewater paddling, camping, and trails for hiking, biking, and cross country skiing.

When asked about recreational whitewater paddling Donison said that one of the most important things to consider is that there are many different types of paddling. Donison explained that there are those that prefer to surf waves, those that mostly run

rivers top to bottom, there are people that paddle steep creek runs, and people that do a bit of everything.

Given that WO owns and operates the Minden Wild Water Preserve Donison has a very good understanding of how paddlers use the site and what the site has to offer. Donison explained that the Preserve is very successful in attracting a big mix of paddlers. The site draws a large range of paddlers because of its varied play features and river running appeal. Donison explained that the general layout of the Preserve is such that the advanced section is at the top and the easier section is at the bottom. This works nicely for beginner/novice paddlers as they can put-in part way down and avoid the difficult whitewater. However, Donison explained that there are a few difficult shallow features at the bottom of the course. These shallow features pose a safety risk for some paddlers. However, although not perfect in its layout of whitewater features, Donison explained that the Minden Wild Water Preserve is a very technical and great training ground for a wide range of paddlers.

Donison explained that it is very important for whitewater parks to have a consistent controlled water source. For those travelling a distance to visit the site it is important that they know there will be adequate water to paddle when they get there. Donison explained that the Gull is good because it is short but offers a lot of different features. Given the varied features, people can simple go straight down in a few minutes or spend up to an hour moving through the course. Furthermore, some sections can be attained back up. Donison explained that the ability to paddle back up the course is important because the Preserve is not a looped course. There is no assisted bottom to top lift system to avoid portaging.

When asked about conflicts between different user groups Donison said that there are very few issues. Donison explained that there are many different features and multiple routes. Therefore paddlers have many different potential routes to choose from to avoid conflict. Furthermore, competitive events are planned and scheduled and operate free of conflict. Donison explained that the there is little conflict between the user groups because the section of whitewater has many different features which appeal to different styles of paddling. There is more than enough water and features for all the users.

Donison highlighted several important features of the Minden Wild Water Preserve. Donison explained that strong eddy lines are important for improving ones whitewater paddling skills. Donison also mentioned that a successful course needs good eddy access for play features. Specifically, waves that are popular for paddlers to surf in need large eddies to hold the queue of waiting paddlers.

When asked about commercial opportunities Donison explained that the more challenging the whitewater, the less likely that there will be commercial opportunities. Specifically, Donison explained that having appropriate whitewater for beginner and novice paddlers will create commercial opportunities for paddling instruction and rental equipment.

Donison explained that there are several safety issues which must be considered when designing whitewater courses. It is important to use smooth materials for channel and obstacle construction. For example, when concrete is used it must have a very smooth finish to avoid being abrasive to swimmers and equipment. Donison further explained that retentive hydraulics, steep drops, shallow slides, and shallow fast water

can be inherently dangerous and will drive beginner/novice paddlers away. In short, Donison explained that it is important that a whitewater course is designed in such a way so that people are not afraid of the consequences of swimming.

4.3 Design Principles Development

The elite informant data was analyzed to look for key design principles in which the design recommendations could be organized. The initial notes from the interviews and the notes made from the recordings of the interviews were analyzed. Similar design recommendations were grouped together. Based on these groupings seven principles of whitewater park design emerged. These design principles include: Entertainment, Safety, Challenge, Accessibility, Performance, Economic, and Adaptability.

All of the design principles are focused on the general course layout, operation, and whitewater features. Specifically, the entertainment design principle comprises design recommendations which affect the level of amusement of those actively and passively participating in the whitewater. The safety design principle comprises design recommendations which affect the general health and safety concerns of those actively engaging in the park. The challenge design principle compromises design recommendations which help provide a challenging paddling experience and encourage competitive excellence. The accessibility design recommendation compromises design recommendations which help facilitate pedestrian and paddler circulation. The performance design principle compromises design recommendations which affect the overall function of the park. The economic design principle is made up of specific design recommendations which generate income, reduce the initial cost of course construction,

or minimize the costs associated with ongoing maintenance, modifications, and operation. Finally, the adaptability design principle encompasses design recommendations which allow for constant modification of the course layout, operation, and specific whitewater features.

Table 4.1 provides a summary of the design principles and recommendations. See Appendix C for a detailed description of each design recommendation. The tables have been organized to separate the specific design recommendations based on the design principles. However, because many of the design recommendations are associated with more than one design principle, some of the recommendations have been repeated in multiple tables. The Tables specifically list the potential impacts of each design recommendation on the three main user groups (professional, commercial, and recreational paddling). Some of the design recommendations potentially affect multiple user groups. In which case, the detailed description takes up more than one column in the table.

		Design Recommendations	Design Principles						
			Performance	Safety	Challenge	Entertainment	Accessibility	Economic	Adaptability
Water	1	Provide consistent and predictable water flow	●	●			●		●
	2	Design course to run at 10-30cms	●		●	●		●	
	3	Ensure adequate depth of water throughout the course (1-2m)	●	●					
	4	Monitor and make publicly available the real-time water flow					●	●	
	5	Ensure easy water access (multiple points of entry)	●	●			●	●	
General Course Layout/ Design	6	Avoid mixing difficult and easy features in one section	●	●			●		
	7	Separate slalom, freestyle and beginner sections		●				●	
	8	Locate intermediate-advanced section above beginner section		●					
	9	Locate main facilities before beginner section		●			●		
	10	Incorporate all features and sections in a single channel design	●					●	
	11	Incorporate hydro generation with course design						●	
	12	Design course as a clearly defined pool-drop	●	●	●	●			
	13	Create a 300-400m long and narrow (5-10m) class 3-4 section	●		●	●			
	14	Create a 200-300m long and 10m+ wide class 1-2 section	●	●		●			
	15	Design beginner section to have multiple routes	●	●	●				●
	16	Design for a pool of calm water at top of course	●	●			●		
	17	Design for a pool of calm water at bottom of course	●	●			●		
	18	Integrate a bottom-top paddler conveyor system within the course	●				●	●	
	19	Accommodate bicycle and walking paths				●	●	●	
	20	Provide space for spectators				●	●	●	
	21	Incorporate bridges over course		●		●	●		
Whitewater Design	22	Avoid repeating the same combination whitewater of features			●	●			
	23	Incorporate fast standing waves into the course			●	●			
	24	Create angled waves/holes		●	●	●			
	25	Place play features in separate location form slalom course	●	●					
	26	Create large eddies adjacent to play features	●				●		
	27	Place features to allow for attainment back up the course	●		●				
	28	Avoid creating holes in beginner-novice section		●					
	29	Ensure holes have exits on either side (avoid channel wide holes)		●					
	30	Limit the number of holes		●		●			
	31	Avoid creating strong recirculation eddies		●					
Construction	32	Incorporate smooth material for channel and obstacle construction	●	●					
	33	Allow for easy modification of the course features		●	●	●		●	●
	34	Use stone blocks to create stepped embankments	●		●			●	●
	35	Create stepped vertical embankments in eddies	●	●	●		●		
	36	Incorporate removable vertical obstructions to create eddies	●		●	●		●	●
	37	Create sloped walls in-between eddies	●	●			●		

Table 4.1 Design Principles Summary Table

4.4 Design Principles Implementation

Based on the site selection criteria mentioned in section 3.3.2, the Chaudière Falls was selected as the location for applying the design principles through a conceptual whitewater park design. The design was not intended to determine the feasibility of developing a whitewater course at the Chaudière Falls or to provide detailed graphic details of the various design recommendations. Instead, the design was simply intended as a practical application and visual representation of the design principles and recommendations in a plan form. The goal was to incorporate as many design recommendations as possible in the design. Furthermore, the process of applying the design recommendations in the preliminary design was used to refine the original design recommendations and principles.

4.4.1 Site Context

The Chaudière Falls are part of the Ottawa River Located just a few kilometres west of Downtown Ottawa. The surrounding islands that make up the falls have been used for various types of water powered industry since the early 1800's. However, as of today, all the mills are closed and the islands are made up predominantly of abandoned and underused industrial sites. A large portion of the land is owned by the National Capitol Commission. To date, no plan has been made to redevelop/regenerate the area. Figure 4.1 shows the location of the Chaudière Falls in reference to downtown Ottawa and Hull (Gastineau). See Appendix D for property ownership maps.

The site has an average slope of 3%. However, the Islands have been heavily developed by industry. As such, retaining walls and Dams make up most of the elevation

change. Furthermore, the original natural sections of whitewater have been modified into flat dam controlled channels.

Table 4.2 lists the flow rates or discharge volume of the Ottawa River at Carillon Dam. Discharge volume is the amount of water passing through a particular point of a river over a certain unit of time. The most common unit of measurement for discharge volume is cubic meters per second (m3/s). The Carillon Dam is the last dam before the Ottawa River's confluence with the Saint Lawrence. As such, the flow rate will be slightly higher than it would be at the Chaudière Falls. However, given that the average flow rate required for whitewater courses is 10-20 m3/s, the Ottawa River has more than enough flow to supply a whitewater park at the Chaudière Falls. The yearly discharge of the Ottawa averages just under 2000 m3/s.

Year	**Maximum Flow** (m^3/s)	**Minimum Flow** (m^3/s)	**Yearly Average** (m^3/s)
2004	4917	534	1960
2003	4792	519	1811
2002	5947	666	2064
2001	4070	563	1700
2000	3205	971	1801

Table 4.2 Average Flow Rate (adapted from ("Ottawa river regulation planning board", 2005))

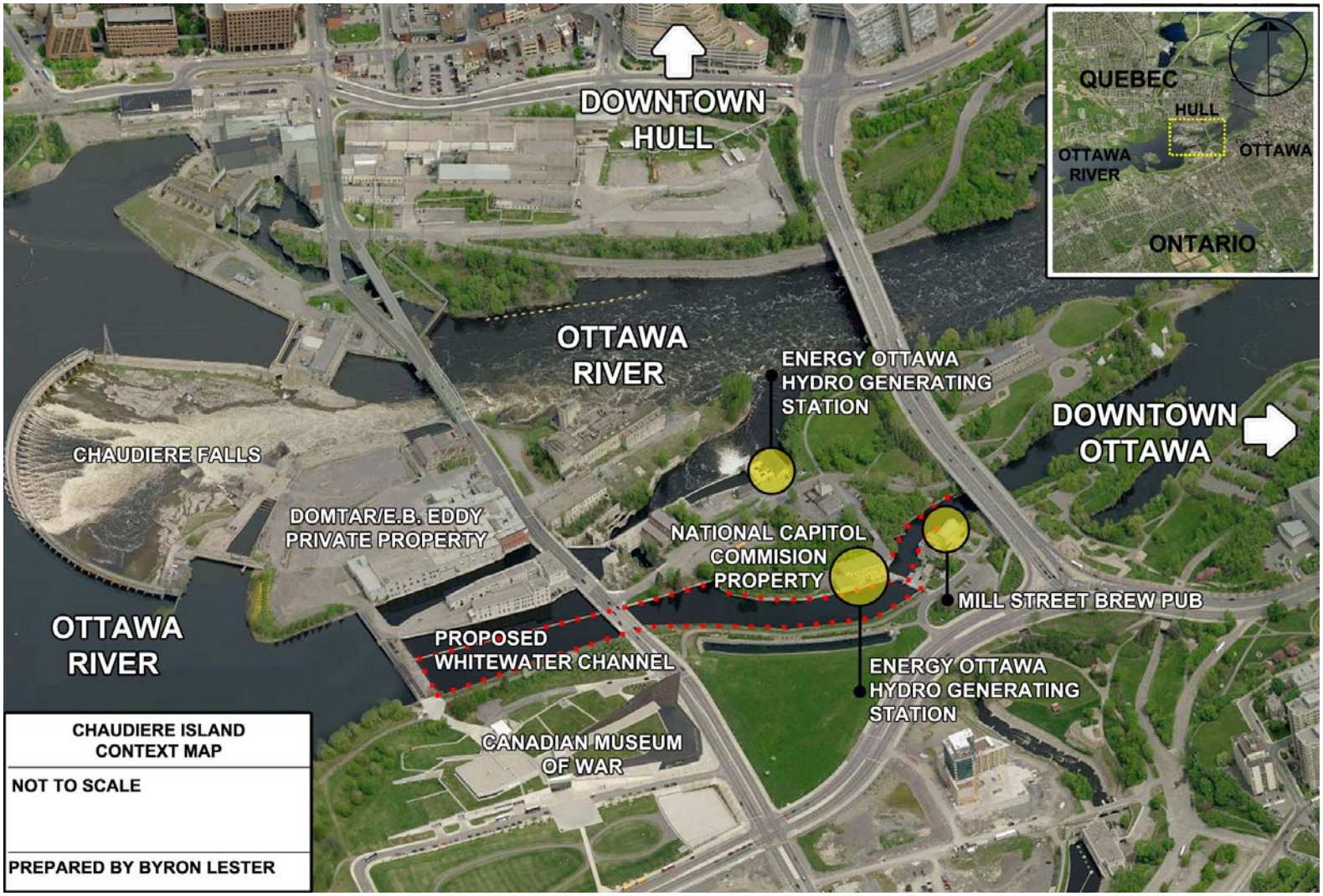

Figure 4.1 Chaudière Falls Context Map

4.4.2 The Design

The conceptual design plan (Appendix E) is a practical application and graphic representation of the layout of some of the design recommendations in a plan form. There are a few limitations of the design. Some of the recommendations were not depicted due to the graphic restrictions of a two dimensional plan. Also, detailed site survey information was not available and sections/elevations were not developed to accompany the plan. Therefore, the conceptual design plan is simply a visual representation of the plan layout of the various appropriate design recommendations.

4.4.2.1 Professional User Group Features

The design features a 300 metre long pool-drop, class 3-4 advanced paddling section. This section is located at the top of the Bronson Channel which runs along the south side of Victoria Island. The length of this advanced whitewater section is typical of the average length of existing international professional slalom courses. The section features five distinct drops and five large pools. Each drop is followed by either an angled hole or a fast cresting wave. Each pool has a stepped vertical embankment which helps create deep fast flowing eddies. The embankments between the pools are sloped which reduced surging. The section features public viewing areas adjacent to major whitewater features. The design also includes a 200 metre class 1-2 whitewater warm-up section at the bottom of the Bronson Channel. The whitewater course is serviced by a conveyor system running from the bottom of the channel to the top. Finally, the advanced section is preceded by a flat water warm-up area.

4.4.2.2 Commercial User Group Features

The design features two distinctly different whitewater sections in a single channel. This allows for beginner/novice whitewater paddling and advanced level whitewater paddling in the same channel. The main Whitewater facilities are located between the two sections. As such, commercial rafters and paddle school students start at the bottom of the difficult section and at the top of the class 1-2 beginner novice section. This section only features beginner/novice appropriate whitewater features. For a more challenging experience paddlers would have to paddle the top section. There is a pool of flat water before the beginner/novice section for flat water instruction and warm-up. There is a conveyor system which brings paddlers from the bottom of the Bronson section to the middle of the course. From there paddlers can either choose to paddle the bottom section again or take a second conveyor system to the top of the advanced section. The course mostly features fast cresting waves and has a combination of sloped and stepped embankments that allow swimmers to easily exit the water.

4.4.2.3 Recreational User Group Features

The design features two separate whitewater sections which include a range of whitewater features. The bottom section is specifically designed so that paddlers can attain back up the rapids. In this way, paddlers can spend a lot of time in the rapids and reduce the number of trips back up the conveyor system. The design includes a range of whitewater features that would appeal to both kayakers and canoeists. For example, the design includes drops, wave trains, eddies, surfing waves, and angled holes for jet ferries

across the course. Difficult whitewater features have been placed in the top section and easy features in the bottom. In this way, people can paddle within their comfort zone while still having the option to experience more advanced whitewater. Also, specific play features have been located separately from the top section. This allows professional paddling competitions to run at the same time as recreational paddling. Finally, the course is dam controlled. This would produce a constant and stable flow rate which would result in consistent whitewater features throughout the course.

4.5 Design Principles Evaluation

Based on the selection criteria mentioned in section 3.3.3, S2o Design was contacted to evaluate the preliminary design and recommendations. S2o Design specializes in creating mixed-use in-stream and pumped whitewater parks around the world. To date, S2o design has created two Olympic facilities and the US National Whitewater Centre. The staff at S2o Design are a mix of professional paddlers and licensed design and engineering professionals. S2o Design is led by Scott Shipley an engineer, Olympian, three-time World Cup Kayak Champion and Freestyle Kayak Champion.

The Lee Valley Whitewater Centre was designed by S2o Design for the London 2012 summer Olympics. This park is one of the first to incorporate an adjustable design to help make the site function as more than just a professional/competitive paddling facility. When asked about the site Shipley was noted to have said, "The more people who can use it the better, that's the name of the game now"
(Blevins, 2011).

A summary of the design recommendations and the final demonstration design was submitted to Scott Shipley at S2o Design in the form of a questionnaire with a mix of scalar and open-ended questions. The questionnaire was intended to assess both the design recommendations and whether the conceptual whitewater park design was successful in incorporating the design recommendations in a way which balances professional, commercial, and recreational users. The evaluative responses can be found in Appendix F.

Shipley's evaluation varied greatly in the extent to which he either agreed or disagreed with the specific design recommendations. Specifically, Shipley strongly disagreed with design recommendations which recommended ideal water flow/depth, general channel layout, and channel embankment/bed construction material. Shipley tended to agree more strongly with design recommendations which were more general and were focussed on whitewater course adaptability. Shipley summarized that the questionnaire attempted to encapsulate the design process. Furthermore, Shipley expressed that the design recommendations tend focus on heavily constructed parks oppose to in stream modification. Shipley suggested that client input is very important in the design process and may belie many of the design recommendations.

As a practical application and visual representation of the design recommendations, a conceptual design of a whitewater park was developed and submitted to Scott Shipley. Shipley was asked to evaluate whether the design was successful in incorporating the design recommendations in a way which would support and balance the needs of professional, commercial, and recreational paddlers. Shipley responded that the conceptual design was success in incorporating the design recommendations and would

appeal to the needs of professional and recreational paddlers. Shipley explained that the course layout was innovative and placed in an ideal location. However, Shipley explained that the paddler conveyor system may be too long to be feasible. As such, Shipley expressed that the design may not appeal to commercial users.

4.6 Conclusion

Three key whitewater user groups were identified and four elite informants were interviewed to gather detailed information on whitewater park design and user group needs. The data was analyzed to group the thirty seven design recommendations into seven general design principles. The design principles and recommendations were applied to the development of a preliminary whitewater park design at the Chaudière Falls on the Ottawa River in Ottawa Ontario. The design recommendations and preliminary design was evaluated by Scott Shipley, a professional whitewater park designer and engineer. Shipley's evaluation varied greatly in the extent to which he either agreed or disagreed with the specific design recommendations. Shipley stressed the importance of client input in the design process and disagreed with recommendations which specified ideal water flow/depth, general channel layout, and channel embankment/bed construction material. Shipley tended to agree more strongly with design recommendations which were more general and were focussed on whitewater course adaptability. Shipley determined that the conceptual design was successful in incorporating the design recommendations in a way which would appeal to professional and recreational user groups. However, Shipley suggested modifications to the design to appeal to commercial user groups.

Chapter Five: Discussion and Conclusion

5.1 Major Findings

This study identified three main whitewater park user groups including professional/competitive, commercial, and recreational paddlers. An analysis of elite informant interviews produced seven design principles and thirty seven detailed design recommendations for incorporating the needs of multiple user groups in one integrated designed whitewater facility. An evaluation of the findings by a professional whitewater park designer revealed that adaptability is an important factor in whitewater park design. Furthermore, design recommendations must be flexible and allow for client input and respect the site context.

A study of whitewater including a review of fluid dynamics, typical river features, whitewater classification, and whitewater recreation was conducted. The basic mechanics of moving water was investigated and major whitewater features were identified. Finally a classification system for the severity of whitewater was presented. This information contributed to forming an understanding of the design properties of moving water.

A study of existing whitewater parks in Canada and abroad was conducted. The different design considerations and general layout of each park was identified and compared. Sixty five existing whitewater parks were identified and compared based on the course layout, source of water and geographic location. Of the sixty five parks identified the majority, at 43%, have a linear channel layout and 50% of the parks were supplied with moving water through flow diversion.

Key whitewater park user groups were identified through the literature review process. Professional/competitive, commercial, and recreational paddlers were identified. Varying types of watercrafts are used by these groups including inflatable rafts, kayaks, and canoes. Elite informants were selected to provide information on the needs of these key user groups in terms of their use of whitewater parks. Elite informant interview data was analyzed to organize similar design recommendations into groups. These various groups were organized in terms of general design principles. The design principles included entertainment, safety, challenge, accessibility, performance, and economic. These design principles included thirty seven detailed design recommendations for whitewater parks which combine and integrate the needs of the three key user groups.

A preliminary conceptual design of a whitewater park at the Chaudière Falls was developed as a practical application and visual representation of the design principles. The design featured two distinctly different whitewater sections in a linear configuration on a single channel of the Ottawa River where it splits between three Islands at the Chaudière Falls in Ottawa Ontario. The design included a 300 metre long pool-drop, class 3-4 advanced paddling section and a 200 metre long class 1-2 beginner/whitewater warm up section. The design included waves, holes, eddies, chutes, and drops of varying degrees of difficulty which are supplied through dam controlled flow diversion of the Ottawa River.

The design recommendations and conceptual design were evaluated by a professional whitewater park designer. Shipley stressed the importance of client input in the design process and disagreed with recommendations which were not flexible in terms of respecting site context and client needs. Shipley tended to agree more strongly with

design recommendations which were more general and were focussed on whitewater course adaptability. Shipley determined that the conceptual design was successful in incorporating the design recommendations. Shipley expressed that the design was successful in appealing to professional and recreational users. However, Shipley suggested modifications to the design to appeal to commercial user groups.

Whitewater parks can provide the means for professional paddling training/competition, provide the facilities necessary to host international competitions, promote active recreation, attract tourists, and provide economic returns. The design principles and recommendations developed in this study are an important part in creating a basic set of design guidelines for developing multi-use whitewater parks. A thorough understanding of user group needs is important in being able to design a park which will successfully serve not only the needs of professional athletes but commercial operations and the general public as well.

A list of design principles for multi-use whitewater parks could inform future design and aid in the initial steps of a park planning process and promote whitewater recreation. It has been revealed that whitewater parks can generate significant economic returns. This study may help promote whitewater recreation within an urban centre as part of an already functional urban centre or as part of an urban regeneration strategy. Finally, the findings from this study may provide an incentive to undertake a feasibility study for creating a whitewater park at the Chaudière Falls in Ottawa.

5.2 Limitations

The number of elite informants interviewed was limited to four. Additional informants may have provided more perspective on whitewater park user group needs and generated additional design recommendations which may have related more strongly to a larger portion of the paddling community. However, there was a lack of previous studies on this topic. Therefore, this was a study with limited resources in which the focus was to identify key user groups and develop the methods to gather and interpret user group needs. Elite informants were selected to start acquiring and categorizing user group needs. However, this process is far from complete and future research is warranted.

The major findings of this study included a listing of basic design principles and recommendations. The design principles were created to organize the design recommendations provided by the elite informants. As such, these principles are intended as a means to organize the data in a legible form as much as they are intended as a basic set of foundational guiding principles for multi-use whitewater park development. The design principles and recommendations were limited to what the elite informants provided. As such they do not form a cohesive foundation for whitewater park development. The recommendations range from broad layout suggestions to detailed specific recommendations and represent a starting point for future research.

The preliminary design of a whitewater park at the Chaudière Falls was limited by several factors. Although adequate aerial imagery and property ownership/boundary maps were acquired, a detailed topographical map/AutoCAD base file was not obtained. Instead, basic elevation data were gathered from the City of Ottawa. As such, the

specific elevation and topographical details of the site had to be interpreted from limited data. Therefore, the preliminary whitewater park design represents and was intended as a practical application and visual representation of the design principles and recommendations. The design was not intended as a test of feasibility for creating a whitewater park at the specific site location.

The number of evaluators was limited to one due to the limited resources of this study. Although the evaluator has a lot of experience designing and developing mixed-use whitewater facilities, additional evaluators might have better determined if the findings of this study represent a valuable addition to the current body of knowledge as it relates to mixed-use whitewater park development. The evaluator may not place equal value between professional, commercial, and recreational whitewater park use. Furthermore, the evaluator may not have a balanced design knowledge base when it comes to professional, commercial, and recreational user groups. As such, the degree to which he agreed or disagreed with each design recommendation may not reflect the actual value/importance of each design recommendation.

5.3 Future Research

This study identified and focused on three key whitewater park user groups. However, throughout literature review and elite informant interviews several more potential user groups were identified. These users included emergency services whitewater rescue training, commercial and recreational whitewater rescue training, and passive park users. Further research would help to identify how to design for the integration of these uses within whitewater parks.

This study identified user group needs through elite informant interviews. However, future research that focussed on gathering data on user needs through surveys collected from actual park users may provide a wealth of additional data. Furthermore, research focussed on case studies of existing parks would provide more data on the specific successes and failures of existing whitewater parks.

The focus of this study was on identifying key whitewater user groups and determining user group needs. Future research could focus on the practical development and application of these needs. For example, it was determined through elite informant interviews that existing whitewater parks have mostly failed in their attempt to create fast cresting waves. Instead, these waves often end up being holes. Future research could focus on investigating not only how to create fast surfing waves instead of holes, but also create design solutions to address the other issues revealed through this research.

Future research could focus on the aesthetics of whitewater parks. It was identified through elite informants that several existing whitewater parks are not aesthetically pleasing. The elite informants identified the type of materials used, lack of vegetation and respect for the surrounding context of the site as the reasons for the poor aesthetics. However, future research is warranted to identify specific aesthetic issues of existing sites and to suggest design considerations for future projects.

This study focussed on human whitewater park user groups. However, there is the opportunity to design and develop these parks in a way which could support and enhance the aquatic habitat. Future research is needed to determine which types of habitat could be reproduced or enhanced and what aquatic species would benefit from this.

Finally, there is the opportunity to develop whitewater parks as part of an overall urban regeneration strategy for abandoned or underused industrial and commercial facilities adjacent to a source of moving water. Many Canadian cities developed along water ways in which the moving water powered the industrial development. As industrial techniques changed many of these old facilities have been abandoned. As with the site chosen for the application of the design principles and recommendations, there is the opportunity to use this moving which powered industry to now power whitewater parks. However, the feasibility of development of whitewater parks within these abandoned sites requires future research.

5.4 Conclusion

There are over sixty five whitewater courses around the world. A majority of these parks were developed as artificially enhanced sections of an active river channel but many others are entirely artificial requiring pumping stations to create the required flow of water to run the course. However, these existing whitewater courses have several design problems relating to their ability to serve the needs of multiple user groups. Specifically, whitewater courses lack in their ability to equally balance professional, recreational and commercial paddler needs. As a result, these parks are often expensive to operate or simply unsustainable and can pose serious safety risks to the various users. This problem is compounded by the fact that there are no publicly available set of design principles for creating whitewater parks which appeal to multiple users.

This study set out to investigate whitewater park design to identify the key user groups, assess their needs, and organise the results into a list of design principles and

recommendations which could be applied to a preliminary whitewater park design. Through elite informant interviews whitewater park design was investigated. The elite informant data was analyzed to develop seven design principles including entertainment, safety, challenge, accessibility, performance, economic, and adaptability. Thirty seven detailed design recommendations were organised under these design principles.

The design principles and recommendations were applied to create a preliminary design of a whitewater park at the Chaudière Falls on the Ottawa River. The preliminary design and design recommendations were evaluated by a professional whitewater course designer. It was established that adaptability is an important factor in whitewater park design. Furthermore, design recommendations must be flexible and allow for client input and respect the site context. When applied to a preliminary design the design principles and recommendations help form a foundation for a balanced whitewater park which helps resolve user conflict and improve functional relationships.

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APPENDIX A: GLOSSARY OF WHITEWATER TERMS

*note: terms are adapted from Peter Woods book, "Running the Rivers of North America" (Wood, 1978) and Bill Riviere's, "Pole, Paddle & Portage" (Riviere, 1969).

Attainment: The act of moving up a whitewater channel against the flow. This upstream movement is facilitated by angled waves (see jet ferry) and eddies.

Boil: See also Pillow. An uplifting of water created by an up welling of the current

CFS: Cubic feet per second. A measure of the volume of water flowing past a particular point.

Chute: A constricted channel which water flows through. The constriction makes the water flow faster and deeper.

CMS: Cubic metres per second. A measure of the volume of water flowing past a particular point.

Crest: The top point on a wave.

Curler: A steep high wave that falls back on itself.

Drop: An abrupt and steep decent in the river. See also Falls.

Eddy: The swirling of water and the reverse current created when water flows past an obstacle. This creates a space devoid of downstream-flowing water on the downstream side of the obstacle. Also, there is often a reverse flow of water behind the obstacle flowing upstream, toward the back of the obstacle. The strength of this counter current it dependent on the strength of the downstream flow and the size of the emergent obstacle.

Eddy Fence: The boundary line between contrary currents (downstream current flowing around an emrgent obstacle and upstream current flowing towards the downstream side of the obstacle). The eddy fence is characterized by turbulent water. The eddy fence and

turbulent water is narrowest directly beside the emergent obstacle and widens as is moeves downstream.

Eddy line: See Eddy fence.

Falls: The freefalling of water over a vertical or near vertical plunge.

Headwaters: The source of a stream.

Hole: Reversals in in current created by backward tumbling water (see Hydraulic).

Hydraulic: An obstacle in fast flowing water which obstructs the flow but also forces water to drop overtop the obstacle can create a hydraulics behind the obstacle where the surface and sub-surface level water flows back on itself. The deep current (often close to the river bottom) exists the hydrauloic and continues its flow downstream. A hydraulic is charecterized as foamy and aerated water which provides less buoyancy and can feel like an actual hole in the river surface. Any floating object can be caught in a hole for an indefinite amount of time depending on the strength or 'retentiveness' of the hydraulic. The amount of water flowing over the drop, the height of the drop, and the steepness of the drop affect the strength and retentiveness of the hydraulic.

Jet ferry: Using an angled wave or hole to surf across from one side of a whitewater channel to another.

Keeper: A hole/hydraulic with enough power to trap a boat or swimmer for an extended period of time.

Pool: Slowly moving and often deep water

Portage/carry: Method used to move overground fom one section of a body of water to another (with or without carrying a boat).

Put-in: The starting point or place where a river or body of water can be entered.

Rapids: Fast flowing and turbulent water. Often found on rivers, rapids are characterized by the water surface being brocken by obstacles and generally erupts into waves. Rapids can also be formed by convergent currents (rip tides) on the ocean.

Riffles: Small waves created by fast flowing shallow water running over an uneven bottom.

Rocker: A curved keel line in the hull of boats. A rockered boat is shaped similar to a bannnan and easily pivots around the centre helping make the caraft highly manueverable.

Slalom: A zig zag course set up in rapids for proffesional paddling and competitions.

Standing Wave: A vertical wave.

Strainers: Formed when an object in the flow blocks the downstream passage of larger objects but allows the flow of water to pass through. Strainers are dangerous whitewater features because swimmers can become entangled or pinned against them and potentially drown.

Tailwaves/ Constriction waves/ Wave trains/Haystacks/Rollers: A series of standing waves often caused by the convergence of a deepwater channel or waterway. This narrowing forces the water to 'pile up' near the centre creating a series of waves just downstream of the channel convergence.

Take-out: The end point or place where a river or body of water can be exited.

Tounge/ "V": Fast flowing (and often deeper) water in a smooth V-formation usually found at the head of rapids or on the drop of a chute.

Trough: The depression or lower point on a wave.

APPENDIX B: TABLE OF WHITEWATER PARKS

* Adapted from ("WhitewaterParks: Considerations and Case Studies", 2007)

	Park Location	Name of Park	Shape	Water Source	River
1	**Australia** Penrith	Penrith Whitewater Stadium	Loop	Pumped	Penrith Lakes
2	**Brazil** Foz do Iguaçu	Itaipu Slalom Course	Loop	Flow Diversion	Itaipu Lake, Paraná River
3	**Canada** Ontario	Minden wildwater Reserve	Linear	Flow Diversion	Gull River
4	**Canada** Ontario	Pump House	Linear	Flow Diversion	Ottawa River
5	**Canada** British Columbia	Rutherford Whitewater Park	Linear	Flow Diversion	Rutherford Creek
6	**China** Nanjing	Whitewater Stadium of Nanjing	Loop	Pumped	Xuanwu Lake
7	**China** Rizhao	Rizhao Canoe Slalom Course	Loop	Pumped	Rizhao Harbor
8	**China** Shunyi	Shunyi Rowing-Canoeing Park	Loop	Pumped	Chaobai River
9	**China** Xiasi	Xiasi Canoe Slalom Course	Linear	Flow Diversion	Qingshui River
10	**Czech Republic** Budejovice	Ceske Vrbne Slalom Course	Linear	Flow Diversion	Vltava River
11	**Czech Republic** Prague	Troja White Water Centre	Linear	Flow Diversion	Vltava River
12	**Czech Republic** Roudnice	Roudnice nad Labem	Linear	Flow Diversion	Labe (Elbe) River
13	**Czech Republic** Veltrusy	Veltrusy Slalom Course	Linear	Flow Diversion	Vltava River
14	**Czech Republic** Zeliv	Trnavka Slalom Course	Linear	Flow Diversion	Zeliv Lake, Trnava Stream
15	**France** Bourg-Saint-Maurice	Bourg-Saint-Maurice	Riverbed	Dam Release	Isère River

	Park Location	Name of Park	Shape	Water Source	River
16	**France** Cergy	Cergy Whitewater Stadium	Loop	Pumped	Oise River
17	**France** Epinal	Epinal Slalom Course	Linear	Flow Diversion	Moselle River
18	**France** Huningue	Parc des Eaux Vives	Loop	Flow Diversion	Rhine River
19	**France** Isle de la Serre	Sault-Brénaz	S-shape	Flow Diversion	Rhône River
20	**France** Lannion	Lannion Whitewater Stadium	Linear	Tidal	Leguer River
21	**France** L'Argentière-la-Bessée	L'Argentière-la-Bessée	Riverbed	Natural Flow	Durance River
22	**France** Millau	Millau Whitewater Course	Linear	Flow Diversion	Tarn River
23	**France** Nancy	Nancy Whitewater Stadium	Linear	Flow Diversion	Meurthe River
24	**France** Pau	Pau-Pyrénées Whitewater Stadium	Loop	Flow Diversion	Gave de Pau
25	**Frace** St Laurent	St Laurent Whitewater Stadium	Linear	Pumped	Scarpe River
26	**France** Vallon-Pont-d'Arc	Slalom Ardeche	Linear	Flow Diversion	Ardeche River
27	**Germany** Augsberg	Eiskanal	Linear	Flow Diversion	Lech River
28	**Germany** Leipzig	Kanupark Markkleeberg	2 Loops	Pumped	Markkleeberger See
29	**Greece** Athens	Heleniko Whitewater Stadium	Figure-8	Pumped	Gulf of Athens
30	**Greece** Nafpaktos	Evinos River Slalom Course	Linear	Flow Diversion	Evinos River
31	**Italy** Ivrea	Ivrea Whitewater Stadium	Linear	Flow Diversion	Dora Baltea River

	Park Location	Name of Park	Shape	Water Source	River
32	**Netherlands** Zoetermeer	Dutch Water Dreams	Loop	Pumped	Plas van Poot
33	**Poland** Krakow	Krakow Whitewater Course	Linear	Flow Diversion	Wisla River
34	**Slovak Republic** Bratislava	Bratislava Water Sports Centre	2 Loops	Flow Diversion	Danube River
35	**Slovak Republic** Liptovsky-	Liptovský Mikuláš Slalom Course	2 Linear	Flow Diversion	Vah River
36	**Slovenia** Ljubljana	Tacen Whitewater Course	Linear	Dam Spillway	Sava River
37	**Spain** La Seu d'Urgell	Parc Olímpic del Segre	2 Loops	Flow Diversion	Segre River
38	**UK** Bala, Gwynedd	Canolfan Tryweryn	Riverbed	Dam Release	
39	**UK** Bedford	Cardington Slalom Course	Linear	Flow Diversion	
40	**UK** Cardiff	Cardiff International White Water	1½Loops	Pumped	
41	**UK** London	Lee Valley White Water Centre	2 Loops	Pumped	Groundwater
42	**UK** Northampton	Nene Whitewater Centre	Loop	Flow Diversion	
43	**UK** Nottingham	Holme Pierrepont National Watersports	Linear	Flow Diversion	Trent River
44	**UK** Stockton	Hi Teesside Whitewater Course			Tees River
45	**UK** Stockton-on-Tees	Tees Barrage White Water Course	Loop	(tidal)	
46	**USA** Boulder, CO	Boulder Creek Whitewater Park			
47	**USA** Charlotte NC	U.S. National Whitewater Center	2 Loops	Pumped	Catawba River

	Park Location	Name of Park	Shape	Water Source	River
48	**USA** Denver, CO	Confluence Park			Cherry Creek and South Platte R.
49	**USA** Dickerson, MD	Dickerson Whitewater Course	Linear	Pumped	Potomac River
50	**USA** Ducktown TN	Ocoee Whitewater Center	Riverbed	Dam Release	Ocoee River
51	**USA** Durango, CO	Durango Whitewater Park			Animas River
52	**USA** Golden, CO	Clear Creek Whitewater Park			Clear Creek
53	**USA** Green River, WY	Green River Whitewater Park			Green River
54	**USA** Ogden, UT	Ogden Kayak Park			Weber River
55	**USA** Rochester, NY	Lock 32 Whitewater Park			Erie Canal
56	**USA** Salida, CO	Arkansas River Whitewater Park			Arkansas River
57	**USA** South Bend, IN	East Race Whitewater Course	Linear	Flow Diversion	St. Joseph River
58	**USA** Steamboat Springs, CO	Dr. Rich Weiss Park			Yampa River
59	**USA** Vail, CO	Vail Whitewater Park			Gore Creek
60	**USA** Wausau, WI	Wausau Whitewater Park			Wisconsin River
61	**USA** Williamston, MI	Williamston Whitewater Park			Red Cedar River

APPENDIX C: DESIGN PRINCIPLES AND RECOMMENDATIONS

PERFORMANCE	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Provide consistent and predictable water flow for all the potential whitewater features and channels	Ensures consistent paddling experience.		
		Creates a more comfortable learning environment.		
		Allows for reliable training/instruction/skill enhancement conditions.		
		Ensures consistent race results.		
	Design course to run at 10-30cms flow rate	Ideal flow rate for whitewater paddling/training.		
		Creates dynamic and exciting whitewater.		
		Allows for paddling breaks.		
		Ideal competition flow rate.		
	Design course as a clearly defined pool-drop	Facilitates possible upstream attainment.		Facilitates possible upstream attainment.
		Allows for in-boat scouting.		
		Creates fast cresting waves at the bottom of the drop because of hydraulic jump.		
	Attempt to incorporate all features and sections in a single channel design	More efficient use of water flow.		
		Ensures that all features/sections are available when the water is flowing.		
	Avoid mixing difficult and easy features in one section	Reduces conflict between the user groups.		
	Create a 300-400 m long and narrow (5-10m) class 3-4 section	Provides Intermediate-advanced whitewater section.		
		Provides a challenging section for professional paddling training.	Provides a challenging section for intermediate-advanced level paddling skill enhancement.	
		Average rating of international slalom and downriver race courses.	Provides an exciting section of whitewater for clients.	
	Create a 200-300m long and 10m+	Provides a beginner/novice whitewater section.		

PERFORMANCE	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	wide class 1-2 section	Can function as a whitewater warm-up area.		
	Design beginner section to have multiple routes	Reduces conflict between user groups.		
	Use stone blocks to create embankments	Allows for modification of embankments to improve course performance.		
		Creates a more aesthetically pleasing naturalized look.		
	Create stepped vertical walls in eddies	Creates deeper eddies (less chance of hitting boat and paddle on bottom).		
		Leads to fast upstream flow in eddy.		
	Create sloped walls in-between eddies	Reduces surging.		
	Minimum 3m wide eddies	Accommodates the length of a slalom boat.	Provides enough eddy space for kayaks and rafts.	Accommodates the length of whitewater canoes and kayaks.
	Integrate a bottom-top paddler conveyor system within the course	Allows numerous top-bottom runs of the course.		
		More efficient use of training session time.		
	Design for a pool of calm water at top of course	Reduces surging.		
		Creates drop off area after conveyor system.		
		Provides flat water warm-up area.		
		Provides waiting pool for course use.		
		Provides flat pool before competition start beam.	Provides instructional area.	
	Design for a pool of calm water at bottom of course	Allows for grouping of boats and collection of lost equipment.		
		Provides staging area for conveyor lift.		
		Provides flat-water training area.		
	Create large eddies adjacent to play features	Provides an access pool for surfing and jet ferries.		
		Provides a waiting pool for paddlers.		

PERFORMANCE	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Place play features in separate location form slalom course	Reduces conflict between user groups.		
	Ensure an adequate depth of water throughout the course (1-2 metres)	Minimizes abrasion and impact damage to water craft and equipment.		
	Incorporate the smoothest possible material for channel and obstacle construction	Reduces abrasion damage to water craft and equipment.		

SAFETY	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Create a 200-300m long and 10m+ wide class 1-2 section	Functions as a whitewater warm-up area which reduces possible strain injuries.		
		Provides beginner-novice paddlers a section to paddle in within their skill range thereby avoiding injury.		
	Place intermediate-advanced section above beginner-novice section	Swimmers from the top advanced section will wash out into the bottom easy section where it is easier to swim to the shore and get out.		
		Beginner paddlers can put in below the top section and paddle in whitewater that is more appropriate for their skill range.		
	Limit the number of holes	Reduces the chance of injury sustained by being stuck in a hole.		
	Make sure holes have exits on either side (avoid channel wide holes)	Allows for boats and swimmers to exit out each side of the hole.		
	Avoid creating holes in beginner-	Holes, as an advanced paddling feature, pose a risk of injury to paddlers. Avoiding creating holes		

SAFETY	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	novice section	in the beginner-novice section will make it more suitable for new paddlers and existing paddlers who need an easy whitewater warm-up area.		
	Incorporate the smoothest possible material for channel and obstacle construction	Reduces common abrasion injuries.		
	Design course as a clearly defined pool-drop	Allows for paddling breaks throughout the rapids thereby reducing strain injuries and allowing paddlers time to prepare for upcoming whitewater features.		
	Create pool of calm water at bottom of course	Provides safety pool for swimmers (creates "catch pool").		
	Incorporate bridges over course	Provides alternate whitewater rescue options.		
	Allow for easy modification of the course features	Allows for modification of potentially dangerous features.		
	Separate slalom, freestyle and beginner sections	Minimizes the potential for boat impacts between the user groups.		
	Ensure an adequate depth of water throughout the course (1-2 metres)	Minimizes abrasion and impact injuries sustained by swimmers and paddlers in upside-down boats.		
	Avoid strong recirculation eddies	Minimizes abrasion and impact injuries to swimmers.		
		Minimizes the risk of drowning or near drowning.		
	Create stepped vertical walls in eddies	Allows swimmers to exit the water.		
	Create sloped walls in-between eddies	Allows swimmers to exit the water.		
	Provide consistent and predictable water flow for all the potential whitewater features and channels	Reduces the injuries sustained because of unfamiliar water features.		
	Avoid mixing difficult and easy features in one section	Ensures that beginner paddlers are not exposed to unnecessary risk associated with paddling in features beyond their skill range.		
			Reduces raft guide and instructor error.	
	Locate main facilities before beginner/whitewater warm-up section	Facilitates the use of the beginner-novice section as a whitewater warm-up (reduces strain injuries).		

CHALLENGE	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Incorporate vertical obstructions to create eddies	Creates strong, well defined eddies with strong upstream flow.		
	Design vertical embankments adjacent to eddies	Creates strong, well defined eddies with strong upstream flow.		
	Incorporate fast standing waves into the course instead of holes	Allows surfers to pop and get air (popular modern freestyle technique).	Creates big splashes when rafts punch through the wave.	Allows for very dynamic surfing.
	Allow for easy modification of the course features	Allows for refinement of features (eddies, waves, holes)		
		Allows for course changes based on competitive needs.	Allows for course changes based on commercial needs.	Allows for course changes based on commercial needs.
	Create angled waves/holes	Allows for jet ferries across the course.		
		Allows for attainment up the rapids.		
	Avoid repeating the same combination of features	Helps keep the course dynamic and interesting.		
	Create a class 3-4 section	Provides an exciting and challenging section of advanced level whitewater.		
		Average rating of international slalom and downriver race courses.		
	Place features to allow for attainment back up the course	Creates challenging and dynamic whitewater.		
	Design course as a clearly defined pool-drop	Creates challenging and dynamic whitewater.		
		Facilitates possible upstream attainment.		Facilitates possible upstream attainment.

ENTERTAINMENT	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Provide space for spectators	Facilitates passive recreation at the whitewater park.		
		Provides a possible audience for paddlers.		
	Incorporate bridges over course	Provides interesting vantage point for spectators.		
		Provides a possible audience for paddlers.		
	Incorporate fast standing waves into the course instead of holes	Provides the feature necessary for professional freestyle events.	Creates big splashes with low risk of flips and uncontrolled surfs.	Allows for very dynamic surfing.
		Popular for spectators to watch.	Popular for spectators to watch.	Popular for spectators to watch.
	Design beginner section to have multiple routes	Helps keep the course interesting for repeat users.		

ACCESSIBILITY	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Incorporate bridges over course	Allows for accessing both sides of the course when portaging.		
	Ensure easy water access	Promotes water recreation.		
	Accommodate bicycle/walking paths	Provides multiple ways to access the park.		

ACCESSIBILITY	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Provide consistent and predictable water flow for all the potential whitewater features and channels	Allows paddlers to access the whitewater course for a longer duration of time.		
	Monitor and make publicly available the real-time water flow	Assists paddlers in determining when it is best to access the park.		
	Create stepped Vertical walls in eddies	Allows for paddlers to enter/exit boats in eddy.		
		Allows for feature-feature portages for training/instruction purposes.		
	Conveyor system	Allows for quick and easy transport between bottom and top of course.		
	Locate main facilities before beginner/whitewater warm-up section	Creates the shortest average travel time between any point of the course and main paddling facilities.		

ECONOMIC	Design Recommendation	Professional Paddling (Slalom, Downriver Racing, Freestyle)	Commercial Paddling (Rafting/Paddling Schools)	Recreational Paddling (river running, play boating)
	Design for a bottom-top paddler conveyor system	People are more willing to pay for commercial trips if they can do multiple runs without having to portage back up.		
		Can charge for use of conveyor.		
		Reduces the time spent looping back to the top and the cost of training.	Reduces the time spent looping back to the top and the cost of paddling instruction.	
	Use stone blocks to create embankments	Reduces labour costs associated with channel modification (easier to move stone than to remove and pour new concrete).		
	Incorporate hydro generation with course design	Makes use of winter water supply and offsets course operational costs.		

Attempt to incorporate all features in a single channel design	Cheaper to construct and operate.

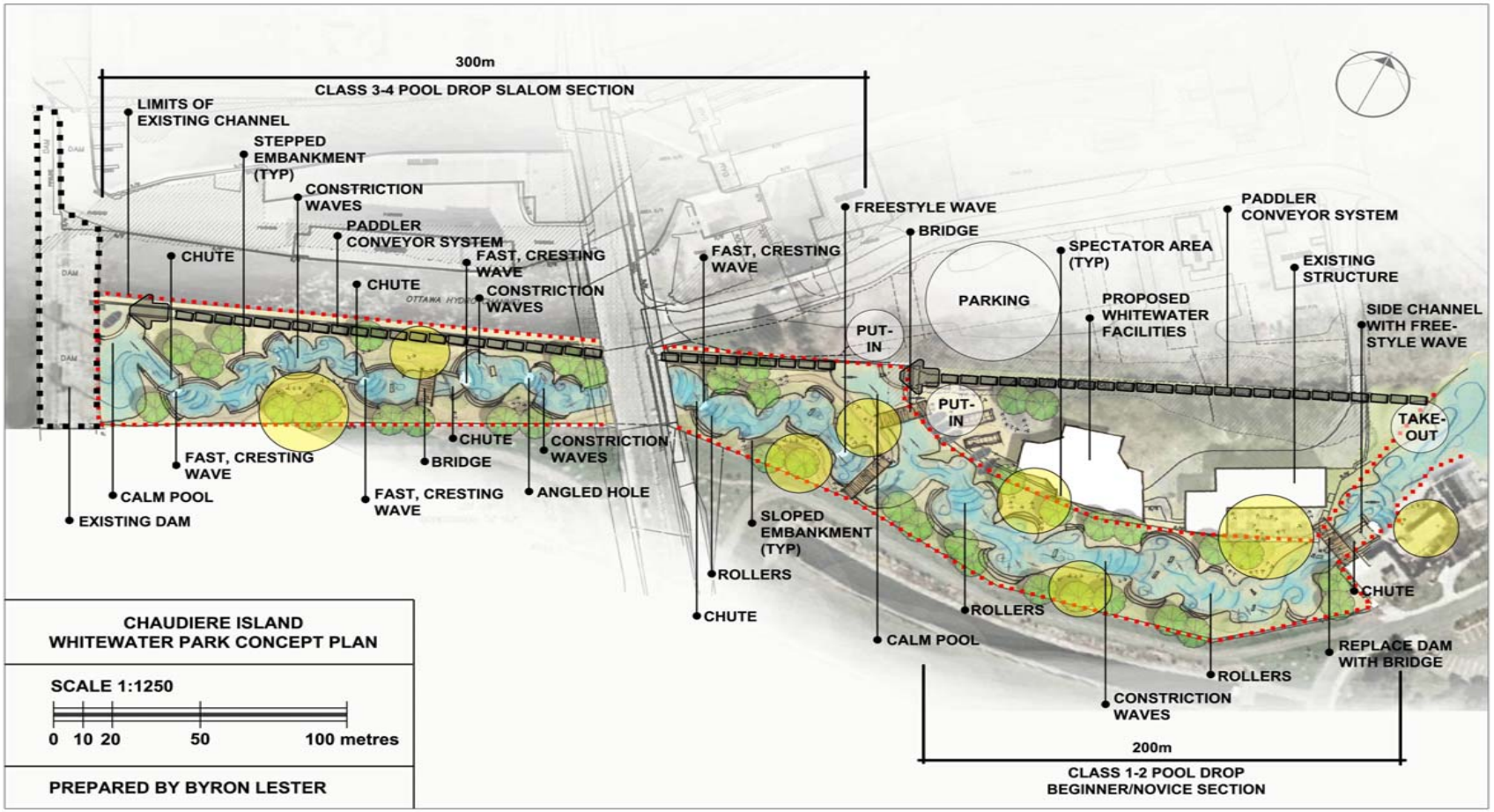
ADAPTABILITY			
Design Recommendation	**Professional Paddling** (Slalom, Downriver Racing, Freestyle)	**Commercial** (Rafting/Paddling Schools)	**Recreational Paddling** (river running, play boating)
Use stone blocks to create embankments	Stone blocks can be moved to modify channel embankments.		
Design beginner section to have multiple routes	Provides users with multiple paddling route options.		
Allow for easy modification of the course features	Ensures ability to constantly modify the whitewater features.		
Incorporate removable vertical obstructions to create eddies	Allows for the modification of existing eddies and the ability to create new ones.		
Provide consistent and predictable water flow for all the potential whitewater features and channels	The ability to control the water allows for potential flow rate modifications.		

APPENDIX D: CHAUDIÈRE ISLAND PROPERTY OWNERSHIP

(*Canada's capitol core area sector plan*, 2005)

(*Canada's capitol core area sector plan*, 2005)

APPENDIX E: CHAUDIÈRE ISLAND CONCEPTUAL WHITEWATER PARK DESIGN



APPENDIX F: DESIGN PRINCIPLES EVALUATION FORMS

SECTION 1

The following questionnaire is designed to evaluate the design principles and recommendations which have been summarized in the table below.

Using the following scale: Strongly Agree (**SA**), Agree (**A**), Agree Slightly (**AS**), Undecided (**U**), Disagree Slightly (**DS**), Disagree (**D**), Strongly Disagree (**SD**), please select the choice which best describes the extent to which you agree with the design recommendations importance in helping to integrate the needs of three main user groups (professional, commercial, recreational) in one whitewater course design.

	DESIGN RECOMMENDATIONS	SA	A	AS	U	DS	D	SD
1	Provide consistent and predictable water flow	○	○	○	○	○	●	○
2	Design course to run at 10-30cms	○	○	○	○	○	○	●
3	Incorporate all features and sections in a single channel design	○	○	○	○	○	●	○
4	Incorporate smooth material for channel and obstacle construction	○	○	○	○	○	●	○
5	Design course as a clearly defined pool-drop	○	○	○	○	○	●	○
6	Avoid mixing difficult and easy features in one section	○	○	●	○	○	○	○
7	Separate slalom, freestyle and beginner sections	○	○	●	○	○	○	○
8	Create a 300-400 m long and narrow (5-10m) class 3-4 section	○	○	○	●	○	○	○
9	Create a 200-300m long and 10m+ wide class 1-2 section	○	○	○	●	○	○	○
10	Place intermediate-advanced section above beginner-novice section	○	●	○	○	○	○	○
11	Locate main facilities before beginner/whitewater warm-up section	○	○	○	●	○	○	○
12	Design beginner section to have multiple routes	○	○	●	○	○	○	○
13	Ensure adequate depth of water throughout the course (1-2 metres)	○	○	○	○	●	○	○
14	Allow for easy modification of the course features	●	○	○	○	○	○	○
15	Incorporate hydro generation with course design	○	●	○	○	○	○	○
16	Avoid repeating the same combination of features	●	○	○	○	○	○	○
17	Incorporate fast standing waves into the course	○	●	○	○	○	○	○
18	Create angled waves/holes	○	●	○	○	○	○	○
19	Place play features in separate location form slalom course	○	○	○	○	●	○	○
20	Create large eddies adjacent to play features	●	○	○	○	○	○	○

	DESIGN RECOMMENDATIONS	SA	A	AS	U	DS	D	SD
21	Place features to allow for attainment back up the course	○	○	○	●	○	○	○
22	Avoid creating holes in beginner-novice section	○	○	○	○	●	○	○
23	Make sure holes have exits on either side (avoid channel wide holes)	○	●	○	○	○	○	○
24	Limit the number of holes	○	○	○	●	○	○	○
25	Use stone blocks to create stepped embankments	○	○	○	●	○	○	○
26	Create stepped vertical embankments in eddies	○	○	○	●	○	○	○
27	Incorporate removable vertical obstructions to create eddies	●	○	○	○	○	○	○
28	Avoid creating strong recirculation eddies	○	○	○	○	○	●	○
29	Create sloped walls in-between eddies	○	○	○	●	○	○	○
30	Design for a pool of calm water at top of course	○	●	○	○	○	○	○
31	Design for a pool of calm water at bottom of course	○	●	○	○	○	○	○
32	Integrate a bottom-top paddler conveyor system within the course	○	○	○	●	○	○	○
33	Monitor and make publicly available the real-time water flow	○	●	○	○	○	○	○
34	Accommodate bicycle and walking paths	○	●	○	○	○	○	○
35	Provide space for spectators	○	●	○	○	○	○	○
36	Incorporate bridges over course	○	○	●	○	○	○	○
37	Ensure easy water access	○	●	○	○	○	○	○

1.1	Do these recommendations contribute to the current body of knowledge as it relates to integrated whitewater park design? **YES** ☐ **NO** ☑ **(Explain)**

I worry that the questionairre has attempted to encapsulate the design process and that it therefore brings evaluations that aren't valid. Most whitewater parks aren't pumped, for example, so questions of roughness vs. smoothness and steep walls vs. not bely the need for the client to input their own constraints. In many cases I worry the answers would be n/a

1.2	Additional Comments

The other point to make is that the client needs to define a model and an objective. Should the freestyle and the slalom go together? Probably for competitions, otherwise you have to have two focal points of your design. Are some of these points the same weight as others? Not in every design.

SECTION 2

As a practical application of the design principles and recommendations, a conceptual design of a whitewater park was developed for a site at the Chaudiere Falls in Ottawa Ontario, Canada. The goal was to incorporate as many design recommendations as possible in the design. The first objective was to simply create a visual representation of the design principles and recommendations to help refine the original design recommendations. The second objective was to test my initial assumption that a single whitewater course could be designed in a way which would appeal to and meet the needs of professional, commercial, and recreational paddlers.

Please review the context map and conceptual plan and answer the questions below.

2.1	Is the conceptual design successful in incorporating the design recommendations? **YES** ✓ **NO** ☐ **(Explain)**

The design and layout is quite innovative in that it uses a two channel system with separate start pools, etc. I like this. It is also located in an ideal situation, is combined with an existing dam, and in a highly used paddler area. Water control and flow availability is also very good.

The facilities also seem appropriately scaled to the venue. I have concerns that the conveyor belt, which has a cost per linear foot, might be a hair long? Perhaps another system for return could be used?

2.2	Does the conceptual design, as a practical application of the design principles and recommendations, represent the foundation for a balanced whitewater park which would appeal to and serve the needs of **professional** users? **YES** ✓ **NO** ☐ **(Explain)**

Yes, it has adequate slope and length and would make a fine whitewater park.

2.3	Does the conceptual design, as a practical application of the design principles and recommendations, represent the foundation for a balanced whitewater park which would appeal to and serve the needs of **commercial** users? **YES** ○ **NO** ○ **(Explain)**
I believe that the return route needs to be better thought out in order for this to appe	
2.4	Does the conceptual design, as a practical application of the design principles and recommendations, represent the foundation for a balanced whitewater park which would appeal to and serve the needs of **recreational** users? **YES** ◉ **NO** ○ **(Explain)**
It seems ideal for this application	
2.5	Additional Comments