Unusual Drainages Of The Americas

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Key Points

- We describe nine river bifurcations and bifurcation lakes in North and South America. They are exceptions to the rules of hydrology.
- These unusual water bodies exhibit bidirectional flow, unresolved watershed boundaries, and river formation in progress.
- We discuss the exploration, geophysical settings, hydrology, ecology, use, and management of these extraordinary drainages.

Abstract

While most rivers and lakes follow predictable principles of hydrology and geology, a few defy the rules. Some rivers diverge rather than converge; some rivers flow two directions; some lakes have not one but two outlets; some watersheds have ambiguous boundaries. The scientific literature on these exceptions is sparse, scattered, and, in some cases, conflicting. We provide an authoritative overview of nine unusual natural drainages in North and South America, including river bifurcations and bifurcation lakes: Casiquiare River, Arroyo Partido, Wayambo River, Atchafalaya River, North Two Ocean Creek, Divide Creek, Committee's Punch Bowl, Echimamish River, and Wollaston Lake. Most instances are found on flatlands and saddles. Some watershed boundaries are still unresolved or even dynamic, suggesting river formation in progress. We discuss the exploration, geophysical settings, hydrology, ecology, use, and management of these extraordinary drainages.

1 Introduction

When the German scientist Alexander von Humboldt traveled through South America in 1800, one of his desires was to verify the existence of the Casiquiare, the purported navigable waterway between the Orinoco and Amazon basins. Such a connection defied scientific understanding and no other instances had been found anywhere else in the world. It would be the hydrologic equivalent of a wormhole between two galaxies. Humboldt eventually found the Casiquiare—the world's largest river bifurcation—and while he did not "discover" it, he brought it to the attention of the scientific community, and several similar cases have been found since.

A bifurcation occurs when a single river splits into multiple branches that continue downstream. It is the opposite of a confluence, where multiple upstream branches merge into a single river. While many rivers have natural bifurcations, the branch typically returns to the main river after some distance, as around an island, or at least to the same floodplain, as in a braided river or delta.

The bifurcations that interest us are entirely different: they branch off and never return. Instead, they diverge into distinct river basins on the interior of continents. They are worth studying because they defy conventions of hydrology. They are distributaries *and* tributaries. The basins below them are *not* closed at the top. A valid delineation *can* have more than one outlet. Likewise, bifurcation lakes have not one outlet but two or more, each draining to a distinct basin.

The scientific literature on such unusual natural drainages is sparse, scattered, obscure, and, in some cases, conflicting. In this article we provide an authoritative overview of known cases in North and South

America. We discuss their historical exploration, geophysical characteristics, origins, future possibilities, and implications for water resources management.

2 Methods

We began with internet searches on known bifurcations. After the initial list, we consulted literature, maps, and firsthand accounts—both historic and modern—on each instance. We then verified their current existence using aerial imagery, digital elevation models (DEM), and photographs where possible. We excluded artificial bifurcations, such as those made for irrigation or flood control, and lakes or rivers that are not perennial (like Lake Isa in Yellowstone National Park). We tabulated pertinent characteristics of each instance and prepared descriptions.

3 Results

Table 1 summarizes our findings of major river bifurcations and bifurcation lakes in the Americas. Their locations are shown in Figure 1. Each is discussed further in the sections below. With the exception of the Casiquiare, with which we begin, they are presented in order from south to north.

Table 1. Major River Bifurcations and Bifurcation Lakes of the Americas

River Name	Geographic Location	Terrain	Coordinates of Bifurcation	Distributary of	Tributary to (Ultimate Basin)
Casiquiare River	Venezuela	Flat	3.140°N, 65.880°W	Orinoco River	Rio Negro (Amazon)
Arroyo Partido	Argentina	Saddle	40.242°S, 71.373°W	Arroyo Partido	Arroyo Culebra (Rio Negro) Arroyo Pil PIl (Rio Valdivia)
Wayambo River	Suriname	Flat	5.324°N, 56.393°W	Boven Wayambo River	East: Coppename River West: Nickerie River
Atchafalaya River	Louisiana, USA	Flat	31.084°N, 91.592°W	Mississippi River	Gulf of Mexico
North Two Ocean Creek	Wyoming, USA	Saddle	44.043°N, 110.175°W	North Two Ocean Creek	East: Atlantic Creek (Mississippi) West: Pacific Creek (Columbia)
Divide Creek	Alberta and British Columbia, Canada	Saddle	51.451°N, 116.286°W	Divide Creek	East: Bow River (Nelson) West: Kicking Horse River (Columbia)
Committee's Punch Bowl	Alberta and British Columbia, Canada	Saddle	52.381°N, 118.185°W	None	Northwest: Whirlpool River (Mackenzie) Southeast: Wood River (Columbia)
Echimamish River	Manitoba, Canada	Flat	54.392°N, 96.705°W	Echimamish River	West: Nelson River East: Hayes River
Wollaston Lake	Saskatchewan, Canada	Flat	58.232°N, 103.318°W	None	Northwest: Fond du Lac River (Mackenzie) Northeast: Cochrane River (Churchill)

Figure 1. Overview map

3.1 Casiquiare

The Casiquiare River in Venezuela is the most famous river bifurcation. Also called the Rio ("River") Casiquiare, Brazo ("Arm") Casiquiare, Casiquiare Channel, or Casiquiare Canal, it splits from the lowlands of the upper Orinoco River and flows southwest and meets the Guainia River to form the Rio Negro, a tributary of the Amazon River. As such, it is a natural, perennial, navigable waterway between the two largest watersheds of South America (Figure 2).

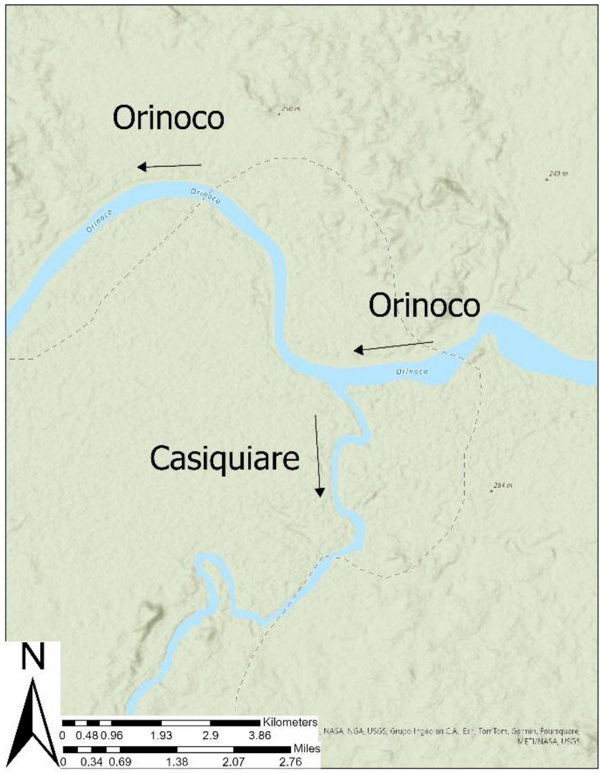

Figure 2. Map of the Casiquiare region

The Casiquiare was known to Spanish conquistadors as early as 1641, and various stories by explorers and missionaries trickled to Europe through the 1700s (Laraque et al. 2019), but no one had provided any empirical evidence of its existence. The prospect of a link between such enormous basins defied scientific understanding; cartographers of the time had even drawn fictitious mountains in the way to make sense of it (Wulf 2015, pp. 61–62). Only after navigating the rivers himself was Humboldt—and the rest of the scientific community—convinced. He described it thus:

> In this stretch [the Orinoco] puts forth the Cassiquiare, an unusual arm little known in Europe which joins the Rio Negro. … This is the only example of a bifurcation in the deepest interior of a continent, a natural connection between the two great river valleys, the Orinoco and the Amazon. … On an uninterrupted boat trip of 230 geographical miles, by way of an extraordinary network of rivers, I succeeded in traveling across the interior of the continent—from the Rio Negro via the Cassiquiare to the Orinoco—from the Brazilian border to the coast of Caracas [Venezuela]. (Humboldt 1849, p. 121)

While the passage was known to others before him, Humboldt was the first to truly explore, document, and map it, bringing it scientific attention for the first time.

The bifurcation from the Orinoco is perpendicular and on the west bank (Figure 3), and the surrounding terrain is very flat. Such level terrain is a natural condition for a bifurcation, and the largest river basin in the world just happens to be next door to receive it. According to current DEMs, the topographic divide is only a few meters above the Orinoco's low stage; Stokes et al. (2018) theorized that in the geologic past, seasonal overflows breached and eroded the divide enough to create today's permanent Casiquiare.

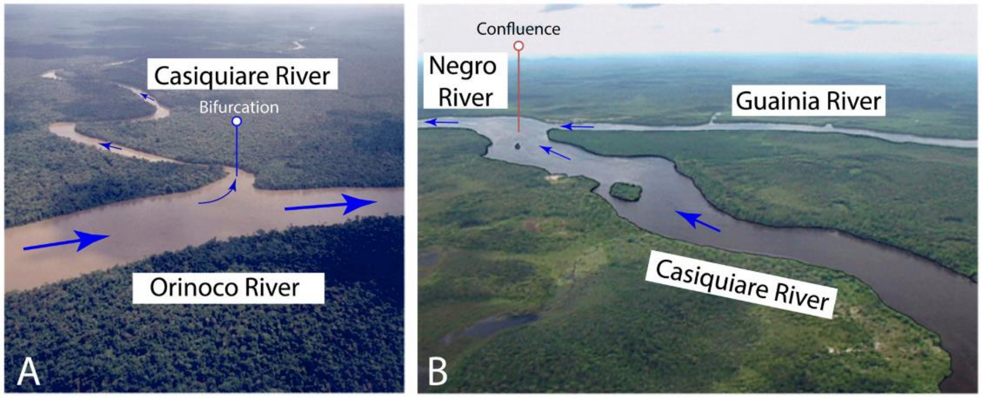

Figure 3. The Casiquiare bifurcation (A) and confluence (B) in 2000 (Laraque et al. 2019)

From the bifurcation the Casiquiare meanders generally southwest to the Rio Negro for over 350 km while dropping only about 20–30 m, making an average slope of less than 0.009%, but still steeper than the Orinoco for an equivalent length downstream. On its course the Casiquiare itself collects drainage from about 33,000 km^2, almost all of which lies on its south side (Laraque et al. 2019), in addition to part of the 40,000 km^2 of the upper Orinoco. The channel width varies from 46 m to 610 m and minimum water depths are 0.3 m upstream and 1.2 m downstream (Laraque et al. 2019). The river's color gradually transitions from light brown to black (Figure 3), becomes more turbid, and increases in pH as it picks up organic swamp water from its south-bank streams. Even though water passes through it, aquatic wildlife may or may not: depending on the tolerance of individual species, the Casiquiare may be an ecological corridor or barrier between the two basins (Winemiller and Willis 2011).

The Casiquiare is, strangely, a distributary of the Orinoco and a tributary of the Amazon. In most hydrologic maps we consulted, the boundary between the Amazon and Orinoco basins passes across the Casiquiare at or near the point of bifurcation. This violates multiple watershed delineation rules, but there is no alternative. Even DEM-derived delineations have their limitations, given the low relief of the terrain in this vicinity and the low resolution of the available data in this remote region.

Delineation rules apply to fully formed basins; the Casiquiare basin is still forming. Laraque et al. (2019) wrote:

> Tracing the boundaries between the watersheds of the Casiquiare and Upper Orinoco is an insoluble problem with the concepts of classical hydrology, since depending on the season, 20% to 30% of the water of the Orinoco above the bifurcation flows into the Casiquiare. Thus, the upper part of the Orinoco watershed feeds two basins and it is a kind of diffuse area which is not well defined.
>
> At its bifurcation and confluence with the Negro River, the problem arises because fuzzy boundaries cross the marshy plains characterized by shallow lagoons and flooded forests under which superficial two-way laminar-flow runs according to the seasons and to the water levels of the rivers they connect. In addition to this, there are small secondary canals connecting the Orinoco to the Casiquiare and the latter with the Guainia River.

Defying logic and passing between such large basins, the Casiquiare is truly singular. Stokes et al. (2018) concluded that "this unusual configuration is the result of an incomplete and ongoing river capture" in which the Amazon is stealing the upper Orinoco. They support their claim with hydraulic calculations, sediment observations, and evidence of past river captures in the same region. It is river formation in progress, they remark, confirming an earlier theory by Stern (1970).

More than 200 years since Humboldt's definitive visit, this part of the world is still one of the most remote and unknown, and understanding of the Casiquiare, along with the river itself, continues to evolve.

3.2 Arroyo Partido

The Arroyo Partido ("parted stream") is a stream located in southern Argentina. Its headwaters are located in the Andes, flowing from a mountain named Chapelco down through a steep forested canyon. Upon exiting the canyons, the stream enters a wider mountain pass called Passo Pil Pil. There, a rocky outcropping divides the stream in two. The stream on the left of the fork turns south and becomes Arroyo Culebra, which becomes part of the Rio Negro watershed and eventually flows into the Atlantic Ocean; the stream on the right turns north, making Arroyo Pil Pil, which becomes part of the Rio Valdivia watershed and eventually flows to the Pacific Ocean (Figure 4, Figure 5).

Figure 4. Arroyo Partido

Figure 5. Arroyo Partido, facing downstream (Two for the World, used with permission)

The bifurcation does not occur in in level lowlands like the Casiquiare or the Atchafalaya but on a mountain saddle. Mathematically, a saddle on a surface is the intersection of a local minimum in one direction and a local maximum in another. This too is a natural condition for a bifurcation.

Little cartographic evidence of the bifurcation can be found for two reasons. First, this area was not well mapped until the late nineteenth century. Second, Arroyo Partido is small, and the large number of rivers and lakes in the surrounding area may have taken up any space on a map of the region.

There are also no public hydrologic models of the area. However, we were able to verify the bifurcation with aerial imagery (Google Maps n.d.) and photographs by visitors (Figure 5), which show a clear bifurcation which continues to deviate downstream. The digital elevation model that was consulted also confirmed that if water was placed near the high point of Passo Pil Pil, it could bifurcate (Instituto Geográfico Nacional n.d.).

The town website of San Martin de los Andes, which is approximately 15 km north of the bifurcation, confirms the bifurcation for tourist reasons. The tourism department of the town gives clear photographs of the stream's division (San Martin de los Andes 2012).

This area of northern Patagonia began to be explored and mapped by Argentinians in the late nineteenth century with the expeditions of Francisco Moreno and the military campaigns that came to be known as the Conquest of the Desert. The earliest mention of Arroyo Partido is in a 1914 report by Bailey Willis, a scientist from the U.S. Geological Survey who volunteered to go to Patagonia as a delegate of the Scientific Congress in Buenos Aires (Willis 1914, 1948). He was tasked with examining ancient human remains in the area. He documented his explorations, including his geographical findings. Willis describes Passo Pil Pil where Arroyo Partido bifurcates. Geographic clues given in his description match the area. He accurately states that the pass is roughly between Lago Lacar to the north and Lago Machonico to the south. He describes a bifurcated stream which matches the description of Arroyo Partido:

> [Passo Pil Pil] lies on the continental divide, since the waters south of it flow to the Atlantic, while those from Lago Lacar, on the north, flow to the Pacific; and we encounter here the curious phenomenon of a stream which, descending from the adjacent mountain slope, divides where it enters the valley of the pass, and its waters, flowing both northward and southward, discharge into oceans on opposite sides of the continent. (Willis 1914, p. 186)

Arroyo Partido had not been named yet, suggesting that it was named following Willis's expedition, but the description above is no doubt this very feature.

Land usage surrounding Arroyo Partido may affect the health of the stream in the future. Argentina is expanding agriculturally, including to the southern part of the country that Arroyo Partido is in (Sili and Soumoulou 2011). Additionally, land ownership is not centralized. Regulations depend on the province, which, according to a report from the International Fund for Agricultural Development, may "lack systemized information on land" (Sili and Soumoulou 2011). Thus, since Arroyo Partido does not lie within any protected land, it does not have any legal protection despite the unique nature of its watershed. Its proximity to National Route 40 may also be a concern, making it vulnerable to pollution and human impacts.

Ultimately, Arroyo Partido has not been very well documented or studied. This is likely due to its relatively recent discovery in the twentieth century and the continued remoteness of the region. More research is necessary to better document and understand the stream, and thus better know any management considerations for the future.

3.3 Wayambo River

The Wayambo River is similar to the Casiquiare, meandering through flat terrain between two major rivers. Located in Suriname in northeastern South America, the Wayambo River splits and flows either east to the Coppename River or west to the Nickerie River (Figure 5, Figure 6). The Wayambo River's direction depends on both precipitation and on built infrastructure, such as locks. Both the Coppename River and Nickerie River eventually empty into the Atlantic Ocean. The Wayambo River also forms the political boundary between Surinamese districts. It divides the Coronie and Sipaliwini Districts in the central and eastern portions of the river; in the west, the Wayambo River divides the Coronie and Nickerie Districts.

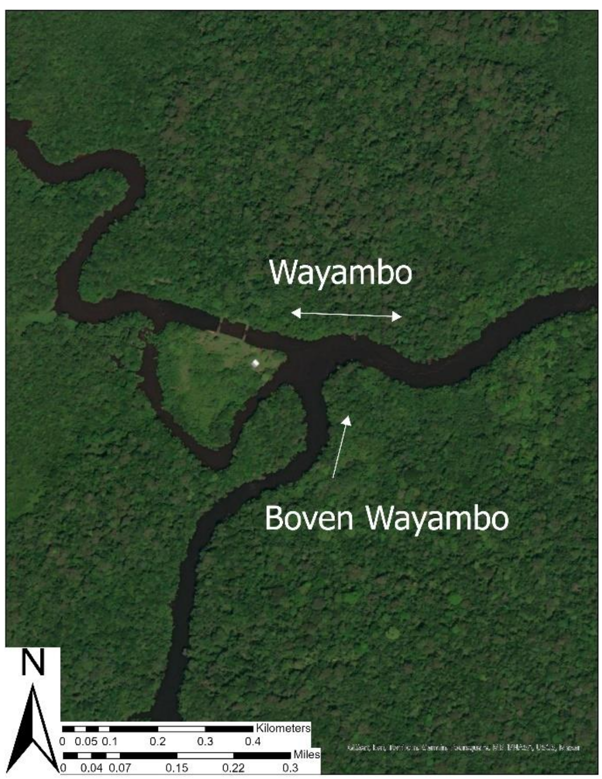

Figure 6. Wayambo River

Figure 7. A *korjaal* (canoe) on the Coppename River, a distributary of the Wayambo River (Jan Willem Broekema, CC BY-SA 2.0)

The head of the river is in the mountains in the southern part of Suriname. At the source, the river is called the Boven Wayambo River. In Dutch, the word Boven means above, over, or beyond (Renier 1949). Thus, Boven Wayambo is like saying the "upper Wayambo River." It is not until the Boven Wayambo bifurcation, located near the village of Donderskamp, that it is actually called the Wayambo River. The river appears to be able to flow either entirely east or west. Thus, there are technically three bifurcations that can occur. One bifurcation is in the middle of the Wayambo River where the Boven Wayambo River enters. The other two possible bifurcations are located on each end of the Wayambo River, where it meets the Nickerie and Coppename Rivers.

Aerial imagery we consulted confirmed the bifurcations (Google Maps n.d.). Similar to Arroyo Partido, we could not find any hydrologic or digital elevation models for the Wayambo River. The earliest physical map we could consult of the region, created in 1800, showed the three bifurcations. This suggests a very early documentation date compared with the other bifurcations presented in this paper.

A 1710 map did not show the Wayambo River at all, but a 1717 map did show the river, with its bifurcation (van Keulen 1710, 1717). This puts the documentation of the Wayambo River at a turbulent time in Surinamese history. In 1667, the colony switched from English the Dutch control. It was not until 1674 that the colony was cemented under Dutch control. The priority was not exploring or mapmaking but military control. Thus, the discovery of the Wayambo River came shortly after a time of political unrest for the region, making the exact discovery of the river difficult to pin down. Both maps consulted were by made by Gerard van Keulen, so it is possible that he is the one who first discovered and mapped this river.

While the exact date and circumstances of the Wayambo River's exploration are uncertain, news articles from Suriname have confirmed the bifurcations of the Wayambo River. Much of the confirmation of the bifurcation comes from statements issued regarding the Arawarasluis, a lock at the intersection of the Wayambo and Nickerie Rivers. The lock is supposed to divert the river heavily to the west to support the rice farmers in the region. However, it recently fell into disrepair and caused the Wayambo River to flow east, causing problems not only for the rice farmers but also a rise in salinity levels from the brackish Nickerie River (Dagblad Suriname 2020).

The Arawarasluis is not a singular occurrence. Infrastructure in the Wayambo region has become a priority for Suriname. Many of the settlements along the Wayambo and its tributaries and distributaries are remote and struggle economically. As a result, infrastructure, like the Arawarasluis and drinking water treatment sites, have been constructed.

Water infrastructure is not the only concern for the Wayambo River. Suriname as a whole is rich in natural resources. Notable exports from Suriname include gold, bauxite, and oil (World Bank 2023; Goodland 2006). With the Wayambo River being located near the coast and near some of the resource extraction sites, the impact of such extraction on the river should be considered.

Mining for bauxite has historically been a large economic driver of Suriname's economy. Much of the bauxite is located in the mountains in the south-central part of the nation. Goodland (2006) calls out the lack of environmental impact studies of such activities. The reasoning from the mining industry is that because the Wayambo River is so remote, there is no need for studies. However, Goodland argues that due to flooding and the reversal of flows in the river system seasonally, pollutants can migrate farther than expected. This illustrates the complexities of a bifurcation: what may normally not need to be considered should be considered due to watershed irregularities.

Bauxite is beginning to become less important to Suriname. However, gold mining is growing in importance, which has similar concerns to bauxite mining. While the mines are not in the floodplain where the Wayambo River sits, watershed irregularities could distribute pollutants to unintended locations, causing harm to the local villages that depend on this complex watershed. Oil too has recently become a major export of Suriname. In 2020, major offshore oil deposits were found, leading to an oil boom (World Bank 2023). Once again, due to the ability for water to flow in any direction, the Wayambo River watershed could be impacted by a potential oil spill if the spill occurs near the mouth of the Nickerie or Coppename Rivers.

The fluctuation of flow direction, caused by both natural and manmade factors, causes the Wayambo River to be a complex watershed. Looking to the future, the watershed should be monitored against potential sources of pollution. If polluted, not only would the environment suffer, but also the rural villages that dot the Wayambo River region that could use infrastructure improvements. Thus, the Wayambo River holds a wide range of social, economic, and environmental concerns.

3.4 Atchafalaya River

The Atchafalaya River is located in southern Louisiana, USA. Its formation naturally occurred in the current geologic epoch of the past 12,000 years (Tye and Coleman 1989; Walker et al. 2009). The Atchafalaya River formed when the Mississippi River—North America's largest drainage—meandered into the basin of the Red River. Thus, the Red River and Mississippi River converged. However, the Mississippi River continued its flow in its same path, while water would continue to flow down what used to be the Red River drainage system. The water flowing down the old Red River basin became what is now the Atchafalaya River. Thus, immediately after the confluence of the Red and Mississippi Rivers, there is a bifurcation of the Mississippi and Atchafalaya Rivers, about 150 km inland from the coast (Figure 8, Figure 9).

Figure 8. Atchafalaya River Bifurcation

Figure 9. Control structures at the bifurcation of the Atchafalaya River (U.S. Army Corps of Engineers, public domain)

During the seventeenth and eighteenth centuries, French explorers mapped much of Louisiana. By the early eighteenth century, the bifurcation of the Mississippi and Atchafalaya Rivers was known (Phares 1952, p. 15). However, the Atchafalaya was unnavigable due to logs blocking the river for a stretch of 48 km (Robert and Salyers 2018). As Europeans began to move to the area, interest increased in using the river for travel. In 1839, the logjam was removed, but this caused hydrological changes to the river, which, if allowed to continue, would threaten the lower Mississippi River.

In the nineteenth and twentieth centuries, structures began to be built to control the at-times chaotic confluence and bifurcation (Figure 9). The structures improved travel times for ships and prevented flooding from impacting infrastructure (Atchafalaya National Heritage Area n.d., “Rivers & flood control”). Today, multiple locks and dams provide safe passage for ships and hydropower while also regulating how much water flows down the Atchafalaya River. Due to the low population and the multiple public lands along the Atchafalaya River, it acts as a safety valve during floods. At the bifurcation, as much as half of the inflowing water can be diverted down the Atchafalaya River.

Given the large size of both the Mississippi and Atchafalaya Rivers, the bifurcation and infrastructure built are clear from aerial photography and ground photography (Figure 9). A digital elevation model of Louisiana also confirms the bifurcation of the two rivers. Lastly, we consulted a hydrologic model. To handle the bifurcation, the model designated multiple subbasins around the control structures (The Nature Conservancy n.d.).

The management of the Atchafalaya River and watershed is a source of major discussion. The history, environment, and future of the Atchafalaya Basin are significant enough for the U.S. Congress to designate the basin as the Atchafalaya National Heritage Area in 2006 (Atchafalaya National Heritage Area n.d., “About”).

One of the biggest topics of research on the Atchafalaya River is what would happen if the bifurcation control system is removed. While there is not a consensus on the how quickly an event may occur, many studies agree that the Atchafalaya River would overtake the Mississippi River and drain the majority of the water in the area (Edmonds 2012; Tye and Coleman 1989; Andrus and Bentley 2023). If this were to happen, much of the shipping, which is built around the Mississippi River, would be adversely affected, as would the economy of New Orleans, which depends on shipping. However, New Orleans would also not have a reliable source of fresh water. In 2023, New Orleans was in danger of losing its fresh water due to low water levels of the Mississippi River (Chow 2023). The Gulf of Mexico began pushing upstream, filling the Mississippi Delta with brackish water. If the Atchafalaya bifurcation were to yield to natural forces, New Orleans would have a more serious drinking water emergency than in 2023.

On the other hand, there are concerns regarding the life of the current river diversion system at the bifurcation. High rates of sedimentation in the Mississippi River may cause issues with current structures in the near future (Andrus and Bentley 2023). If the same structures are left in place, New Orleans may be placed in a dangerous situation within the next 75 years due to increased sediments and failing water diversion structures.

While Louisiana has had a long history of western settlement, relative to much of the rest of the continent, the Atchafalaya Basin is still fairly remote and wild. Apart from the bifurcation, there is no other water control on the river, making the bifurcation flow control vital to the basin’s health. Even with control, the water level changes naturally with the seasons, the greatest range of 6.5 to 11.2 m being near the bifurcation (Ford and Nyman 2011). Near the mouth of the river, water levels change less dramatically, a range of 1.1 to 2.1 m.

While flooding has historically been an important component to the Atchafalaya River, the current range is not near historic levels. To have water levels near historic spring flooding, and to gain the resulting ecological benefits, the maximum water level would have to be over 4 m in the central part of the river, which is not currently being achieved (Piazza 2014, p. 236).

Environmentally, the Atchafalaya River is an important area. There are multiple state and federal reserves that protect approximately 50% of the river and the surrounding basin (Ford and Nyman 2011). The biodiversity that the river supports is significant: 45 species of mammals, 40 species of reptiles, and 250 species of birds.

However, there are also challenges in managing this unique river. Sedimentation threatens to turn lakes into swamps and swamps into forests. Seasonally, sediment-laden flood disturbances threaten the dissolved oxygen in the river, killing fish by hypoxia (Hupp et. al. 2008; Rutherford et al. 2001). Hypoxia also is resulting from invasive non-native plants establishing themselves in the river (Kelso and Rutherford 2004). Similar to New Orleans, the Atchafalaya River is threatened by sea level rise, which causes saltwater to push upstream from the mouth of the river, further harming the existing freshwater ecosystem. In combining these factors, not only is the health of the ecosystem being impacted, but also the population of the region that depends on these natural resources. Each of these problems stems from water flow at the point of bifurcation.

The forests of Water Tupelo and Bald Cypress have been an important part of the region's economy. The large stands of these trees were heavily harvested, especially from the 1880s to the 1930s (Piazza 2014, p. 83). There are significant stands that have regrown within the Atchafalaya Basin, but these trees face a new threat. In order to continue regeneration, Water Tupelo and Bald Cypress must have the correct amount of water season to season. Current river release patterns do not match the natural, historic levels. Instead of having short, intense floods during spring, the volume of water is spread out, causing less intense but prolonged periods of flooding. The trees are not biologically adapted to prolonged floods. Instead, prolonged flooding damages mature trees and creates conditions where tree regeneration is no longer favorable, putting these forests, a significant regional carbon sink, at risk (Piazza 2014, p. 208).

The oil and gas industry, similar to the conditions near the Wayambo River, threatens the stability of the Atchafalaya ecosystem. The structures built for the transport of these fossil fuels fragment the ecosystem (Piazza 2014, p. 234). Pockets have been created where natural flows and sediment transport have been disrupted (USGS National Wetlands Research Center n.d.). The disruption of flows and sediment transport originating at the bifurcation impact the Atchafalaya Basin's health significantly. Thus, a more natural flow pattern as released from the bifurcation may not solve every environmental health challenge in the basin.

Lastly, land ownership and access continue to be difficult challenges in the Atchafalaya River Basin. In part, the river itself causes difficulty for boundaries drawn by physical features. Due to flooding and sediment transport, these physical features can change quickly. Additionally, there are multiple easements and agreements, mostly with the state or federal government, that dictate land use in the basin (Piazza 2014, p. 153). The amount of governmental presence in the drainage basin is alarming to some residents, which may further complicate any management issues in the future, especially regarding water flows released from the bifurcation.

The Atchafalaya River is a unique river with a flow that is managed as a byproduct of another river, the Mississippi River, the largest on the continent. The Atchafalaya River's bifurcation is heavily engineered to ensure that the Mississippi River is not damaged. Despite this, its environmental quality is notable but under the threat of many sources of ecosystem imbalance and outside pressures.

3.5 North Two Ocean Creek

In northwest Wyoming, USA, North Two Ocean Creek drains part of the Two Ocean Plateau. Initially it flows through a steep canyon. Just as the stream leaves the canyon it divides into Atlantic Creek, which flows into the Yellowstone River, and Pacific Creek, which flows into the Snake River. This "Y" shaped point has been called Parting of the Waters and can be observed in person (Figure 10, Figure 11).

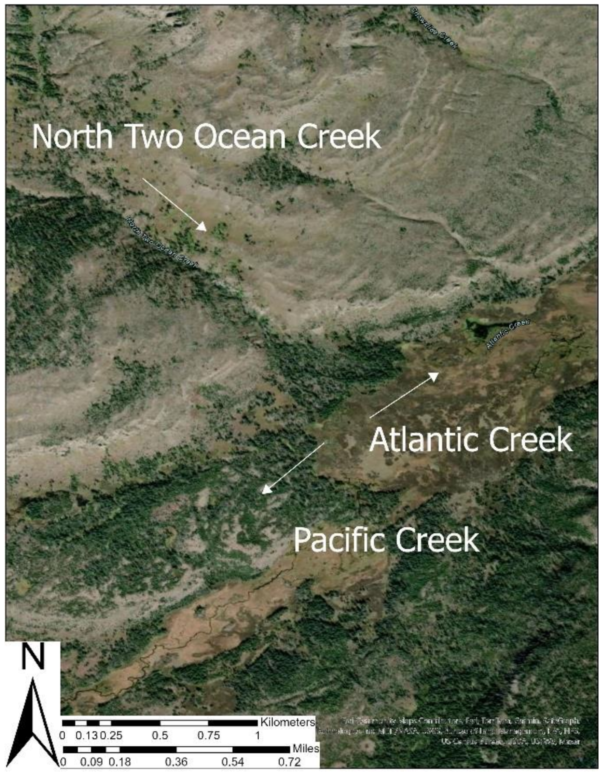

Figure 10. Parting of the Waters (North Two Ocean Creek)

Figure 11. Parting of the Waters, facing downstream and showing directions to the Atlantic (left) and Pacific (right) Oceans (Ericshawwhite, CC BY 3.0)

According to topographic maps we consulted, the bifurcation is caused by a high point in the alluvial fan just above a shallow mountain saddle. The point of bifurcation occurs in a relatively flat and heavily forested area, causing aerial photography to be ineffective in verifying the exact point of the creek splitting. Using a DEM, we confirm that slight changes in elevation would cause the Parting of the Waters.

The bifurcation of North Two Ocean Creek may be the most famous North American bifurcation due to the popularity of the Yellowstone region. The northwest corner of Wyoming is prized for its natural environment since the creation of Yellowstone National Park. As a result, there has been a history of continuous outdoor recreation near North Two Ocean Creek. For example, in 1892, Theodore Roosevelt, who would become the 26th president of the United States, hunted elk in Two Ocean Pass (Righter 2021). Most recently, a long-distance hiking trail, the Continental Divide Trail, leads directly past the bifurcation of North Two Ocean Creek, allowing many outdoor enthusiasts to view this hydrologic anomaly (Clifford 2002).

The first report of North Two Ocean Creek came from Jim Bridger, an early mountain man and fur trapper. Learning from the Native American peoples near the present-day Montana-Wyoming border, he found that the headwaters of multiple major rivers started in approximately the same area, which is now Yellowstone National Park. In 1826, Bridger led a group of trappers into the high country of the Yellowstone area. He explored multiple watersheds, eventually leading to North Two Ocean Creek (Alter 1962). After finding the bifurcation, he spread the word of a stream that connects the Atlantic and Pacific Oceans (Evermann 1895).

Expeditions in the late 1800s confirmed Bridger's remarkable claim. North Two Ocean Creek was verified by Captain William Jones from the Union Pacific Railroad (New York Tribune 1873), Ferdinand Hayden from the U.S. Geological Survey, Arnold Hague (Evermann 1895), and Barton Evermann from the U.S. Fish Commission (Evermann 1895).

A newspaper account of the Jones expedition described the bifurcation:

> The stream is but a little thread of water and only flows a short distance before it is embarrassed by a choice of destiny. A little island or peninsula splits the waters. On one side of this little peninsula is the Atlantic Ocean, and on the other side the Pacific. Thousands of miles away from these great bodies of water, each separate drop in the tiny stream must elect which one of these shall be its destination, and the choice made here cannot be altered. (New York Tribune 1873)

Evermann's expedition approached North Two Ocean Creek with a different goal than simply verification. He wanted to certify a hypothesis that trout were present in Yellowstone Lake by migrating from the Snake River by way of Pacific Creek and North Two Ocean Creek (Evermann 1895). This is the first instance of the river and ecological management of North Two Ocean Creek being a concern.

In 1891 Evermann and his group from the U.S. Fish Commission found North Two Ocean Creek:

> [The stream] divides as if to flow around an island; but the stream toward the meadow, instead of returning to the portion from which it had parted, continues its westerly course … and a continuous water way from the mouth of the Columbia, via Two-Ocean Pass, to the Gulf of Mexico is established. Two-Ocean Creek is not a myth but a verity. … A creek flowing along the ridgepole of a continent is unusual and strange, and well worth watching and experimenting with. (Evermann 1895)

After some whimsical description about lying face-down in the stream and drinking water from two oceans just by turning his head a little, Evermann presents his conclusion about fish migration. Trout could enter Yellowstone Lake by way of North Two Ocean Creek, he says, for trout were found along both Pacific Creek and Atlantic Creek. He frames the discovery as a thought experiment:

> Indeed, it is possible, barring certain falls in Snake River, for a fish so inclined to start at the mouth of the Columbia, travel up that great river to its principal tributary, the Snake … and, under the shadows of the Grand Tetons, enter the cold waters of Pacific Creek, by which it could journey on up to the very crest of the Great Continental Divide to Two-Ocean Pass; through this pass it may [reach] Atlantic Creek, in which the down-stream journey is begun. Soon it reaches

> the Yellowstone … into the turbid waters of the Missouri … before reaching the Father of Waters [the Mississippi River], which will finally carry it to the Gulf of Mexico. (Evermann 1895)

The discovery of a trout migration route is significant for the management of Yellowstone National Park. A recent study shows that, just as Evermann theorized, invasive Lake Trout may have entered Yellowstone Lake from the Snake River by way of North Two Ocean Creek (Koel et al. 2020).

Historical maps verify the early history of discovering the bifurcation. As early as 1870, Two Ocean Pass, and by implication the division of North Two Ocean creek, was identified in the correct area. Some exact meandering of the creeks was not accurate, but the general idea of the watershed was properly captured. By 1883, both upstream and downstream reaches of the bifurcation were accurately mapped.

Unlike other rivers considered in our review, North Two Ocean Creek appears to have a stable point of bifurcation. A former forest supervisor of Bridger-Teton National Forest, in which the bifurcation is located, commented on the history of the split:

> High water stages do not overflow the banks … and the streams have never gone dry; thus it is not apparent that the "Y" or division point has been moved by floods or erosion. From all appearances, and considering the size and age of the trees on the banks, the "Y" has remained where it is for several hundred years. (Alter 1962)

Due to its small size, North Two Ocean Creek will likely not move its point of bifurcation significantly for the foreseeable future. Rather than having to manage a meandering river, the issues of this creek involve fish migration and recreation management.

3.6 Divide Creek

Divide Creek is located in Canada on the boarder of British Columbia and Alberta. This border also distinguishes Yoho and Banff National Parks, both of which have portions of Divide Creek. Its headwaters are located on the east side of Divide Mountain. Being high in the watershed, the discharge is quick but small, contrasting with the Orinoco and Mississippi. The creek flows down the mountainside to a mountain saddle called Kicking Horse pass, where the stream bifurcates (Figure 12, Figure 13).

Figure 12. Divide Creek

Figure 13. Divide Creek bifurcation (R. Siebe, CC BY 3.0)

The reason for the bifurcation is nearby Summit Lake, located just west of the continental divide. Summit Lake used to span the entire saddle, possibly bifurcating in the past (Willard 1930; Zernitz 1933). Over time, the lake shrunk to its present site on the west side of the pass. This shrinkage has created a swampy wetland at the crest of the pass. It is through this wetland that Divide Creek flows. Following the historic path of Summit Lake, Divide Creek flows west to Summit Lake and east to the Bow River.

Kicking Horse Pass was not documented until the mid-nineteenth century. John Palliser led an expedition into the area, officially documenting the pass in 1858 (Spry 1963). Although the pass was found, there is no mention from Palliser nor his group of the discovery of Divide Creek nor its bifurcation.

Similar to Arroyo Partido, there is little cartographic evidence of Divide Creek until recently, likely due to its small size. Likewise, we could not find a DEM of Kicking Horse Pass. Due to the heavily forested area in which the stream bifurcates, aerial photographs are inconclusive (Google Maps n.d.).

Additionally, there is dispute on different maps and models that we consulted as to the extent of Divide Creek and the existence of its bifurcation. One marked a clear bifurcation of the creek (Mapcarta n.d.). Others do not show a distributary at all for Divide Creek (Google Maps n.d.). The Canadian National Hydro Network (n.d.) shows Divide Creek stopping once it reaches Kicking Horse Pass, not giving an indication as to where the water flows to afterward. However, the topographic lines indicate a saddle where a bifurcation is possible.

The most conclusive evidence of the Divide Creek bifurcation comes from the Yoho National Park Interpretive Service: a marker describing the bifurcation has been erected (Pfingsten 2022). The marker is located on a hiking trail near the site. A spur off of this trail leads to the bifurcation itself. Pfingsten (2022) also shows a photo of a wooden “arch” marked “Great Divide” over an old road near the bifurcation, and this feature is visible in aerial images.

Kicking Horse Pass, in which the bifurcation of Divide Creek occurs, is a main thoroughfare of the Canadian Rocky Mountains, making the creeks vulnerable to pollution. The Trans-Canadian Highway and the Canadian Pacific Railway run through Kicking Horse Pass. The stretch of rail through Kicking Horse Pass is notorious. The line was opened in the mid-1800s to connect British Columbia with the rest of Canada (Parks Canada 2023). The first train use of the route resulted in its derailment and the death of three people. To make the route safer, two spiral tunnels were drilled into the mountain side to create a more gradual slope. This feat was celebrated by the creation of the Kicking Horse Pass National Monument in 1971. However, despite the improvement of the spirals, the rail line through Kicking Horse Pass remains dangerous. Train derailments still happen in that stretch. For example, due to extremely cold winter conditions and possibly faulty brakes, a train derailed at Kicking Horse Pass in 2019 (Grant and Seglins 2022). Thus, a derailment near the bifurcation is a possibility and could impact watersheds on both sides of the divide if fuels or other pollutants are spilled.

Divide Creek is a small stream that flows in the remnants of a bifurcated lake. The creek is relatively unknown, with little authoritative literature. Divide Creek is well protected by lying in two national parks, Banff and Yoho. However, the point of bifurcation is near a historically dangerous rail line, which could pose the biggest management problem should a spill occur.

3.7 Committee’s Punch Bowl

While not a bifurcated river, Committee’s Punch Bowl, a lake, has many of the same features. Straddling the North American continental divide at Athabasca Pass (elevation 1753 m), it has two outlets which drain to different oceans. The northwest outlet discharges into the Whirlpool River, which leads to the Mackenzie River and to the Arctic Ocean; the southeast outlet discharges into the Wood River, which leads to the Columbia River and to the Pacific Ocean. Like Divide Creek, the Bowl is situated on a mountain saddle. The saddle also happens to be on a continental divide and the provincial boundary of Alberta and British Columbia, making it all the more interesting (Figure 14, Figure 15).

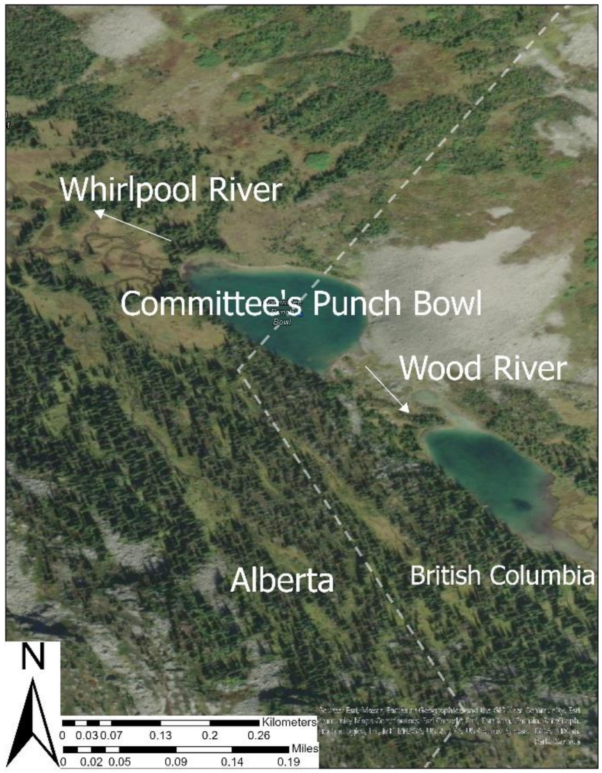

Figure 14. Committee's Punch Bowl

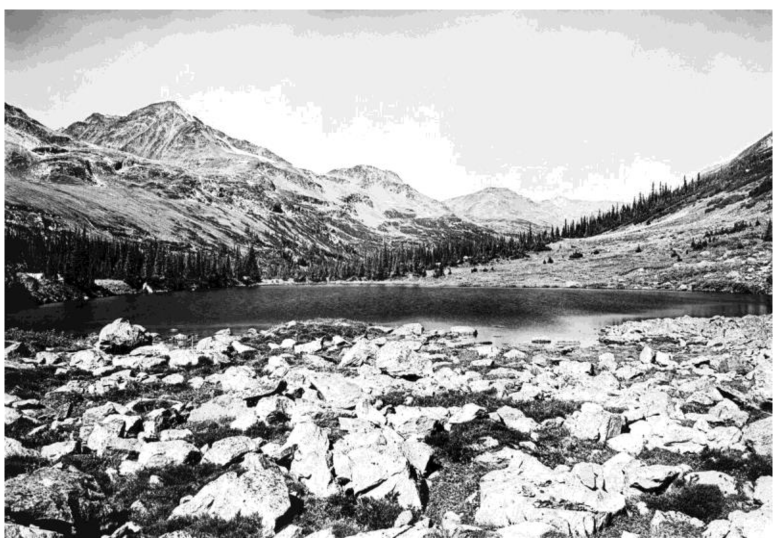

Figure 15. Committee's Punch Bowl circa 1930 (Royal Canadian Geographical Society collection, public domain)

The lake is technically classified as a tarn (MacLaren 2007, p. 61). Tarns are formed when a glacier carves out a low spot for water to collect, typically in a cirque at the head of a glacier (U.S. Department of the Interior n.d.). The water collects in this low spot due to some form of natural dam, usually a moraine.

Committee's Punch Bowl was documented early in Canadian history. The tarn, and Athabasca Pass in which it lies, were known to the native peoples in the area. It was with an Iroquois guide, Thomas the Iroquois, that David Thompson explored the pass for his fur trading company in 1811 (Parks Canada n.d.). Thompson used the pass to shuttle supplies from the Athabasca River to the Columbia River basin (MacLaren 2007, p. 10). The pass would be used sporadically until the early 1820s.

A Scotsman, George Simpson, saw Athabasca Pass as a promising route to get through the Canadian Rockies (MacLaren 2007, p. 16). Although the pass had been used many times before, the tarn at the pass's summit had not yet been named. During one of his many travels through the pass, he decided to name it. On an 1825 expedition for the Hudson's Bay Company, he wrote in his journal:

> At the very top of the pass or height of Land is a small circular Lake or Basin of Water which empties itself in opposite directions and may be said to be the source of Columbia & Athabasca Rivers as it bestows its favors on both these prodigious streams. … That this basin should send its Waters to each side of the continent and give birth to two of the principal Rivers in North America is no less strange than true … having examined the currents from east & West and the circumstance appearing remarkable I thought it should be honored by a distinguishing title and it was forthwith named the "Committee's Punch Bowl." (Merck 1931, p. 34)

The fur trade would continue to use the pass throughout their time in the Canadian Rocky Mountains. Athabasca Pass would become a well-known route, attracting people outside of the fur trade too. One man, Paul Kane, would travel through the area, sketching Committee's Punch Bowl in the process (MacLaren 2007, p. 61).

Due to the relatively early documentation of the Committee's Punch Bowl, maps from the mid-1800s were found with the lake labeled explicitly and a clear bifurcation shown. This is to be expected with the high fur trade traffic that went through Athabasca Pass.

Many of the sources we consulted in verifying the bifurcation simply implied the bifurcation. An online map we considered had the correct topography of a saddle and placed the headwaters of two streams very close to Committee's Punch Bowl (Mapcarta n.d.). The Canadian National Hydro Network likewise showed two streams beginning near the Committee's Punch Bowl (Figure 16). Additionally, it places a watershed boundary south of the lake, implying that any runoff would run north while explicitly showing an outflow to the south.

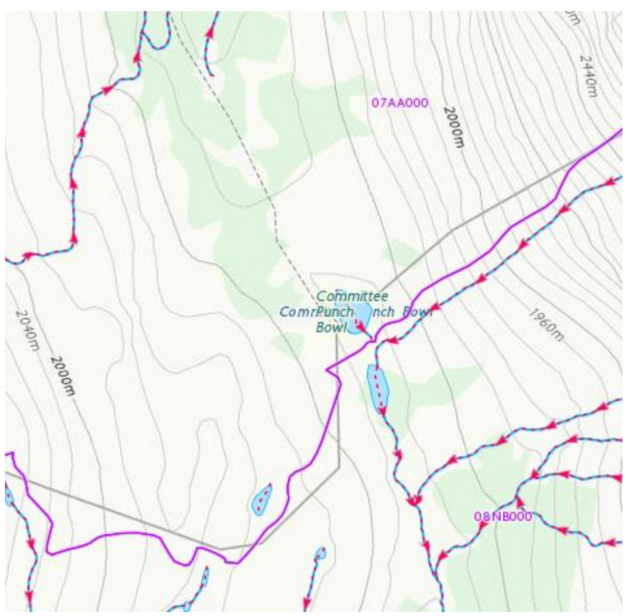

Figure 16: The Canadian National Hydro Network map of the Committee's Punch Bowl area (Canadian National Hydro Network n.d.)

Aerial photography was inconclusive, since the photographs were taken around winter, causing the lake and surrounding area to be covered by snow. No traces of any outlets were seen from the aerial photography (Google Maps n.d.).

Today, Committee's Punch Bowl lies within Jasper National Park. Additionally, there is a special designation of Athabasca Pass National Historic Site to the area (Parks Canada n.d.). Thus, the tarn and its unique bifurcation are under federal protection.

To allow access to the beauty and history of the historic site, there is a hiking trail that traces the historic Athabasca Pass route, passing by Committee's Punch Bowl. One concern with this trail is its popularity. The national park has decided to not replace trail infrastructure, such as foot bridges, that has been damaged by natural causes in the past decade (Harrap 2023). This is due not only to the high foot traffic in summer months, but also to saving money on construction and maintenance.

Committee's Punch Bowl is part of the historic Athabasca Pass and is under protections from the Canadian government. The tarn and its bifurcation have been extensively documented in the 1800s. However, modern models and maps do not demonstrate the bifurcation very well, if at all.

3.8 Echimamish River

In central Manitoba, Canada, the Echimamish River connects the lower Hayes River and the upper Nelson River, which both flow northeast to Hudson Bay. From a point 3 km west of Robinson Lake on the Hayes, the Echimamish runs some 70 km westward to its confluence with the Nelson, a point about 45 km north of Norway House, north of Lake Winnipeg (Figure 17). Curiously, the river flows from the middle out toward both ends.

Figure 17: The Echimamish River

Traders learned of the drainage anomaly from the native Cree; "Echimamish" in their language means "water flowing both ways" or "river that flows downstream in both directions." The connection proved highly useful because the lower Nelson, with its rapids and high flows, is unnavigable. As early as the 1700s, a canoe route was established between York Factory (on Hudson Bay) and Norway House (near Lake Winnipeg) by ascending the Hayes, crossing the Echimamish (with a few portages) and descending to the Nelson. The so-called "Hayes River Passage" or "Painted Stone Passage" was used through most of the 1800s and involved several portages where York boats had to be carried short distances over land (Figure 18). In 2006, portions of the Hayes and Echimamish were designated parts of the Canadian Heritage River System.

Figure 18. An 1821 painting by Peter Rindisbacher of a York boat portage (Archives Canada, public domain)

The Echimamish's course though the swamplands is so flat that even today there has been some uncertainty about its direction—or directions—of flow. Early accounts report that the divide was the Painted Stone Portage, an island named for a bygone rock painting. In 1819, traveler John Franklin recorded that water flowed in different directions on either end of the island:

> The Painted Stone is a low rock ten or twelve yards across, remarkable for the marshy streams which arise on each side of it, taking different courses. On the one side, the water course which we had navigated from York Factory commences. This spot may therefore be considered as one of the smaller sources of the Hayes River. On the other side of the stone the Echimamish arises, and taking a westerly direction falls into Nelson River. (Newbury 1979)

Morse (1969), describing his 1956 trip, attempted to clarify Franklin's account:

> At Painted Stone Portage, canoes and their cargo are carried for twenty paces, *not* over a divide—as is commonly stated in the early journals—but between two parallel streams, both of which are flowing eastward. A contour line crosses the course here, and the Painted Stone offered the shortest, simplest way to take the drop [west to east]. (Emphasis in original.)

By "two parallel streams" we believe Morse means the Nelson and the Hayes Rivers, which both flow to Hudson Bay. But the language is still misleading; there is nothing hydrologically significant about the Painted Stone Portage itself. Instead, Morse explains that the divide is a headwater pond farther west:

> In totally flat, swampy country the Echimamish boasts the unusual feature of rising, not at one end, but in its "middle"; two streams, from north and south, meet in a beaver pond which flows

> out both west and east—respectively into the Nelson and the Hayes. … At the first beaver dam on the Echimamish [starting westward from the Painted Stone Portage] the canoes are simply dragged *up* over the dam; and a long beaver-flooded section follows, still proceeding westward. Shortly after the two source streams enter, another beaver dam is encountered, where the water now is flowing *down*. (Emphasis in original.)

McLeod (1975), on his own trips in 1973 and 1974, found Morse's description imprecise and observed the divide in a different point, immediately west of the Painted Stone Portage:

> It is indeed true that the water in this stream flows both ways. The headwaters of the two flows is a long, narrow pond. It drains to the east (to the Hayes River) and to the west (to the Nelson River) and is navigable throughout its length, except for a short distance at the eastern edge of the outlet of the headwater pond. Here a short portage of 30 paces leads over a low, smooth rock. This portage is known as the Painted Stone Portage …

McLeod and Morse later conferred. McLeod then reasoned that the headwater pond can shift by several kilometers depending on the state of beaver dams which control water levels in the river, even on the order of 0.3 m. He concluded that "not only does the flow split in the Echimamish, but the point at which the flow splits also appears to be capable of movement." McLeod, in his Appendix C, discusses this argument at length and shows several figures to illustrate it.

Online, a pair of canoers reported on their 2016 trip ("Hayes River trip report summer 2016"):

> Close to Painted Stone, we had to lift over 3 beaver dams. Painted Stone Portage was fascinating. As you approach it, it seems as though the Echimamish terminates abruptly in a dead-end. The portage is on the left, and the Hayes is about 4 feet lower than the Echimamish. … We made our way down the sloped slab of rock onto the Hayes.

The conflation of the Painted Stone Portage with the hydrographic divide is due to 1) its geological and cultural prominence and 2) its colocation with a beaver pond for much of recorded history—a beaver pond which, however, did not exist during Morse's 1956 journey. Both Morse and McLeod agree that a beaver pond somewhere in the middle of the river is the true headwaters, even though the location varies.

However, a third source, the Canadian National Hydro Network (n.d.), shows just a single flow direction throughout the Echimamish—east to west, from the Hayes to the Nelson. On this map, a portion of which we have reproduced as Figure 19, the Echimamish begins at bifurcation of the Hayes approximately 3 km west of Robinson Lake. The east fork continues as the Hayes River, running generally northeast; the west fork becomes the Echimamish River. We note that the watershed boundary crosses the river at this point, similar to the Casiquiare. By this definition, contrary to discussion up to this point, the Echimamish is exclusively a distributary of the Hayes and a tributary of the Nelson, without two-way flow. We note the apparent contradiction that the flow direction goes opposite to the contours of the Painted Stone Portage, which drop west to east. We did not find any documentation for the data that support this map, and it may be just for the purpose of consistency in a very unusual watershed. Still, it represents yet another opinion on the river's identity.

Figure 19. Official map of the Echimamish River (Canadian National Hydro Network n.d.)

Following the same logic that Stokes et al. (2018) presented for the Casiquiare, the Echimamish may be an example of river formation in progress. It may eventually capture the upper Hayes at the bifurcation near Robinson Lake. Another possibility is that a true hydrographic divide will form to permanently split the eastern and western portions of the river between the Hayes and the Nelson basins.

In our review, the Echimamish River was the most obscure, the most baffling, and the most unique to investigate. It is far more subtle than the grand bifurcations of the Amazon and the Mississippi, so subtle that some otherwise observant paddlers failed to notice a change in its direction of flow when crossing it. Further, it is so flat that its headwaters—the point where the flow splits—can actually *move* by several kilometers. The conditions have resulted in conflicting historical records, if not mythical musings, some of which are still not resolved. In any case, the Echimamish remains a curious river that eludes strict definition.

3.9 Wollaston Lake

Wollaston Lake (Figure 20, Figure 21) is located in the northeastern corner of Saskatchewan, Canada. The topography is very flat, as is typical of the midwestern boreal forest region (Figure 21). The lake is mainly fed by the Geikie River from the southwest. It bifurcates roughly at the northern end of the lake, splitting into the Fond du Lac River in the Mackenzie River watershed to the northwest and the Cochrane River in the Churchill River watershed to the northeast.

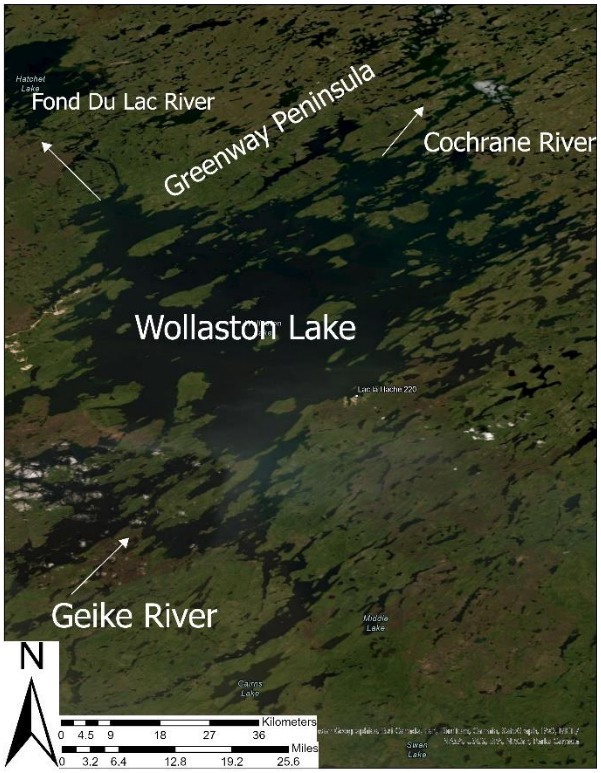

Figure 20. Wollaston Lake

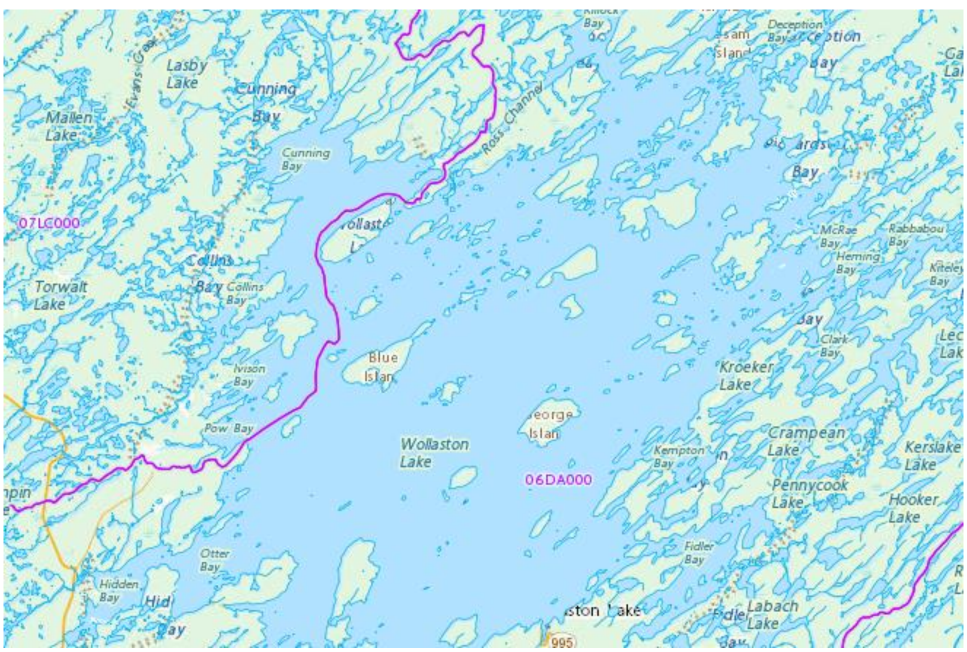

Figure 21: The watershed boundary going through Wollaston Lake (Canadian National Hydro Network n.d.)

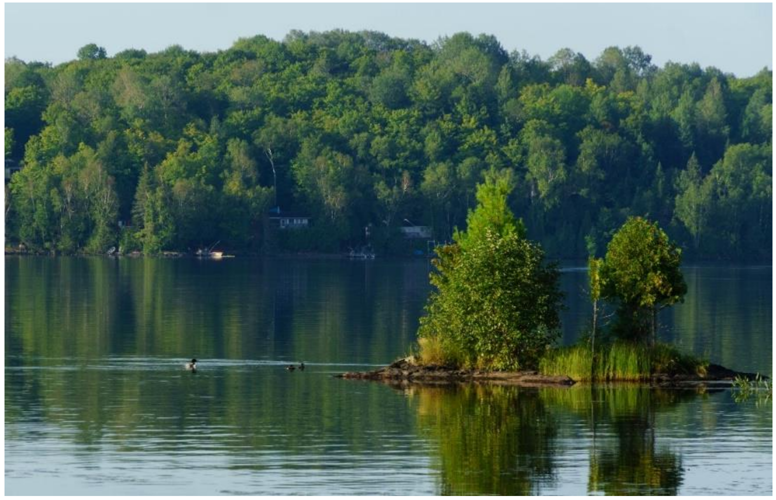

Figure 22: Loons and trees on Wollaston Lake (Gary J. Wood, CC BY-SA 2.0)

As water flows north, its ultimate destination is decided by which side of the Greenway Peninsula it is located on (Figure 23). However, in consulting the Canadian National Hydro Network (n.d.), we realized that this is not a definitive bifurcation. There is some flow between the two sides of the peninsula, as shown by the dashed line (representing flow) crossing the solid line (the watershed boundary) in Figure 23. Geologically speaking, this peninsula will not last long as it is between an inlet and outlet, subject ti erosion. However, judging by the surrounding topography, the lake will still bifurcate due to the natural "Y" shape that it has, whether the peninsula is there or not.

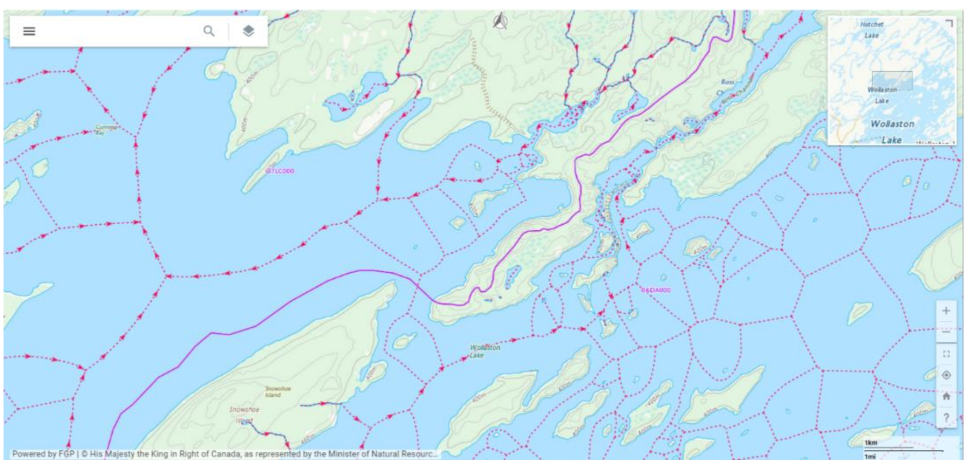

Figure 23: The bifurcation of Wollaston Lake caused by Greenway Peninsula (Canadian National Hydro Network n.d.)

Due to the both the flat topography and the large number of lakes and streams in the area, aerial photography does not provide a clear picture of how water in the region flows. Additionally, DEMs were difficult to find due to the remoteness of the region. We were only able to find one DEM of the area, but it only included the western half of the lake, which was not sufficient to confirm a bifurcation.

The native Chipewyan, or Denesuline, people knew of Wollaston Lake's bifurcation and its uniqueness. As such, they called it Lake Manito (Cochrane 1924). The name Manito, meaning "spirit," came from the Cree who lived farther south (Vaillancourt 1992). Thus, they believed that this lake, located in the high country of two major watersheds, had supernatural properties.

In the late eighteenth century, the Hudson's Bay Company, a fur trapping company, sent explorers into this region of Canada. The first of the explorers to learn about Lake Wollaston was David Thompson. In his expedition party were trappers and two Chipewyan guides. Upon following his guides' advice, Thompson's group bypassed the fast-flowing Cochrane River, trudging through small creeks to reach Wollaston Lake in 1796 (Cochrane 1924). There, Thompson was able to see the bifurcation for himself, which had been told to him by the Chipewyan (MacGregor 1966). To leave the lake, Thompson departed to the northwest side of the bifurcation down the Fond du Lac River.

The second explorer to visit Wollaston Lake was Peter Fidler. Like Thompson, Fidler was employed by the Hudson's Bay Company to explore the area. He was accompanied by fur trappers and Chipewyan guides. Fidler already knew about the bifurcation of the lake from Thompson's guides. Over 10 years since the discovery of the lake, it was given a name. In 1807, Peter Fidler named it "Lake Wollaston in honour of Mr. Wollaston a member of the Hounourable Hudson's Bay Company" (MacGregor 1966).

In examining historical maps of Canadian geography, we confirmed this explosion of exploration in the early 1800s. In a map from 1793, there is very little detail in the northern prairie provinces, including the absence of Lake Wollaston, as it had not been discovered yet. The next map we found was from 1834. By that time, many of the watersheds in the northern plains area had been mapped, including the bifurcation at Wollaston Lake, complete with arrows to show the division of flow to the Fond du Lac and Cochrane Rivers.

A potential management concern for Wollaston Lake could be land holdings. The Denesuline are still the majority of people in the Wollaston Lake area. There are 4,500 people of the Athabasca Denesuline Nation living in northern Manitoba and northern Saskatchewan (Executive and Indigenous Affairs n.d.). One band, the Hatchet Lake Denesuline, has a population center on the shores of Wollaston Lake in the town of Wollaston (University of Saskatchewan n.d.). The census records show that a significant portion of the population in the Wollaston Lake region speaks either Dene or Cree (Statistics Canada 2012). As of writing this review, there are ongoing legal disputes with the Athabasca Denesuline over land and harvesting rights in northern Manitoba, including around Lake Wollaston (Executive and Indigenous Affairs n.d.).

Another potential management concern is the Rabbit Lake uranium mine, located on the southwest side of the lake and on the edge of a large, uranium-rich deposit stretching west. The threat for environmental impact is not as great since the mine was decommissioned in 2016 (Cameco n.d.). However, the mine's effluent does continue to run into Wollaston Lake. The Canadian Nuclear Safety Commission (2023) compiled an environmental protection review report on the safety of the mine. As of 2022, the mine was releasing water and uranium at "levels similar to natural background." The mine's license expired in 2023 and will need to be renewed. At the time of this writing, there have been no updates on its renewal.

Unlike many of the other bifurcations already discussed, Wollaston Lake does not have a hard bifurcation. Water can flow between the two northern parts of the lake and is only set in its ultimate destination once it flows into one the rivers. Due to it being an early water route for Canadian explorers, the lake has been known for centuries. Regardless, the northeastern corner of Saskatchewan is still a very remote region, causing management disputes and policies to still be in flux.

4 Discussion

Taken together, the set of nine unusual drainages presents some points worth further discussion.

4.1 Formation

A few of the bifurcations illustrate particular stages of river formation. The Casiquiare, as discussed earlier, is a case of river formation in progress. It is currently in limbo between two basins but may eventually, with the Upper Orinoco, become a tributary exclusively of the Amazon, a preview of the future. The Atchafalaya is the opposite: a relic, for the moment, frozen in time. The bifurcation is now manually controlled to preserve the vital functions of the Mississippi, but if the control structures were never built and the river were left to its natural course, the Atchafalaya may have become the dominant route.

4.2 Settings

Five of the nine bifurcated water bodies are located in flat terrain and the other four are located on mountain saddles. In geologic time, the flat rivers meander in their channels, and this sometimes leads to permanent bifurcations. Some flat cases, including the Casiquiare and the Atchafalaya, are wide, dramatic channels in low places where large flows have had time to accumulate. Other flat cases, in particular the Echimamish, are so subtle as to hardly be noticed. The saddle cases are ones where the streams are ambivalent in sensitive topography. They flow down a ridgeline to a saddle and, encountering equal slopes right and left, split to both sides. Being high in the mountains, such streams are steep and quick but small because very little flow has accumulated; they are narrow enough for one to leap across, unlike the wide expanses of the Mississippi and Orinoco. The North American continental divide is home to three bifurcations—North Two Ocean Creek, Divide Creek, and Committee's Punch Bowl. The characteristics of flatlands and saddles suggest where to look for other existing bifurcations as well where to expect new bifurcations to form.

4.3 Modeling

It is not clear how bifurcations are handled in hydrologic models, especially runoff models and other surface models. Where DEMs usually dictate watershed boundaries, these special cases, and ones like them, need special attention. The Casiquiare, for example, naturally diverts significant portions of the Orinoco's flow into the Amazon, and typical models may not account for this split. Likewise, models of the Mississippi may omit effects of flow regulation through the Atchafalaya. Such considerations may be important as national and international hydrologic modeling capacity evolves to be used more in decision making for flood control, ecological management, and water supply planning.

4.4 Management

The unusual water bodies present some challenges for management. Their very irregularities raise interesting questions: How should their watershed boundaries be defined on maps? Whose water is it before or after it bifurcates? If contaminated, who is responsible? Should flows in a bifurcated river be manually controlled, or left to nature? Several bifurcations are protected in national parks, but others are not; how can these interesting features be preserved and studied?

5 Conclusion

We described nine unusual drainages in North and South America that are exceptions to the rules of hydrology. They are rivers that bifurcate into different basins or lakes that have multiple outlets to different basins. Some exemplify water bodies in formation; others exemplify water bodies caught in sensitive topography; other exemplify water bodies whose flow direction is determined by wildlife. Some water bodies are streams small enough to step over and others are lakes over 100 km long. Some are remote and wild; others are highly developed and controlled. Each is unique in its own way. Together, these hydrologic oddities illustrate how much we have still to learn about Earth's dynamic surface.

Open Research

No datasets or code were used or generated during the study.

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