Ralph Parshall and Water Engineering in Northern Colorado[1]

Michael Weeks

Early in the summer of 1874, Fort Collins was one of a handful of recently settled agricultural towns situated in Northern Colorado along the banks of the Cache la Poudre River. Like every settlement in the area it depended on irrigation for its existence. Parched by drought that year, Fort Collins' farmers chose a path of dubious legality: they drained the Cache la Poudre River dry to feed their thirsty crops. While this may have saved the day for Fort Collins farmers, it enraged downstream users who depended on that same water. The town of Greeley was chief among them. Originally named the Union Colony in 1870, Greeley was a cooperative venture founded by New York newspaper editors Horace Greeley and Nathan Meeker. And, the vast majority of water users in Greeley had claimed the right to draw water from the Cache la Poudre River prior to the residents of Fort Collins. So, naturally, they cried foul at Fort Collins' usurpations. Finally, amidst threats of armed conflict, Fort Collins farmers agreed to release some of the river's flow. Heavy late summer rains dampened further conflict. Prior to 1874, Greeley residents trusted that their earlier appropriation of water would protect them from later arrivals who settled upstream. As a result of the conflict with Fort Collins, Greeleyites pushed for laws that would recognize their right to divert water before those who arrived after them.[2]

Michael would like to thank the Poudre Heritage Alliance for their generous funding as well as the following individuals who shared their time and expertise: Tom Trout, Robert Ward, Kathleen Benedict, Harold Duke, Gordon Kruse, Ray Chamberlain, Thomas van Putten, James Hansen. Michael is also grateful to Patricia Rettig and the excellent she and her team of students do at the Water Resources Archive at Morgan Library on the Colorado State University Campus. Most of the archival research for this article was found there.

[1] A condensed version of this article, tentatively titled "Measuring Expertise: How Engineers and Water Managers Shaped Irrigation on the Plains from 1910-1940," will appear in *The Greater Plains: Rethinking a Region's Environmental Histories* (Forthcoming, University of Oklahoma Press).

[2] David Boyd, *A History: Greeley and the Union Colony of Colorado* (Greeley, Colo: Greeley Tribune Press, 1890), 29–64; James F. Willard, *The Union Colony at Greeley, Colorado, 1869-1871*, University of Colorado

Over the next decade, as Colorado transitioned from territory to state status, the new entity developed a sophisticated set of water laws that prioritized water access based on the seniority of the users' claims and on whether users were able to put that water to what the law termed 'beneficial use.'[3]

While legal statutes could clarify water rights on paper, they could not measure allocations equitably. And this was no small matter. Water is a slippery resource that defies quantification. In a river, water rushes downhill in torrents or backs up into calm pools. The same stream that rages in June can run dry October, or dive underground in one spot only to reappear magically downstream. Moreover, rivers carry more than water as they carve their way downward. Natural erosive forces tear sand, silt, and minerals from the land, and deposit them downstream. Determining the quantity of water carried by a stream is no easy task. Moreover, breaking water into measurable units required expertise beyond that supplied by farmers and legal experts. It required engineering.

During the first half of the twentieth century, no individual contributed more to fairly and effectively distributing water to farmers than Ralph Parshall. Born in Golden, Colorado in 1881, Parshall spent his entire life in Northern Colorado. Over a career that spanned nearly fifty years, Parshall worked as an irrigation engineer for Colorado Agricultural College (CAC) and the United States Department of Agriculture (USDA). Parshall's greatest contribution to efficient water management came from a device he invented with the help of graduate students at CAC. Eventually named after him, it was called the Parshall Flume, and it revolutionized the

---

Historical Collections, v. 1 (Boulder, 1918) xiv–xxxi; Rose Laflin, *Irrigation, Settlement and Change on the Cache la Poudre River* (Fort Collins: Colorado Water Resources Research Institute, 2005) 16–22.

[3] On the development of the Doctrine of Prior Appropriation see David Schorr, *The Colorado Doctrine: Water Rights, Corporations, and Distributive Justice on the American Frontier*, Yale Law Library Series in Legal History and Reference (New Haven [Conn.]: Yale University Press, 2012).

measuring of water in canals and ditches, making water diversion more equitable. Over the course of his career, Parshall worked out the complex math necessary for installing flumes that could measure water in ditches less than a foot wide all the way up to canals that spanned fifty feet in width.[4] Today, Parshall Flumes remain ubiquitous in canals and ditches in Colorado and throughout the world. Parshall also engineered devices that could remove sand and silt from irrigation canals and was responsible for leading a team of scientists who measured annual snowpack in the South Platte watershed so that water users could predict the quantity of water available in a given year. Additionally, Parshall researched and wrote the primary economic analysis in support of the Colorado-Big Thompson Project – a massive trans-mountain water diversion project that added twenty percent more water to the South Platte watershed. Despite his relative obscurity, Parshall left a legacy beyond measure.

The geography and year of Ralph Parshall's birth illuminate vital facts that are essential to understanding his career and impact. Parshall was born in Golden, Colorado on July 2, 1881 to Eliza and Thomas. That year, the Colorado Supreme Court handed down its most pivotal water decision in a case called *Coffin v Left Hand Ditch.* That case essentially confirmed that water in Colorado streams would be distributed according to the seniority of a users' water rights. Further, it authorized water users to cross private property lines in order to obtain their lawful share of water.[5] Though not a legal scholar, Parshall nonetheless spent much of his career engineering irrigation works so that they could accurately distribute water in accordance with that 1881 court case. It is also instructive to note that Parshall's birthplace, Golden, situated

[4] Gordon Kruse and Wayne Willis, "Role of the Parshall Measuring Flume in Water Conservation," July 1, 1985, Irrigation Research Papers, Water Resources Archive, Colorado State University (hereafter Irrigation Papers), Box 63, folder Dedication Ceremony.

[5] Schorr, 9-64.

along the banks of Clear Creek, is one of the primary mountain streams providing irrigation water to Northern Colorado farmers. During his formative years, Parshall witnessed firsthand the region's dependency on water even as irrigators struggled to harness nature so that it would offer a predictable supply. Parshall's ability to communicate effectively to Colorado farmers throughout his career was borne out of a life lived in close proximity to them.

From 1899-1904, Ralph Parshall studied civil engineering at CAC where he was actively engaged in both studies and extra-curricular activities. Studying under irrigation engineer Louis Carpenter, Parshall was elected Secretary Treasurer of the Colorado Civil and Engineering Society in 1902. Records show that Parshall also participated in oratorical competitions, plays, and the college orchestra as second violinist. In May, 1904, Parshall graduated with the highest grade point average of any student in the engineering department, earning the Langridge Gold Medal for the Best Scholarship at CAC in 1904. After graduating, he worked at the state engineer's office in Denver. Among his many assignments during the next two years, Parshall surveyed reservoir sites to expand water storage and rail lines used to transport sugar beets, the region's most lucrative crop, to factories in the Arkansas Valley. In June, 1906, Parshall married Florence Stuver of Fort Collins. The two then spent one year at the University of Chicago, where Parshall completed a graduate degree in physics.[6]

After completion, Parshall was hired at CAC in the physics department, but was quickly transferred to the Department of Civil Engineering prior to the fall of 1907. For the next six years Parshall taught several courses in the department, but his practical research always focused on hydrology and irrigation engineering. During that period, Parshall was actively involved in the construction of reservoirs, dams, and irrigation canals, occasionally leading CAC students on

[6] *Fort Collins Weekly Courier*, 19 November 1902, 17 February 1904, 1 June 1904, 10 August 1904, 5 July 1905, 13 June 1906, 11 September 1907; *Colorado Transcript* [Fort Collins], 2 June 1904.

trips to complete the work. It was clear from the start of Parshall's academic career that he had a clear sense of the practical applications of his engineering work. Within a few years of his hire, Parshall was contributing pragmatic irrigation knowledge to Colorado newspapers. For example, in a series of articles written in 1911 and 1912, Parshall explained how farmers should best conserve their water, how to rotate crops in order to retain moisture in soils, and how flood irrigation failed farmers from the standpoint of economics and soil and water conservation. During this period, Ralph's wife Florence gave birth to two children, in 1907 and 1913.[7] In addition to teaching at CAC, Parshall remained closely tied to the social life of his alma mater playing the violin at college functions and even participating in faculty/student sporting competitions. However, Parshall's formal employment with the university came to an end in 1913 when he took a position as an Assistant Irrigation Engineer with the Bureau of Agricultural Engineering of the USDA.

On the surface, Parshall's new position appeared to be a significant change. In reality, it was not. Understanding that requires some historical context and perspective. As Colorado's original land grant college, CAC received its founding mandate from the Morrill Act of 1862 which provided federal support for the establishment of colleges in every state. The principal purpose of the Morrill Act was to support the development of the agricultural and mechanical arts. Though not directly stated, it implied that land grant colleges would collaborate with researchers at the USDA. That relationships was codified in law in 1887 when Congress passed the Hatch Act which established experiment stations that focused on applied agricultural science. Experiment stations were physically located at land grant colleges but overseen by the USDA. Congress further solidified that relationship in 1914 when it passed the Smith-Lever Act,

[7] *Weekly Courier*, 11 September 1907, 12 August 1908, 6 September 1908, 7 April 1911, 25 April 1913.

establishing extension services throughout each state responsible for disseminating the research findings of USDA and land grant scientists to farmers. Though territorial battles between land grant researchers and those at the USDA sometimes erupted, over time, state and federal researchers developed collaborative projects, shared data and resources, co-authored articles, and conducted farm demonstrations together. Colorado State University historian James Hansen has argued that "there was almost a symbiotic relationship between the two."[8] For Parshall, this meant that he worked alongside the same CAC employees he had worked with previously, in the same engineering building-designed by Louis Carpenter, Parshall's undergraduate adviser-and on many of the same projects.

In taking the USDA position, the most significant change came from how Parshall allocated his time. Officially divorced from the teaching requirements of university employment, Parshall could focus full-time on research. However, Parshall was still reliant on CAC campus facilities. And, when Parshall began his career in 1907, the university did not possess a lab capable of modeling irrigation research. Without this, Parshall and his colleagues could not simulate their research in real-world conditions. The design and use of hydrology labs for irrigation investigations would occupy much of Parshall's early career with the USDA, and from those labs would emerge his most important breakthroughs.

Victor Cone, the director of USDA's irrigation investigations unit, and Parshall's colleague stationed in Fort Collins, was also concerned with the lack of suitable irrigation laboratories. Like Parshall, he viewed the need for fair and accurate measurement of irrigation water as a paramount concern. Cone opined that most research on water measurement prior to

---

[8] Charles E. Rosenberg, *No Other Gods: On Science and American Social Thought*, Revised and expanded ed. (Baltimore, MD: Johns Hopkins University Press, 1997), 153–99; Jim Hansen, interview by author, Fort Collins, Colo, 13 July 2017.

1913 was designed for hydropower facilities that operated under water pressures far in excess of those found in irrigation canals and ditches. The same research, when applied to diverting water to farmers, yielded gross measurement inaccuracies. The result, according to Cone, was that "theory and the practice have often been at variance." Animated by the need for a hydraulics lab designed for the needs of agriculture, Cone and Parshall completed designs for a lab in 1912. Built with the labor of college students and funded jointly by the USDA and CAC, it was completed in May, 1913 on the CAC campus. The USDA contracted with the City of Fort Collins to provide water. However, that water could only generate a flow of 20 cubic feet per second (cfs), so Parshall and Cone designed two small reservoirs on a small hill above the laboratory. Gravity, in coordination with electric pumps, facilitated more pressure and researchers could calibrate the quantity and velocity of the water that moved in and out of the building.[9]

[9] V.M. Cone, "Hydraulic Laboratory for Irrigation Investigations, Fort Collins, Colo., *Engineering News*, Vol. 70, No. 14, 662.

Figure 1. Left, Ralph Parshall; Right, Victor Cone, circa 1917. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

No research subject occupied Parshall's time more than accurately distributing water to each of Northern Colorado's shareholders-and with good reason. If water was abundant in Northern Colorado, concerns over water measurement would be purely academic. Of course, it was not. Every last drop was allocated via Colorado's prior appropriation system. When all of the South Platte's tributaries are considered the river carries an annual average of 1.6 million acre feet of water, paltry when compared to the 15 million acre feet carried by the Colorado River, or the astounding 190 million acre feet carried by the Columbia River.[10] During Parshall's early career, he witnessed water demands increase dramatically, in large part due to the growth

[10] An acre-foot is the amount of water necessary to cover one acre of land in a foot of water. It is the measurement most commonly used by farmers to describe their water appropriations. When feasible, the acre-foot will be the unit of measurement used in this article.

of the beet sugar industry. Between 1901 and 1914, sugar beets went from a novelty crop in Northern Colorado, to center of the region's most important industry, providing the nation with over 20% of its domestic sugar. As farmers oriented their crop rotations around sugar beets – a thirsty crop - their water requirements grew apace. Between 1900 and 1920, the state led the nation in irrigated acres, and Northern Colorado dominated irrigated agriculture in the state. In 1930, the South Platte Watershed boasted 1.4 million irrigated acres, 40% of the state's total. Where water flowed, so did money. The value of water rights for irrigation from the Cache la Poudre averaged $400 apiece in 1880, and $4,500 in 1917. Lands with excellent water rights, such as those near Greeley, had escalated in value as well. By 1922, land near Greeley was going for more than $300 per acre. Back in 1870, $300 could buy eighty acres of Union Colony lands. While numerous factors played roles in land value escalation, water was prime among them. According to Fort Morgan's newspaper, when local boosters and farmers combined forces to build Jackson Lake in 1904 – making more water available to local farmers - "application of the lake water had almost a magical effect upon land values. Land(s) that had been offered for $50 per acre the previous year doubled (in value) almost overnight, and have continued to rise…" While perhaps hyperbolic, the newspaper's claims accurately correlated irrigation water with farmers' livelihoods. Parshall occupied himself with the irrigation engineering necessary to sustain those livelihoods.

As Parshall viewed it, the single most significant barrier to efficient water management was measurement. He argued that at least 25-30% of water was unavailable to junior appropriators due to measurement inaccuracies that enabled senior appropriators to take far more than their legally allotted share of water. Parshall further argued that only one-quarter of all water in the South Platte watershed was measured accurately as late as the 1920s. The most common devices at the time used to measure water volume and flow were the weir - generally installed at diversion dams and in canals and ditches - and the rating flume - more commonly placed in streams. Both devices were situated in waterways and calibrated to measure the volume of water passing a particular point based on a known flow and the depth of water in the channel. This enabled irrigation companies to measure the water passing through their main canal, into their reservoirs, and through the ditches that carried water directly to farmers. Unfortunately, the devices were only known to be accurate at the moment of installation. In his numerous writings, speeches, and radio addresses, Parshall emphasized how changing conditions caused gross inaccuracies. Conditions upstream of weirs and flumes altered depth and flow. Gravel and sand built up in a particular spot, while tree branches and debris clogged waterways, causing water to pool at greater depths in one location and allow it to flow swift and shallow in others. Any of those factors could hinder accurate gauge readings. The floors of the flumes and weirs themselves were problematic. Irrigators placed the devices in a level spot on channel floors so that depth could be accurately measured. This presented particular problems when sand and gravel accumulated in the flume. When this happened, the gauges misread the depth of the water, leading water managers to conclude that there was less water in the channel than in reality.[11]

[11] Ralph Parshall, "The Improved Venturi Flume," 18 March 1927, Irrigation Papers Box 7, Folder Agricultural Radio Program, KOA; Parshall, "Importance of Measuring Irrigation Water," Ralph L. Parshall Collection, Water Resources Archive, Colorado State University (hereafter Parshall Papers), Box 1, Folder KOA Radio Talks, 1931-1935.

Figure 2. A Typical weir. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

It was at CAC's new irrigation lab that Victor Cone initiated experiments with a new measuring flume that Parshall would eventually perfect. Named the Venturi Flume, it was based on experiments performed by Italian scientist and philosopher Giovanni Battista Venturi in 1797. Venturi Flumes were meant to be placed in irrigation canals and ditches and were intended to create controlled and measurable flows by generating the critical water flows necessary to measure flow. They contain three sections. In the upstream portion of the flume, also called the convergence section, water is forced into an increasingly narrow channel until it enters the narrowest portion of the flume called the throat. As designed by Cone, the throat was one foot long and contained a floor that was level with the irrigation channel. At the downstream end of the throat, the flume's divergence section widened until it was the same width as when water entered the structure. Venturi designed the divergence section to be the same length as the convergence section. In order to get an accurate measurement, Cone placed rating devices at the midway points of the convergence and divergence sections. The Venturi Flume was simple to operate, relatively inexpensive, and contained no moving parts. Writing in 1921, Parshall stated that the Venturi Flume had an error factor of less than 5%.[12]

Under most irrigation applications, the Venturi Flume was a significant improvement over previously available technologies, and some farmers and irrigation companies in Northern Colorado had begun to install them. Yet Parshall noted several problems with the Venturi Flume.[13] First, he observed that downstream conditions could still alter measurements significantly. Unless the flume were re-calibrated constantly, conditions could noticeably impact accuracy. This presented practical problems for ditch companies and engineers who would be responsible for the labor of monitoring and removing downstream obstacles. Also, Parshall noted that the design required not two but four measurement points inside the flume for greater accuracy. If any of the four measuring devices failed to read accurately, the flume would produce inaccurate readings. Each added piece represented increased possibilities for flume failure. Finally, Venturi Flumes could clog with silt, sand, and debris, also impairing accuracy and requiring costly maintenance. Despite this, Parshall was convinced that the essential design was excellent and could be improved upon.[14]

Parshall's hurdles went beyond design to available facilities. While the hydraulics lab at CAC offered opportunities to model and calibrate measuring devices it was limited by weak water pressure. In order to calibrate flumes for larger canals and ditches, the Bureau of Agricultural Engineering (BAE) signed a temporary agreement with Cornell University,

[12] Parshall and Carl Rohwer, *The Venturi Flume* (Fort Collins: The Agricultural Experiment Station of the Colorado Agricultural College, 1921).

[13] Sometime between 1914 and 1918, Victor Cone left his position with the USDA in Colorado. From that point forward, Parshall assumed most of the labor in improving the Venturi Flume.

[14] Parshall and Rohwer, *The Venturi Flume.*

allowing Cone and Parshall to briefly test Venturi Flumes at up to 400 c.f.s. (cubic feet per second). However, this was not a long-term solution. Consequently, Parshall cast about for a lab location that would supplement his on-campus work. In 1919 he found it. Located just east of the tiny town of Bellvue and eight miles from CAC, the Jackson Ditch Company had built a diversion dam to siphon water to their users. The dam, situated on the Cache la Poudre River added additional water pressure to a river that, for much of the year already offered greater flows than could be achieved at the campus lab. Parshall then requested that the ditch company enable him to cut a channel in the side of the Jackson Lake Ditch through which he could conduct his experiments prior to returning the water back into the river. Seeing that Parshall's experiments had the potential to benefit water management and possessing a positive view of CAC, the ditch company agreed. So, Parshall partnered with fellow BAE researcher Carl Rohwer to build a concrete channel that fit neatly between Jackson Lake's diversion and the river. When completed, the Bellvue lab, as it was called, was 150 feet long, 14 feet wide, and 6.5 feet deep and constructed of reinforced concrete. It boasted an adjustable headgate where the researcher could vary flows, and a weir at the downstream end over which water spilled into an earthen channel that returned water to the river. Parshall began to perform experiments at the Bellvue Lab in May, 1920. Though no formal contract was signed with the Jackson Ditch Company until 1952, irrigation research continued uninterrupted until then. Parshall now possessed an on-campus lab where flumes could be designed, built, and tested under theoretical conditions, and a field lab that allowed him to evaluate his work in real-world conditions.[15]

[15] Peter van Putten, interview by author, 18 July 2017; Susan Boyle, National Park Service, Fort Collins to Roger Morgan, Jackson Ditch Company, Fort Collins, "Letter in Support of Historic Designation for Bellvue Irrigation Hydraulic Laboratory," 21 May 2003, copy in possession of author; Parshall to O.C. Merrill, Stockholm, Sweden, "Report on the Hydraulic Laboratories in the United States," 16 May 1933, copy in possession of author.

Figure 3. Water passing through riffle deflectors during an experiment at the Bellvue Hydraulics Lab. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

During the early 1920s Parshall was busy developing what was initially called the Improved Venturi Flume. Parshall, with labor and support from BAE and CAC's experiment station, capitalized on the previous work of hydrologists who had determined that there was a unique relationship between the depth of water and its flow. In streams where water slows and appears to stagnate, deep pools are often formed. At the downstream end of that pool, the flow increases and the stream becomes shallow. Hydrologists had identified what they called "critical flow," the point where water transitioned from slow and deep to fast and shallow. They also identified a critical depth at which that flow could be accurately measured. Parshall developed flumes that could generate critical flows in irrigation ditches. These flows were ordinarily not possible in irrigation canals since engineers and farmers dug their ditches with minimal slope. This resulted in slow-moving waters that were ideal for delivering water but not for measuring it. To solve this, Parshall placed his flume on the floor of irrigation canals and ditches, across their entire width. As with the original Venturi Flume, water entered the flume and converged into a narrow section called the throat. In the throat of the flume, Parshall introduced something new - a downward slope significant enough to replicate the critical flow found in natural streams. He then installed a water gauge at a single point in the convergence section to measure its volume. Water then emerged out of the throat, through the divergence and eventually back into the channel. The flume effectively solved the problem of upstream and downstream obstacles. As long as critical flow could be introduced within the flume, conditions in the irrigation canal might impede water but not its measurement. The Improved Venturi Flume also minimized complications from debris within the flume itself. Critical flow generally introduced enough force to clear obstacles that might otherwise accumulate on the flume floor. According to tests made by Parshall and his students, this new innovation had an error factor of less than 3%. If Parshall's estimates were correct, this breakthrough could make 20% more water available in the South Platte watershed by simply measuring water fairly and accurately.[16]

[16] Parshall, "Improved Venturi Flume"; Chris Thornton, interview by author, 22 December 2015; Parshall, 14 March 1932, Parshall Papers, Box 1, Folder KOA Radio Talks.

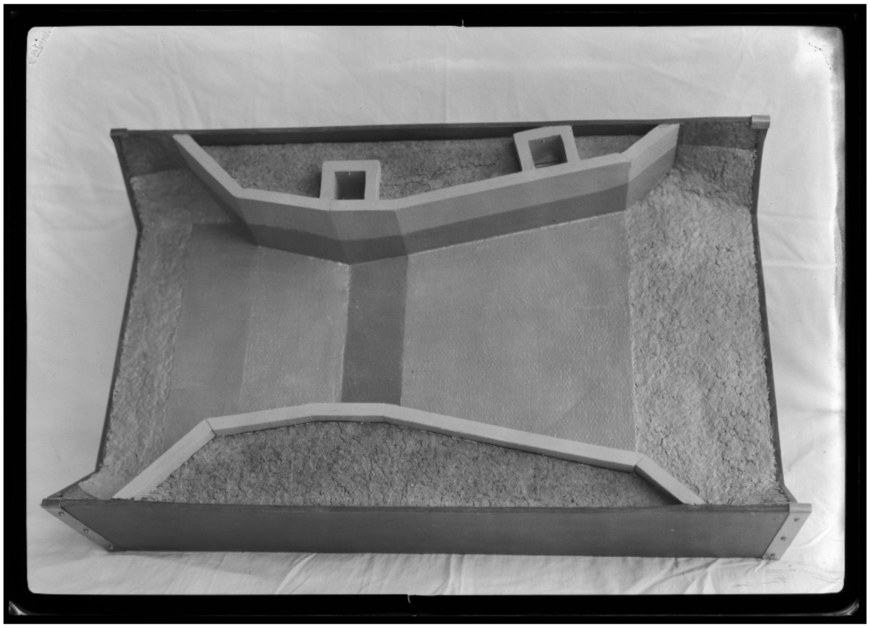

Figure 4. Overhead view of a Parshall Flume (called an improved Venturi Flume until 1930). Water flows in from the right through the convergence section. The throat, where Parshall introduced a drop, is the narrowest portion. Water exits the Flume through the divergence section to the left. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

The Improved Venturi Flume had several additional advantages. First, like Cone's model, it possessed no moving parts, and "has plane surfaces and may be constructed in the field." They could be built of wood, concrete or, for small industrial applications, sheet metal. Further, by 1923 Parshall had developed a single measuring gage that could be placed inside the flume, along with a stage recorder that provided flow readings. Those who maintained irrigation canals – commonly called ditch riders – used the stage recorders to determine if water users within their ditch company were receiving their legal shares of water without siphoning off more than their fair share.[17]

The Improved Venturi Flume quickly found wide usage. The first recorded flume to be used in the field – at Rocky Ford, on the Arkansas River – possessed a six foot wide throat and

[17] Kruse and Willis, "Parshall Measuring Flume."

was constructed of wood. By 1927, when Parshall gave his first radio address on the flume, it was in wide use in the Arkansas Valley, was finding applications in western Colorado, and had been installed in Hawaii, South Africa, Argentina, Honduras, and Canada. Five years later, a Colorado newspaper reported that 1,500 of these flumes were operating throughout the state and the flumes were being used in municipal sewage systems in Los Angeles, South Carolina, and New York State.[18]

Figure 5. Forty foot Parshall Flume installed near Ft Lyon, Colorado, near the Arkansas River in 1932. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

One of the primary reasons the Improved Venturi Flume found such wide usage had to do with Parshall himself. Soon after Parshall completed his initial design and testing for the Improved Venturi Flume, he began working out the mathematical formulas necessary to build

[18] *Ibid;* "1,500 Parshall Irrigation Flumes Being Used in State," *Craig Empire Courier*, 20 July 1932.

flumes with a host of throat widths that could measure water within a variety of canals. In addition, though Parshall's position with the USDA did not require him to conduct demonstrations in the field to farmers, he eagerly took on that responsibility. Further, Parshall frequently appeared as a guest on radio programs, touting the flume's advantages. According to Thomas Trout and Harold Duke, long-time engineers for the USDA, this was unusual. USDA researchers were not responsible to bring their findings to users. That was the job of experiment station and extension employees. According to Trout, Parshall willingly took on that role. Thus, while the invention of the Improved Venturi Flume constituted a major advance in irrigation engineering, Ralph Parshall's promotional work and his willingness to adapt the new flume to agricultural and industrial needs may have been equally important.[19]

In December, 1929, Parshall's work was formally recognized within the engineering community. Five years previous, the Special Committee on Irrigation Hydraulics within the American Society of Civil Engineers had selected the measurement of irrigation water as one of the ten most important subjects for research in the field. Three years later, Parshall wrote "The Improved Venturi Flume," which was published both by the Society and by CAC's Experiment Station. While Parshall's letters and public correspondence reflected modesty regarding his work, the Society thought otherwise. Recognizing that the improvements on the original Venturi Flume involved a significant advance in irrigation technology, the Special Committee on Irrigation Hydraulics recommended that the Improved Venturi Flume be renamed the Parshall Measuring Flume. Parshall's supervisor with BAE, W.W. McLaughlin, and Charles Lory, president of CAC, agreed. The matter was then submitted to Clemens Herschel, inventor of the

[19] Tom Trout, interview by author, 18 July 2017; Kruse and Willis, "Parshall Measuring Flume."

Venturi meter for consideration. Herschel wholeheartedly agreed with his colleagues. The Improved Venturi Flume has been referred to as the Parshall Flume ever since.[20]

The Parshall Flume quickly became the most important tool for measuring water in ditches and canals and found wide application beyond agriculture. By the time Parshall published his final article on the flume in 1953, he had calibrated flumes whose throats ranged from just a few inches wide up to fifty feet. Parshall flumes could measure flows from 1 to 3,300 cfs. Through his employment with the USDA, Parshall designed flumes for steel companies, municipalities, waste management, and paper manufacturing. Parshall occasionally altered the basic design of the flume to accommodate for canals with atypically steep elevation drops. At Parshall's death in 1959, his flume was among the most widely used devices for measuring water in the world. Presently (2018), it remains ubiquitous and many of the flumes installed in Parshall's lifetime remain in place, measuring flows for well over half-a-century.[21]

Ironically, while Parshall Flumes were quickly adapted to a host of uses, their integration into Northern Colorado ditches and canals was relatively slow. Why was that? The answer is found more in the practical politics of water than in its engineering. Stockholders in irrigation companies received their water allocations based on measurements in ditches and canals. Since older technology often registered flows that were lower than the reality, irrigators were actually receiving more water than these outdated gauges showed. Installing new Parshall Flumes would require ditch companies to collect money from their stockholders for the installation of devices that could potentially reduce their allocation of water. Further, when it came to their most

[20] "Proceedings of the American Society of Civil Engineers," May 1930, Parshall Papers, Box 9, Folder Articles on Parshall and the Flume.

[21] Harold Daubert, "The Parshall Flume," *The Slide Rule*, Colorado State University, Vol. 3, No. 2 (1960); Parshall, *Parshall Flumes of Large Sizes*, (Fort Collins: U.S. Department of Agriculture, 1953); Gordon Kruse, Interview by author, 21 July 2017; Kruse and Willis, "Parshall Measuring Flume."

important resource, farmers and their irrigation companies did not wish to invest money on new technology, especially when it might curb their water allocations. As irrigation engineer Chris Thornton pointed out, "there is something inherently conservative in ditch companies; they don't want to spend money and they don't want to mess with (their water)." As long as they received their water, farmers had little interest in altering the system that delivered it to them.[22]

Of course, Parshall disagreed since he sought to correct the same inefficiencies that allowed some water users to take more than their fair share. To understand Parshall's conflict with irrigation companies, it is essential to see him beyond the narrow confines of engineering. Parshall was also a crusader for efficiency, and a Northern Colorado native who possessed an abiding interest in the region. As Parshall surveyed how water was employed throughout the region, he observed that humans failed to manipulate water as they should, and he concluded that technocratic solutions were necessary in the engineering of water and in its governance. For example, in 1922 Parshall provided one of the first complete expositions of water seepage in the region. His research showed that 30% of all the water withdrawn from the watershed returned back to it as a result of seepage. In financial terms, Parshall calculated that this water was worth $2 million annually. According to Parshall, Colorado farmers should be alarmed that so much of this water flowed out of the state into Nebraska when the system could accommodate more downstream reservoirs. Parshall measured water efficiency in quantities of crops as well as money earned. In advocating for two new dams on the Cache la Poudre River in 1925, Parshall's metric was Colorado's most lucrative crop, sugar beets, stating that these dams would provide the necessary water to grow two additional tons of beets per acre. Elsewhere, Parshall complained that reservoirs were notoriously leaky, losing half of their water to seepage and

[22] Chris Thornton Interview.

evaporation, implying that farmers could have more secure water supplies if only they invested more money – through their irrigation companies - in the modern engineering necessary for delivering this precious resource. If water draining from creaking structures presented one kind of inefficiency, then water that failed to drain presented another. Parshall pointed out that plenty of good farmland was out of production because farmers either applied too much water to their lands, or water seeped onto their lands from neighboring farms. Better drainage could add more water into the system, and it involved the simple technique of installing underground tiles to divert water to the nearest waterway. For Parshall, engineered solutions, many of them quite simple, would alleviate the Piedmont's water woes and foster a more productive and lucrative agriculture.[23]

Then why were these solutions not employed more consistently? For Parshall, much of the answer lay in what he viewed as outdated business practices. He decried what he saw as the "lax and crude methods" characteristic of mutual irrigation companies. According to Parshall, addressing problems such as seepage in leaky reservoirs and ditches, draining flooded farmland, and building new storage to corral return water were all primary responsibilities of irrigation companies. Parshall opined that these companies lacked the foresight to plan for their water futures, and consequently were unwilling to invest the money necessary to upgrade their aging systems. Moreover, Parshall argued that mutual irrigation companies were "managed by men with limited business experience" who "lack aggressiveness and individuality of purpose." Believing that effective management required centralized control over irrigation waters, Parshall argued that "it will be necessary to combine several units into a common organization and operate the federated systems under efficient management." Parshall further stated that, as the

[23] Parshall, *Return of Seepage Water to the Lower South Platte River in Colorado*, Bulletin 279 (Fort Collins, Colo: Agricultural Experiment Station of the Agricultural College of Colorado, 1922).

region's population continued to increase and the demand for water with it, irrigation management would need to be run by a group of specialists with business acumen, implying that small irrigation companies led by farmers/stockholders were incapable of managing water effectively.[24]

While Parshall never advocated vesting these powers in agents of the state directly, his belief that resources such as water should be managed by a group of specially trained experts reflected his support of progressive ideals. Though not trained by Elwood Mead, Parshall's viewpoints reflected Mead's desire to employ public science to manage water more efficiently. In describing some of the same inefficiencies in water management in 1903, Mead argued, "if the water of streams is public property, the public should show the same business ability in disposing of its property as those to whom the control is transferred."[25] By that philosophy of conservation, resources should be put to their highest use and not wasted. Leaky reservoirs, failure to use flows that returned to streams, unbuilt storage, and water flowing out of the state untapped by farmers were all examples of waste in the system. According to Parshall, centralized control of water resources by irrigation experts would plug many of the gaps left by poor management.

Parshall's faith in technocratic expertise also helps to explain his particularly instrumental view of rivers. As a water engineer, Parshall's work drew fairly clean lines between conservation and preservation. When evaluating a river, he was concerned with its ability to supply water for people in perpetuity. Water unappropriated for human use was water wasted.

---

[24] Parshall to Gillette, 30 April 1925, Irrigation Research Papers, Box 5.

[25] Elwood Mead, *Irrigation Institutions; a Discussion of the Economic and Legal Questions Created by the Growth of Irrigated Agriculture in the West*, Use and Abuse of America's Natural Resources (New York: Arno Press, 1972), 167.

Further, the highest and wisest use occurred when the same water could be employed on multiple occasions, which is why Parshall valued return flow so much. It also explains his disdain for the management practices of mutual irrigation companies. By allowing so much water to be lost to seepage, poorly measured allocations, and ditch-side vegetation that gulped the passing flow, Parshall believed that these water managers were not just incompetent but also poor conservationists. Parshall did not value river water for its mere existence in the stream, for its support of flora and fauna, or for its ability to create esthetic beauty. Those were desirable only insofar as they supported a resource that could be renewed and re-used in perpetuity.[26] Moreover, as an engineer, his primary interaction with water occurred after it had been drawn from streams, when it flowed through engineered channels and into constructed lakes. The pre-eminent value of a watershed was in its ability to deliver water efficiently and in sufficient quantities. As an irrigation engineer, his primary purpose was to make a watershed yield the greatest quantity of usable water. And the highest praise Parshall could give to water managers was that they wasted not a single drop of the resource they were entrusted with.

The failure of irrigation companies to quickly integrate Parshall Flumes into Northern Colorado agriculture figured heavily into Parshall's crusade for efficiency and in the specifics of his message. From the late 1920s through the 1930s, Parshall was a regular guest on the radio station, KOA. Nicknamed "the blowtorch of the West," KOA broadcast radio shows throughout Northern Colorado. Since Parshall grew up around farmers in the region and interacted with them regularly through his work, he understood quite well how to appeal to this target audience. During several interviews, Parshall argued that accurate water measurement would result in

---

[26] The literature on the conservation/preservation divide is extensive. For a historical explanation see Thomas Wellock, *Preserving the Nation: The Conservation and Environmental Movements, 1870-2000*, (Wheeling, Illinois: Harland Davidson, 2007), 13-73.

better farmers. Pointing out that too much irrigation could often be just as detrimental to a crop as too little, he stated that Parshall Flumes would enable farmers to know exactly how much water they were applying to their crops, facilitating better harvests and more wealth. Speaking to the junior appropriators in the region, he called attention to their stresses over water scarcity, stating that better measurement would result in more water security since senior appropriators could not take more than they were allotted. He also appealed to the time and money saved through technical improvements, arguing that the critical flows generated by the Parshall Flume made it effectively self-cleaning, saving the time and money usually needed to clean debris from ditches. Parshall tugged at notions of fairness and logic, arguing "it is just as reasonable to have one's water measured as measuring one's crop for sale." Throughout all of his broadcasts, Parshall played the role of educator, explaining how his flume operated, hoping for converts amongst those who doubted its engineering or were repelled by their own lack of installation know-how. Parshall had long been a champion of technocratic efficiency. The radio offered him the platform to broadcast his ideas.[27]

The simplicity, relative cost-effectiveness, and accurate measurement offered by the Parshall Flume were essential in the device's eventual adoption in the South Platte watershed. However, for some irrigation companies, it was neither accurate measurement nor Parshall's public arguments that eventually carried the day. For irrigation companies such as the Louden Ditch Company and Home Supply, which watered lands near Loveland, timing and public aid were the key factors. The simple fact was that irrigation works designed around 1900 or before were wearing out, and irrigation companies slowly conceded that they would suffer financially if they did not upgrade. Louden and Home Supply installed Parshall Flumes throughout their

[27] Parshall, "Suggestions for Increasing our Irrigation Supply," 14 September 1931, 14 March 1932, 1 April 1932, 1 May 1933, Parshall Papers, Box 1, Folder KOA Radio Talks, 1931-1935.

systems beginning in the late 1950s when the federal government made attractive loans available to upgrade crumbling infrastructures.[28] While various factors played a role in the delay, there is no doubt that the conservative nature of irrigation companies and the fact that the flume would hold senior water rights holders more accountable for overuse of water were certainly important. Regardless, Parshall Flumes became nearly universal in canals and ditches. According to Peter van Putten, former ditch rider for the Jackson Ditch Company, a Parshall Flume exists at practically every point of river diversion and just beyond every lateral headgate in Northern Colorado.[29]

While the bulk of Parshall's research revolved around precise water measurement, when it came to efficient use of water resources, Parshall weighed in on a host of subjects pertinent to Northern Colorado farmers. Storage reservoirs occupied much of his thinking. Since the bulk of irrigation water came from snow melt, and most of that snow melted between May and July, rivers carried elevated water volumes during those months. The only way to put that water to economic use was to store the excess volume. Of course, that meant building more reservoirs. Every irrigation company in the region had done this and was subject to specific rules for how much they could draw and/or the window of time within which they were allowed to divert. Depending on the seniority of the irrigation company's right, the storage capacity of their reservoirs, and the water quantity in a given year's snowpack they might have to release excess from their reservoirs. Parshall viewed this as poor conservation, bad economics, and inefficient farming. In 1925, he supported a plan that would have assessed farmers along the Cache La

[28] W. R Keimes, *Water: Colorado's Most Precious Asset : The Consolidated Home Supply Ditch & Reservoir Company Contributed to Its Development, 1881-1986* (Loveland, Colorado: Mile-High Printing, 1986), 17–39; Thornton Interview.

[29] Van Putten Interview.

Poudre River a one-time fee of $10-$15 per acre farmed in order to build two additional storage reservoirs along the river. Using the language of the region's most lucrative crop, Parshall argued that the additional stored water would result in, on average, two additional tons of sugar beets per acre. Insufficient support sank that project. Parshall also complained that reservoirs in the region were inefficient. Citing three reservoirs – Jackson, Prewitt, and Riverside – he claimed that evaporation and seepage caused these storage lakes to lose 50% of their water before it could be delivered to users. This was a plea both for more research on evaporation as well as a call for irrigation companies to shore up their leaky infrastructure. Parshall's push for efficiency extended as well to subjects such as snow surveys, draining waterlogged lands, and forestation – with the twin goals of adding more water into the system and accurately predicting how much water would be available.[30]

While Parshall struggled to gain converts for his gospel of efficiency on the Piedmont, he had little trouble finding those who simply wanted more water. In the tension between technocratic efficiency and decentralized control, all sides agreed that irrigating the arid landscape demanded more water. During the 1930s, farmers obtained it by convincing the Federal Bureau of Reclamation to build a massive project for moving water from the west side of the Continental Divide to Northern Colorado. The method was called trans-basin diversion. Simply put, it involved moving water from one watershed into another. Of course, it was not that simple because moving water between basins required forcing water to flow uphill before it could flow downhill. Hence, engineers had to manipulate the landscape to accommodate the unnatural act. In truth, trans-basin diversions were nothing novel in the 1930s. The 1882 Colorado Supreme Court decision, *Coffin v. Left Hand Ditch Co.,* established the legality of such

[30] Parshall to Gillette, 30 April 1925.

projects. The largest of these, The Grand River Ditch, transported water in an unlined ditch and wooden flumes to Fort Collins through an area that would eventually be added to Rocky Mountain National Park. By the early 1930s, there were several trans-basin projects that reversed the flow of waters from the wetter west slope of the Continental Divide to the arid east slope. In all, these projects accounted for more than 30,000 acre-feet of water, enough to provide sufficient irrigation to grow 12,000 acres of beets in an average year, or 7.4% of the total number of acres in beets in 1936.[31] This was more than a drop in the bucket, but it was not enough to meet the demands of Northern Colorado farmers and industry.[32]

Nature, politics, and economics conspired in the mid-1930s to resurrect a trans-basin project that transcended all previous efforts in scale and scope. Eventually named the Colorado-Big Thompson Project (C-BT), it tapped into Grand Lake, Colorado's largest natural body of water. Grand Lake is situated directly west of the Continental Divide from the major farming and population centers of Northern Colorado. Operating as a catch-basin for the headwaters of the Colorado River, Grand Lake's waters were coveted by regional farmers, boosters, and irrigation companies at least as far back as 1904. In fact, Parshall participated in one of those early engineering surveys as a graduate student at CAC.[33] However, the lake was situated at over 8,000 feet in elevation and the range of mountains arrayed between it and Northern Colorado

---

[31] The typical water requirement to grow an acre of beets in Colorado during the mid-1920s was between 2 and 2.5 acre feet. Experiments in the early 1930s suggested that yields would increase with slightly more water. Thus, I calculated water requirements for an acre of sugar beets at 2.5 acre feet. In 1936, farmers on the Piedmont contracted to grow 162,000 acres. See *Through the Leaves*, (January 1936): 3; Samuel Fortier, "Irrigation Requirements of the Arid and Semiarid Lands of the Missouri and Arkansas River Basins," *USDA Technical Bulletin 36* (Washington: U.S. Government Printing Office, 1928), 29.

[32] Christine Pfaff, *The Colorado-Big Thompson Project Historic Context and Description of Property Types* (Denver: Bureau of Reclamation, 1999), 76-87; Daniel Tyler, *The Last Water Hole in the West: The Colorado-Big Thompson Project and the Northern Colorado Water Conservancy District* (Niwot, Colo: University Press of Colorado, 1992), 3.

[33] *Fort Collins Weekly Courier*, 10 August 1904; *Colorado Transcript*, 31 August 1935.

hovered at a lofty 13,000 feet. Consequently, moving the water required boring through miles of rock, bringing into question the cost of such a project and whether engineers could accomplish the Herculean feat. Farmers, local boosters, and Great Western Sugar revived the project in 1933 as crop prices plummeted on the Piedmont and drought constricted the region's water supply. Based on preliminary estimates, early advocates projected that 285,000 acre-feet of water could be added annually to Northern Colorado's water supply through such a trans-basin diversion.

Five separate Northern Colorado counties and cities as well as Great Western Sugar lined up behind the idea. They formed the Grand Lake Committee and pooled their monies to fund a feasibility study. In 1934, the federal Bureau of Reclamation agreed to conduct engineering studies in advance of a project proposal. The Federal Public Works Administration then provided $150,000 to complete it. Over the next three years support for the project emerged from a variety of sources, including all but one member of Colorado's Congressional delegation, editors of all of the newspapers in Northern Colorado, a majority of local elected officials, mutual irrigation companies and their farmers/stockholders, and scientists such as Ralph Parshall.[34]

Two major hurdles stood in the way of this massive project. The National Park Service (NPS) initially blocked federal surveyors from entering Rocky Mountain National Park, arguing that their work constituted a commercial violation of the park's mission to preserve natural and scenic values and that the project would drive away tourists. However, since the 1915 act that established the park contained a clause allowing for reclamation projects, NPS eventually backed down in exchange for the rights to free power from the hydroelectric features of the water project and a guarantee that no future federal reclamation projects would be allowed in the national park. Edward T. Taylor, Colorado's lone congressman from west of the Continental Divide, also

---

[34] Tyler, *The Last Water Hole,* 26-36.

objected, arguing that a trans-basin diversion stole water from his constituents. As an influential and long-time member of the House Appropriations Committee, he could effectively withhold funding for the project. C-BT proponents eventually placated Taylor by agreeing to build a 150,000 acre storage reservoir west of the divide and placing it first on the construction docket. Called Green Mountain Reservoir, it would effectively replace some of the water lost to the C-BT by adding additional water storage on the west side of the divide.[35]

Approved by Congress in 1938 and finally completed by the Bureau of Reclamation twenty years later, the C-BT was a costly engineering marvel that eventually added 320,000 acre feet of water annually to Northern Colorado supplies. Put in perspective, that bolstered regional water supplies by 20%-the equivalent of doubling the entire average annual flow of the Cache la Poudre River. To divert the water to the eastern slope of the Rockies, engineers siphoned it from the Colorado River through four dikes and stored it in the massive 540,000 acre foot Granby Reservoir. They then pumped it nearly 200 feet uphill into the much smaller Shadow Mountain Reservoir, also constructed for the C-BT. Behind Shadow Mountain Reservoir, engineers constructed a channel to move water into Grand Lake. The water then entered the Alva Adams Tunnel just one-quarter mile outside Rocky Mountain National Park, emerging 300 feet east of park boundaries 13.1 miles later. From there, engineers diverted water into the Big Thompson River, as well as into a series of dams, tunnels, and canals. Finally, the water plunged 2,900 feet and through nineteen additional dams until it flowed into the irrigation canals of farmers in Northern Colorado. Though primarily intended as an irrigation project, the C-BT also supplied

[35] Tyler, *The Last Water Hole,* 26-57.

power and municipal water to local communities, including Boulder, Longmont, Loveland, Fort Collins, and Greeley.[36]

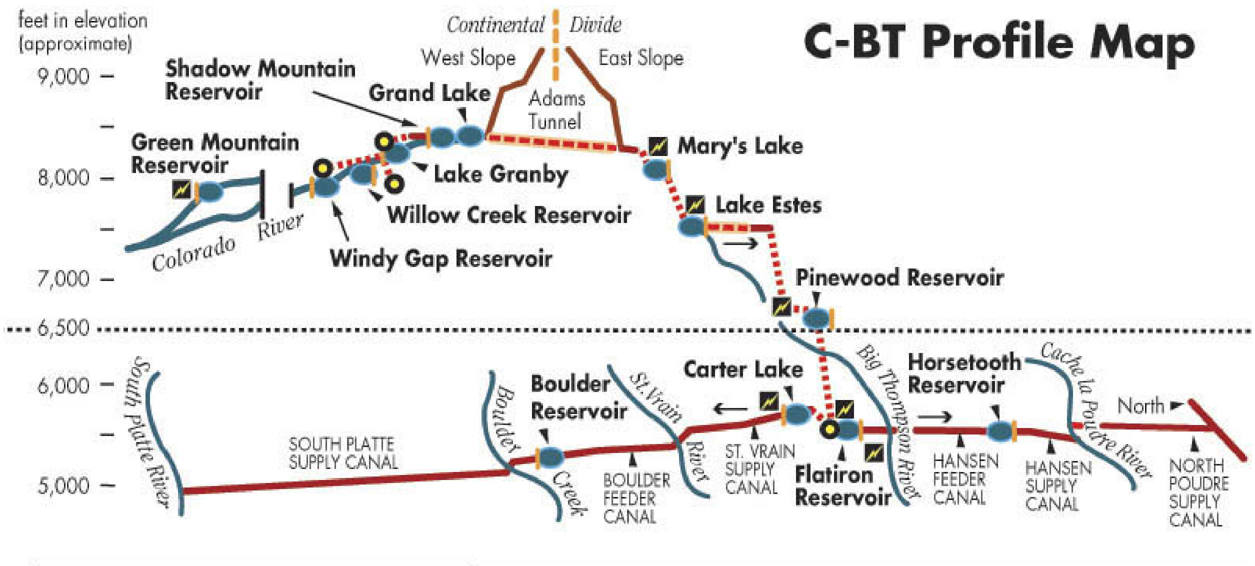

Figure 6. This C-BT Profile Map provides an overview of the facilities built for moving water from the west to the east side of the Continental Divide. Diagram courtesy of Northern Water and available from https://www.northernwater.org/docs/Water_Projects/cbtPoweSystem_june2011.pdf

Voices that united behind the C-BT on the Piedmont rallied around the economic value of increased water set against fears over the consequences of its scarcity – arguments that would have sounded quite familiar to water users back in 1900. As Colorado's resident expert on irrigation engineering and a well-respected public figure, Ralph Parshall was enlisted by the USDA's Department of Agricultural Engineering and CAC to research and write the primary economic analysis on the benefits of the C-BT. He published his report in January, 1937. Parshall, aware that a massive reclamation project might be viewed as a government handout to wealthy farmers in the midst of the Depression, characterized the farmers on the Piedmont as

[36] Robert Autobee, *Colorado-Big Thompson Project* (Denver: Bureau of Reclamation, 1996), 17. For a list of C-BT features, including construction dates, see Christine Pfaff et al., *The Colorado-Big Thompson Project: Historic Context and Description of Property Types* (Denver, Colo., publisher not identified, 1999), 76–87.

“hardy, self-reliant American farmers and townspeople” who needed additional water to “stabilize the present economic achievement and make secure the possibilities of future progress.” In a nod to popular Depression-era programs, Parshall stated that the guarantee of sufficient water would be like “social security” for existing farmers, enabling them to gain the same security in their later years that working class Americans were beginning to realize. Seeking to demonstrate that the C-BT was a difference-maker, Parshall argued that its greatest value was that its flows would be available late in the growing season, when junior water users often ran out of water and when an additional application of water to high value crops such as sugar beets and potatoes might make the difference between a modest profit and debt. In stark financial terms, Parshall stated that irrigation provided $64 million worth of property value to Northern Colorado, a region valued at $200 million. This additional property value resulted in local, state, and federal taxes that could be invested in schools, infrastructure and economic development. Knowing that C-BT detractors might argue that the nation was suffering from too much agricultural production, Parshall turned that caution on its head by claiming that more water would shift agricultural production away from crops grown in surplus and toward crops not grown in sufficient quantities. For example, he argued that wheat, whose national supply had far outstripped its demand, was a crop of choice in Northern Colorado only when water was in short supply. By contrast, domestic sugar beets, which demanded more water than wheat, supplied less than 50% of the nation’s sugar demand. Consequently, according to Parshall, increasing Northern Colorado’s water supplies would push farmers to grow more beets and less wheat, thus aligning the nation’s agriculture more closely with consumer demand. This was a tendentious argument in 1937, since sugar beet acreage was based on an acreage quota system, adjusted annually by the Secretary of Agriculture. However, there was some accuracy to

Parshall's conviction that more water would supply more beets since studies in the 1930s revealed that slightly more water yielded larger beet yields.[37] Parshall concluded that more water in Northern Colorado resulted in self-reliant, productive Americans who created real economic value in their region and beyond. In short, the C-BT was an overwhelmingly good investment.[38]

The sheer volume and variety of economic data collected by Parshall lent further support to the C-BT. While Parshall directed the economic investigations for the Bureau of Agricultural Engineering, at least five other individuals and one consulting firm were on the project payroll.[39] They gathered economic and water data from all six of the irrigation districts that were slated to receive water through the C-BT. In Parshall's analysis of the seventy years of irrigation in the region prior to 1935, he concluded that land values had risen by over $60 million, primarily because of "greater assurance that crops will be produced and the possibility of growing crops of higher value than could be grown w/o irrigation." Those increased land values were well above the initial $44 million price tag attached to the C-BT when Parshall wrote his report in 1937. But Parshall extended his analysis far beyond the farm, arguing that prosperous Piedmont farmers resulted in the expansion of local businesses, more railroad traffic, the growth of construction, strengthened regional financial institutions, and the sort of increased highway traffic that carries with it travelers and tourists eager to spend their money in Northern Colorado businesses.[40]

---

[37] N.R. McCreery, "What More Water Means to You," *Through the Leaves*, (July 1936): 110.

[38] Ralph L. Parshall, *Agricultural Economic Summary Relating to the Colorado-Big Thompson Project* (Fort Collins, Colo.: s.n, 1937).

[39] Irrigation Papers, Box 26, Folder, Grand Lake-Big Thompson Project.

[40] Parshall, *Agricultural Economic Summary Relating to the Colorado-Big Thompson Project*.

While these were effective arguments, they were tied to the history of the region and to tenuous economic predictions. Parshall's strongest arguments in support of the C-BT came from tying available irrigation water to crop productivity. By doing this, Parshall could make accurate projections as to how C-BT water would lead to agricultural growth. To show that cause-effect relationship, he compiled data from Northern Colorado ditch companies that showed water quantities available to farmers in the previous thirty years. He correlated that data with crop census statistics which compared the amount of acreage devoted to a particular crop planted in the region with the quantity of the crop harvested. By doing this, Parshall was able to develop charts linking water availability to productive capacity. Parshall did this for oats, barley, wheat, potatoes, and sugar beets. In every case he demonstrated that an increase in available water resulted in significantly larger harvests. While the expanded harvests varied depending on the crop, Parshall's data showed that productivity increased most when available water grew from one to two acre feet. In the case of sugar beets, Parshall's analysis, adapted from a 1922 USDA report on Northern Colorado, demonstrated that one acre foot of water resulted in an average of six tons of beets per acre, while two acre feet of water netted a huge increase to fifteen tons per acre.[41]

[41] Robert G. Hemphill and United States, eds., *Irrigation in Northern Colorado*, USDA Bulletin No. 1026 (Washington: U.S. GPO, 1922).

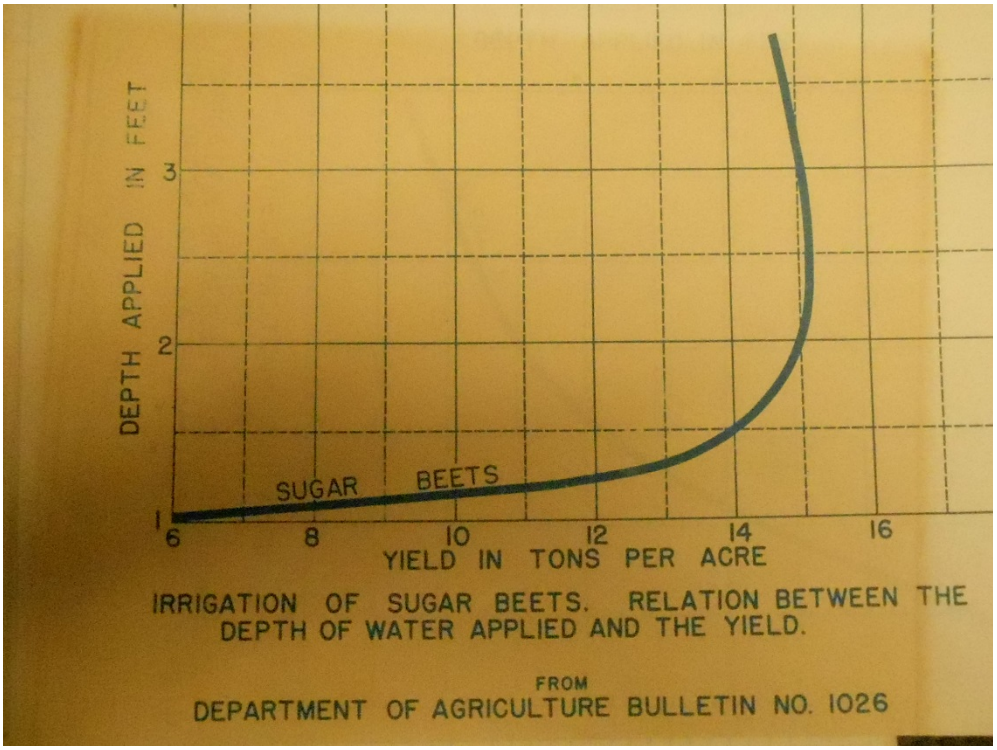

Figure 7. Sugar beet yields correlated with acre-feet of water applied. Ralph Parshall used statistics such as these to justify the building of the Colorado-Big Thompson Project. Taken from *Department of Agriculture, Bulletin No. 1026*. Public Domain.

Though Parshall's economic data clearly supported the need for more water in the region, he employed some statistical analyses that were packaged specifically to bolster support for the C-BT. While Parshall gathered historical data as far back as the late 1800s, many of the charts he developed to display his findings were bookended by the 10-year period between 1925 and 1934. This enabled Parshall to assemble charts that emphasized the dramatic difference more water could make. Near one end of each graph was the year 1926, one of the wettest years in recorded Northern Colorado history. During that year, farmers had access to nearly 1.4 million acre feet of water. In that year, sugar beet farmers were able to harvest nearly 15 tons of sugar beets per acre. In 1934, due to extensive drought, only 400,000 acre feet of water was available, and some junior irrigators received little or no water at all. In that year, sugar beet farmers averaged less than 10 tons of beets per acre.[42] For each year between 1926 and 1934, Parshall was able to show how available water strongly correlated with harvest totals. Parshall's charts for the period 1925-1934 were drawn to provide subtle support for the increased water that the C-BT would supply. Every chart that displayed available water supplies were normalized to the year 1926. By crafting his visuals in this way, Parshall planted in viewers' minds that 1926 was not so much an abnormally wet year, but that the water available to farmers that year could be normalized into the future through the water supplies made possible by the C-BT.[43]

[42] The year 1934 is strongly associated with massive dust storms on the Great Plains known collectively as the Dust Bowl. While Northern Colorado suffered from drought during that year, it was not ravaged by the dust storms that hammered Southern Colorado. For a provocative treatment of this topic see Donald Worster, *The Dust Bowl: The Southern Plains in the 1930s*, (New York: Oxford Press, 1979).

[43] Parshall, *Agricultural Economic Summary Relating to the Colorado-Big Thompson Project.*

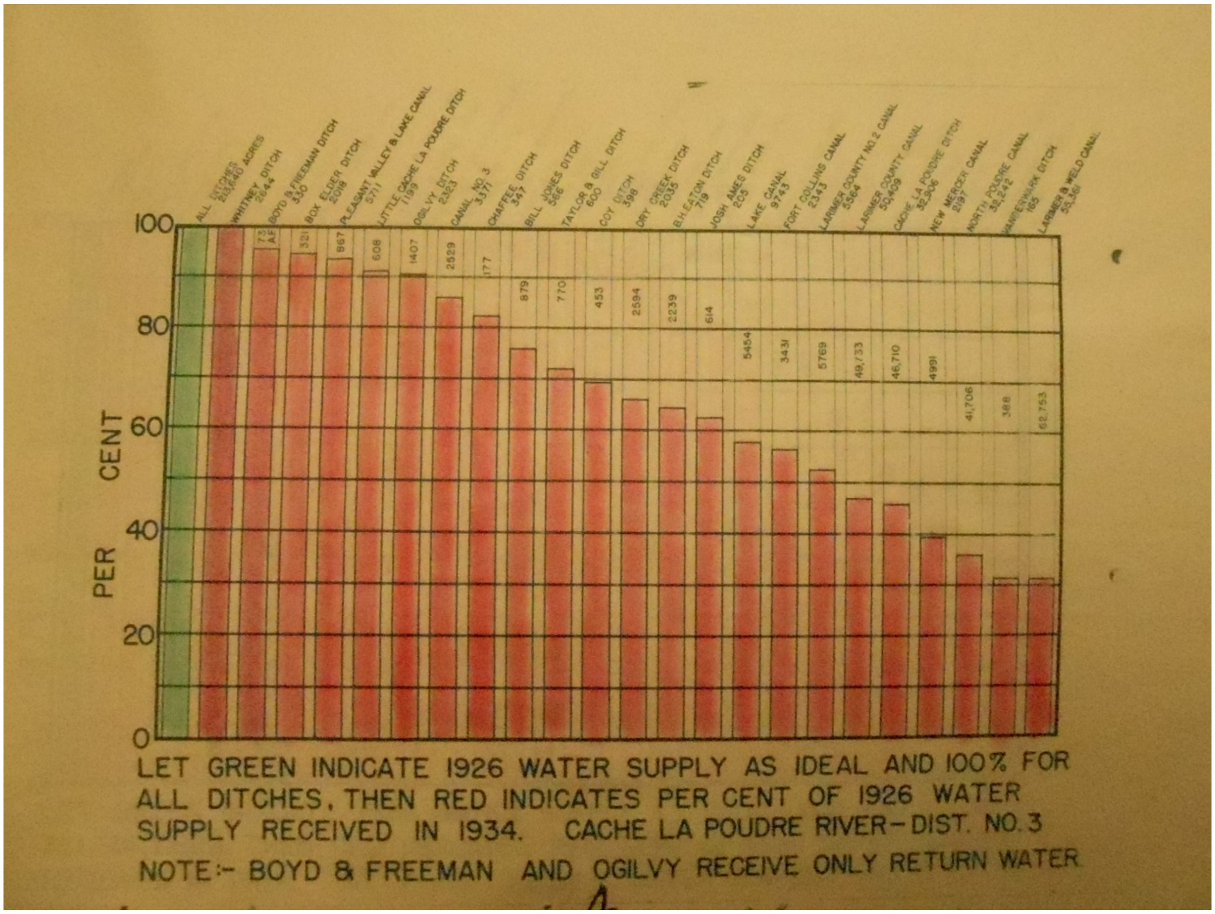

Figure 8. This is one example of how Parshall used 1926 water statistics to justify the C-BT. Each of the red bars represents an irrigation company supplied by water from the Cache la Poudre River and the water available to their farmers in 1934 as a percentage of what they received in 1926. Parshall described 1926, an abnormally high water year, as an ideal that could be reached through projects such as the C-BT. Diagram courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

While Parshall was an unqualified supporter of the C-BT in 1937, he left out any mention of water inefficiencies in Northern Colorado in favor of a narrative that left no doubt as to the region's water needs. Until 1937, Parshall had built his engineering career around shoring up the cracks in the South Platte's irrigation infrastructure. Fixing dams, controlling seepage, measuring water, surveying snow, and removing silt were all attempts to make the most use of water that was already within the watershed. His research and advocacy, prior to the advent of the C-BT, emphasized that a watershed was a sealed system, and that the goal of the engineer was to create as much utility as possible within that system. In fact, during the early 1930s, he generally tried to re-direct conversations about trans-basin diversion.[44] In his mind, reversing water's flow during the Depression would result in costly water that farmers could not afford. The best answer was found in efficient use of the watershed. However, by the time the idea of the C-BT entered broad Northern Colorado consciousness, Parshall had witnessed the uneven progress of his flume and the reticence of mutual irrigation companies to shore up their creaky systems. The C-BT promised more water without local districts having to pay much for the works that would deliver it, since the region was only required to re-pay $25 million of the overall cost of a project that was budgeted to cost $50 million (actual costs later exceeded $150 million). The water from the C-BT was supposed to cost $2 or less per acre-foot, much less than what famers were currently paying for water on-demand late in the season.[45] Whether Parshall foresaw that the C-BT would run far over budget or not, he understood that it was a good financial deal for Piedmont farmers. So, for a time, Parshall stopped beating the drum of efficiency, and instead preached the water gospel of abundance.

It is difficult to tell how much influence Ralph Parshall wielded when it came to Congressional approval of the Colorado-Big Thompson Project at the end of 1937. Drought and depression were certainly factors, as was the boosterism of communities throughout Northern Colorado, as well as support from Great Western Sugar, and the Colorado Congressional Delegation. Additionally, we should consider the efforts of the Bureau of Reclamation, whose

[44] For one example of his misgivings about trans-basin diversion, see Parshall to M.R. Lewis, 21 September 1930, Irrigation Research Papers, Box 5.

[45] In 1938, when the C-BT passed Congress, water users on the Piedmont paid $1.50 per acre foot of water on demand. Parshall points out that, from 1925-1934 in the Cache la Poudre Valley, the average cost of water on demand was $4 per acre foot. See Tyler, *The Last Water Hole,* 102; Parshall, *Agricultural Economic Summary Relating to the Colorado-Big Thompson Project,* 32-33.

growth and relevancy were based largely on the construction of massive irrigation projects.[46] Finally, the tireless efforts of CAC President, Charles Lory, who jettisoned his administrative duties in 1937 to lobby Congress for the C-BT, should not be overlooked.[47] However, all of the aforementioned individuals, institutions, and interests relied on economic data to justify their conclusions. And, no one compiled more statistical data on the relationship between water and productivity than Ralph Pashall.

During the 1930s and 1940s, Ralph Parshall's irrigation research extended far beyond flumes and reclamation projects. As an irrigation engineer animated by the desire for expansive water supplies that were fairly and efficiently distributed, Parshall immersed himself in a host of projects that contributed to these goals. During the early 1930s, he conducted research with devices that could remove sand, silt and debris from irrigation canals and return them to their rivers of origin. Further, aware that the need for water research had grown beyond the capacity of hydrology laboratories to meet, Parshall put together a successful proposal to expand CAC's hydrology lab. Finally, Parshall joined forces with the burgeoning science of snow-surveying in order to more accurately predict annual runoff, thereby helping farmers predict the quantity of water that would be available to them.

Anyone interested in moving water from a natural stream to a human-constructed canal must wrestle with the reality that streams carry more than water. Sand, silt, rocks, and a host of debris are immersed in the flow. And, whatever moves through the stream also passes through

---

[46] On the role of the Bureau of Reclamation in the West see Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West*, 1st ed (New York: Pantheon Books, 1986); Donald J. Pisani, *Water and American Government: The Reclamation Bureau, National Water Policy, and the West, 1902-1935* (Berkeley: University of California Press, 2002); Norris Hundley, *Water and the West: The Colorado River Compact and the Politics of Water in the American West*, 2nd ed, The Stephen Bechtel Fund Imprint in Ecology and the Environment (Berkeley: University of California Press, 2009).

[47] For an example of his work and his use of Parshall see Charles Lory to Parshall, December 1937, Irrigation Papers, Box 26, Folder Grand Lake Project.

headgates and diversion structures. All of that material accumulates over time, reducing the carrying capacity of a ditch and occasionally clogging water delivery mechanisms. Some of that material is inert and, according to Parshall, “raises the land surface near the margins of fields, interfer(ing) with the spread of water evenly.” Consequently, ditch operators and farmers, charged with maintaining ditches and canals, expend time and energy removing the offending matter. To address this, Parshall developed experiments at the Bellvue Lab using devices, called sand traps, aimed at removing sand, silt, and debris at the point of diversion from the river. The sand trap that proved to be most successful in the long term was called a vortex tube. Partnering with colleagues within the Bureau of Agricultural Engineering and CAC in the early 1930s, Parshall constructed a six-foot-wide channel and placed a tube at a fifty-three degree angle across it. The vortex tube, as it was called, was seven inches wide on the upstream side and 10 inches on the downstream end. It contained a large opening that ran its entire length such that, when debris passed over the tube it became trapped within it. Using flows of between one and three c.f.s. Parshall observed that the action created by water and debris within the tube created a vortex, whereby matter moved at a “uniform speed of one-half foot per second” down the tube. At the downstream end, the vortex tube ejected its contents into a sluiceway that diverted its contents back into the stream. In this way “cobblestones as large as 7.5 pounds” were removed from the irrigation channel. Vortex tubes initially installed in 1933 were reported to efficiently remove 90% of all sand, silt, and debris before they found their way into irrigation systems.[48]

[48] “Vortex Sand Trap Gage,” August 1933, Irrigation Papers, Box 2, Folder 11.

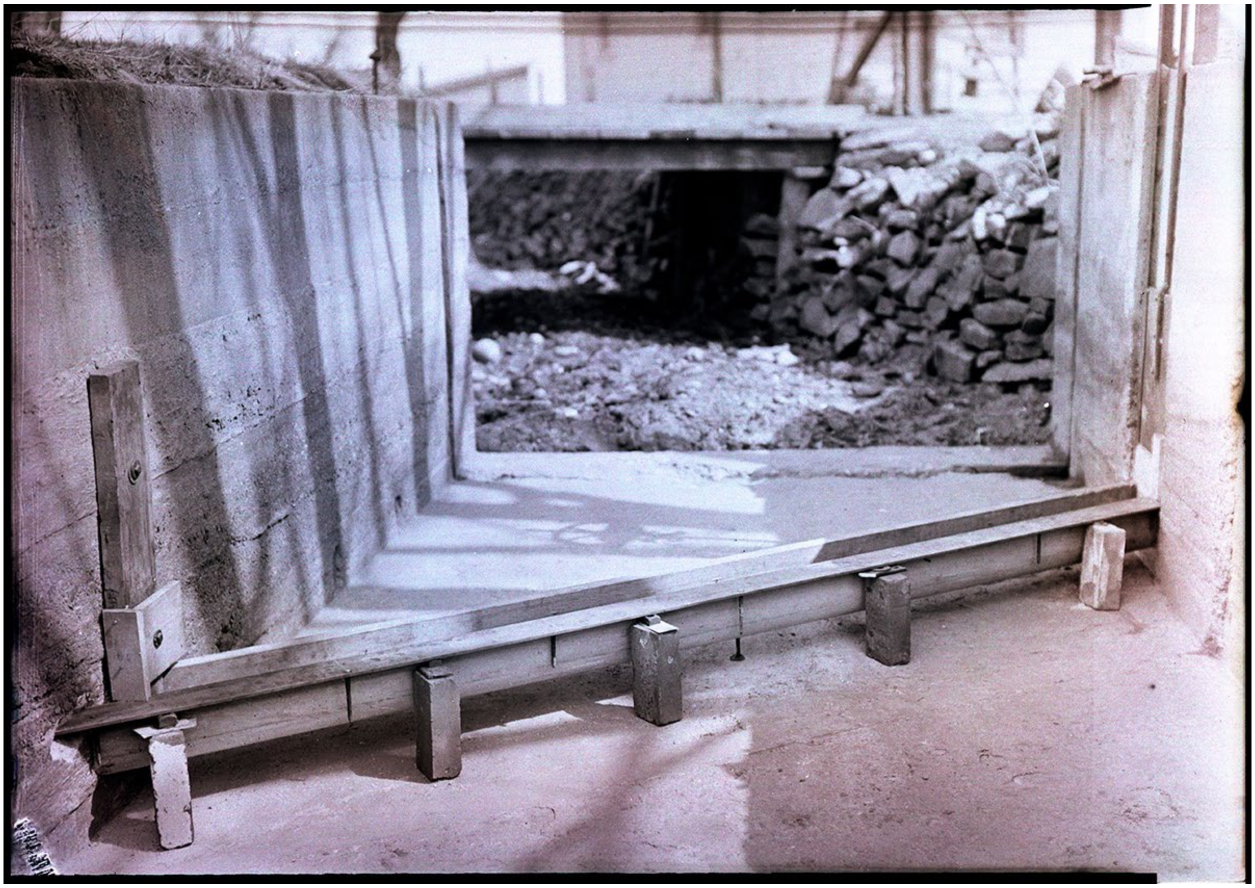

Figure 9. Vortex Tube installed in the Jackson Lake Ditch Company's intake canal. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

Today, there is plentiful evidence in Northern Colorado of the value of these vortex tube sand traps. On a warm summer day in 2017, I accompanied retired irrigation engineers Thomas Trout and Harold Duke to the now defunct site of the Bellvue Lab. We were joined by Colorado State University Archivist Patricia Rettig and former ditch rider Peter van Putten. At a point along the Cache la Poudre River just above the Bellvue Lab is a diversion from which the Jackson Lake Ditch Company takes its water. As we meandered along the canal, it was easy to spot a Parshall Flume. Just above that flume, and far less obvious, was a submerged vortex tube. Van Putten, who once maintained this canal, stated that the this particular vortex tube was 95% effective in removing sand, silt, and debris and that, further, it reduced his canal-cleaning labors by about 80%. When asked how common they were, van Putten replied that he is not aware of a single irrigation company without one at the point of river diversion. While Parshall was not the only irrigation researcher conducting experiments with various sand traps during the 1930s, his handiwork retains an indelible imprint on the irrigation infrastructure of Northern Colorado.[49]

The field of irrigation engineering expanded rapidly during Ralph Parshall's career, and the need for facilities that could accommodate the pace of change was essential. The hydraulics lab which Parshall and colleague Victor Cone designed on the CAC campus in 1913 had, in just two decades, become too limited for the demands placed on it. In Parshall's 1935 proposal to expand the facility, he justified the request in part by explaining how essential the lab had been to advances in water engineering – in Colorado and beyond. Parshall and his colleagues had designed and built weirs, headgates, and other irrigation structures in the hydraulics lab. They had modeled theories on how to reduce reservoir evaporation, and conducted experiments on how to limit evapotranspiration loss from plants. Various sand traps, including the vortex tube were assembled there. Parshall himself worked on recording instruments for use with the Parshall Flume there. Beginning in the late 1920s, the Bureau of Reclamation utilized the facility to model structures for use in building some of the American West's largest water projects, including Boulder Dam (later called Hoover Dam), Grand Coulee, Madden Dam in the Panama Canal Zone, and several structures built to divert water and generate power from the Columbia and Snake Rivers in the Pacific Northwest. The lab was also used to model parts of the Norris

[49] Van Putten Interview.

Dam, a power and flood control structure built as part of the New Deal's Tennessee Valley Authority.[50]

Parshall's case for an expanded hydraulics lab was bolstered by a clear economic rationale. Referring to the recent work of the Bureau of Reclamation at the lab, Parshall argued that the agency had invested over $100 million in various projects and that the federal government could not afford to skimp on related research. In what appeared to be a rather modest proposal, Parshall requested $5,500 from the Depression-era Public Works Administration for a new forty-by-forty foot workshop, expanded storage and sanitation facilities, and increased space to house tanks used to calibrate a host of water-measurement devices. While Parshall was not the only engineer working at CAC pushing for expanded facilities, his arguments proved effective. One year after he wrote his proposal, CAC conducted a ceremony to dedicate the improved lab.[51]

Ralph Parshall spent much of his career attempting to make nature operate in rational and predictable ways. Research and development into practical devices and structures for delivering and storing water in a manner timed to meet human needs and in sufficient quantity were at the core of his work. Rationalizing an unpredictable resource requires year-over-year knowledge of how much will be available. However, since 75% of all water in the American West originates from snowmelt, and annual snowfall varies widely, that knowledge did not come easy. To determine how much water would be available in a given year, available weather statistics were insufficient. Scientists also had to obtain representative snowpack samples within a given river

---

[50] "Memorandum Concerning the Request for a Grant of Public Works Administration Funds for the Construction of an Addition to the Irrigation Hydraulic Laboratory of the Colorado Agricultural College at Fort Collins," 21 May 1935, Irrigation Papers, Box 16, Folder Addition to the Laboratory.

[51] Ibid; "Dedication Ceremony for Plaque Honoring Parshall Measuring Flume as a Historical Landmark in Agricultural Engineering by the American Society of Agricultural Engineers," 1 July 1985, Irrigation Papers, Box 63, Folder Dedication Ceremony.

basin and then accurately measure the widely varying water content within a given volume of snow at various times during the winter season. They required knowledge of soil science, since much of the snowpack did not flow into rivers, but seeped into the soil, often percolating into underground aquifers or emerging elsewhere in springs. Scientists also needed to understand how sun and shade, trees and meadows impacted the rate at which the winter snowpack melted. Further, to apply the science to hydroelectric power and irrigation, they had to understand something about the irrigation infrastructure into which runoff flowed since water power was a function of the potential energy in a given flow and efficient irrigation required the ability to store winter runoff before it flowed downstream. The most skilled water engineers possessed skills in each of these areas. As Colorado's senior irrigation engineer for the Federal Bureau of Agricultural Engineering (BAE), Ralph Parshall assumed a pivotal role in the evolution of snow science in Colorado and in adjoining states.

The timing of Parshall's snow science research, beginning in the 1930s, was deeply intertwined with depression and drought. While the first snow surveys in the West began in 1905, when James Church established a high mountain weather station in the Sierras, the science of measuring snow proceeded slowly and sporadically. Until the 1930s, snow surveys were conducted on a limited basis by water users and their allies within industry. However, in 1934, the West was devastated by drought, with much of the Southern Plains experiencing intense soil erosion and dust storms, collectively referred to as the Dust Bowl. That year Walter McLaughlin, head of the BAE, and Parshall's immediate superior, met with Secretary of Agriculture, Henry Wallace, to discuss the use of federal resources to conduct snow surveys. McLaughlin argued that snow surveys could have provided essential knowledge about water, enabling farmers to plan more carefully, thereby cushioning the blows of the drought. He then requested and received an initial outlay of $15,000 in 1935 from the Depression-era Works Progress Administration to buy snow sampling equipment, weighing devices, skis and snowshoes. By the end of 1935, one-quarter of all the necessary snow survey courses in the West were established. In 1940, 753 snow surveyors were making readings at 14,295 sampling points on 1,000 snow courses in the West.[52]

In the winter of 1934-35, Ralph Parshall assumed responsibility for overseeing snow surveys in Wyoming and Colorado. By the end of 1935, Parshall and his colleagues had established 68 snow courses in Colorado, and at least 50 in Wyoming. Though most of Parshall's direction was provided from afar, he directly oversaw the establishment of several snow courses in the South Platte Basin. According to Parshall, each course covered an area of a few acres and consisted of "two intersecting straight lines varying from 500-1,000 feet." Course builders blazed tree marks at several end points within the course. Flatter ground, north-facing slopes, and some tree cover were preferred since, cumulatively, they minimized wind erosion and snow drift. Parshall marked various points within the snow course with Masonite boards. Snow surveyors then measured the depth of the snowpack at 25-50 points within the snow course on the first day of each month from January through May. Each snow tube was then weighed to determine water content and then surveyors averaged those measurements to determine the available water within a snow course. Surveyors then compared numbers with those from other snow courses in the same watershed and the figures were extrapolated to predict the available water in a given season. Parshall and other snow surveyors compared their predictions with actual runoff the following season to determine accuracy. By this method, Parshall believed that it would take 3-5

[52] Douglas Helms, "Bringing Federal Coordination to Snow Surveys,' available from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043910.pdf, accessed on 6 September 2017.

years before data from an established snow course could yield accurate predictions of runoff in acre feet.[53]

Figure 10. Measuring the snow pack in a Northern Colorado snow course. The person on the right is holding a cylinder of packed snow extracted from the snow pack. The person on the right is weighing it. Photo courtesy of Irrigation Research Papers, Water Resource Archive, Colorado State University.

Parshall viewed snow surveys not only as a logical engineering problem but as a task requiring cooperation across numerous public and private boundaries. Parshall's support for coordinated water planning added to his engagement in snow surveying. Snow surveys were labor intensive projects that initially operated with insufficient federal funding. Further, given that water moved across various public and private boundaries before it found its way into farmers' ditches, cooperation was essential. At the federal level, the U.S. Forest Service and

---

[53] Parshall, "Snow Surveys as a Means of Forecasting Streamflow," Irrigation Papers, Box 30, Folder 340; "Parshall, "Snow Course Markers," Parshall Papers, Box 9**,** Folder American Geophysical Union Snow Reports; Parshall to W.W. McGlaughlin, Chief of the Division of Irrigation, U.S. Bureau of Agricultural Engineering, 28 December 1937 Letter of Dec 28 1937, Irrigation Research Papers, Box 26, Folder Colorado Big Thompson.

National Park Service granted exclusive access to lands for conducting snow surveys. The Army Corps of Engineers, Bureau of Reclamation, and the U.S. Geological Survey built structures to store and move water in the mountains. The National Weather Bureau provided predictions on snowfall. Cities such as Denver, Boulder, and Fort Collins, whose primary interests were in water for residential use, cooperated with irrigation companies, whose mission revolved around agriculture. Land grant colleges such as CAC also played pivotal roles by providing engineering and hydrology expertise and labor in the form of students who could make the long treks into the mountains to maintain snow courses and conduct samples. Though the accuracy of initial snow surveys widely varied, water users came to rely on them. For example, by 1943, beet sugar companies such as Great Western used the work of snow surveyors when adjusting acreage contracts with its growers.[54]

Ever conscious of communicating his research findings to the public, Parshall regularly contributed to a series of articles published through CAC titled "Irrigation Water Prospects." In each article, Parshall was interviewed about the progress of statewide snow surveys and asked to provide an outlook for farmers regarding how much water would be available from runoff in that year. When Parshall retired in 1948, he had become Northern Colorado's recognized expert on how snowfall translated to available water.[55]

Ralph Parshall's retirement from the USDA in 1948 did not mark the end of his engineering career. During the next decade, Parshall continued to research and write on water measurement and poured time and effort into the next generation of Northern Colorado water

---

[54] Parshall, "Memorandum Concerning Water Storage and Conservation prepared by the Colorado Experiment Station for the State Agricultural Clearing Committee," Irrigation Papers, Box 20, Folder 268; Helms, "Snow Surveying Comes of Age," available from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043910.pdf, accessed on 6 September 2017.

[55] "News Notes: 1944-1947," Records of the Colorado State University Faculty," Morgan Library, Colorado State University, Box 2, Folder Parshall, Ralph L - News Notes, 1944-1947, undated.

engineers. From the time that Parshall developed his namesake flume until the 1950s, he rarely strayed from the work of improving the device. Motivated by the various needs and applications of farmers, industry, and municipalities, Parshall developed flumes with throat widths ranging from 3 inches to 50 feet that could accurately measure water flowing at rates up to 3,000 cubic feet per second. Due to variances in flow, depth, and site conditions, Parshall calibrated flumes to meet a panoply of needs. Parshall even played the role of consultant on occasion, visiting a site of installation and working with irrigators to determine the Parshall flume most suited to the need. In 1950 Parshall published his final article on the installation and use of small Parshall flumes. In 1953, he did the same for large flumes. The articles, though published in routine and rigorous scientific fashion, represented more than four decades of dedication to water measurement.[56]

During the 1950s, Parshall continued to conduct primary research in water measurement. He could be spotted overseeing controlled experiments at the Bellvue Lab, or advising Colorado A&M's next generation of hydraulic engineers. In fact, Parshall was doing just that when he died on December 29, 1959. At the time, Parshall was investigating a type of irrigation measuring device called a vane meter, used to provide spot water measurements in farm laterals and other small ditches. He had planned to deliver his findings to farmers and irrigation engineers while attending the Four States Irrigation Council on January 14-15, 1960. Parshall was hopeful that improvements in the device might bring more accurate water measurement down to the level of the individual farmer. The paper was delivered posthumously.[57]

---

56 Parshall, "Measuring Water in Irrigation Channels with Parshall Flumes and Small Weirs, Washington, D.C.: U.S. Dept. of Agriculture, 1950; Parshall, "Parshall Flumes of Large Sizes," U.S. Dept. of Agriculture, Soil Conservation Service in Coop w/ Colorado Agricultural Exp Station, May 1953.

57 Parshall, "The Vane Meter and Division Problem," Prepared for the Four States Irrigation Council, Jan 14-15 1960, Colorado State University, Ft. Collins, Irrigation Papers, Box 63.

Though there is plentiful evidence of Ralph Parshall's life and work, it is easy to miss. One site where Parshall's imprint abounds is the Bellvue Lab where he spent countless hours channeling water flows, measuring it under various conditions, and calibrating flumes and other devices to meet agricultural needs. Within five years of Parshall's death, that lab had become obsolete. Retired irrigation engineers Harold Duke and Gordon Kruse, who are among the last generation of engineers to have worked with Parshall at the Bellvue lab, explained that most of the research that would have otherwise been completed at Bellvue moved to a new hydraulics lab at the base of Horsetooth Reservoir in Fort Collins, situated to take advantage of the water power that could be generated by the new structure. In a telling nod to Parshall's legacy, Horsetooth Reservoir was built in the 1950s to store water from the Colorado-Big Thompson Project, a project whose economic rationale was written by Parshall himself. When I visited the site of the Bellvue Lab in the summer of 2017, it was overgrown with vegetation. The branches of cottonwood, maple, and ash trees hung low over the concrete channel once used to manipulate the flow of water. Heavy deposits of sand, silt, and other debris accumulated on the outer edges of the flume and at the downstream end of the structure. Weeds and tubers abounded in the channel, aided by water that flowed through the length of the channel. At intervals of approximately twenty feet, four-by-six boards – now rotting – were placed across the flume. These were likely used to vary the width of the channel and regulate flows in order to perform controlled experiments. The Bellvue lab, located just a stone's throw from a moderately trafficked country road, provides plentiful evidence of Parshall's work. Yet it has been obscured by a half-century of neglect. It is hidden in plain sight.

Figure 11. The Bellvue Hydraulic Laboratory in 2017. Large parts of the channel have been filled in with sand and silt, while weeds and trees grow in the area once used for Parshall's research. Photo by author.

The same words could be used to describe much of Ralph Parshall's work. Even within irrigation engineering, a field that largely escapes public notice, Parshall's specialty is especially elusive. Dams and reservoirs draw our attention to how humans have harnessed water to provide for agricultural, municipal, and power needs. Canals and ditches command far less attention. It follows that Parshall Flumes go largely unnoticed. Yet they are ubiquitous and essential. According to the CRC Handbook of Irrigation Technology, Parshall Flumes are the "most commonly used device for measuring flow in irrigation channels all over the world." They are simple, inexpensive, and easy to operate. And they show little sign of losing that status. For example, the Thompson Pipe and Steel Company of Denver, Colorado has been selling Parshall Flumes since 1940. They can still be purchased in throat sizes ranging from one inch to ten feet, constructed of aluminum, fiberglass, galvanized and stainless steel. The staying power of the Parshall Flume is a testimony to both its accuracy and simplicity.[58]

The Parshall Flume is also an essential, yet little recognized piece of the history of the modern American West. Identified strongly by both aridity and settlement patterns that revolved around agriculture, water diversion was essential for success. However, without accurate water measurement, senior irrigators often appropriated far more water than they were entitled to, leaving later arrivals with insecure water rights that could make the difference between success and failure. Thus, the Parshall Flume, by vastly increasing the measurement accuracy of water in irrigation canals, contributed to the water security of junior appropriators as well as enabled more land to be brought into production. It made the movement of water both more efficient and egalitarian. In that respect, Ralph Parshall deserves a reputation as a steward of the public good.

Beyond the Flume, Ralph Parshall's life and work make the United States in the first half of the twentieth century more legible. An increasingly urban nation demanded an agriculture that could harness its natural resources efficiently to deliver food to the American table. Parshall,

---

[58] Gordon Kruse Interview; Harold Duke, interview by author, 18 July 2017; Kruse and Willis, "The Role of the Parshall Flume in Water Conservation,"; Herman J. Finkel, ed., *CRC Handbook of Irrigation Technology*, Volume 1, (Boca Raton, Florida: CRC Press, Inc., 1982), 151.

along with other employees of the USDA and land grant colleges were charged with the task of increasing the food supply by making agricultural lands more productive. Few public employees were more successful or tireless in that pursuit. In addition to the Flume, Parshall wrote the primary economic rationale for the Colorado-Big Thompson Project, which vastly increased water supplies in Northern Colorado. He developed vortex tubes aimed at eliminating the sand, silt, and debris that clogged canals and ditches. Parshall played a leading role in the science of snow measurement, directing USDA efforts in Colorado and Wyoming. During a period in which efficiency and rationalizing natural resources for public consumption characterized the nation, Parshall's work enabled farmers and municipalities to predict annual water quantities, thus demystifying water planning. Because he was a publicly-minded scientist who succeeded in rationalizing an essential resource, Ralph Parshall's life and career provides a road map for understanding transformations in the United States during the first half of the twentieth century.

Selected Bibliography

Manuscript Collections

Water Resource Archive, Morgan Library, Colorado State University, Fort Collins, Colorado
Irrigation Research Papers
Ralph Parshall Papers
Records of the Colorado State University Faculty
Records of the Consolidated Home Supply Ditch and Reservoir Company

Articles, Pamphlets, Reports, and Government Documents

Big Thompson Soil Conservation District, Consolidated Home Supply Ditch and Reservoir Company, Handy Ditch Company, United States, Soil Conservation Service, and Colorado Water Conservation Board. *Watershed Work Plan Home Supply Watershed, Larimer and Weld Counties, Colorado*. Lincoln, Neb.: U.S. Soil Conservation Service, 1964.

Cone, V.M. "Hydraulic Laboratory for Irrigation Investigations, Fort Collins, Colo." *Engineering News*, Vol. 70, No. 14, 662.

Fortier, Samuel. "Irrigation Requirements of the Arid and Semiarid Lands of the Missouri and Arkansas River Basins," *USDA Technical Bulletin 36*. Washington: U.S. Government Printing Office, 1928.

Hemphill, Robert G., and United States, eds. *Irrigation in Northern Colorado*. Agric. Dept. Bull. No. 1026. Washington: U.S. GPO, 1922.

Hutchins, Wells A. *Mutual Irrigation Companies*. Technical Bulletin / United States Department of Agriculture, no. 82. Washington: U.S. Dept. of Agriculture, 1929.

Laflin, Rose. Colorado Water Resources Research Institute. *Irrigation, Settlement, and Change on the Cache La Poudre River*. Colorado Water Resources Research Institute, Colorado State University, n.d.

Parshall, R.L. *Agricultural Economic Summary Relating to the Colorado-Big Thompson Project*. Fort Collins, Colo., 1937.

______. "Measuring Water in Irrigation Channels with Parshall Flumes and Small Weirs. Washington, D.C.: U.S. Dept. of Agriculture, 1950.

______. *Parshall Flumes of Large Sizes*. Fort Collins: U.S. Department of Agriculture, 1953.

______. *The Parshall Measuring Flume*. Bulletin 423. Fort Collins, Colo.: Colorado State College, Colorado Experiment Station, 1936.

______. *Return of Seepage Water to the Lower South Platte River in Colorado*. Bulletin 279. Fort Collins, Colo.: Agricultural Experiment Station of the Agricultural College of Colorado, 1922.

______, and Rohwer, Carl. "*The Venturi Flume.*" The Agricultural Experiment Station of the Colorado Agricultural College, 1921.

Periodicals

Colorado Transcript
Craig Empire Courier
Fort Collins Courier
Through the Leaves

Interviews

Duke, Harold
Hansen, James
Kruse, Gordon
Thornton, Chris
Van Putten, Thomas

Books

Autobee, Robert. *Colorado-Big Thompson Project* . Denver: Bureau of Reclamation, 1996.

Boyd, David. *A History: Greeley and the Union Colony of Colorado*. Greeley, Colo: Greeley Tribune Press, 1890.

Committee, Colorado Irrigation Centennial. *A Hundred Years of Irrigation in Colorado: 100 Years of Organized and Continuous Irrigation, 1852-1952*. Biblio Gov, 2013.

Fiege, Mark. *Irrigated Eden: The Making of an Agricultural Landscape in the American West*. Weyerhaeuser Environmental Books. Seattle: University of Washington Press, 1999.

Finkel, Herman J. *CRC Handbook of Irrigation Technology*, Volume 1. Boca Raton, Florida: CRC Press, Inc., 1982.

Hobbs, Greg. *The Public's Water Resource: Articles on Water Law, History, and Culture*. 2nd ed. Denver, Colo: CLE in Colorado, 2010.

Hundley, Norris. *Water and the West: The Colorado River Compact and the Politics of Water in the American West*. 2nd ed. The Stephen Bechtel Fund Imprint in Ecology and the Environment. Berkeley: University of California Press, 2009.

Keirnes, W. R. *Water: Colorado's Most Precious Asset : The Consolidated Home Supply Ditch & Reservoir Company Contributed to Its Development, 1881-1986*. Loveland, Colorado: Mile-High Printing, 1986.

Kluger, James R. *Turning on Water with a Shovel: The Career of Elwood Mead*. 1st ed. Albuquerque: University of New Mexico Press, 1992.

May, William John. *The Great Western Sugarlands: The History of the Great Western Sugar Company and the Economic Development of the Great Plains*. Garland Studies in Entrepreneurship. New York: Garland Pub, 1989.

Mead, Elwood. *Irrigation Institutions; a Discussion of the Economic and Legal Questions Created by the Growth of Irrigated Agriculture in the West*. Use and Abuse of America's Natural Resources. New York: Arno Press, 1972.

Pfaff, Christine. *The Colorado-Big Thompson Project Historic Context and Description of Property Types.* Denver: Bureau of Reclamation, 1999.

Pisani, Donald J. *From the Family Farm to Agribusiness: The Irrigation Crusade in California, 1850-1931*. Berkeley: University of California Press, 1984.

_____. *To Reclaim a Divided West: Water, Law, and Public policy,1848-1902*. 1st ed. Albuquerque: University of New Mexico Press, 1992.

_____. *Water and American Government: The Reclamation Bureau, National Water Policy, and the West, 1902-1935*. Berkeley: University of California Press, 2002.

Rosenberg, Charles E. *No Other Gods: On Science and American Social Thought*. Revised and expanded ed. Baltimore, Md: Johns Hopkins University Press, 1997.

Schorr, David. *The Colorado Doctrine: Water Rights, Corporations, and Distributive Justice on the American Frontier*. Yale Law Library Series in Legal History and Reference. New Haven: Yale University Press, 2012.

Tyler, Daniel. *The Last Water Hole in the West: The Colorado-Big Thompson Project and the Northern Colorado Water Conservancy District*. Niwot, Colo: University Press of Colorado, 1992.

Wellock, Thomas. *Preserving the Nation: The Conservation and Environmental Movements, 1870-2000*. Wheeling, Illinois: Harland Davidson, 2007.

Willard, James F., *The Union Colony at Greeley, Colorado, 1869-1871*. University of Colorado Historical Collections, v. 1. Boulder, 1918.

Worster, Donald. *Dust Bowl: The Southern Plains in the 1930s*. Oxford: Oxford University Press, 1979.

_____. *Rivers of Empire: Water, Aridity, and the Growth of the American West*. 1st ed. New York: Pantheon Books, 1986.

Wyckoff, William. *Creating Colorado: The Making of a Western American Landscape, 1860-1940*. New Haven: Yale University Press, 1999.

About the Author

Michael Weeks is a Lecturer in the History Department at Utah Valley University in Orem, Utah where he teaches courses in Environmental History, Modern America, and the History of the American West. Michael completed a Ph.D. in History at the University of Colorado, Boulder in 2016. Beyond this article, Michael's work has appeared in *Environmental History*, *the Western Historical Quarterly*, *The Journal of Arizona History*, and *Annals of Wyoming History*. Michael is currently working on a book project titled, *Industrializing Place: Colorado and the Making of Agriculture in the Twentieth Century*, to be published by University of Nebraska Press.

Michael lives in Provo, Utah with his wife, Sacha, and dog, Sienna. When he is not teaching, researching, and writing, Michael can typically be found exploring the American West, growing food in the back yard, or seeking out stimulating conversation over a good cup of coffee.