Design Evolution: Reconstructed Timber Swing Bridges on the Rideau Canal

Robert W. Passfield

When Parks Canada acquired the Rideau Canal in 1972 under a mandate to conserve its historic structures, there were five reconstructed timber swing bridges extant on the canal that were considered to be replicas of an early 19th-century design prototype. Otherwise, little was known about them. Generally speaking, in researching historic timber bridges the available information sources are not comprehensive and complete enough to date and document the design and construction of a historic structure, as well as its subsequent modifications and upgrades. However, this was not the case for the historic Rideau Canal swing bridges. When research commenced it was found that there was an amazingly complete collection of federal government archival records—historic drawings, contract specifications, maintenance records, and engineering correspondence—that enabled a detailed history of the design evolution of these particular structures to be written. Thus, this article records and documents the provenance, original design, and structural evolution of the reconstructed timber swing bridges on the Rideau Canal from the introduction of the centre-bearing swing bridge design prototype in 1866 through to 1972 when Parks Canada acquired the canal. It also identifies the information sources used to record and document the evolving form of the reconstructed timber swing bridges, and provides insights into the art of empirical engineering as it was practised in the 19th century.

Introduction

The Rideau Canal was built in 1826–1832 as a military canal by the British Army Ordnance Department, employing Canadian contractors under the supervision of officers of the Corps of Royal Engineers commanded by Lieutenant-Colonel John By, the chief engineer on the canal construction project. To construct the canal, two rivers were canalized—the Rideau River, a tributary of the Ottawa River, and the Cataraqui River, which flowed into Lake Ontario at Kingston. Joined at their Rideau Lake summit level, the canalized rivers formed a 123-mile-long slackwater navigation with numerous stone masonry dams and waste weirs, and 47 stone masonry locks. The canal was intended to form part of a secure interior water communication by which troops, heavy guns, munitions and supplies could be forwarded inland in wartime from the ocean port of Montreal, via the Ottawa River and the Rideau Canal, to Kingston on Lake Ontario for transshipment into lake steamboats, thereby avoiding the more exposed St. Lawrence River route that ran along the American frontier.[1]

When the historic Rideau Canal was transferred in 1972 from the Department of Transport to the Parks Canada program under a heritage conservation and recreational development mandate, the stone masonry canal locks, dams, and the cultural landscape of the Rideau Canal corridor were amazingly well preserved.[2] In addition, there were five reconstructed timber swing bridges extant of the canal, which were purportedly replicas of an historic prototype. (Figure 1)

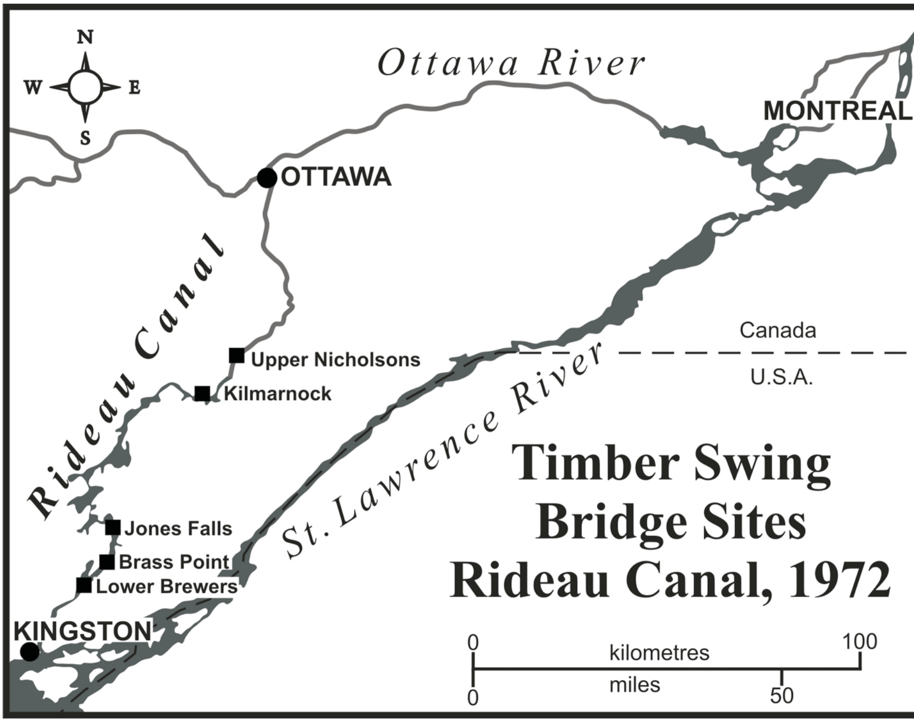

Figure 1. Regional Map, Rideau Canal, showing the locations of the five reconstructed timber swing bridges extant on the waterway in 1972. (Ken Watson, 2006)

Initially little was known about the reconstructed timber swing bridges extant at Jones' Falls, Lower Brewer's, Brass Point, Kilmarnock, and Upper Nicholson's on the Rideau Canal. A site study, undertaken by Parks Canada at the Jones' Falls lockstation in 1973, assessed these bridges as follows:

> The historic interest of this structure is not that it is the original bridge on the site, but that it is a replica in lineal descent from that original. ... the Jones Falls bridge, and four others like it remaining at other stations, is of a type contemporary with the construction of the canal itself, ca. 1830–1840, and would appear to be unique to the Rideau waterway, so far as Canada is concerned.[3] (Figure 2)

Subsequently historical research was undertaken to identify and date the various types of historic bridges along the Rideau waterway, and the existing bridges were photo recorded. Government records and historic drawings on deposit at the Public Archives of Canada (now Library and Archives Canada) were consulted, as well as published departmental annual reports pertaining to the operation of the canal. At Parks Canada, the bridge maintenance files and engineering drawings inherited from the Department of Transport were also examined and analysed.

Through historical research in government archival records, the design prototype for the extant timber swing bridges was discovered, and its introduction to the Rideau Canal dated. Two historic engineering drawings of the design

Figure 2. Jones' Falls Swing Bridge, a historic unequal arm, centre-bearing Rideau Canal type of timber swing bridge, reconstructed in 1960. (Photo by author, July 1974)

prototype were found, dating from June 1866 and August 1871, as well as a list of materials for the swing bridge from 1866, and a complete set of specifications, dated September 1872. Moreover, historic engineering drawings were found for two other types of swing bridges that were erected on the Rideau Canal in the decades prior to the introduction of the existing swing bridge design. These documents enabled the extant timber swing bridges to be placed within an historical and technological context.[4]

Design Prototype, 1866

The timber swing bridges extant when Parks Canada acquired the Rideau Canal in 1972 were of an unequal-arm, centre-bearing pivot type that was introduced on the canal during the summer of 1866 when the design prototype was erected on a new crossing of the canal channel at Mutchmore's Cut on an extension of Bank Street in Ottawa.[5]

The new swing bridge was developed to replace two earlier timber swing bridge design prototypes on the Rideau Canal that were similar to the new structure in appearance, in their unequal-arm configuration, and in some of their structural components, but differed significantly from the new structure in their basic design principle. The earlier swing bridges comprised a conventional rim-bearing timber swing bridge, first constructed on the Rideau Canal in 1843, and an off-set pivot swing bridge, of much heavier construction and load carrying capacity, introduced in 1851. As of the early 1860s both types of swing bridge were in service on the Rideau Canal, with the offset pivot structure being gradually introduced as the lighter rim-bearing swing bridges required renewal. It was recorded, however, that the existing swing bridges were difficult to swing, requiring the exertions of two men and a crab (windlass) to open and close the swing span.[6]

The new type of swing bridge differed from the earlier swing bridges in that it was balanced to rotate on a central pivot that bore the whole weight of the bridge structure when swung. It had six truck wheels that ran on a circular iron track, centred around the pivot assembly, but they were employed simply to prevent the swing span from tipping when swung off the abutments. The truck wheels did not carry any of the dead weight of the bridge structure when closed on the abutments. The superstructure of the swing bridge was of an unequal arm, or bobtail configuration with a long arm, that swung out over the canal channel, and a short heel span of heavier construction that counterbalanced the superstructure over the central pivot. The design intent was that the swing span, in being finely balanced on a central pivot, could be readily swung by one man.[7]

In the terminology of the day, the superstructure of the new swing bridge comprised a "mainframe" consisting of two heavy "main stringers" or girders, framed together with transverse "beams" and a "heel beam" and "toe beam" at either end, and a "corbel frame," or underframe, that provide additional support for the mainframe for half its length. The weight of the superstructure was transferred to the central pivot, on which it was balanced, by means of a "pivot beam," a transverse loading beam, 9" deep by 18" wide and 13'–6" long, that ran over beneath the corbel frame of the superstructure over the central pivot. The new centre-bearing swing bridge was approximately 69' long and 12' wide (centre to centre girders), and provided a 37' clear span between the pivot pier and the abutment of the long arm—the span needed to cross the 33' width of a Rideau Canal lock chamber.

The pivot consisted of a cast-iron cone, or pintle, of 7" in diameter, which was fixed to the bottom of the pivot beam, and rotated in a cast-iron socket that was anchored at the centre of the pivot pier turntable. The pintle surface was faced with steel to make the span swing more easily, and to reduce wear. The six cast-iron trucks, each with a 17" diameter spoked iron wheel, were bolted to the underside of the corbel frame of the bridge superstructure in a concentric circle about the pivot. These so-called "balance wheels" had a flat, 3¼"-wide running face and ran on a circular track of 12' diameter that was centred on the pivot and anchored to a timber framework on the pivot pier.

The turntable track was constructed of six cast-iron rail segments. For ease of opening and closing, small cast-iron rollers were mounted at both ends of the swing span, at the heel and toe beams under each corner of the structure. On the swing-span closing, the end rollers ran onto a cast-iron stop, anchored on the abutment, which raised the balance wheels 3/16" clear of the track. By supporting the ends of the swing span in its closed position, the end stops served to maintain the bridge deck level, longitudinally and transversely, and relieved the balance wheels from having to support any of the dead load when closed, or the live load during the passage of road traffic over the bridge.

In the centre-bearing swing-bridge design, the weight of the long arm of the unequal arm structure was counterbalanced through increasing the weight of the short arm, or heel section, in three different ways: by tapering one side and the underside of the two 69'-long girders from 18" x 12" (depth to width) at the heel to 9" x 6" (depth to width) at the toe; by the weight of the corbel frame on the heel section of the span; and by placing heavier floor beams in the heel section of the swing span than on the long arm.

The girders were to be constructed of a single stick of large-dimensioned white oak, 69' long, hewn with squaring axe and adze to the required tapers. In the mainframe over the pivot pier, there were three heavy, 12" x 12", transverse floor beams—a centre beam positioned in line with the pivot beam below, and a beam positioned 6' to either side of the centre beam over the arc of the turntable rail. In addition, there was a fourth lighter 12" x 6" (depth to width) transverse floor beam in the outer heel section of the mainframe. The heel beam was a massive timber, 18" x 20" (depth to width). In contrast, on the long arm of the mainframe there were three lighter, 12" x 6" (depth to width) transverse floor beams, and a 6" x 10" (depth to width) toe beam, and the joinery details differed. The floor beams in the heel section were framed inside the two girders with mortise and tenon joints, and pinned with trenails (trunnels); whereas the floor beams on the long arm were bolted up, with a slightly bevelled half-lap joint, against the underside of the tapered girders. At the outer ends of the mainframe, the ends of the girders were framed and pinned into the toe and heel beams with mortise-and-tenon connections.

Over the pivot pier, the heavy transverse floor beams on either side of the centre beam were reinforced with 12" x 12" diagonal corner braces, framed and bolted into the corners of the mainframe directly over the radius arc of the turntable rail below. The mainframe was further strengthened by corner braces bolted at the junction of the girders with the heel and toe beam—a large tamarack knee in the heel beam corners, and a lighter brace of wrought iron in the toe beam corners. In addition, two transverse tie rods of wrought iron, 1⅛" in diameter and 13'–6" long, were carried through the two girders on the long arm to tighten the framework laterally.

At Mutchmore's Cut, where stone masonry abutments were to be constructed, the outer edge of the toe and heel beams of the mainframe were cut on the turning radius of the long arm and heel section, respectively, to facilitate the swinging of the bridge clear of the abutments. Likewise, the stone masonry abutments were constructed with a concave face on slightly larger radii, to provide clearance while keeping the roadway gap to a minimum.

The corbel frame provided structural support for the mainframe, as well as additional weight in the heel section of the superstructure. It was 36' long—just over half the length of the swing span—and was composed entirely of 12" x 12" oak beams and corner braces. They were positioned to match the layout and spacing of the heavy transverse floor beams and the interior corner braces in the mainframe, directly above. In addition, large tamarack knees were bolted into the corners of the corbel frame at the heel beam, as in the mainframe above. The corbel beams were bolted to the girders of the mainframe with 1¼" diameter wrought-iron bolts, spaced five feet apart for their full length of contact; and the trucks of the six balance wheels were lagged to the underside of the corbel frame on the four diagonal braces and the two transverse beams positioned directly over the turntable track.[8] (Figure 3)

No specifications were provided for the framing of the connections of the mainframe and corbel frame other than the stipulation, found in the extant 1872 specifications, that "all framing of the bridge to be housed in with double tenon joints in the most careful manner."[9] This lack of detail in the specifications is not surprising as at that time, joinery details did not need to be specified. Carpentry trade practice governed the dimensions, layout, and type of joinery to be used in framing heavy timbers, which was determined by the size

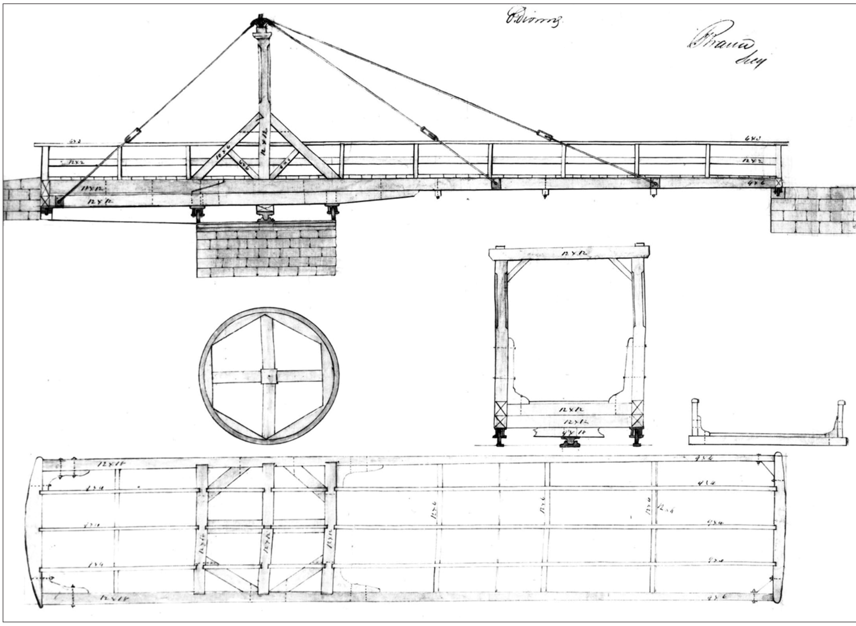

Figure 3. Plan, Elevation & Cross-sections of the Rideau Canal centre-bearing timber swing bridge design prototype of 1866. (Library & Archives Canada, detail of "Rideau Canal, Design for Swing", NMC # 43043, June 18, 1866)

of the timbers being framed, the particular type of member being framed, and the location of the joint.[10]

In the mainframe, the "joisting," or floor joists, were of white pine, and ran in a longitudinal direction in three rows. On the long arm, each 4" x 9" joist was a single piece, 38' long, and ran across the top of all the underslung floor beams on the long arm, with the outer ends of the joists notched down into the toe beam and centre beam of the mainframe. On the heel section, the joists were heavier, 6" x 9" and of a much shorter length. They crossed only one floor panel width, and were notched down into the heavy transverse floor beams to provide a level surface for the deck planking. The swing span was floored with 3" x 12" pine planks spiked to the two girders and the floor joists with 6" iron spikes.

The railings mounted on the girders were almost four feet high, and of a heavy construction. They had 6" x 6" end posts and 4" x 4" intermediate posts, supporting a 3" x 6" top rail, with a single 2" x 12" guard rail at mid-height. The posts were framed into the top rail and the girder with a single-tenon mortise-and-tenon connection, and were pinned with a trenail. To provide lateral stability for the heavy railing, they were supported by a small tamarack knee—24" vertical arm and 18" horizontal arm—bolted to the inside of each post and lagged to the floor planking.

The new centre-bearing swing span incorporated a supporting truss system that prevented the outer end of the long arm from sagging when the swing span was swung off its abutments. The truss was mounted on each side of the structure, directly in line with the centre line of the bridge girder. Each truss comprised a "mainpost," positioned on the girder directly over one end of the transverse pivot beam, and three stay rods that radiated downwards from a "cap beam" on top of the mainpost, to the girder below. The cap beam strengthened the mainposts laterally by joining them together in the form of a gallows frame. The trusses rendered the beam structure more rigid when supported solely on the pivot assembly on being swung off the abutments.

The gallows frame was built of oak timbers, 12" x 12", that were framed with mortise-and-tenon joints. The transverse cap beam, 15' long, was mortised to the top of the mainposts, which were 14' high. Each mainpost was mortised into the girder beneath, and was supported at its base by a trussed side brace on each side, and an interior tamarack knee. Each side brace consisted of a 10" x 6" angle brace (depth to width), about 8'–6" long, framed into the mainpost and the girder at a 45-degree angle, and strengthened with a 6" x 6" strut, framed between the mid-point of the inclined brace and the base of the mainpost. Transversely, each mainpost was strengthened by a large tamarack knee—6" thick, with a 6' vertical arm and 2' horizontal arm—bolted to the inside of the mainpost and the centre beam of the mainframe.

The wrought-iron stay rods were referred to as "suspension rods" or "adjusting rods," which indicated their intended function. Two of the rods were anchored to the long arm of the swing span, and the third rod to the short arm: one near the toe of the long arm; one at mid-span on the long arm; and one near the outer end of the short arm. The stay rod on the short arm was of 1¼" diameter, and the two long arm rods were lighter, of 1⅛" diameter. Each of the rods was equipped with an "adjusting swivel" (turnbuckle) for tightening to eliminate any sag at the outer end of the long arm of the swing span. This support was necessary to ensure that the rollers on the outer end of the long arm would remain aligned horizontally with the elevation of the stops on the abutment, to avoid difficulties in closing the swing span.

In the initial design of the truss system, the lower end of each stay rod was bolted to the side of the bridge girder. On the long arm, each stay rod was anchored to the end of a transverse tie rod where it passed thorough the girder; whereas on the heel section, the stay rod was anchored to a horizontal bolt passing through the side of the girder. Small flat iron reinforcing plates were countersunk and lagged to both sides of the girder, around the head of the tie rod or bolt at each anchorage point to prevent the tensioned stay rod from crushing the wood.

The upper ends of the stay rods were pinned to a cast iron saddle, called a "regulator," that was anchored to the top of the cap beam directly over each mainpost. It housed an "adjusting crank," which was free to rotate within the saddle casting. The cast-iron crank was shaped like an inverted triangle with rounded points. The lower point was bored and pin-connected to the saddle, and both points of the upper arms of the inverted triangle were bored. One of the upper crank arms was pin-connected to the stay rod radiating to the heel of the span; the other upper crank arm was connected, with a single pin, to the two stay rods radiating down to the long arm of the swing span. (Figure 4)

It would appear by its design features, and original name, that the regulator was intended to serve as an indicator to enable the carpentry crew to maintain an equilibrium of tension in the truss system. When tightening the suspension rods on the long arm to eliminate any sagging in the outer end of the long arm of the span when swung open, the position of the crank would indicate the extent to which the heel rod had to be tightened as well to maintain the truss system

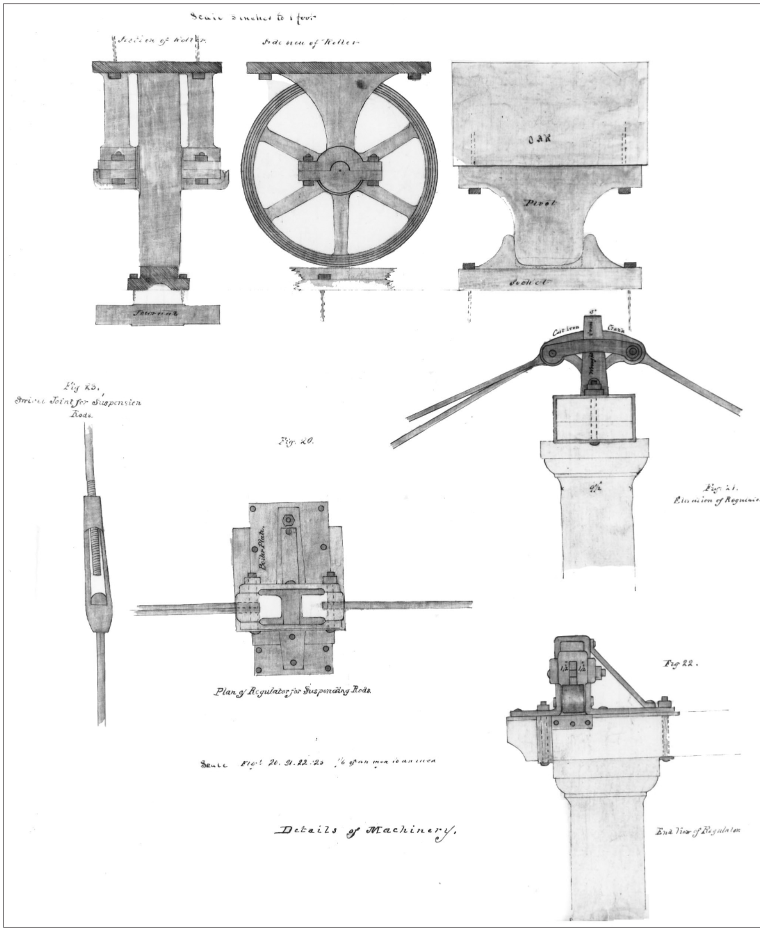

Figure 4. Ironwork and Machinery of the Rideau Canal centre-bearing timber swing bridge design prototype of 1866. (Library & Archives Canada, detail of "Rideau Canal, Design for Swing," NMC #43043, June 18, 1866)

in an equilibrium. In that manner the compression forces in the truss system could be maintained directly over the saddle, thereby minimizing any bending stresses acting on the mainpost. Moreover, if there was any deformation of a girder on the long arm due to a heavily loaded wagon passing over the swing span, the crank could rotate slightly in that direction to relieve the stress on the loaded stay rods. This was possible because any downward deflection of a girder on the long arm would tend to raise the heel of the span on the opposite side of the pivot, thereby producing slack in the heel stay rod. Thus the crank would rotate to relieve the stress on the loaded stay rods, and potentially keep them from snapping. Such deformations of the girders under a moving load would not have greatly stressed the pivot assembly as the rounded pintle was free to lift and rotate away from the vertical, to some degree, in its cast-iron socket seat.

The function of the regulator crank indicates clearly that the swing span was simply a beam bridge rather than a truss bridge when closed, and that the stay rods system was not designed to carry any of the dead or live load. More precisely, when closed the swing span was a continuous beam structure, supported on two abutments and the central transverse pivot beam.

The new centre-bearing swing bridge was a strictly utilitarian structure, with practically no architectural adornment, although attention was paid to appearance and finish. The corbel beams were tapered beyond the pivot pier and rounded up at their outer ends; the ends of the heel and toe beams were rounded off; the ends of the cap beam and the pivot beam were rounded up; and the top rail was rounded with a slight crown along the top of the railing. A drawing detail from a swing bridge plan of June 1866 shows the mainposts were to be finished with trim segments forming a capital at the top, and with the mainpost immediately below rounded down to a 9½" diameter column. Apparently this was the architectural embellishment given the mainposts on the centre-bearing swing bridges on the St. Lawrence Canals, from which these drawing details were taken by DPW. However, if the mainposts were finished in that manner, it was but a temporary adornment.

The cross-section view of the gallows frame in the same June 1866 drawing shows that the mainposts were only to be chamfered on the corners; and the surviving specifications dating from September 1872, shortly after the introduction of the centre-bearing swing bridge to the Rideau Canal, calls only for the timbers "to be dressed neatly and chamferred."[11] Moreover, architectural ornamentation was not as important on the Rideau Canal as on the St. Lawrence Canals. On the Lachine Canal, for example, the earlier DPW centre-bearing swing bridges were erected in populated areas, or on busy city street crossings of the canal, in the City of Montréal—at that time Canada's leading port and commercial-industrial centre, as well as the hub of its canal and railway transportation systems. In contrast, most of the Rideau Canal swing bridges would be erected over the canal at isolated lock sites, at small villages, or in sparsely populated rural areas along the waterway. Hence, the finishing of the new Rideau Canal swing bridge was guided simply by the prevailing carpentry standards of good workmanship in the framing of heavy timber structures, rather than by any need for architectural ornamentation.

To conserve the swing span the cast-iron components were to be heated to a blue heat, and immersed in a heated mixture of linseed oil and mineral tar, and all of the ironwork and the timber joints were to be "bedded in a thick Coat of White Lead and oil." Mineral tar—a ship carpenters' varnish—was to be applied to seal all wood joints, and two coats of mineral tar applied to the girders and the transverse beams. All of the exterior woodwork was to be painted a white color with three coats of a linseed oil-white lead paint, the last of a stone color, and the ironwork painted black. In the 19th century, carpenters were acutely aware of the need to use well-seasoned wood, and to ensure that all joints and knots were well sealed against water penetration. Otherwise the painting of the structure was counterproductive as the paint would merely seal in the moisture, facilitating decay.[12]

The composition of the white lead and oil sealant was not recorded. However, it was probably a commonly used sealant for bedding heavy framing timbers as exactly the same specifications were in force for the timber lock gates on the Rideau Canal. In the contemporary building-trades practice, a common putty was made by beating "whiting" (powdered white lead) with linseed oil to form a thick, strong adhesive or cement. It was also widely used in shipbuilding for bedding timbers, and as a facing on caulked planking joints. A mixture of 50% white lead and 50% linseed oil yielded a very plastic or pliable sealant that would not crack with the expansion and contraction of a ship's planking. For thicker joints, powdered chalk was sometimes mixed with the linseed oil component. Either mixture, with or without the chalk thickener, would have made an excellent sealant for the timber joints of a swing bridge subject to changing stresses under live loads and when swung off the abutments.[13]

The fine balancing and leveling of the bridge was done just before the plank decking was spiked on. It consisted of adding stone to a small ballast box in the heel section to balance the unequal arm structure. Shims were placed under the pivot assembly and/or the abutment stops to level the bridge, so that it would seat properly on the abutments for ease of opening and closing. Then the deck planking was placed on and the balance further fine-tuned, before the stay rods were given a final tightening to equalize the tension in each truss system and eliminate any slack in the rods. The deck planks were not painted, as traffic would have worn off the upper surface paint. The swing spans were designed to be swung open and closed manually by one man pushing and pulling, respectively, on the heel of the swing span, although a simple push bar was added at the heel of the swing span at an early date.

The turntable consisted of a timber framework anchored to either a masonry platform at the coping of a lock wall, or to the top of cut-stone masonry pivot pier constructed adjacent to a canal cut, as at Mutchmore's Cut, or in water adjacent to the navigation channel of a canalized river section of the Rideau Canal. The turntable rail consisted of cast-iron rail segments—cast with a curvature matching the radius arc of a 12' diameter circle—that were anchored in turn to the timber turntable.

One significant difference between the new centre-bearing swing bridge and the earlier rim-bearing structure was in the materials of construction. For the rim-bearing type of swing bridge introduced to the Rideau Canal in 1843 from the Grenville Canal on the Ottawa River navigation, all of the heavy timbers were of white oak, as well as the deck planks.[14] Just over two decades later, the Bill of Materials for the Mutchmore's Cut Bridge, the first of the new centre-bearing type of swing bridge on the Rideau Canal, indicates that pine was to be used for the lesser-stressed components. All of the heavy timbers of the main frame and the corbel frame, with the exception of the tamarack knees, were still to be constructed of white oak, but the three floor beams and the joists on the long arm were to be of white pine, as well as the transverse cap beam, the cap beam braces, the railings, and the deck planking.[15] These changes were driven by major increases in the cost of oak timber, but soon other substitutions had to be made because of the scarcity of a structural timbers of the required long lengths and large dimensions. Although the specifications continued to call for

> All the timber used to be of the best quality—straight grained and free from defects or blemishes, and of the full size and dimensions given; ...

that was no longer always possible.[16]

When the Mutchmore's Cut swing bridge was let to contract in June 1866, the contractor was unable to procure the large-dimensioned white oak timber required for the two bridge girders. Hence, he was permitted to substitute white pine, but with an added stipulation that each girder was to be hewn out of a single stick of pine, rather than two pieces spliced together.[17] By the mid-1860s white oak was becoming difficult to obtain in the long lengths and large dimensions required for the two girders. Apparently the contractor had already been given the option of splicing two oak sticks together to form a single girder 69' long — as indicated by a scarf joint splice shown on the heel section in the Mutchmore's Cut Swing Bridge contract plan. However, even the shorter lengths of large-dimensioned structural timbers in white oak proved unobtainable.[18] On the other hand, white pine timber was still procurable in the large dimensioned long lengths required for the two swing bridge girders. There was no need to resort to splicing two sticks of pine to form a girder.

Origin of the Design Prototype

Although the centre-bearing type of swing bridge introduced on the Rideau Canal at Mutchmore's Cut in 1866 was unique in some of its design features, it was based on a well-known design principle. Moreover, it was a revised version of a standard centre-bearing timber swing bridge design that the Department of Public Works (DPW) had already introduced elsewhere on Canada's canals system.

The evolution of the Rideau Canal swing bridge prototype began during the winter of 1864–1865 when the superintending engineer on the Rideau Canal, James D. Slater, decided to design a new type of swing bridge to replace the existing swing spans, which were difficult to operate. The new design would be similar to what he had seen on another DPW canal—the Welland Canal, a 27-mile-long canal that connected Lake Ontario and Lake Erie, and enabled Great Lakes' schooners to be towed over the Niagara Peninsula past Niagara Falls. Slater explained to the Chief Engineer's Office, DPW, that his new design differed from the existing swing bridges on the Rideau Canal in that "it is proposed to support the whole weight of the bridge (while being swung) on the center pivot, which will be 7½" to 8" in diameter, the truck wheels are intended only to keep the bridge from tipping."[19] (Figure 5)

Subsequently, in February 1865, Slater had forwarded a plan and specifications for a centre-bearing swing bridge at a proposed new crossing of the Rideau Canal at Manotick on Long Island.[20] After comparing Slater's plan to existing departmental swing-bridge plans, the department sent a plan and specifications for a centre-bearing swing bridge of a somewhat different design that DPW had introduced earlier on the St. Lawrence Canals—the Lachine, Beauharnois, Cornwall, and Williamsburg canals on the St. Lawrence River. The DPW centre-bearing swing bridge was working well on the St. Lawrence Canals, and Slater was instructed to adopt the same bridge for the Rideau Canal.[21]

Slater adopted the approved swing bridge design, as instructed, but responded that he would "like the bridge beams to be stronger" and would endeavour to "make minor improvements" in the approved design.[22]

Figure 5. James Dyson Slater (1813–1876), the designer of the Rideau Canal centre-bearing swing bridge introduced in 1866. (Association of the Land Surveyors of Ontario, Annual Report, 1921, p. 130)

Initially, he had strengthened the cast-iron pivot of the DPW-approved centre-bearing swing bridge plan by increasing the pintle from 4" to 7" in diameter, and made the swing span easier to swing by specifying that the rounded end of the pintle be faced with steel. Otherwise, the approved design was followed in preparing a new plan and specifications for the proposed Manotick bridge.[23] However, when a dispute arose between two adjacent counties over whether the Long Island bridge should be located at the newly established mill village of Manotick or two miles downstream at the Long Island lock station, the bridge contract tendering was postponed. Slater took that opportunity to re-work the approved swing bridge design.[24]

In the approved St. Lawrence Canals swing-bridge design forwarded to James Slater, the swing span was an unequal arm, centre-bearing, Howe pony-truss type, with light lower chords of 10" x 9", tapering to 9" x 9" at the toe of the span, and the Howe pony truss was reinforced with a secondary truss that provided additional support to keep the long arm from sagging when swung off its abutment. The secondary truss system consisted of a vertical mainpost, positioned in line with the pivot beam over the pivot pier, with wrought-iron stay-rod arms that radiated down from the top of the mainpost to the lower chord of the Howe truss—two rods to the long arm, and one rod to the short arm in each truss. A cap beam joined the tops of the two mainposts, which were braced in the manner of a gallows frame, to provide lateral stability for the two stay rod trusses.[25] (Figure 6)

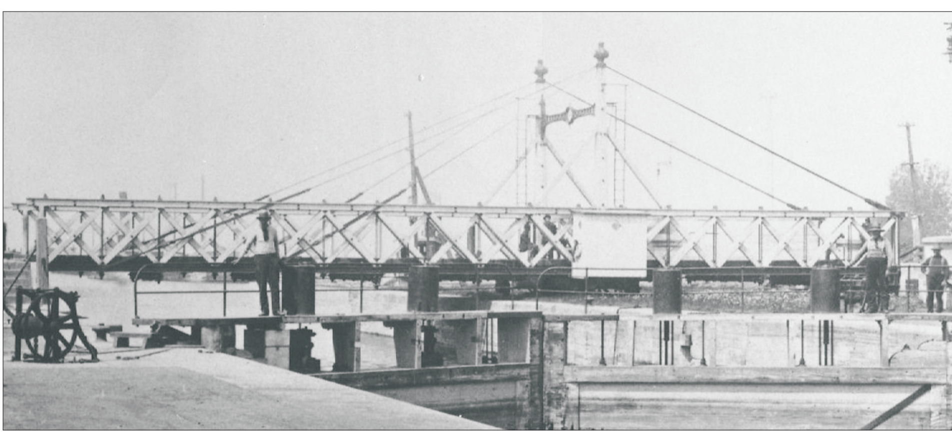

Figure 6. Lachine Canal Timber Swing Bridge, showing the evolved form of the mid-19th century Howe pony truss type of centre-bearing swing bridge designed by the Department of Public Works. (Library & Archives Canada, "Bridge at Lachine above Lock No. 5," C-081815, June 1903)

In preparing the Rideau Canal design prototype of 1866, Slater discarded the Howe pony-truss design, and installed the much heavier 18" x 12" girders tapering to 9" x 6" at the toe, with non-structural railings placed along each side of the swing span. This modification changed more than just the appearance of the swing bridge span, it was highly significant structurally. It converted the DPW structure from a Howe pony-truss swing span to a simple beam swing bridge structure similar to the rim-bearing and offset pivot swing spans erected on the Rideau Canal in previous decades. Some additional changes also were made in the spacing of the floor beams in the interior of the mainframe.

Through introducing changes in the approved DPW plan, Slater developed the design prototype erected at Mutchmore's Cut in 1866—a centre-bearing type of unequal arm swing bridge that was unique to the Rideau Canal—but that retained the function, balance, and basic design principle of the St. Lawrence Canals Howe pony-truss centre-bearing type of swing bridge. Over the next few years, James Slater continued to refine some of the features of the new Rideau Canal design prototype. By the time of his retirement in October 1872, he had produced the final refinement of his swing bridge design—the prototype would be widely constructed on the Rideau Canal during the following decades.[26] The improvements made by Slater can be readily identified by comparing the June 1866 plan of the Mutchmore's Cut swing bridge—the original design prototype —with an August 1871 plan for a Rideau Canal swing bridge, and the specifications prepared for a swing bridge that was erected at Lower Brewer's lock station in the fall of 1872.

The Refined Design Prototype, 1872

As indicated in the plan and specification for the Lower Brewer's swing bridge, it is clear that Slater's main concerns were to strengthen the long arm of the swing bridge at the toe of the structure, to lighten the swing span, and to strengthen and increase the weight of the corbel frame.

To strengthen the swing span, the taper on the two 18" x 12" girders was reduced to 9" x 9" at the outer end, rather than 9" x 6" (depth to width); the dimensions of the toe beam were increased from 9" x 9" to 9" x 12" (depth to width); and the depth of the pivot beam, which supported the superstructure, was increased with a 12" x 18" beam replacing the former 9" x 18" beam (depth to width). The rigidity and strength of the mainframe was further strengthened by framing the floor beams on the long arm up inside the girders, rather than bolted beneath them as previously. The railings along the sides of the swing span also were strengthened by replacing the light 3" x 6" top rail and the 4" x 4" interior posts with heavier 5" x 6" pieces, and replacing the 6" x 6" endposts with 6" x 8" posts. Otherwise, the railings remained the same with the posts on the same spacing, and a single 2" x 12" guard rail at the mid-height of the railing.

To lighten the structure, Slater introduced a number of design modifications. In the mainframe on the long arm, he eliminated one of the transverse floor beams, decreasing their number from three to two, and reduced their size from 12" x 6" to 9" x 6" (depth to width). On the heel section, he decreased the dimensions of the heel beam from 18" x 20" to 18" x 12" (depth to width); replaced the tamarack knees reinforcing the heel beam corner joints with lighter wrought-iron braces; and removed the single 6" x 12" floor beam in the outer heel section. He also eliminated the heavy 12" x 12" diagonal timber corner braces on the transverse floor beams of the mainframe over the pivot pier, and replaced them with lighter Tamarack knee braces—6" thick, with arms 4' and 2' in length—bolted on the opposite side of the transverse floor beams to further strengthen the mainframe on both the heel section and the long arm.

On the long arm, the placing of the floor beams up between the bridge girders, rather than bolted beneath them, necessitated another change. The three rows of 4" x 9" longitudinal floor joists were retained on the same spacing, but single joists no longer ran along the tops of the floor beams for the full 38' length of the long arm. The joists now spanned only a single floor panel, and their ends were notched down, presumably with half-lap joints, into the transverse floor beams and the toe beam. Likewise, on the heel section, the joists were notched down into a transverse floor beam and the heel beam. The toe and heel beams were also framed inside the girders, rather than being framed across the ends of the girders; and the shape of the toe and heel beams was also simplified. In keeping with a contemporary decision to save costs by erecting timber crib abutments on new bridge crossings rather than stone masonry abutments, the toe and heel beams were no longer cut on their respective turning radii at the ends of the swing span. They were simply cut on a bevel over a section of their length to clear the abutments in being swung. (Figure 7)

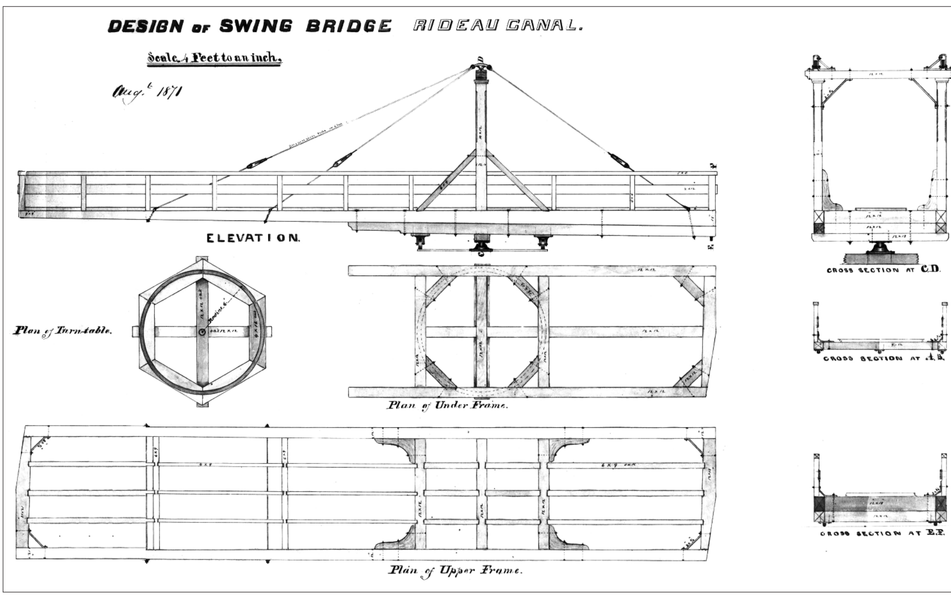

Figure 7. Refined swing bridge design prototype erected at Lower Brewer's in 1872. (PWGSC, Rideau Canal microfiche drawings, R-2.118.2, "Design of Swing Bridge, Rideau Canal," August 1871)

While lightening the mainframe, Slater strengthened and increased the weight of the corbel frame by adding a 12" x 12" beam along the longitudinal centre of the heel section. Otherwise the corbel frame remained as originally constructed.

The gallows frame was lightened through reducing the mainposts from 12" x 12" to 12" x 10"; by inserting lighter wrought-iron braces in place of the wood cap beam braces; and by replacing the trussed side braces of heavy timber at the base of each mainpost with a simple wood brace, 6" x 9", on each side. The side braces were mortised into the mainpost and stringer, and held in place with a single horizontal bolt of wrought iron, which passed through the mainpost and the beveled top of the brace on either side.

The reason for lightening the mainframe and gallows frame timbers of the swing span may well be revealed in one additional change. The specifications for the 1872 swing bridge at Lower Brewer's called for a crab, endless chain and pillow blocks apparatus to be used to swing the revised swing span, whereas the original 1866 prototype was designed to be swung by a single man without any mechanical-assist devices. Perhaps the 1866 design prototype had proven to be too heavy, and not as easy to swing as James Slater had anticipated.

One of the less noticeable changes was a modification of the anchorages for the stay rods. In the new anchorage arrangement, the lower end of each stay rod was pinned to an eye-bolt anchor that passed vertically through the girder, and was inclined at a slight angle towards the mainpost. A triangular iron shoe on the underside of the girder provided an inclined base, perpendicular to the stay rod, against which the lock nut of the eye-bolt anchorage was tightened. The inclined vertical eye-bolt replaced the simple horizontal bolt and tie rod ends anchorages by which the stay rods had been anchored to the side of the chord in the June 1866 swing-bridge plan. The two horizontal tie rods were retained in the mainframe on the long arm to tighten the framework laterally, but were no longer used to anchor the stay rods. In the new arrangement, the inclined vertical anchor bolt was directly in line with the stay rod so that the stresses acted along its length for the most part. Thus the shearing and bending stresses, which had acted on the horizontal anchor bolt and tie rod ends in the original design of the stay rod anchorage, were greatly reduced. At the same time, the regulator on the cap beam was moved inward slightly to keep it in line with the new alignment of the stay rods directly over the centre of the girders of the swing span.

Two changes were made in the species of wood to be used for structural members. To increase design strength, the two 6" x 9" floor beams framed into the main frame on the long arm were constructed of oak rather than pine, which had been specified for the three heavier 6" x 12" pin beams that they replaced; and it was specified that the girders were to be made "of the best white pine 68'-4" in length, 12" x 18" at the heel and 9" x 9" at the Toe," with no splicing permitted. No longer would there be any effort to procure oak sticks of the substantial dimensions required for the two girders of the swing span, or any countenancing of splicing to make a girder of the required length. In addition it was specified that the iron components were to be "of the best Scotch-American or Sweeds iron," and that "all the journals and working parts of the bridge to be accurately turned and fitted, so as to ensure easy and smooth working."[27]

In sum, during the first five years of operation of the new centre-bearing type of swing bridge, James Slater introduced a number of significant changes to improve the strength, weight, balance and working of the design prototype. More generally, the changes comprised: a modification of the size and/or spacing of structural members that Slater saw as too heavy or over-designed; the substitution of different species of wood for some members as the preferred structural material became scarce; and the strengthening of the framed structure in specific areas, in response, no doubt, to empirical knowledge gained through observing the behavior of the new centre-bearing swing bridge structure in operation.

Proliferation of the Design Prototype

The centre-bearing timber swing bridge was introduced to the Rideau Canal during a period when the towns, villages and rural areas in the canal corridor were experiencing a rapid population growth with the establishment of new villages, mills and factories, and the expansion of existing mill complexes, utilizing waterpower sites along the canal and in the canal corridor watershed. This development gave rise in turn to an unprecedented demand for new bridge crossings of the Rideau Canal. Under James D. Slater, and after October 1, 1872, his successor as superintending engineer of the Rideau Canal, Frederick A. Wise, the centre-bearing swing bridge prototype was widely constructed on the Rideau Canal to replace the scows and ferries that formerly provided access across the canal to the mill establishments and villages along its banks.

Following its introduction on the Mutchmore's Cut Bridge (1866) in Ottawa, the new centre-bearing swing bridge was erected at almost a dozen new road crossings opened across the Rideau navigation over the next two decades. These included six at lock stations along the canal: at the Narrows (1867); Lower Brewer's (1872); Long Island (1874); Jones' Falls (1883); Chaffey's Lock (1884); and the Hogs Back (1887). Swing spans were incorporated into multi-span, low-level fixed bridges erected over river sections of the waterway: at Beckett's Landing (1867); Manotick (1868); Oliver's (Rideau) Ferry (1874); and Brass Point (1887). Moreover, yet another centre-bearing swing span was incorporated into a multi-span, low-level bridge erected across the Rideau River by the County of Carleton: the Wellington Village (Kars) Bridge (1879).

In addition to the new crossings, the centre-bearing swing bridge prototype also replaced older types of swing bridges on existing lock station crossings: at Smith's Falls combined locks (1868); Kingston Mills (1868); Upper Brewer's (1869); Maitland's (Kilmarnock, 1871); and Merrickville (1877); and an existing river crossing at Burritt's Rapids (1884). Moreover, during this period of prolific bridge construction on the Rideau Canal, two private bridges that mill owners had erected at lock stations adjacent to their mill complexes were taken over by the government and replaced with a centre-bearing timber swing bridge. These replacement bridges were erected at Upper Nicholson's (1877), and Old Sly's (1886).[28]

New bridges were erected by the Department of Public Works, and after 1879 by the Department of Railways and Canals, in response to petitions from local county or township ratepayers requesting that a bridge be constructed over the waterway to replace a scow or ferry crossing. When a bridge was built over a river section of the canal, a bridge tender's house was erected as well, and a bridge tender employed to operate the swing span; whereas a swing bridge erected at a lock station was swung by the canal lock staff.

Whenever a new bridge was to be constructed, the Superintending Engineer of the Rideau Canal would put the work out to public tender on the basis of a standard plan and specifications, and it was let to a reputable contractor on the basis of the best bid received. The contract would include the construction of the swing bridge superstructure, the pivot pier and abutments, the road approaches, and the construction of a rest pier to support the swing span when swung fully open. On occasion a contract would include additional fixed spans and piers where a multi-span bridge was needed to span a wider part of the waterway. However, on the Wellington Bridge, built by the County of Carleton, the Department of Public Works contributed the plan for the swing span, as well as a percentage of the total cost of the bridge construction project, based on a calculation of the extent to which the Rideau Canal slackwater dam downstream of the bridge site had raised the natural water level and increased the cost of constructing the piers.[29]

Once a swing bridge was erected, a Rideau Canal carpentry crew was responsible for the routine maintenance and repair, including the removal and replacement of individual decayed members, and the periodic re-planking of badly worn decks. When a bridge deteriorated to the point where it required replacement, the work was let to contract. Generally, the swing bridges constructed of white oak timbers lasted upwards of twenty years, whereas the later structures of white pine had to be reconstructed every 12 to 15 years, as was the case subsequently with the bridges constructed of Douglas fir. All of the timber swing bridges were preserved through a long-established practice of replacement-in-kind reconstruction in which decayed timbers were replaced with new timbers of the same or a like type, and the metal castings and hardware were salvaged for re-use.[30]

By 1890 there were twenty timber swing bridges on the Rideau Canal.[31] (Figure 8) Thereafter the number declined as the Department of Railways and Canals had begun to erect more modern types of bridge structures in place of the timber swing spans on the major bridge crossings. As late as 1930, there were still fourteen timber swing bridges on the Rideau Canal out of a total of 25 road bridges of all types (moveable and fixed), and a survey two decades later, in August 1950, recorded eleven reconstructed timber swing bridges extant on the Rideau Canal.[32] The number of timber swing bridges experienced a further decline during the 1950s–1960s under a bridge modernization program. It called for the replacing of the timber swing bridges, and the older steel truss swing bridges, with bridges of a 20-ton highway loading capacity, comprising either a plate girder swing span or a fixed, high-level reinforced concrete bridge just off site. As of 1972, there were only five reconstructed timber swing bridges extant on the Rideau Canal; and they were found on county and township road crossings with light traffic demands.[33]

Tracing the Design Evolution

When Parks Canada acquired the Rideau Canal in 1972, the five surviving timber swing bridges were located at Jones' Falls (1960), Brass Point (1964), Lower Brewer's (1967), Kilmarnock (1970), and Upper Nicholson's (1971). Four of these extant bridges were single-span structures crossing over a canal lock, and one a timber swing span in a low-level multi-span steel truss bridge crossing the navigation channel at Brass Point on an arm of Cranberry Lake. Only one of the structures was under any immediate threat. At Jones' Falls a modern high-level bypass bridge was under construction a short distance upstream of the lock station. It was intended to replace the existing road crossing at the lock station where the timber swing bridge was in an advanced state of decay.

Initially, Parks Canada confined its research efforts to identifying the provenance of the timber swing bridges and the date of their introduction on the Rideau Canal, and undertook a photo-survey recording of the historic bridges on the Rideau Canal. Once the origin of the centre-bearing swing bridge was discovered in archival records, and the historic plans were found for the design prototype erected at Mutchmore's Cut (1866) and Lower Brewer's (1872), as well as the specifications for the Lower Brewer's Bridge, there was no further effort made to trace the design evolution of the centre-bearing swing bridge over the intervening century prior to Parks Canada's acquisition of the Rideau Canal. Based on the general configuration and appearance of the extant timber swing bridges, it had appeared obvious that all five structures were replicas of the newly identified design prototype; and that the process of replacement-in-kind reconstructions had served to maintain the timber swing bridges basically unaltered over the course of the previous century.

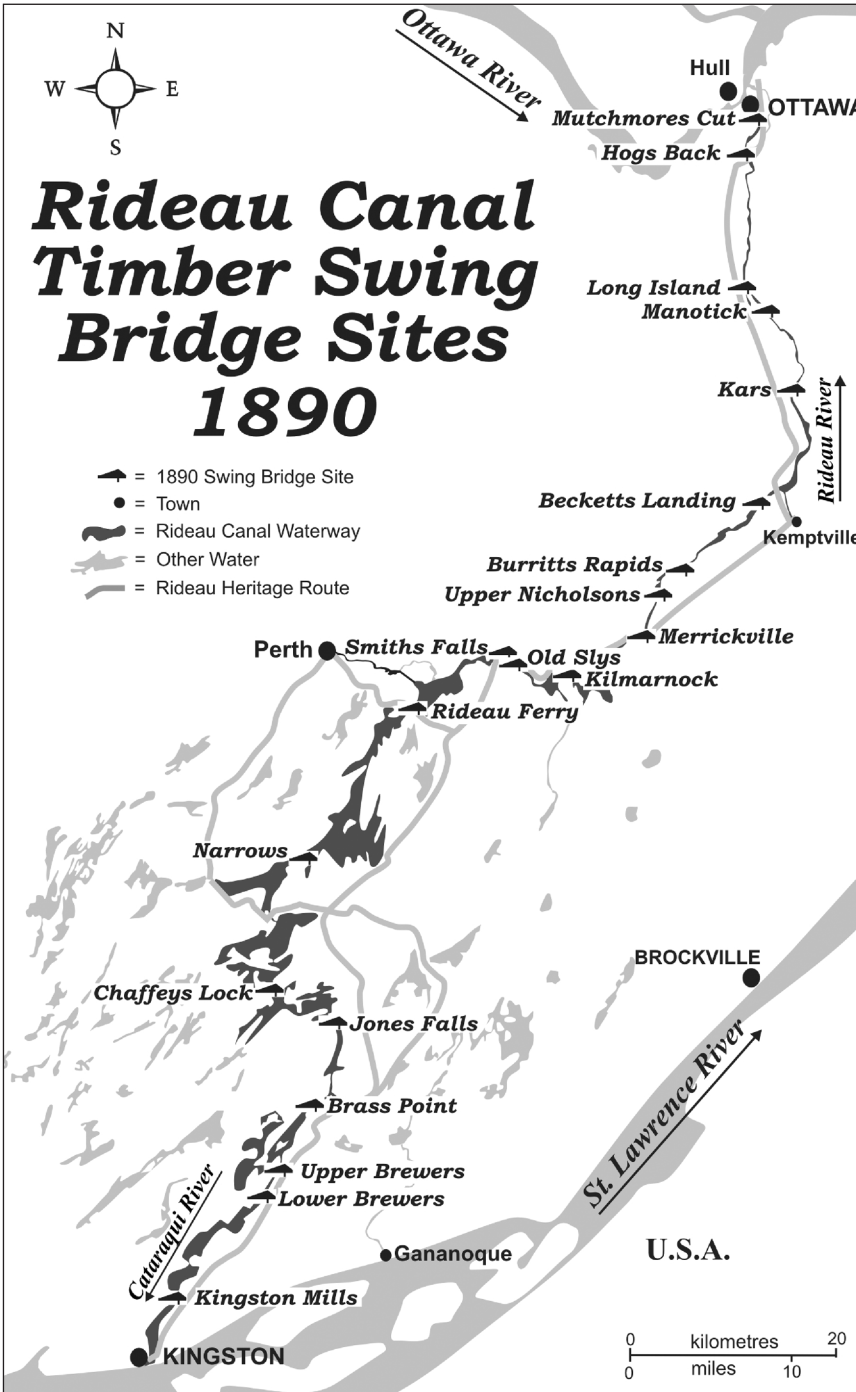

Figure 8. Map of Rideau Canal in 1890, showing timber swing bridge sites. (Ken Watson, 2006)

Subsequently, a further study of the evolution of the timber swing bridges was undertaken, supplemented by additional historical research, an analysis of the existing historic plans and specifications, and a detailed examination of photo-recordings of the extant historic swing bridges dating from 1974. These information sources were supplemented by a newly located drawing of the original Oliver's (Rideau) Ferry timber swing bridge of 1874; and an "as-found" measured drawing recording of the Lower Brewer's timber swing bridge prepared by the Canals Engineering Branch of Parks Canada in 1984. This follow-up study revealed that a number of significant, but not readily visible design modifications were introduced into the design prototype of the Rideau Canal centre-bearing timber swing bridge during a succession of reconstructions and upgrades over the course of more than a century.

The design had evolved principally in three areas: the continued substitution of different species of wood as the earlier species in use became unprocurable in large-dimensioned structural-quality timber; the insertion of additional members in the corbel frame and in the flooring system of the mainframe, on closer spacings, to upgrade the load carrying capacity of the swing span; and a simplification of the framing details and connections.

After succeeding James D. Slater as Superintending Engineer, Rideau Canal, in October 1872, Frederick A. Wise introduced several changes in the design prototype for the timber swing bridge to further simplify and strengthen the structure. This can be seen in the plan prepared for the construction of the Oliver's (Rideau) Ferry Bridge of 1874.

The severely tapered girders were replaced with straight girders, thereby eliminating a great deal of labor with adze and squaring axe. Where formerly the girders were 12" x 18" (width to depth) tapering to 9" x 9" at the toe of the swing span, the replacement girders were 12" x 16" throughout, with only a slight taper upwards beyond the corbel frame to a 12" depth at the toe beam. To match the changed depths of the girders at the toe and heel of the swing span, the toe beam was increased in size to 10" x 12" (width to depth) from 9" x 9", and the heel beam to 18" x 16" (width to depth), from 12" x 18" (width to depth). The mainframe was further strengthened on the long arm by increasing the number of floor beams from two to three, on closer spacings, and their size from 6" x 9" to 8" x 12", and by placing an additional 8" x 12" floor beam in the heel section.

The 4" x 9" joists on the long arm, and 6" x 9" joists in the heel section of the 1872 refined design were replaced by 3" x 12" joists throughout. Each joist spanned only a single floor panel, with its ends notched down into the transverse floor beams. The toe and heel beams were now placed across the ends of the bridge girders as in the original design, but the floor beams on the long arm of the mainframe continued to be framed inside the bridge girders in keeping with the arrangement introduced in 1872. A wrought-iron tie rod was inserted beside each floor beam to tighten the mainframe against the mortise-and-tenon connections of the floor beam ends with the bridge girders. The girders, which were spliced in the heel section under the mainpost brace, were of white pine, as were all of the mainframe members with the exception of the heavier 12" x 16" transverse floor beam on either side of the pivot beam over the turntable track radius, and the 12" x 12" centre beam, which were of white oak.

To restore the balance of the unequal arm swing span, the weight of the corbel frame was increased, as well as strengthened. It was constructed of 12" x 16"

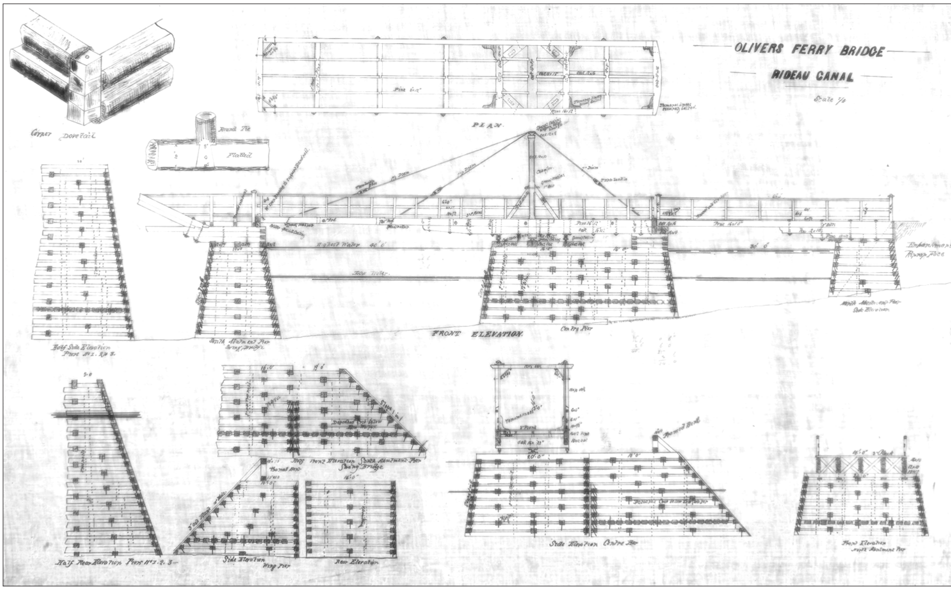

Figure 9 Modified timber swing bridge design prototype, erected at Oliver's Ferry in 1874. (Library & Archives Canada, NMC # 130281, "Olivers Ferry Bridge," n.d.)

timbers, rather than the 12" x 12" timbers employed previously; and both the corbel frame and the gallows frame were constructed of oak. The only change in the gallows frame timbers was a reduction in the size of the cap beam from 12" x 12" to 8" x 12" (depth to width). The hardware of the stay rods system remained as originally designed, with the exceptions of the use of inclined bolt anchorages, introduced earlier in the 1872 Lower Brewer's swing bridge plan, and an increase in the cross-section of the stay rods. The two wrought-iron stay rods on the long arm of the truss were increased from 1⅛" to 1½" in diameter, and the single stay rod on the heel section was increased from1¼" to 2" in diameter. (Figure 9)

In the Oliver's Ferry Bridge of 1874, the size and configuration of the pivot beam was modified. Previously, the pivot assembly introduced on the Lower Brewer's Bridge of 1872 had comprised three beams bolted together: a 12" x 18" (depth to width) pivot beam under the corbel frame; a 12" x 12" centre beam inside the corbel frame; and a 12" x 12" centre beam in the mainframe, which was on a level with the top of the tapered bridge girders.

In the Oliver's Ferry Bridge, the pivot beam was a large block of oak, 22" x 16" (depth to width) in cross-section, with a 12" deep shoulder at each end that extended outwards under the corbel frame. The enlarged, and stepped, pivot beam extended up inside the corbel frame to a depth of 10", and was bolted to a enlarged centre beam of 22" x 18" (depth to width), which brought the height of the new pivot beam assembly level with the top of the newly adopted, 12" x 16" straight bridge girders. The large tamarack knees on the inside of mainposts were lagged to the top of the centre beam, and the 3" x 12" joists were notched into the centre beam with a half-lap connection. The 3" x 12" pine planks of 13' length were laid transversely and spiked to the bridge girders.

Although the corbel frame and mainframe were strengthened, most of the railing components were made lighter. At Oliver's Ferry, the 6" x 8" end posts and the 5" x 6" intermediate posts and top rail were replaced by 6" x 6" posts throughout, and a 4" x 6" top rail. The single 2" x 12" guard rail at mid-height was replaced by two side rails: a 1" x 6" middle rail; and a 1½" x 10" bottom rail at the deck level. Both side rails were notched for their full depth into the inside face of the railing posts, and were nailed in place. The railing posts were mortised into the girders and pinned. It is not known how the 4" x 6" top rail was affixed to the railing posts.[34]

The lack of drawings of the timber swing bridge pertaining to the late 19th century and early 20th century precludes any further design analysis during that period, but judging by later drawings the timber swing bridge design appears to have changed very little in substance during that era. However, by the 1890s the depletion of white oak and the formerly large stands of white pine did necessitate the substitution of Douglas fir for all of the heavy structural timbers of oak used in reconstructing the timber swing bridges on the Rideau Canal, as well as for the two girders which had been constructed of white pine during the previous two decades. Only the deck planking and railings continued to be constructed of pine. The Douglas fir timbers were brought from British Columbia on Canada's first transcontinental railway, the Canadian Pacific Railway, completed in 1885. Whether the introduction of Douglas fir enabled the girders to be constructed once again of single sticks of 68' to 70' lengths, or whether they continued to be spliced together from two shorter sticks is not known.[35]

The tamarack knee that provided lateral support on the inside of each mainpost of the gallows frame was replaced near the turn of the century by a large cast-iron bracket with arms of a similar length. The metal bracket, with a 4'-long vertical arm and a 2'-long horizontal arm, was lagged to the inside of each mainpost and the centre beam of the mainframe in the same manner as the tamarack knee that it replaced. One other change can also be seen in historic photos taken in the early 20th century. The wrought-iron cap beam brace introduced in 1872 in the top corners of the gallows frame was replaced with a wood brace, which constituted a return to the 1866 design.[36]

By the 1930s, it was the Rideau Canal carpentry crew, rather than contractors, that was responsible for reconstructing the timber swing bridges and, generally speaking, engineering drawings were not prepared for guiding the carpentry crew in their work. There was a standard plan of construction, and when more precise information was needed measurements were taken directly off the swing span to be reconstructed. For example, the exact length of the girders of the bridge to be reconstructed was measured off the existing span, and the turning radii of the toe and heel of the swing span, which varied slightly from bridge site to bridge site, were measured on site and used to make templates to guide the cutting of the curvature of the toe and heel beam of the replacement structure. Templates also were maintained and used for positioning the bolt holes required for the metal hardware. If a casting was damaged or badly worn, a new casting was made at a local foundry from a wooden pattern kept in the Rideau Canal shop. The casting was then machined and bored to match the original artifact.[37] In this manner, through the use of a standard bridge drawing, and a process of replacement-in-kind involving the re-use, or if necessary the re-casting of the metal hardware, and the replacing of the decayed wood components, the Rideau Canal swing bridge prototype remained remarkably constant through a series of reconstructions over an extended period of time.

The replacement structure was erected on a framework beside the existing swing span, or on a scow if there was insufficient room at the bridge site. Most of the work was done with hand tools—saws, chisels, slicks, adzes and augers. Once the timbers were framed together, the old bridge was cut up, and the metal hardware removed and installed on the reconstructed span. Even the bolts were driven out and re-used. Then the reconstructed structure was slid sideways on a platform of skids by "bull work," with the carpentry crew working block and tackles to seat the reconstructed swing span on the pivot pier.[38]

Upgrading the design prototype: Rideau Ferry, 1947

Further changes were introduced into the design prototype of the centre-bearing, timber swing bridge on the Rideau Canal in 1947 during the reconstruction of a timber swing span at Rideau Ferry. There a multi-span, low-level bridge of 530' length crossed a 30'-deep river section of the Rideau Canal. The bridge comprised five fixed steel through-truss spans with a 15' clear roadway width and 8-ton highway loading capacity, and a lighter and narrower timber swing bridge of 69'–6" span and 12' width, with a posted 5-ton load capacity.

For over two decades previously, the canal's engineering staff had been concerned about the increasingly heavy live loads that the timber swing bridges were subjected to by heavy trucks. That problem was met by gradually replacing the timber swing spans on the heavy traffic crossings of the Rideau Canal, with steel truss and steel plate girder swing bridges of 20-ton loading capacity, and 18' to 24' roadway widths. On county and township roads where traffic was light, the timber swing bridge design prototype continued to be reconstructed with a 5-ton load-carrying capacity, while retaining its single-lane width.[39]

At Rideau Ferry, on a county road with heavy traffic, it was decided to widen and upgrade the timber swing span to accommodate two lanes of traffic. It appears that this was an experiment as none of the timber swing bridges reconstructed thereafter were widened, although some of the interior structural modifications introduced at Rideau Ferry were subsequently incorporated into the standard Rideau Canal timber swing bridge. In August 1947 plans were prepared for the reconstruction of the Rideau Ferry Bridge with a widened deck; the extant historic drawing reveals how the timber swing span was widened and upgraded to carry the extra weight imposed by traffic on a two-lane structure.

The major changes were in the widening the swing span to 16' (c. to c. girders), the strengthening of the mainframe and corbel frame of the wider structure, and an increase of the diameter of the turntable track from 12' to 16'. In the mainframe an additional 12" x 16" girder (width to depth) was inserted on the longitudinal centre of the structure, and the girders were no longer tapered on the underside over the full length of the long arm. The three girders now were continued at their full 16" depth for almost their whole length, with only a slight taper in the outer floor panel, where the underside of the girder sloped upwards to a 14" depth. The heel beam remained at the same depth, but was made heavier by increasing its width with a 16" x 24" beam replacing a 16" x 18" beam (depth to width). The toe beam was likewise made heavier. It was increased in size from 12" x 10" to 14" x 16" (depth to width) to match the increased depth of the long arm girders with the reduced taper. Both end beams were cut on a radius of curvature matching the turning radii of the heel section and long arm of the swing span.

On the long arm of the mainframe, beyond the corbel frame, the transverse floor beams of the evolved 1874 timber swing bridge design were increased in number from three to five, thereby decreasing their spacing to 4'-10" from 10', but they were decreased in size from 8" x 12" to 6" x 12". With the insertion of a central longitudinal girder in the mainframe, the floor beams on the long arm were no longer framed between the bridge girders. They were bolted up to the underside of the three girders, and were stepped on their outer ends, and notched at their centre, to fit 4" up inside the mainframe. The new configuration of the floor beams on the long arm marked a revival of the "pin-beams" arrangement of the original 1866 design prototype in their underslung position, their dimensions, and in being bolted up to the girders.

In the mainframe of the upgraded Rideau Ferry Bridge, the floor joists were increased from 3" x 12" to 4" x 12", and two rows of joists were inserted on either side of the new central longitudinal girder, whereas the contemporary timber swing bridge had simply three rows of joists between two bridge girders. Thus the joists on the wider bridge were placed on a closer spacing, at 2'-6" centres rather than the 3' centres in the single lane swing spans previously reconstructed. The heavier floor joists now rested again on top of the underslung floor beams on the long arm as in the original 1866 plan. However, rather than extending the whole length of the long arm, the joists were now much shorter in length. Each spanned just two floor panels, with the ends of the joists overlapped at every second floor beam.

In the heel section of the mainframe a major interior structural modification was introduced. The two transverse floor beams in the heel section of the evolved 1874 design were discarded in favour of running the floor joists straight through the heel section from the centre beam to the heel beam. With the floor beams of the mainframe removed, the joists in the heel section were supported by the transverse beams in the corbel frame below. To make up the difference in depth between the 4" x 12" joists and the three 12" x 16" girders of the mainframe, pine 6" x 6" spacers were placed along the top of the transverse beams in the corbel frame between the bridge girders and the joists were notched down 2" into the spacers. In effect, the transverse beams of the corbel frame now acted as floor beams in the heel section of the swing bridge.

To increase the strength and rigidity of the long arm of the wider mainframe, the corbel frame was increased in length to provide additional support under the mainframe—where previously the ratio of the length of the corbel frame to the mainframe was 5:10, it was now 7:10. Moreover, the central 15" x 16" longitudinal beam in the heel section of the corbel frame on contemporary timber swing bridges was extended out under the long arm of the swing span at Rideau Ferry for the full length of the corbel frame. The three longitudinal beams of the corbel frame were then bolted to the three longitudinal girders of the mainframe, with bolts spaced close together at roughly 8" centres to form deep laminated girders over the full length of contact. Moreover, several minor modifications were introduced into the corbel frame. The heel beam was increased in width, to 16" x 24" (depth to width), to match the enlarged heel beam in the mainframe of the upgraded superstructure, and the two heel beams were also bolted tightly together. Over the pivot pier, the heavy 15" x 16" transverse beams on either side of the pivot beam were spaced wider apart on 8' centres from the centre beam. This was done to keep the transverse beams, and their heavy corner braces, aligned over the radius arc of the turntable track of the wider bridge structure to facilitate the mounting of the balance wheels.

With the rebuilding of the pivot pier to accommodate a wider bridge with a 16'-diameter turntable track, the pivot had to be moved back four feet to maintain the same clearance for the navigation channel adjacent to the swing span. Hence the Rideau Ferry Bridge was reconstructed with a greater length of span than previously. The swing span increased in length from 69'-6" to 75'-6", making it the longest-span timber swing bridge erected on the Rideau Canal to that date. Unable to obtain large-dimensioned Douglas fir girders of the requisite length, a scarfed joint splice was made in the heel section, near the mainpost, and the two spliced components of each girder were pinned with steel bolts passing down through the corbel frame beams beneath.

As the changes in the interior structure and length of the swing span altered the balance of the unequal arm swing span, the ballast box in the heel section of the corbel frame was enlarged. This was done by planking over the bottom of the entire outer floor panel to form a ballast pocket capable of holding much more stone and scrap iron than previously.

To support the wider and heavier swing span, the former 22" x 16" stepped pivot beam of 13'–6" length was replaced by an even more massive 18'–6" long pivot beam, 26" x 24" (depth to width), with a notch 4" deep at each top corner and in the centre. The shoulders of the enlarged pivot beam were 22" deep by 24" wide in cross section, and extended outwards under the corbel frame. The stepped ends of the massive corbel beam, and the notch at its mid-length, enabled it to be inserted 4" up inside the corbel frame around the central longitudinal girder of the corbel frame. The pivot beam was bolted to a 12" x 24" (depth to width) centre beam, which was comprised of two seven-foot-long segments, one on either side of the central longitudinal girder of the mainframe and of the corbel frame beneath.

The metal bracket on the inside of each mainpost was anchored to the top of the centre beam in the traditional manner. However, with the centre beam being 4" below the level of the bridge girders, the bracket was lower than previously. As a result, its lower arm did not protrude above the roadway as it had on the earlier bridges, and the full 15' width of the roadway under the gallows frame was usable for vehicles. The deck clearance over the lower bracket arm was augmented further by the constructing the enlarged swing span with 4" x 8" planking, rather than 3" x 12" planks, as was previously the case on the Rideau Canal timber swing bridges.

The gallows frame of the upgraded Rideau Ferry swing span retained the same 10" x 12" mainposts, but the side braces were increased from 6" x 9" to 6" x 10", and the 8" x 12" cap beam introduced in the earlier 1874 bridge design was replaced with a heavier 12" x 12" cap beam matching the dimensions of the original design prototype of 1866. Moreover, wood cap beam braces were reintroduced in place of the light wrought iron braces in a throwback to the original swing bridge design. However, there was one innovative design feature introduced into the gallows frame on the upgraded and enlarged Rideau Ferry swing bridge. The mainposts were moved outwards to overhang the outside face of the mainframe girder by 3" on each side of the swing span, and the 3" overhang extended downwards about 6" along the outside face of the girder. The mainpost continued to be mortised into the girder with a double tenon connection, but it is unclear why they were moved outwards, other than perhaps to increase the clearance for vehicles passing beneath the gallows frame on the two-lane highway bridge. With the moving outward of the mainposts, the metal bracket on

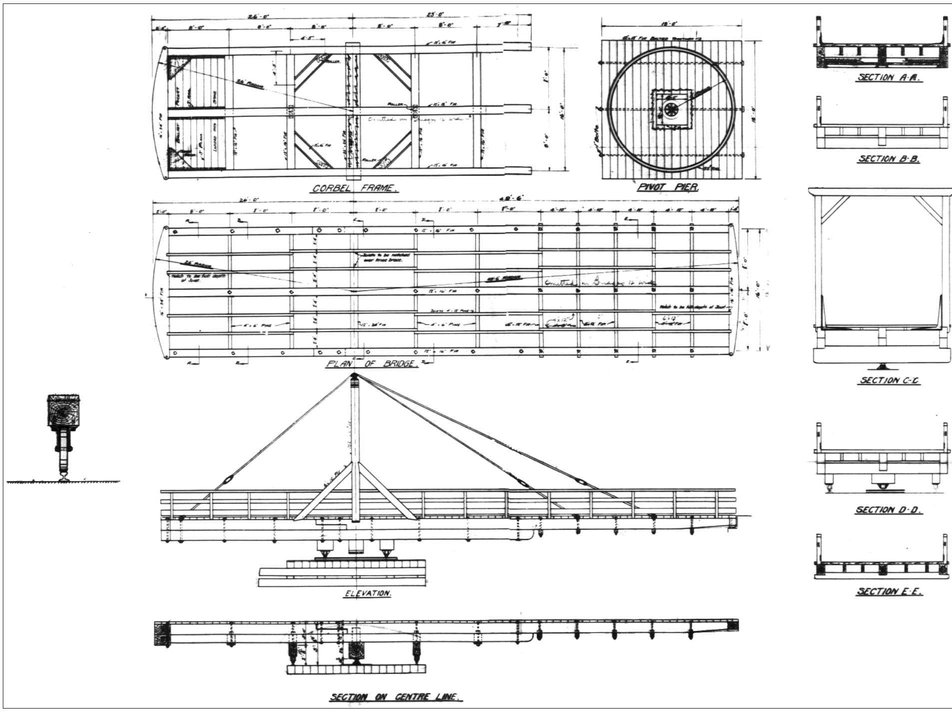

Figure 10. Upgraded and widened version of the Rideau Canal timber swing bridge design prototype, erected at Rideau Ferry in 1947. (PWGSC, Rideau Canal, microfiche drawings, R-2-106, "Rideau Ferry Plan & Sections," n.d.)

their inside face had to be notched down 4" into the side of the bridge girders to bring the lower arm of the bracket on a level with the centre beam. (Figure 10)

An additional change was made in the supporting truss system. The eye-bolt for anchoring the stay rods to the girder was now perfectly vertical, and no longer inclined towards the mainpost. Moreover, the eye-bolt anchors on the long arm served a dual purpose. Each bolted a transverse floor beam to the underside of the girder, as well as served as an anchorage for a stay rod. This was a novel arrangement. In the 1866 design prototype the stay rods were anchored to a horizontal bolt, or the end of a wrought iron tie rod that passed through the girders of the mainframe, whereas in the 1873 and 1874 swing bridge designs, the anchor bolts were inclined, in a vertical plane, towards the mainpost, and were totally independent of the floor beams.

Almost all of the metal hardware of the traditional timber swing bridge was re-used on the upgraded Rideau Ferry span. The regulator, stay rods, balance wheels, and pivot assembly were not modified despite a major upgrading of the loading capacity of the timber swing bridge span. The stay rods were now of a uniform 1¼" diameter throughout, as opposed to the 2"-diameter heel section rod and 1½"-diameter long arm rods of the earlier 1874 swing bridge structure. However, the rods by this time were probably steel, rather than wrought iron, and of greater strength proportional to any given cross-section. Nonetheless, the introduction of the lighter stay rods pre-dated the upgraded Rideau Ferry bridge, as the rods of the former swing bridge were salvaged and re-used. The new circular turntable track rail of 16' diameter was no doubt of steel rather than cast iron and, as indicated by an extant drawing, was made in the form of a single circular rail, rather than constructed of cast-iron segments as was the case previously.

With the insertion of the much deeper pivot beam under the swing bridge superstructure, it was no longer possible to lag the trucks of the balance wheels directly to the underside of the corbel frame timbers. Hence, a supplementary frame, or undercarriage, composed of 16" x 12" (depth to width) timbers was bolted under the corbel frame directly over the turntable, with the spacing of the transverse beams and diagonal corner beam braces in the undercarriage frame matching the positioning of the corbel frame timbers over the radius arc of the turntable track.

All of the structural timbers of the Rideau Ferry swing bridge of 1947 were of Douglas fir, as well as the deck planking. Only the 6" x 6" spacers resting on the transverse floor beams of the corbel frame were of white pine; and they were non-structural members. One surprising omission in the upgraded Rideau Ferry Bridge design was the omission of corner braces in the outer corners of the mainframe, which were traditionally strengthened with tamarack knees, although wrought-iron corner braces were substituted at the toe beam in the evolved designs of 1872 and 1874. Moreover, large tamarack knees were also traditionally placed in both the mainframe and the corbel frame to support the heavy transverse beams over the arc of the turntable track on either side of the centre beam and pivot beam, respectively. Although these transverse beams had been eliminated from the mainframe in favor of supporting the floor joists on the corbel beams beneath, the tamarack knee braces were omitted from the transverse beams of the corbel frame as well. The only corner bracing in the corbel frame, other than the heavy diagonal beams over the radius of the turntable track for mounting the balance wheel trucks, was a wide steel gusset placed in the heel beam corners. Presumably tamarack knees were no longer procurable, but the absence of a substitute corner bracing on the Rideau Ferry swing span is rather odd.

The railings continued to be constructed of pine. They closely approximated the appearance of the railings on the 1874 design, but with a slight difference in the dimensions of some of the scantlings. The posts were now 4" x 6" instead of 6" x 6", but the top rail remained 4" x 6", and the dimensions of the two guard rails were modified only slightly. The upper guard rail was 2" x 6" instead of 1" x 6", and was set between the posts to which it was mortised at each end, whereas the bottom railing was 2" x 8" rather than 1½" x 10", but was still notched and nailed into the inside face of the railing posts. The railing posts continued to be connected with mortise-and-tenon joints to the girder beneath, and were pinned with a wood trunnel. The altered position of the upper guard rail, now mortised between the posts, may have been an effort to make the railing more rigid, but otherwise the slight changes in the dimensions of the scantlings of the railings were not significant structurally, and did not alter the historic appearance of the swing span to any appreciable degree. More generally, at this period the reconstructed timber swing bridges continued to be framed with mortise-and-tenon connections, which were hidden in the interior of the framing joints.[40]

The design changes introduced by the Department of Transport in upgrading and widening the reconstructed the Rideau Ferry Bridge greatly modified the spacing and dimensions of the interior structural members of the swing span; the historic appearance of the traditional timber swing bridge was altered, principally by the addition of the highly-visible undercarriage introduced at Rideau Ferry and the widening of the structure to accommodate two lanes of traffic. Otherwise, almost all of the structural modifications were in the interior of the structure, or not readily discernable. The wider deck was highly visible, but the increased length of the corbel frame proportional to the mainframe, and the slight change in the anchorage system for the stay rods were not.

The changes introduced during the reconstruction were part of the ongoing evolution of the historic design prototype with modifications incorporated and passed on through subsequent reconstructions to enable the timber swing bridge to meet evolving traffic needs. Moreover, several of the changes introduced at Rideau Ferry, such as the 6" x 12" underslung floor beams on the long arm, the wood cap beam braces, and the spliced girders, were restorations of features from the original design prototype of 1866; it was the structural modifications introduced at Rideau Ferry that enabled the historic timber swing bridge to be upgraded sufficiently to remain in service on a crossing with heavy traffic demands. In addition, through upgrading the swing bridge design prototype, rather than abandoning it in favor of a more modern type of structure capable of meeting evolving traffic needs, the traditional skills and carpentry trade practices that the Rideau Canal carpentry crews employed in reconstructing the timber swing spans were kept alive.

At Rideau Ferry, however, the changes made in upgrading and widening the timber swing bridge compromised the design integrity of the timber swing bridge prototype, and pushed the traditional practice of preserving Rideau Canal timber swing bridge through replacement-in-kind reconstructions to immoderate limits. In sum, it compromised to an appreciable degree the historic character of the centre-bearing timber swing bridge developed by James D. Slater in the period 1866–1872; this was not the case with swing bridge reconstructions undertaken subsequently on the Rideau Canal.

Timber Swing Bridge Evolution, 1947–1964

As the timber swing bridges on the Rideau Canal were reconstructed after 1947, a number of the design modifications introduced at Rideau Ferry were incorporated into their design, although none of the swing bridges reconstructed subsequently were widened, or upgraded to the same extent, to meet contemporary highway traffic needs. Otherwise, the traditional 12' wide swing span continued to be constructed very much in keeping with the original design prototype. There were four major departures that were carried over from the Rideau Ferry timber swing bridge design into timber swing bridges reconstructed subsequently. They were the introduction of:

- the 6" x 12" underslung floor beams (pin beams) on the long arm, which represented a restoration of the 1866 swing span arrangement, but with the underslung beams placed on a much closer spacing than in the design prototype;
- the 4" x 12" floor joists on close spacings;
- the elimination of the transverse floor beams in the heel section of the mainframe, in favor of supporting the joists on the transverse beams of the corbel frame beneath;
- and the longer corbel frame, with a 7:10 ratio proportional to the mainframe rather than the traditional 5:10 ratio.

The central longitudinal girder added to the mainframe of the widened Rideau Ferry bridge was not retained in subsequent timber swing bridge reconstructions, and the massive pivot beam introduced at Rideau Ferry was reduced in size and reconfigured to make it conform more closely to the traditional pivot beam configuration, thereby eliminating the need to introduce an undercarriage for mounting the balance wheel trucks. Thereafter the balance-wheel trucks were mounted directly on the corbel frame timbers, fully restoring the historic arrangement and appearance of the timber swing bridge.

During the 1960s an additional change was introduced on the reconstructed timber swing bridges. On the Jones Falls swing span erected in 1960, the stay rod anchorage on the girders was still of the simple vertical eye-bolt anchor type. However, commencing with the erection of the Brass Point swing bridge in 1964, the eye-bolt anchor was replaced with a stirrup-type anchor, which became a standard feature on the timber swing bridges constructed thereafter at Lower Brewer's (1967), Kilmarnock (1970), and Upper Nicholson's (1971).

The new stay rod anchor was shaped like a stirrup through which the girder passed. Each stirrup consisted of two parallel steel straps, 4" wide x ½" thick, which were slightly longer than the depth of the girder at each anchorage point. The stirrup straps extended downwards along opposite sides of the girder, and were joined together, above and below the girder, by a connecting pin—a horizontal bolt of 1¼" diameter—that passed through a pipe sleeve spacer set between the stirrup straps. The bottom pipe sleeve was welded solidly to two small steel plates, which were countersunk and lagged to the underside of the girder, whereas the upper sleeve had welded tabs that were pin-connected to the stay rod. The upper part of the stirrup anchor was thus free to rotate through a short-radius arc about the bottom anchor pin of the stirrup. With the stay rod fully tensioned, the stirrup was inclined slightly towards the mainpost, and rested on two steel plates that were countersunk into the top of the girder. It appears that the new stay rod anchor had a structural function in that the stirrup could rotate slightly upwards and outwards with any reversal of stresses in the stay rod caused by an upwards deflection in the girder on the release of a moving load.

This supposition is further evidenced by a later modification introduced on several of the timber swing bridges. At Upper Nicholson's, for example, steel bands were arched over the upper pipe sleeve of the stirrup and welded to the two steel resting plates on the top of the girder. The restraining bands are positioned against the forward edge of the pipe sleeve, in the normal inclined position of the stirrup, but there is a gap between the top of the pipe sleeve and the restraining bands. This gap maintains the freedom of the stirrup to rotate upwards and outwards, and yields two insights into the actual working of the modified stirrup anchorage: first, that the stirrups do rotate outwards on occasion under a load/unload cycle; and, secondly, that there was obviously a perceived need to prevent a stirrup anchor from over-rotating, possibly on a heavy load moving rapidly off the swing span causing it to kick upwards.[41]

The traditional mortise-and-tenon system of heavy timber framing of the swing bridge prototype of 1866 was carried down through generations of carpenters and over a hundred years of bridge reconstructions well into the 1960s. However, none of the mortise-and-tenon details were recorded in the plans of the Rideau Canal swing bridges. The Rideau Canal carpenters in the 1960s, as was the case with their predecessors in the 1860s, were expected to know the proper proportioning of tenons and mortises, which varied with the size of the timbers, their function, and whether the joint was supported or not. Hence, there was no need to record the joinery details in working plans. According to Ashton Dale, the former maintenance supervisor on the Rideau Canal, the carpenters worked from dimensioned sketches and rough notes in laying out the framing work for cutting the mortises and tenons during swing bridge reconstructions. Unfortunately, these notes and sketches have not survived in the Rideau Canal Office.[42]

Extant Timber Swing Bridges, 1964–1972

The post-Second World War timber swing bridges reconstructed on the Rideau Canal did incorporate several of the interior structural modifications introduced at Rideau Ferry in 1947, and subsequently the stay rods stirrup anchor introduced in 1964. However, the overriding question on examining the five timber swing bridges extant on the Rideau Canal in 1972 must be: to what extent was the design integrity of the original timber swing bridge of 1866—the design prototype—preserved in the reconstructed structures, following a succession of replacement-in-kind reconstructions, and upgrades, carried out over the course of more than a century? In sum, what was preserved? What had been lost? This can only be ascertained through a final analysis of the evolved form of the Rideau Canal timber swing bridge—the reconstructed bridges at Jones' Falls (1960), Brass Point (1964), Lower Brewer's (1967), Kilmarnock (1970), and Upper Nicholson's (1971)—in comparison with the original design prototype of 1866.[43]

The timber swing bridges extant in 1972 embodied the basic character, structural design and design function as the 1866 swing bridge structure, and were build on the same scale. They were an unequal arm (or bobtail), centre-bearing swing bridge structure balanced on a transverse pivot beam that rested in turn on a single central pivot about which the swing span swung horizontally, and were counterbalanced by a heavier heel section of the swing span. The superstructure continued to comprise a mainframe, composed of two heavy girders framed together with transverse beams and a rounded toe and heel beam at each end, a corbel frame providing support beneath the mainframe, and a transverse pivot beam on which the superstructure was balanced over the central pivot. A concentric circle of balance wheels, on a 12' diameter turntable track centred on the central pivot, provided stability for the structure on it being swung off its abutments in keeping with the original design.

The superstructure continued to be supported by a stay rods truss system on each girder of the mainframe. Each truss consisted of stay rods that emanated from a saddle on the cap beam of a gallows frame, mounted over the transverse pivot beam, with two stay rods emanating down to the girder on the long arm and one stay anchored to the girder on the heel section, and the flexible "regulator" at the apex of the truss on the cap beam over a mainpost of the gallows frame. Structurally, the timber swing bridge remained a beam bridge, or continuous beam bridge supported on its two abutments and the central transverse pivot beam, with the primary function of the truss system being to prevent the long arm from sagging or being swung off its abutment.

Thus, the key defining features of the 1866 timber swing bridge design prototype were preserved in the reconstructed swing spans extant in 1972. However, it is clear that over the years some minor modifications had been introduced in the sizing of structural members, the spacing of the interior structural members, and components of the hardware, as well as in the framing technique and the balancing, as indicated by an "as-found" recording made in 1984 of the extant reconstructed swing bridge at Lower Brewer's. (Figure 11)

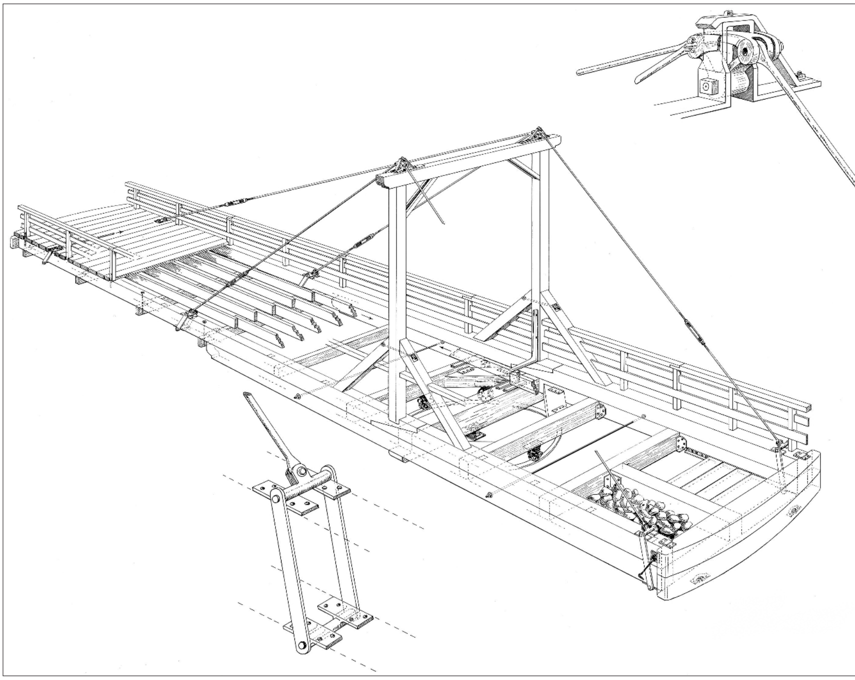

Figure11. Lower Brewer's Swing Span, an orthographic projection drawing of a later 1984 reconstruction based on the "as-found" recording of the 1967 swing bridge. The traditional design details, as well as the stirrup anchor and the regulator are shown; however, the mortise-and-tenon framing was abandoned, and the floor joists were carried over the pivot beam in the 1984 reconstruction as shown. (Gaétan Forest, 1993)

Where the counterbalancing of the unequal arm swing span was concerned, there was a change of emphasis. In the original design, the swing span was counterbalanced through tapering the girders for their full length, the employment of heavier joists in the heel section than on the long arm, the additional weight of the corbel frame in the heel section, and the addition of some pig-iron ballast to fine-tune the balance. However, on the reconstructed bridges extant in 1972, the girders were not longer severely tapered, the joists were the same size throughout, and the corbel frame extended out further under the long arm. Hence, a much greater ballast had to be added, and large ballast pockets were constructed in the heel section of the corbel frame to hold the stone, gravel and scrap iron needed to balance the unequal arm swing span.

With the exception of the abandonment of tapered girders, which necessitated changes in the dimensions of the heel and toe beam, the design modifications were for the most part in the interior of the structure. The girders which had been tapered along their full length from 18" x 12" at the heel to 9" x 6" (depth to width) at the toe, were now straight beams, 16" x 12" (depth to width), with only a slight taper upwards on the underside, in the outer floor panel, to a depth of 14" at the toe. Consequently, the heel beam was now 16" x 20", rather than the original 18" x 12" (depth to width), and the toe beam was 14" x 16" (depth to width) rather than the original 9" x 9".

With concrete abutments replacing timber crib abutments during the early 20th century, the abutments had a convex face as was the case with the stone masonry abutments constructed when the design prototype was introduced. Hence, the toe and heel beams were once again rounded on the turning radius of the long and short arm, respectively, of the swing span, in keeping with the original design; and they were framed across the ends of the girders as in the original design.

Originally, there were large tamarack knees at the junctions of the heel beam with the bridge girders, and wrought-iron braces at the junctions of the toe beam with the bridge girders to reinforce the mortise and tenon joints; however, the 1984 "as-found" recording does not show any braces in the outer corners of the mainframe at the toe and heel beams on the extant Lower Brewer's Bridge. Mainframe corner braces were discarded earlier on the Rideau Ferry reconstruction of 1947, and apparently were not inserted on the reconstructed bridges thereafter. In 1981, steel angles were lagged into the corners of the toe and heel beams by Parks Canada to reinforce the mainframe of the Lower Brewer's swing span, which may well be an indication that a mistake was made in discarding the mainframe corner braces of the design prototype. The two swing bridges reconstructed with modern steel connectors—Kilmarnock (1970) and Upper Nicholson's (1971), had steel angles lagged into the outer corners of the mainframe.

Although the original design specifications of 1866 had called for each girder to be hewn out of a single stick 69' long, from almost the introduction of the timber swing bridge it had proved necessary to splice two sticks together to form the girders, as was the case with the timber swing bridges extant in 1972. However, the scarfed joint was now positioned directly under the mainpost, rather than where the joint had traditionally been located, more towards the heel of the bridge under the side brace of the main post.

On the long arm of the mainframe, the floor beams were bolted up to the underside of the two girders as in the original design prototype. These "pin beams" were of the same size, 6" x 12" (width to depth) as in the 1866 swing bridge plan, and were stepped on their outer ends to extend 4" up inside the girders. However, there were now five floor beams on the long arm, spaced at 5' intervals, whereas in the design prototype there were just three pin beams spaced at 10' intervals. The size and the spacing of the longitudinal floor joists also was different. The joists were now 4" x 12" throughout, rather than 4" x 9" on the long arm and 6" x 9" on the heel section; and there were five rows of joists rather than the three rows in the mainframe of the design prototype. In the heel section of the extant bridges, the joists rested on spacers supported by the transverse beams of the corbel frame below, whereas in the design prototype there had been two transverse floor beams in the heel section of the mainframe to support the joists.

Over the pivot beam, the centre beam was now 12" x 16", matching the depth of the mainframe, and the lower arm of the metal bracket on the inside of each mainpost was bolted to the centre beam on the same level as the girders. In contrast, in the 1866 swing bridge design the 12" x 12" centre beam was 3" below the top of the tapered girders, and the lower arm of the tamarack knee was lagged to the centre beam at that level. The recessed centre beam had been revived at Rideau Ferry in 1947, but was not carried forward. The 3" x 12" deck planking replicated the design prototype, in contract to the heavier 4" x 8" planking introduced earlier on the upgraded Rideau Ferry Bridge.

The corbel frame was constructed of the heavier 16" x 12" timbers, introduced on the Oliver's Ferry Bridge in 1874, rather than the 12" x 12" timbers of the design prototype, but otherwise maintained its structural integrity. Over the pivot pier, heavy transverse beams were still positioned six feet to either side of the pivot beam, and were reinforced with heavy diagonal corner beam braces; all of these beams were directly over the radius arc of the turntable rail to enable them to serve as a base for mounting the balance wheel trucks in the traditional manner. Otherwise, the framing of the corbel frame followed the pattern introduced on the upgraded Rideau Ferry swing bridge. A heavy, 16" x 12" transverse beam divided the heel section into two floor panels, and the outer floor panel was sub-divided with a longitudinal beam on the centre line of the structure to help support the ballast pockets. In contrast, the corbel frame of the design prototype had a 12" x 12" transverse beam in its heel section, with a single 12" x 12" centre longitudinal beam.

On the evolved swing spans, the ratio of the length of the corbel frame to the mainframe was 7:10, as on the upgraded Rideau Ferry plan, rather than the 5:10 ratio on the design prototype, and the heel beam was increased in size from 12" x 20" to 16" x 20" (depth to width) to match the increased depth of the corbel frame timbers. The outer corners of the corbel beams at its junction with the heel beam were reinforced in the design prototype, or more correctly in the 1872 refined version, with a heavy 12" x 12" diagonal brace; but in the extant reconstructed structures, there were no corner braces in the corbel frame. However, the large ballast pockets built into the outer floor panel of the corbel frame, no doubt, contributed to its rigidity.

Although not readily noticeable, in one respect the structural nature of the evolved timber swing bridge was transformed. It no longer consisted of a mainframe strengthened by a lighter corbel frame bolted beneath. With the increasing of the size of the corbel frame timbers to match the girders, and the elimination of the transverse floor beams in the heel of the mainframe, the corbel frame became much more structurally important. It now provided the main lateral support and rigidity to the bridge girders in the heel section of the swing span, in addition to its primary function of supporting the girders for the greater part of their length to increase their load carrying capacity.

The increased structural importance of the corbel frame is attested to further by the relocation of the transverse tie rods from the long arm of the mainframe on the design prototype, to the corbel frame. At Lower Brewer's, the 13'-6" long transverse tie rods were positioned alongside the heavy transverse beams in the corbel frame, rather than alongside the transverse beams in the mainframe as they were previously. Over the years the wrought-iron tie rods had gradually been replaced by steel rods. However, what is surprising is that on the reconstructed bridges extant in 1972, the steel tie rods positioned in the corbel frame were only ¾" in diameter whereas on the design prototype the wrought-iron tie rods on the long arm of the mainframe had been 1⅛" in diameter.

On the extant reconstructed bridges, the pivot beam was the traditional 13'-6" long, but was a massive block of wood, 20" x 26" (width to depth), in keeping with the massive cross-section of the pivot beam introduced on the upgraded Rideau Ferry Bridge. However, the massive pivot beam was now deeply stepped at its outer ends to fit up inside the corbel frame to its full depth, with 10" x 20" shoulders that extended out under the corbel frame.

The massive pivot beam was bolted to a 12" x 16" centre beam in the mainframe, which was on the same level as the mainframe girders. Hence, the centre beam was no longer recessed below the bridge girders, and the lower arm of the mainpost bracket was on the same level as the bridge girders, as had been the case previous to the Rideau Ferry plan of 1947. Once again the deck planking was 3" x 12", as on the design prototype structure, and it was spiked to the girders in the same manner. The planks were notched over the lower arm of the mainposts brackets to provide a level surface over the full width of the bridge deck, whereas on the design prototype the lower arm of the large tamarack knee had protruded above the 3" x 12" deck planking, narrowing the clear width of the roadway under the gallows frame.

In its overall configuration, placement, and level, the pivot beam assembly on the post-war timber swing bridge reconstructions closely matched that of the design prototype. The only difference was that in the design prototype the pivot assembly was made up of three components bolted together: a 9" x 18" pivot beam (depth to width), 13'-6" long, that extended out under the corbel frame; a 12" x 12" centre beam in the corbel frame; and a 12" x 12" centre beam in the mainframe, with the centre beam on the same level as the top of the tapered girders.

This revival of the traditional configuration and placement of the pivot beam yielded a significant advantage. With the shoulders of the pivot beam extending 10" below the corbel frame, the height of the pivot assembly was such that the balance wheel trucks could be, and were, bolted directly to the underside of the corbel frame in the traditional manner. The undercarriage added earlier on the upgraded Rideau Ferry Bridge was no longer required. Moreover, the 10" x 20" shoulder of the pivot beam projecting out under the corbel frame almost matched the original 9" x 18" beam that supported the historic swing span superstructure. Hence, the symmetry and historic appearance of the traditional timber swing bridge were restored. (Figure 12)

By the 1960s the cast-iron rail segments of the original turntable rail had been replaced by a 55# steel rail matching the general appearance, scale, and function of the original 12'-diameter track. However, the cast-iron balance-wheel trucks and the end rollers under the heel and toe beams were of the original design. They had been salvaged and re-used time and time again, as was the practice elsewhere on the canal whenever a timber swing bridge underwent a reconstruction. When replacement castings were required, they were obtained from a local foundry at Merrickville on the Rideau Canal, and were prepared from the original wood patterns. The cast-iron pintle and socket of the pivot assembly, however, had been replaced some years earlier with a steel shaft pintle and cast-steel socket of a similar design, performing the same function.

The gallows frame on the reconstructed Lower Brewer's swing bridge of 1967 was very similar in its scale, configuration, and appearance to the original swing bridge design prototype. The changes were very minor. On the design prototype of 1866 the gallows frame was constructed of 12" x 12" timbers throughout, with trussed side braces, and a tamarack knee on the inside of each mainpost, whereas on reconstructed timber swing bridges extant in 1972, the gallows frame replicated James D. Slater's refined 1872 design with a 12" x 12" cap beam mounted on 12" x 10" mainposts, supported by simple 8" x 10" side braces at its base. Moreover, on the reconstructed Rideau Canal swing bridges the steel mainpost bracket had long since replaced the tamarack knee on the inside of each mainpost, and there were differences evident in the cap beam braces. The reconstructed bridges at Jones' Falls (1960) and Brass Point (1964) had 6" x 6" cap beam braces with a single brace in each corner, as did the design prototype of 1866; however the extant Lower Brewer's swing bridge had two parallel 2" x 4" cap beam braces. Moreover, the beveled ends of the twin braces were only screwed to the cap beam and mainpost. This more recent modification detracted somewhat from the historic appearance of the reconstructed timber swing bridge, and it is not clear what the rationale was for the change to the lighter twin cap beam braces. In the subsequent reconstructions by the Department of Transport at Kilmarnock (1970) and Upper Nicholson's (1971) the twin cap beam braces were also adopted.

In one minor respect, the gallows frame differed from the design prototype. The mainposts were moved outwards to overhang the outer face of the girders by three inches on both sides of the swing span, whereas on the design prototype the mainposts were directly over the girders. This off-setting of the mainposts was an innovation introduced at Rideau Ferry in 1947 to provide a maximum clearance for vehicles crossing that widened, two-lane structure. Why that positioning was retained on the single-lane swing bridges reconstructed thereafter is not known. (Figure 12)

Figure 12. Upper Nicholson's timber swing bridge, as reconstructed in 1971. (Photo by author, July 1974)

On the reconstructed timber swing bridges extant when Parks Canada acquired the Rideau Canal in 1972, the stay rods system remained as originally designed, with the metal hardware having been salvaged and re-used through a series of reconstructions. Over the years since the introduction of the design prototype in 1866 there were only three significant changes in the truss system: the standardization of all the suspensions rods at a uniform 1¼" diameter; the introduction of the stirrup anchor for the stay rods in1964; and the gradual conversion from wrought iron to galvanized steel rods as damaged or corroded rods were replaced. As of 1972, only the Jones' Falls reconstruction had the older bolt anchor for the stay rods; the other four reconstructions had the novel stirrup anchors.

The railings of the reconstructed swing spans extant in 1972, differed slightly from the design prototype, and more closely approximated the railings introduced on the Oliver's Ferry Bridge in 1874. In effect, the railings were constructed of smaller dimensioned scantling than the design prototype, and had two smaller guard rails, 2" x 6" and 2" x 8", in place of the single 2" x 12" guard rail on the original centre-bearing swing span. However, they were constructed in the same manner. The railing posts were mortised into the bridge girder with a single-tenon mortise-and-tenon connection, and were pinned with a ½"-diameter oak trenail, pointed on one end. The top rail was simply spiked onto the posts. Otherwise, the upper guard rail was mortised into the posts on the centre line of the railing, and the lower guard rail was notched into the interior side of the posts, and nailed into place. Overall, with the exception of the additional guard rail, the appearance of the railings was very similar to the original design prototype. At Lower Brewer's the railing posts were reinforced by short lengths of steel angles bolted securely to the railing post and girder, but this was a later intervention post-dating the 1967 reconstruction.[44]

On three of the extant reconstructions, the superstructure continued to be framed with mortise-and-tenon joinery. The heavy timbers of the mainframe and corbel frame were connected with double-tenon mortise-and-tenon connections, as were the mainposts to the girders. However, the top of the mainpost had a single-tenon connection with the cap beam. The side braces on the mainpost and the cap beam braces, which were positioned at a 45-degree angle with beveled ends, also had single-tenon mortise-and-tenon connections, and their haunches were inset into the face of the girders and mainposts. None of the gallows frame connections were pinned, as all of the joints were in compression. Although the "as-found" drawing does not record this feature, there was a single horizontal bolt that passed through the top of the side braces and the mainpost to pin them together. It was a standard feature on all of the reconstructed timber swing bridges, as well as the 1866 design prototype.[45] In all respects, it appears that the framing details of the evolved structure had remained the same as on the design prototype; although the "as-built" drawing of the Lower Brewer's swing bridge did not record the hidden joinery details. Nonetheless, from information gained through worker interviews and photographs of the cut-up swing span, it is clear that the traditional mortise-and-tenon framing technique were replicated in the Lower Brewer's reconstruction of 1967, as well as in the earlier reconstructions at Jones' Falls (1960) and Brass Point (1964) swing bridges. (Figure 13)

Where the material of construction was concerned, there were changes necessitated due to the original materials no longer being procurable, or readily so

Figure 13. Double-tenon framing connections in evidence on the cut-up members of the Lower Brewer's swing bridge. (Eric Sunstrum, PWGSC, June 1984). The steel angles in evidence were added in 1981 to reinforce the interior joinery connections.

at any reasonable cost. Hence, the extant structures were reconstructed entirely of Douglas fir, with the exception of the pine spacers in the heel section, whereas on the first centre-bearing swing bridge erected at Mutchmore's Cut in 1866, all of the heavy timbers of the mainframe, corbel frame, and gallows frame were of white oak, with the exception of two girders, the three floor beams on the long arm, and the joists on the long arm, and the cap beam, which were of pine. Moreover, the cap beam braces, the railings, and the planking were also of white pine. Initially, the stay rods were of wrought iron, and the hardware castings were of cast iron, whereas on the extant swing bridges in 1972, the wrought-iron and steel components had been replaced long since by steel components of similar dimensions and design, which were salvaged from the structures that they replaced.

The extant swing bridges were finished in the traditional manner of good carpentry workmanship. The corners on the upper part of the main posts were chamfered; the ends of the toe and heel beams were rounded; and the outer ends of the cap beam, the corbel beams, the pivot beam, and the projection of the mainpost at its base, were rounded up. Thus the workmanship and finish was the same as on the original design prototype.[46] On the three bridges framed with mortise-and-tenon connections, all of the joints were sealed with linseed oil and an oil-based paint, and the completed bridge, with the exception of the deck planking, was painted with an oil-based paint. In contrast, the tenons of the design prototype of 1866 were bedded in a thick coat of white lead and oil, and a mineral tar was applied to seal all joints before the bridge was painted with a linseed oil-white lead paint.

The Lower Brewer's span reconstructed in 1967 was the last Rideau Canal swing bridge to be constructed with the mortise-and-tenon joinery typical of heavy timber framing for centuries past. With the reconstruction of the swing bridges at Kilmarnock (1970) and Upper Nicholson's (1971), the traditional mortise-and-tenon joinery was abandoned in favor of employing modern steel connectors used in the heavy timber construction practice of the day.

At Kilmarnock, and subsequently Upper Nicholson's, all of the connections of the heavy timbers in the main frame and the corbel frame, including the timber braces, were constructed with butt joints and joined by modern steel connectors—joist hangers, angles, and plates—lagged or bolted into the timbers. The railing posts and heavy timbers with visible joints in the gallows frame had butt connections as well, but were joined internally with a steel dowel.[47] (Figure 12)

In a new departure, at both Kilmarnock and Upper Nicholson's the bridge construction work was contracted out through a public tendering process, abandoning the previous practice of in-house construction by the Rideau Canal carpentry crew. This marked a revival of the 19th-century construction practice, as well as a major loss. All of the trade skills and knowledge pertaining to traditional framing of heavy timbers, including the mortise-and-tenon joinery, that had been passed down through generations of carpentry crews on the Rideau Canal was jettisoned and eventually lost.

Conclusion

As of 1972 when Parks Canada acquired the Rideau Canal, the five extant timber swing bridges were clearly the product of a succession of reconstructions at roughly 12- to 15-year intervals over the course of more than a century during which a number of modifications were introduced. These changes were intended to simplify the construction of the design prototype, to replace component materials no longer procurable, to improve the functioning of the swing span, and to upgrade the load-carrying capacity so that the timber swing bridge could remain a viable structure capable of meeting evolving traffic needs. These modifications, or departures, were relatively minor as they comprised mostly changes in the spacing and dimensions of the interior structural members, some slight increases in the dimensions of the framing timbers, a new type of stay rod anchor, and the abandonment of mortise-and-tenon framing technique in the framing of two of the five reconstructed structures.

The modifications and upgrades introduced over the course of a century having been identified, dated, described, and analysed, it can be categorically stated that the five reconstructed timber swing bridges extant in 1972 were an evolved form in a lineal descent from the original design prototype introduced on the Rideau Canal in 1866; that the historic timber swing bridge had been widely constructed on the Rideau Canal during the previous century; and that the extant timber swing bridges had been preserved within a living cultural tradition of replacement-in-kind reconstructions.[48]

Notes

1. Robert W. Passfield, *Building the Rideau Canal: A Pictorial History* (Don Mills, Ontario: Fitzhenry & Whiteside, 1982). On the origins of the Rideau Canal project see Robert W. Passfield, “Ordnance Supply Problems in the Canadas: The Quest for an Improved Military Transport System,” *HSTC Bulletin: The Journal of the History of Canadian Science, Technology, and Medicine*, Vol 5, No 3, Sept 1981, 187–209.
2. Technically the Rideau Canal was transferred in 1972 to the Department of Indian Affairs and Northern Development (DIAND), which then had responsibility for Canada’s National Parks, and its National Historic Parks & Sites. The Parks Canada program was created the next year, within DIAND, to administer Canada’s National Parks, National Historic Parks and Sites, and the Rideau Canal and several other heritage canals but newly transferred from the Department of Transport. See Robert W. Passfield, “The Heritage Canals: Status and Significance” (Parks Canada, In-House Report, Oct 1987). Today, Parks Canada is a separate agency of the federal government.
3. Parks Canada, “Preliminary Site Study, The Jones Falls Site and Lock Station” (internal report), Aug 1973, 40–41.
4. The research report was printed at a later date: Robert W. Passfield, “Historic Bridges on the Rideau Waterways System: A Preliminary Report,” Manuscript Report Series, No. 212 (Parks Canada, 1976), 1–50. The engineering drawings and archival documents are cited below.
5. Library and Archives Canada (LAC), RG43 B61, Volume 2006, reel T–2469, James D. Slater, Superintending Engineer, Rideau Canal, to Frederick Braun, Secretary, Department of Public Works, 6 Sept 1866, p287.

6. Robert W. Passfield, "Swing Bridges on the Rideau Canal," *IA: The Journal of the Society for Industrial Archeology*, Vol I, No. 2, 1976, 60–62; and LAC, RG 43 B61, Volume 2006, reel T–2469, Slater to Braun, 30 Nov 1864, p213. The IA article includes a brief description and historic drawings of the earlier rim-bearing and off-set pivot types of Rideau Canal swing bridges.
7. On the Rideau Canal the centre-bearing timber swing bridge was, and is, commonly referred to as a "kingpost truss swing bridge," as the configuration of the truss system resembles a kingpost truss. (Indeed, the author in a previous publication used the phrase "kingpost truss swing bridges" to describe these bridges.) However, the centre-bearing swing bridge was designed as a beam or girder span, with a truss system incorporated simply to prevent the long arm of the swing span from sagging when swung open off its abutment. Thus, structurally the Rideau Canal swing bridge is not a kingpost truss structure. In a kingpost truss the inclined arms are in compression, and the kingpost in tension is holding up the span at its mid-point, whereas when the Rideau Canal bridges are swung open, the stay rod arms of the truss are in tension, and the mainpost is in compression directly over the pivot beam.
8. LAC, Cartographic and Architectural Archives Division, Rideau Canal, V2/410, 1866, NMC 43043, "Rideau Canal, Design for Swing, Contract No. 2906," 18 June 1866; and Parks Canada, Rideau Canal Records, Bridges & Tunnels, Mutchmore's Cut Bridge, File No. 4052–234, Vol I, James D. Slater, "Bill of Materials, Swing Bridge near Mutchmore's Cut, 1866."
9. Parks Canada, Rideau Canal Records, Bridges & Tunnels, Lower Brewer's Bridge, File 4052–248, Vol I, J.D. Slater, "Rideau Canal, Specification for Swing Bridge proposed to be built at Brewer's Lower Mills across the Lock above the upper Gates," 11 Sept 1872.
10. See, for example, Thomas Tredgold, *Elementary Principles of Carpentry; A Treatise* (London: J. Taylor, 1820).
11. LAC, "Rideau Canal, Design for Swing," 18 June 1866. The timber dressing specification quoted is from Slater, "Specification for Swing bridge," 11 Sept 1872.
12. No contract specifications were found for the 1866 swing bridge at Mutchmore's Cut, only the drawing for the swing bridge and the Bill of Materials. Hence, the painting specifications are taken from Slater, "Specifications of a Bridge at the Upper Site [Manotick], Long Island," 16 May 1865, and Slater, "Specification for Swing bridge," 11 Sept 1872.
13. See R.W. Passfield, "Canal Lock Design and Construction: The Rideau Canal Experience, 1826–1982," Parks Canada, Microfiche Report Series, No. 57, 1983, Appendix E, James D. Slater, "Lock Gate Specifications," 21 Aug 1861; Anon., *The Builder's Practical Director or Buildings for all Classes containing Plans, Sections, and Elevations* (London: J. Hagger, n.d.), 230–231; and Peter Nicholson, *The New Practical Builder and Workman's Companion* (London: Thomas Kelly, 1823), 410–411, 420. The author is indebted to Richard Fairweather, Conservation Technologist (ret.), Architectural & Engineering (A & E) Services, Public Works and Government Services Canada (PWGSC), for the information on the use of the white lead/linseed oil sealant in shipbuilding. This sealant has been discontinued in constructing wooden-hulled vessels because of environmental and health concerns.
14. Great Britain, Board of Ordnance, *Papers on Subjects Connected with the Duties of the Corps of Royal Engineers*, Vol. 6, 1843, 163–164, Lt. William Denison, RE, "Description of a Wooden Swing Bridge erected on the Grenville Canal, Canada." To provide a greater overhead clearance for vessels, a fixed bridge on the Grenville Canal, and all fourteen fixed bridges on the Lachine Canal, were removed in 1841 and 1842, respectively, and replaced with swing bridges. See Frank MacKey, *Steamboat Connections: Montreal to Upper Canada, 1816–1843* (Montreal/Kingston: McGill-Queen's Press, 2000), 172.
15. Slater, "Bill of Materials, Swing Bridge near Mutchmore's Cut," 1866.
16. Slater, "Specification for Swing Bridge," 11 Sept 1872.

17. LAC, RG 43, B61, Volume 2006, reel T–2469, Slater to Braun, 11 May 1866, p275.
18. LAC, RG 43, B61, Volume 2006, reel T–2469, Slater to Braun, 1 Feb 1865, p225, 11 May 1866, p275, and 7 July 1866, p280. Slater also noted that oak was becoming expensive, and deteriorating in quality. White oak from the Rideau Canal corridor had lasted upwards of 20 years whereas the oak then being procured from the western part of the province lasted only 12 to 14 years.
19. LAC, Department of Railways and Canals, RG 43, B61, Volume 2006, reel T–2469, Slater to Braun, 30 Nov 1864, p213, and 7 Feb 1865.
20. LAC, Department of Transport, RG12, Volume 3596, file 4052–255, Part 1, Slater to Braun, 7 Feb 1865, enclosing specifications and a drawing of Slater's original centre-bearing swing bridge design. In the late 1990s Parks Canada transferred the Rideau Canal bridge maintenance records, an intact collection dating back to the 1860s, to the Library and Archives Canada. Unfortunately, that collection was broken up subsequently by the National Archives, and the bridge files are now dispersed through different record groups (RG11, R12, and RG43). Hence, the updated references cited herein are quite diverse.
21. LAC, Department of Public Works, RG11, B1Ci, Volume 780, letter 53427, Braun to Slater, 29 March 1865; and RG12, Volume 3596, file 4052–255, Slater to Braun, 28 April 1865, marginalia. The Chief Engineer's Office, DPW, calculated that Slater's bridge would weigh 44,351 lbs and carry a uniform load of 8.5 tons, whereas the approved departmental swing bridge weighed 23,456 lbs, and could carry a uniform load of 10.7 tons (*ibid.*).
22. LAC, Department of Railways and Canals, RG 43, B61, Volume 2006, reel T–2469, Slater to Braun, 28 April 1865, p233, and 16 May 1865, p235. Slater had already tested his design for the proposed new 7"-diameter cast-iron pintle-and-socket pivot in converting an existing rim-bearing swing bridge at Smith Falls to a centre-bearing swing bridge during the winter of 1864–65. Hence, he had the wooden patterns already made for the casting of a 7"-diameter pintle-and-socket pivot assembly, which he used for the centre-bearing swing bridge at Mutchmore's Cut.
23. LAC, RG 12, Volume 3596, file 4052–255, Slater, "Specification of a Bridge at the Upper Site," 16 May 1865.
24. LAC, RG 43, B61, Volume 2006, reel T–2469, Slater to Braun, 9 Jan 1865, p219, and 7 Feb 1865, p226.
25. LAC, RG 12, volume 3596, file 4052–255, Slater, "Specification of a Bridge at the Upper Site," 16 May 1865, 4–5.
26. James Dyson Slater (1813–1876) served as Superintending Engineer, Rideau Canal, from 10 June 1858 to 1 Oct 1872. Previously he had worked as a land surveyor locating railways and canals, and in the employ of DPW had served as assistant engineer on the Welland Canal, and later assistant engineer on the Ottawa River Works where he was responsible for maintaining timber slides, dams, roads and bridges (Canada, *Sessional Papers*, 1891, "Engineers Employed on Public Works, Canada, 1779–1891"; and Ontario Land Surveyors Association, *Annual Report*, 1921, 129–130, "J.D. Slater."
27. Public Works and Government Services, Canada (PWGSC), Architectural & Engineering Services, Technical Documentation Centre, "Rideau Canal," Drawing R-2-118.2, "Design for Swing Bridge, Rideau Canal," August 1871; and Slater, "Specification for Swing Bridge," 11 Sept 1872.
28. DPW, *Annual Reports* (Ottawa: Queen's Printer), 1866–1878, "Rideau Canal" appendices; and Department of Railways and Canals, *Annual Reports* (Ottawa: Queen's Printer), 1879–1890, "Rideau Canal" entries. The original private bridges were erected at Old Slys in 1862 and Upper Nicholson's in 1864. As of the mid-1860s, 19 waterpower leases had been granted for the establishment of grist mills, saw mills, and shingle mills on the Rideau Canal waterway.
29. LAC, RG 43, B61, volume 2006, T–2469, Slater to Braun, 12 June 1867, p326, 19 July 1867, p10, 19 Feb 1870, p166; and RG 43, B61, volume 2007, T–2470, F.A. Wise to Braun, 5 Jan 1877, p100–101; and *ibid.*, Wise to Braun, 20 Nov 1877, p189,

"Memorandum of Conditions for granting permission to the County of Carleton to construct a Bridge over the Rideau Navigation at the Village of Wellington."

30. For example, the swing bridge constructed of oak at Lower Brewer's in 1872 was rebuilt in Douglas fir in 1896. Thereafter reconstructions followed in 1910, 1921, 1933, 1943, 1958, and 1967. The cost of this type of swing bridge escalated from $1,927.68 at Lower Brewer's in 1872, to $30,000 in 1958, to $50,000 in 1967.

31. In 1887 contracts were let for several metal truss swing bridges to replace wood structures on the Rideau Canal, and the superintending engineer planned to begin to systematically replace all of the wooden bridges, both swing and fixed, with either iron or steel bridges. (LAC, RG 43, B61, volume 2008, T–2471, F.A. Wise, Superintending Engineer, Rideau Canal, to Manager, Lachine Iron and Steel Bridge Company, Montreal, 6 Sept 1887, p253–254). However, an increasingly severe decline in canal traffic, and the onset of the 1893 depression, precluded any follow-through on a comprehensive modernization program.

32. PWGSC, Rideau Canal bridge files: "Rideau Canal, Highway Bridges and Steam Railway Bridges over Locks or Navigation Channels," 27 March 1930; and File #4040–11, Vol. II, "Rideau Canal, Table of Bridge Details," 29 Aug 1950. The total number of 25 bridges included four municipal bridges crossing the canal channel in Ottawa: the Bank St. Bridge; Pretoria Avenue Bridge; Laurier Avenue Bridge; and Confederation Plaza Bridge.

33. Passfield, "Historic Bridges on the Rideau Waterways System," 2–5, 18–19. The timber swing span at the Narrows, on a low traffic volume crossing, was replaced by an older steel truss swing span moved there in 1964 from Beveridges Lock on the Tay Canal branch where a new high-level reinforced concrete bridge was constructed.

34. Library & Archives Canada, "Oliver's Ferry Bridge, Rideau Canal," [1873], NMC #130281.

35. As early as 1892, if not earlier, the British Columbia Mills Timber and Trading Company was shipping large-dimensioned sticks of Douglas fir to eastern markets in 60' lengths, carried on two coupled 33' flat cars. Moreover, there are historic photos of these shipments showing the timbers topped with a few sticks of even greater length overlapping a third flat car by several feet. Hence, there is no doubt that the railway was capable of shipping large-dimensioned 16" x 12" Douglas fir timbers of upwards of 68' to 70' in length for use as girders on a Rideau Canal swing bridge. (Fax communication, Stephen Lyons, Archivist, Canadian Pacific Archives, to Robert W. Passfield, 29 Jan 1993, conveying memorandum prepared by James S. Shields.)

36. Parks Canada, Rideau Canal Historic Photos and Prints Collection, R4-018-G-0028, Chaffey's Lock swing bridge (Pennock Photo, 1907).

37. Interview, Ashton Dale to Robert Passfield, 29 Oct 1992. Dale began work on the Rideau Canal in December 1934 as an apprentice timberman, repairing timber crib waste weirs and reconstructing timber swing bridges. He became a carpenter in 1937, was appointed Carpenter Foreman in 1949, and retired in April 1977 as the Maintenance Supervisor, Rideau Canal.

38. Interview, Ashton Dale to Robert Passfield, 12 Jan 2005.

39. Public Works & Government Services Canada (PWGSC), Canals Engineering, "Rideau Canal Highway Bridges and Steam Railway Bridges over Locks or Navigation Channels," A.T. Phillips, Superintending Engineer, 27 March 1930; and Parks Canada, Canal Registry Files, Rideau Canal, Bridges & Tunnels, File #4040–11, Volume II, "Rideau Canal, Table of Bridge Details," 29 Aug 1950. As of 1947, there were plate girder swing spans on heavily traveled crossings at Beckwith St., Smiths Falls (1922) on highways #15 & #29; at the Hogsback, Ottawa (1930), Merrickville (1933), and Bronsons Ave., Ottawa (1938).

40. PWGSC, Architectural & Engineering Services (A & E), Technical Documents Centre, Rideau Canal, Drawing R-2-106, "Rideau Ferry Swing, Plan & Dimensions," 16 Aug [1947]. On the re-use of the metalwork, including the stay rods, *see* Parks Canada, Canal Registry Files, Rideau Canal, Bridges & Tunnels, File 4652/

R85–261, Volume I, A.R. Whittier, Superintendent, Rideau Canal, memorandum, 8 June 1949. In 1968–69 the Rideau Ferry Bridge was replaced with a modern high -evel, reinforced-concrete structure with a 20-ton highway rating.

41. Parks Canada, Rideau Canal Historic Photos and Prints Collection, R.W. Passfield, photo recording of timber swing bridges, July 1974: R4-020-G-0062, Jones Falls; R4-026-G-0059, Brass Point; R4-024-G-0018, Lower Brewer's; R4-010-G-0014, Kilmarnock; and R4-007-G-0012, Upper Nicholson's.

42. Interviews, Ashton Dale to Robert Passfield, 29 Oct 1992 and 12 Jan 2005. Tenons were generally made about 1/3 of the thickness of the timber. If the mortise-and-tenon joint was horizontal at an unsupported joint, the tenon was reduced to roughly 1/5 of the timber thickness, to avoid any compression force on the tenon breaking out the cheek of the mortise (Nicholson, *The New Practical Builder*, 227).

43. The analysis that follows is based primarily on a comparison of a 1984 "as-found" recording of the Lower Brewer's timber swing bridge with the extant plan and sectional drawings of the 1866 design prototype, a 1974 photo recording of the five extant timber swing bridges, and interviews with Ashton Dale.

44. PWGSC, Rideau Canal, Drawing 10–891, "Lower Brewer's Swing Bridge, Existing Bridge," Sheet #103, 31 Jan 1984. As of this date, the Canadian federal government had converted to the metric system, and the dimensions on these drawings are metric. However, for ease of comparison with the historic bridges, the dimensions have been converted to the imperial system of measurement.

45. Interview, Ashton Dale to Robert Passfield, 12 Jan 2005.

46. PWGSC, Rideau Canal, Drawing 10–891, "Lower Brewer's Swing Bridge, As-built-New Bridge Details," Sheet #104, 31 Jan 1984; and personal communication, Eric Sunstrum, Senior Bridge Engineer, PWGSC, to Robert Passfield, 6 Oct 1992.

47. Interview, Ashton Dale to Robert Passfield, 29 Oct 1992; and Slater, "Specification for Swing bridge at Brewer's Lower Mills," 11 Sept 1872. Ironically, the strengthening of the mortise-and-tenon joints at Lower Brewer's with steel plates and angles by Parks Canada in 1981 marked a revival of a feature of an earlier plan. In his original, abortive, swing bridge design of 7 Feb 1865, James D. Slater had planned to employ wrought-iron angles and boiler plates to strengthen the mortise-and-tenon framing connections.

48. In this paper only the design evolution of the reconstructed timber swing bridges is being treated. However, a major question remains unanswered: To what extent did the five reconstructed timber swing bridges extant within their respective settings preserve the totality of the heritage values of the original timber swing bridge prototype within their settings? That question will be dealt with in a companion piece, Robert W. Passfield, "Evaluating Authenticity: Reconstructed Timber Swing Bridges," in a forthcoming publication.