Water Over Water: Hoosier Canal Culverts, 1832-1847

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A modern student of nineteenth-century technology once observed that the technology of canals has been their least-studied aspect.[1] Works on canals have examined their politics, financing, folklore, and economic impact but nearly ignored technical matters. This paper treats the least-studied aspect of this little-studied technology: canal culverts. Though obscure, the topic is important. Culverts were by far the most frequently used devices to get canals past intersecting streams, a vital task without which there could be no canals.

In the design and construction of a canal there are four primary tasks that an engineer must accomplish: survey a useful route with minimum elevation changes; deal with any unavoidable elevation changes present on the route; guarantee an ample supply of water for the canal; and cross lateral water-courses. The Wabash and Erie Canal, built to connect Lake Erie with the Wabash River, followed the relatively flat valleys of the Maumee and the Wabash. The much shorter Whitewater Canal in southeastern Indiana connected the east-central part of the state at the National Road with the Ohio River. Necessary changes in elevation on these canals were effected by locks which sealed one elevation from another and which served to pass canal boats up or down. The generally low relief of the Maumee, Wabash, and Whitewater valleys meant that no tunnels were required in Indiana, although the Whitewater extension to Cincinnati went through one ridge. The numerous tributaries generally provided ample supplies of water, with occasional exceptions during the dry summer months. All of

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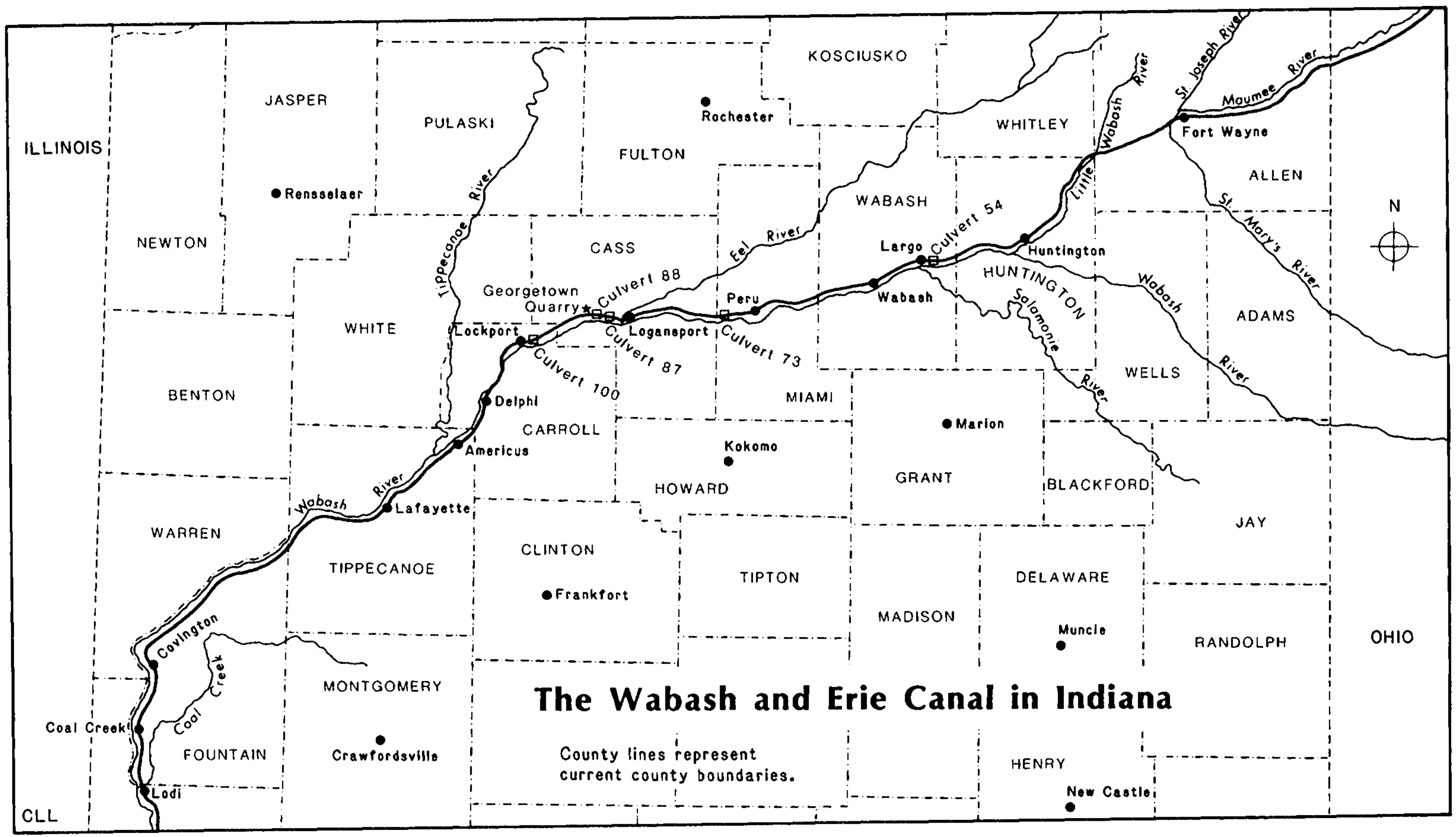
[1] Brooke Hindle, *Technology in Early America: Needs and Opportunities for Study* (Chapel Hill, 1966), 56.



Map prepared by Cathryn L. Lombardi.

these aspects of canal construction have frequently been discussed because of their political and economic implications or because of the interesting technical problems they present.

The last engineering problem faced by the builder was to carry the canal across lateral streams, ensuring either separation or controlled mingling of the two lines of water. This subject apparently has seldom been the subject of historical research; certainly no published research exists for Indiana.[2] On the rare occasions that scholars have studied stream-crossing on other canals, they have given their attention to aqueducts.[3] Yet these, interesting as they are, constitute only a small percentage of canal stream-crossing structures for the simple reason that most watercourses are too small to merit such elaborate water-bridges. Indiana's Wabash and Erie, for example, from the Ohio state line over the 195.5 miles of the 1847 survey used in this study, crossed over or through 159 watercourses and only ten required aqueducts. The canal crossed five streams in slack-water pools formed by dams, but the remaining 144 crossings utilized culverts.[4]

It is the problem of canal culverts in Indiana in the period 1832-1847 which is examined here. The methods used to carry Indiana canals of the 1830s and 1840s across lateral streams are surveyed and discussed. Three distinctly different kinds of data are used: archival materials from the 1830s showing with

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[2] For example, Paul Fatout, *Indiana Canals* (West Lafayette, Ind., 1972), has no discussion of culverts, and Dora T. Mayhill, *Old Wabash and Erie Canal in Carroll County* (Knightstown, Ind., 1953) mentions two culverts only in passing. An exception, dealing with the eastern United States, is Thomas F. Hahn, *Towpath Guide to the Chesapeake and Ohio Canal* (4 parts; Shepherdstown, W.V., 1971-1978), which measures and describes extant culverts and all other structures and features on that canal. This work has been published in various editions. A survey of *The Franklin Journal* and the *Journal of the Franklin Institute*, 1826-1846, reveals numerous articles on American canals but nothing on culverts.

[3] Culverts and aqueducts may be differentiated as follows: a culvert is a stone, wood, concrete, or metal tube carrying water under or through the foundation of a right-of-way, while an aqueduct is a bridge carrying water over an essentially undisturbed stream, railroad, or road. A stone arch culvert may be thought of as a very wide, (usually) single-span stone bridge of the type which has existed since antiquity. Wabash and Erie Canal aqueducts were not sophisticated stone bridges reflecting late-eighteenth-century French engineering advances. Rather, they used simple wooden channels (trunks) which were supported by stone piers and roofed like covered bridges.

[4] Jesse L. Williams, "Report of the Chief Engineer Descriptive of the Condition of the Canal at the Commencement of the Trust," included in "Annual Report of the Trustees of the Wabash and Erie Canal, to the General Assembly of the State of Indiana, December, 1847," in Indiana, *Documents of the General Assembly. . . .* (Indianapolis, 1848), 213-37.

what presuppositions a canal engineer approached the problem; a canal survey report of 1847 showing what was actually constructed on one Indiana waterway during the first round of culvert building; and the results of a recent on-site examination of one particularly well preserved but typical Indiana canal culvert from 1840. These data permit a coherent survey of canal culvert technology in one state during a fifteen-year period of canal construction.

The Hoosier state is an apt subject for such a study because it was far enough west to benefit from the ideas and practices that had earlier been developed in the older part of the nation. Little additional canal building was done west of Indiana, as the entire transportation method was soon rendered economically unviable by the railroad. The men who thought about, designed, and supervised the building of Indiana's canals were themselves the inheritors of several decades of accumulated experience and informal education. But the engineers are not the main focus here; beyond a few names and references to earlier canal experience in states further east, one will find little about the men.[5] Canal culvert technology has center stage.

Nothing can be imagined that is more prosaic than a modern culvert. The simple task of passing relatively small quantities of water under rights-of-way is now inconspicuously managed by metal or pre-cast concrete tubes. In the 1830s, however, at the time Indiana canals were begun, engineers gave substantial attention to the design and installation of culverts, and they developed rules to help them decide when to install a culvert in preference to other structures.

The engineering records of the Wabash and Erie, Indiana's longest canal, have apparently been lost, but the Indiana Commission on Public Records holds the notebooks and drawings of M.S. Webb, an engineer in about 1836-1840 on the Whitewater Canal, then under construction.[6] The narrative

[5] The best background on the men is David Hovey Calhoun's *The American Civil Engineer: Origins and Conflict* (Cambridge, Mass., 1960). Jesse L. Williams (1807-1886) is virtually the only Indiana engineer about whom information is available: see Calhoun, *American Civil Engineer*, 48, 80, 149-51, 217; Dumas Malone, ed., *Dictionary of American Biography* (20 vol., New York, 1928-1936), XX, 268-69; Charles R. Poinsatte, *Fort Wayne During the Canal Era, 1828-1855* (*Indiana Historical Collections*, Vol. XLVI; Indianapolis, 1969), 39-40; and Charles B. Stuart, *Lives and Works of Civil and Military Engineers of America* (New York, 1871), 141-69.

[6] Specifications for Masonry; M.S. Webb Excavation Book; and Engineer's Pocketbook 1837-1840, in Whitewater Canal Papers (Indiana Commission on

sections of his notebooks include guidelines that amount to a canal-builder's handbook. The drawings provide additional information on dimensions and bills of material. Stone-arch culverts are emphasized and wooden culverts slighted. All information is general and not identified with specific sites where culverts were to be built.

Ohio and the older eastern states were the fonts of knowledge for Indiana canal builders. Webb noted, for example, that he had obtained much of his information, especially that on hydraulic calculations, from an Ohio engineer named Cooper. Similarly, Jesse L. Williams, Indiana's chief engineer for all internal improvements and author of the important 1847 Wabash and Erie survey, had come to Indiana from the Ohio canal system in 1832.[7]

M.S. Webb gave his canal rules in narrative form under three headings: (1) General Rules for Crossing Streams; (2) Culverts; and (3) Arched Culverts. The treatment was not systematic. Table I summarizes the solutions he recommended. Note that he did not offer a rule for some cases, but in others he suggested two or three possibilities.

Under "General Rules," Webb described how a canal is to be carried across watercourses according to the varying sizes of the streams. He divided them into three classes according to the maximum amount of water each carried when in flood.[8]

Public Records, Indiana State Library Building, Indianapolis). My thanks to Steve Novak for their initial survey. M.S. Webb, Culvert Drawings (Indiana Commission on Public Records). Webb's exact job title remains unclear, and little is known about him. He was apparently one of the twelve resident engineers, seven senior assistant engineers, or eleven junior assistant engineers reportedly at work on the Whitewater in 1837; see James M. Miller, "The Whitewater Canal," *Indiana Magazine of History*, III (September, 1907), 111-12. Simpson Torbet was the Whitewater chief resident engineer, but he died on March 23, 1838, while working on the canal's Ohio extension; James M. Miller, "The Richmond and Brookville Canal," *Indiana Magazine of History*, I (Fourth Quarter, 1905), 192. The number of engineers on the Whitewater went down from forty-five to three in 1840, when the depression finally reached Indiana. Webb's diary stops then, when he probably lost his job; see Calhoun, *American Civil Engineer*, 141, and Logan Esarey, *Internal Improvements in Early Indiana* (*Indiana Historical Society Publications*, Vol. V, No. 2; Indianapolis, 1912), 105.

[7] Williams had surveyed for the Whitewater in 1834; Esarey, *Internal Improvements*, 93; Poinsatte, *Fort Wayne During the Canal Era*, 39; Frank Trevorrow, *Ohio's Canals* (n.p., 1973), 72-74. For a discussion of "on the job training" in this field, see Calhoun, *American Civil Engineer*, 47-53.

[8] There are other ways of thinking about the problem. The French engineer Joseph-Mathieu Sganzin, for example, described the possibilities as passage of the other stream over, under, or through the canal. The 'over' solution was neither discussed nor carried out in Indiana. Joseph-Mathieu Sganzin, *Programme ou Resumé des Leçons d'un Cours de Constructions*, 4th ed. (3 vols.,

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Reproduced from Jacob Piatt Dunn, *Indiana and Indianans: A History of Aboriginal and Territorial Indiana and the Century of Statehood* (Chicago, 1919), 390.

The smallest, Class 1, could be accommodated at flood by a semicircular culvert of four-foot chord or span (6.3 square feet in cross-section). The largest, Class 3, had a maximum flow greater than could be passed through a semicircular arch of thirty-foot span (353 square feet in cross-section). Between these extremes fell the middling creeks, which represented the vast majority of all streams encountered in Indiana canal building. For these middle-size (Class 2) watercourses Webb recommended passing the water under the canal by means of a culvert or set of culverts, an answer which, as Table I shows, he recommended less frequently for the largest and smallest streams.

Paris, 1839-1841), II, 128. A modern irrigation canal treatise says, "Storm and drainage water must be controlled to prevent erosion of the uphill canal bank, and accompanying silting of the canal prism. Storm and drainage water must have either: (1) controlled entrance into the canal through a drain inlet; (2) controlled conveyance over the canal in an overchute; (3) controlled conveyance under the canal through a culvert; or (4) the canal must be routed under the cross-drainage channel in a siphon." The last is of course not possible on a navigation canal. U.S. Department of the Interior, Bureau of Reclamation, *Design of Small Canal Structures* (Denver, 1978), 179.

TABLE I: Solutions for Crossing Lateral Streams with a Canal

Stream Class	Stream Bed Well Below Canal Level				Stream Bed Near Canal Level			
	Suitable Stone Available		Suitable Stone Not Available		Clear Water		Sediment-laden Water	
	Water Required*	Not Required	Water Required	Not Required	Water Required	Not Required	Water Required	Not Required
1. Less water than that passed by a 4 ft. arch. (less than 6.3 ft.² cross-section)	B	C1 C2	B	C2	B	B C2	B**	C2
2a. Water passed by an arch of 4-12 ft. (6.3 ft.²-56.5 ft.² cross-section)	C1***	C1 C2		C2		C2		C2 D
2b. Water passed by an arch of 12-30 ft. (56.5-353 ft.² cross-section)	C1***	C1	C4*** D	C4	D	D	D	D
3. Water requiring an arch of over 30 ft. span. (greater than 353 ft.² cross-section)	A D	A C1 C3	D	C4 D	D	D	D	D

SOURCE: Specifications for Masonry, in Whitewater Canal Papers, Indiana Commission on Public Records, Indiana State Library Building, Indianapolis.

Abbreviations:
A Aqueduct
B Pass stream into canal
C1 Culvert, stone arch
C2 Culvert, wooden box
C3 Culvert, multiple stone arches
C4 Culvert, wooden arch or arches
D Dam and pool

*Sites where engineer calculated additional water was needed for canal
**If basin is large
***With separate feeder

The arrangements designed to cover the mid-range conditions, Classes 2a and 2b in Table I, received most of Webb's attention, but before examining them in detail it may be best to place them in context by examining Webb's solutions for the largest and smallest streams. In most cases he recommended letting the small Class 1 brooks flow directly into the canal, avoiding the trouble and cost of any elaboration at all. His only proviso in such cases was that a sufficient number of waste weirs or overflow outlets be provided nearby so excess water might leave the canal without damaging the banks. If the stream carried so much sand or gravel that it might tend to fill the canal, he indicated that a small culvert should be built to pass the water under the canal.

At the upper end of the scale, Webb wrote that large streams and rivers of Class 3 ought to be crossed by aqueducts because these provided the surest navigation. He described an aqueduct as an especially happy solution when the stream had high banks and the canal therefore passed far above the stream bed. But an aqueduct required that adequate building materials—stone for the piers and wood for the trunk—be close to the site, a distance Webb defined as no more than six to ten miles.[9] If a feeder (additional supply of water for the canal) was necessary or desirable on that section of the canal, a dam could be built on the downstream side of the canal crossing, and the canal itself conducted through the pool formed by the dam. In that case the problem of carrying the towpath over the pool had to be resolved with a towpath bridge, rope ferry, or horse ferry.

When a culvert was the answer, Webb prescribed two distinctly different types depending upon the circumstances: if the culvert could be set very low in its stream bed and if the size of the stream fell toward the lower end of Class 2 (maximum flow passable through a twelve-foot chord semicircular culvert), he recommended an inexpensive wooden rectangular culvert, placed low so as to be permanently under water. Because wood deteriorates when not completely submerged, it was important that not only the bottom, but also the 18-36-inch sides and the horizontal top, be kept under water. This required a nice calculation to assure that there would be sufficient water to maintain this cover, and frequently a small dam was placed across the stream just below the culvert to maintain the water

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[9] Webb did not mention all-stone aqueducts, although in the East there were many, with arches up to ninety feet; Hahn, *Guide to C & O, passim.*

depth.[10] On the other hand, the culvert had to be open enough and to have great enough capacity to handle even spring floods so that the water would not back up and damage or erode the canal embankment. If a wooden rectangular culvert was not suitable because the stream was larger in flood than a twelve-foot arch could handle, or if the stream bed was so far below the level of the canal that insertion of a low, wooden rectangular culvert would leave a high, exposed bank, Webb prescribed a stone arch or in rare circumstances a wooden arch.

The guidelines found in Webb's manuscripts may be compared with Jesse L. Williams's report of the actual structures found on the Wabash and Erie in 1847. Williams examined minutely all the structures on the 189 miles of the canal that had been built since 1832, from the Ohio line to near Coal Creek south of Covington, Indiana, as well as the 6.5 mile St. Joseph feeder.[11] Except for infrequent remarks on the condition of the bank, he concentrated on the dams, bridges, aqueducts, culverts, locks, and waste weirs—the "works of art," in the terminology of the time.

Williams's report is organized differently than Webb's Whitewater notebooks. Williams did not state the quantity of water or flow rate of each stream, nor did he indicate the probable flows in flood-time. He simply reported the location, dimension, and condition of the mechanical structures that he found on the canal. From these data one can only surmise the relative size of each stream from the dimensions of the structure erected upon it, precisely the opposite approach from Webb's *a priori* classification explained above. There can, therefore, be no precise ranking of stream size on the Wabash and Erie that would strictly parallel Webb's Whitewater classifications. The general size of the streams crossed by the Wabash and Erie can be estimated from the 1847 report, but erroneous deductions could be drawn, as, for example, in cases where large arches or even aqueducts might have been put up, not for the quantity of water that they could handle, but to gain height for the canal bed.[12]

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[10] A similar small dam, which was used in conjunction with a stone arch culvert, appears incidentally in Fig. 3. It ensures that water will cover the horizontal wooden foundation that underlies the spring points and entire stream bed at this stone arch site.

[11] For a map of the St. Joseph feeder, see Poinsatte, *Fort Wayne During the Canal Era*, 42.

[12] Canal hydraulic arrangements could not be fixed permanently. As settlers cleared the Wabash Valley lands the quantity of runoff increased and its timing changed. Williams commented that greater spring floods occurred as the

Williams concentrated on the elaborate structures and did not necessarily mention the very small brooks of Class 1 that simply flowed into the canal. He did mention the location of moveable-gate waste weirs, and since there were only four or five on the canal not accounted for by proximity to large feeders, one may deduce that there were probably not many other small streams that simply flowed into the canal.[13] Only three non-urban culverts of less than 6.3 square feet of cross section (Webb's Class 1) were found on the Wabash and Erie in 1847; such other streamlets as may have existed at that time apparently fed into the canal. Even the four or five weirs mentioned may not have had any purpose other than general control of water depth since they were used also to drain a canal level whenever maintenance was required.

Williams's report provides complete coverage only for larger streams. Selection of a particular culvert dimension did not necessarily imply a stream of a certain size—there was simply too much latitude, as the rules in Webb's Table I show and as the empirically derived information in Table II indicates. The latter provides a breakdown of the classes and types of culverts on the Wabash and Erie in 1847, classifying all the lateral watercourses that Williams thought worth mentioning and providing totals by type and size.

The rarer culvert installations—stone arches, multiple wooden boxes, and wooden arches—occur in a variety of sizes, but they are infrequent in the smaller categories. These relatively complicated styles, however, along with aqueducts and dam/pool crossings, appear at all locations providing more than 40 square feet of cross-sectional capacity.[14] This is no surprise and merely confirms the common-sense expectation that the

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valley was settled, while summertime flows decreased noticeably; Williams, "Report of the Chief Engineer," 215. The result was that over time canal mechanical structures might have to be enlarged, combined, or abandoned.

[13] A search produced no photos of waste gates or weirs from Indiana, but for photos of a weir from the East see William J. McKelvey, Jr., *The Delaware & Raritan Canal: A Pictorial History* (York, Pa., 1975), 41.

[14] No detailed descriptions, drawings, or photos of wooden arches have been unearthed. The clearest information appears in Williams's description ("Report of the Chief Engineer," 222) of culvert number 36 over Cow Creek in eastern Huntington County: "This is a large wooden arch of 18 feet chord, semicirc[u]lar. A structure of this size and shape could not be submerged, and the arch timbers have therefore been exposed to the air. Experience shows however, that timber thus situated under a moist bank of earth, is not subject to rapid decay, and it is bel[i]eved that this arch may stand 3 or 4 years longer, when it should be rebuilt of cut stone. The head walls will need some repairs within two years."

TABLE II: Frequency and Method of Crossing Lateral Streams, Wabash and Erie Canal in Indiana, 1847

Cross-section (ft.^{2})	Single Wooden Rectangle (1)	Multiple Wooden Rectangle (2)	Single Wooden Arch (3)	Multiple Wooden Arch (4)	Stone Arch (5)	Multiple Stone Arch (6)	Aqueduct (7)	Dam and Pool (8)	Totals (9)
0-10	29*	...	...	...	...	...	...	...	29
11-20	52	...	1	...	3	...	...	...	56
21-30	11	5	1	...	5	...	...	...	22
31-40	3	5	1	...	1	...	...	...	10
41-50	...	3	...	...	...	...	...	...	3
51-60	...	1	...	...	...	...	...	...	1
61-70	...	1	...	...	...	...	...	...	1
71-80	...	2	...	...	1	...	...	...	3
81-90	...	4	...	...	1	...	...	...	5
91-100	...	2	...	...	...	1	...	...	3
101-200	...	4	1	1	1	...	...	...	7
201-300	...	1	2	...	...	...	...	...	3
301-400	...	...	...	...	1	...	...	...	1
Unknown, large	...	...	..	...	...	...	10**	5	15
Total	95	28	6	1	13	1	10	5	159

SOURCE: Jesse L. Williams, "Report of the Chief Engineer Descriptive of the Condition of the Canal at the Commencement of the Trust," included in "Annual Report of the Trustees of the Wabash and Erie Canal, to the General Assembly of the State of Indiana, December, 1847," in Indiana, *Documents of the General Assembly*. . . . (Indianapolis, 1848), 219-36.

NOTES: * Six were less than 6.3 ft.^{2} in cross-section.
** Spans ranged from 28 to 200 feet, heights above streams unknown, capacity therefore cannot be calculated.

larger the river crossed, the more sophisticated the engineering solution required. Conversely, Table II implies that wherever possible the engineer chose the cheapest and simplest device that he thought would work, with the result that wooden rectangular boxes, single or multiple, carried the canal over three-quarters of the streams, and even over some of apparently large dimension.

Table III amplifies column 2 of Table II by showing how many openings or elements there were at the twenty-eight streams where multiple-box rectangular wooden culverts were built.[15] In some instances these were sizeable installations, as much as 72 feet wide.[16] Wooden rectangular culverts were low and flat, typical dimensions being 10 by 1.5 feet, or 12 by 3 feet in each element. For wooden culverts Webb specified a length of 94 feet under the canal, exclusive of head or wing walls, 6 feet longer than the stone arch culvert tubes which normally had much more elaborate protective head and wing walls. Probably the two types similarly varied in length on the Wabash and Erie.

Metal was rarely used on the Wabash and Erie except in the fittings of the lock gates. However, four rectangular wooden culverts (numbers 112-115) between Delphi and Americus were banded with iron straps to give them added strength against upward pressure when the nearby Wabash River was high. On older canals in the East, iron had sometimes been used for the entire body of the culvert.[17]

There also was a certain variety among stone culverts. One stone culvert, described only as "small," was rectangular. For convenience it has been grouped with the smallest wooden culverts in Table II. And one stone arch culvert had double arches, each eleven feet in span.[18] From a similar extant double culvert in Ohio and from Webb, it is clear that both arches

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[15] Multiple wooden culverts were not mentioned by Webb, either in rectangular or arch form. He did say, however, that it was possible to substitute a wooden semicircular arch for a stone one where that form was required but no suitable stone was available.

[16] Culvert number 14, made of six 12-by-3-foot elements, just west of New Haven, Allen County, carrying Six Mile Creek; Williams, "Report of the Chief Engineer," 220.

[17] Williams, "Report of the Chief Engineer," 231; *A View of the Grand Canal* [Erie Canal] *from Lake Erie to the Hudson River* (New York, 1825), 13.

[18] Webb's table of proportions and materials included provisions for such structures. See Tables V and VI where they are denoted, e.g., 10+10. For a larger 1843 twin stone arch at Turtle Creek, Shelby County, Ohio, twenty-two feet in each span, still standing but in danger of imminent collapse, see Trevorrow, *Ohio's Canals*, 51.

TABLE III: Frequency of Culvert Sites with Multiple Wooden Rectangular Openings, Wabash and Erie Canal in Indiana, 1847

Total Cross-Section of Culvert at each Site (ft.^{2})	Number of Openings				
	2	3	4	5	6
21-30	5				
31-40	4				
41-50	3				
51-60	1				
61-70	1				
71-80	2				
81-90	1	4			
91-100	1	1			
101-200	...	1	2	1	
201-300	...	...	...	...	1
Totals	18	6	2	1	1

SOURCE: Jesse L. Williams, "Report of the Chief Engineer Descriptive of the Condition of the Canal at the Commencement of the Trust," included in "Annual Report of the Trustees of the Wabash and Erie Canal, to the General Assembly of the State of Indiana, December, 1847," in Indiana, *Documents of the General Assembly*. . . . (Indianapolis, 1848), 219-36.

were erected on a common foundation and formed one structure. The only other deviation from standard types on the Wabash and Erie was a small stone arch that sprang from vertical stone walls 2.5 feet high.[19] In later years, this form was very common under railroads.

Greater detail on the stone culverts listed in columns 5 and 6 of Table II is provided in Table IV, but in this table they are listed in geographical order westward from the Ohio border, the numbering method that Williams used. The remarks column shows that during the initial round of construction, until about 1840, almost all stone arches were built of rough material and displayed poor workmanship. The Burnett's Creek arch (number 100), built ca. 1839-1840, is the earliest arch of over ten-foot span described as still in sound condition in 1847. The other three of that size then in good condition—culvert number 1 on the St. Joseph feeder and canal culverts 73 and 88—had been built or rebuilt just before the survey was made; obviously

[19] There are a few examples on the C & O; see Hahn, *Guide to C & O*, Section 4, miles 114.21-121.19.

TABLE IV: Stone Arch Culverts, Wabash and Erie Canal in Indiana, 1847

Culvert Number	Span (ft.)	Cross-Section (ft.^{2})	Location	Williams's Remarks
1*	13.5	72	Beckett's Run	cut stone, new excellent [built 1845]
27	6	14	Ewing's Warehouse	good condition
48	6	29		2.5 ft. abutments
54	11 ea.	95	Lagro Creek	not of durable quality
60	8	25		rough stone; badly constructed
61	8	25		rough stone; imperfectly built
63	6	14		rough stone; material and workmanship imperfect
73	15	88	La Fontaine's Creek	recently rebuilt from Georgetown cut stone; stone excellent; arch perfect
76	8	25		rough stone
78	6	14		rough stone; imperfect
87	8	25		rough stone; imperfect
88	10	39		built last winter of Georgetown stone; excellent
100	20	157	Burnett's Creek	hammer-dressed stone; good repair except ring stones
132	30	353	Bear Creek	very soft cut sandstone; some doubt of durability; workmanship appears good.

SOURCE: Jesse L. Williams, "Report of the Chief Engineer Descriptive of the Condition of the Canal at the Commencement of the Trust," included in "Annual Report of the Trustees of the Wabash and Erie Canal, to the General Assembly of the State of Indiana, December, 1847," in Indiana, *Documents of the General Assembly. . . .* (Indianapolis, 1848), 219-36.

NOTE: * on St. Joseph feeder; all others on canal itself.

the first versions had been inadequate or they would not have been replaced. Williams's report is peppered with statements alluding to the poor quality of the work, the insecurity of the arches, and the need to rebuild a number of them soon with good cut stone.

The tension between the two opposing philosophies of building quickly and cheaply in order to get the canal into service, or building securely of good stone from the outset, had long been a feature of American canal building. In general, the first method implied construction of locks, culverts, dams, and aqueducts from wood, with the goal of quickly opening the canal and using the revenues generated from operations to rebuild with stone or to renew repeatedly with wood. Undercapitalized projects relied on this strategy, and immigrant engineers thought it a typically New World trait. But these engineers saw it less as a result of capital shortage than as a psychological characteristic of Americans, a part of the feverish activity of the new United States.

Whether undercapitalization or mere hyperactivity caused the American proclivity for wooden construction, European-trained engineers preferred to build monumentally, in stone, from the beginning, and they were critical of wood. The immigrant Benjamin Henry Latrobe, trained in England and Germany, wrote condescendingly in 1807 and again in 1810 that if his customers wished to build of wood they needed nothing more than a "New England bridge builder."[20] For all that, Latrobe did use wood on the canals and other works that he designed.

Latrobe was long dead when others built the Wabash and Erie Canal, but the conflict between the engineer's desire to build in a manner of which he could be proud and the exigencies of capital shortfall or great hurry were still in evidence in Indiana in the 1830s and 1840s. The problem of financing Indiana's internal improvements lies beyond the scope of this paper, but funds were short, and the people of the Wabash Valley applied great pressure to see that their canal was pushed to rapid completion.[21]

One very practical problem was obtaining suitable stone. When he was building the Chesapeake and Delaware Canal feeder in Maryland in 1804, Latrobe had had part of the canal dug and filled with water and then used the completed section to transport stone.[22] A similar method was used on the Wabash and Erie. This canal did not reach a source of suitable stone until it came to the Georgetown quarry in Cass County. As a result, until that source of good stone was reached southwest of Logansport, wooden culverts went up quickly at sites where they could not long endure or rough stone arches were thrown

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[20] Quoted in Darwin H. Stapleton, ed., *The Engineering Drawings of Benjamin Henry Latrobe* (New Haven, 1980), 26-27, 64-65.

[21] Consider the following from 1845: "Having lived for the last seven years in a community whose only sentiment and only hope was the completion of this canal . . . every possible effort was made to hurry forward the work. . . . "; Jos. H. Nelson, "Report of the Chief Engineer of the Wabash and Erie Canal," included in "Report of the Superintendent of the Wabash and Erie Canal, to the General Assembly, December 1, 1845," in Indiana, *Documents of the General Assembly. . . .* (Indianapolis, 1845), 143.

[22] Stapleton, ed., *Engineering Drawings of Latrobe*, 15.

up where quality building stone lay too distant to be economically transported by wagon.[23] Once the canal reached the Georgetown quarry, however, stone could be shipped back on the completed canal for distances that had theretofore been uneconomical. Early defective arches and locks could be replaced. The remarks column of Table IV shows that this was done in 1845-1847. Even at that early date, builders shipped stone back as far as LaFontaine's Creek (culvert number 73) in Miami County, about seventeen miles from Georgetown.[24]

The Georgetown quarry sat beside the canal between culverts 88 and 100. Table IV shows that number 100 was not only the earliest large arch still in good shape in 1847, but also that it was the only major arch on the canal built of adequate stone on the first attempt. All the others to that point were either rough and not durable or had been rebuilt just before Williams conducted the survey.

On the Wabash and Erie Williams did not provide specific information on the source of the poor stone used in the arches, although he did comment upon the *locks* built of inferior stone.[25] The raw material for all of these had come from the "Salamania" quarry, and in every instance it was found wanting. The "Salamania" stone locks were distributed over that section of the canal from about the Huntington-Wabash County line westward to near Peru, or approximately where stone arches 54 through 73 were located (see Table IV and Map). In all probability the unsatisfactory stone used in the culverts on that stretch had come from the same quarry. The "Salamania" quarry was apparently located about where part of the Salamonie Reservoir now stands, between Lagro and the Wabash-Huntington County line.

As the foregoing shows, the builders did not easily or quickly accomplish the task of obtaining good stone and employing it in arches on the Wabash and Erie. Few large stone arches existed at any time, and it is remarkable that at least

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23 The Georgetown quarry is now the site of France Park, a Cass County park located on the property of the former France Stone Company, Inc. The present hamlet of Georgetown is 2.5 miles southwest, immediately on the banks of the Wabash.

24 LaFontaine's Creek is now called Edwards Ditch or Prairie Ditch.

25 Williams, "Report of the Chief Engineer," 225-27, concerning Locks 12-20. As late as 1843 not all officials on the canal realized that Salamonie (Lagro) stone was unsuitable. In that year Commissioner Fisher wrote that the St. Mary's aqueduct piers and abutments ought to be rebuilt with stone from "Lagro"; see S. Fisher, "Report of the Commissioner of the Wabash and Erie Canal East of the Tippecanoe River," in Indiana, *Documents of the Senate. . . .* (Indianapolis, 1843), 20.

FIGURE 1—BURNETT'S CREEK ARCH, 1974: NORTH PORTAL OF TWENTY-FOOT ARCH CARRYING WABASH AND ERIE CANAL OVER BURNETT'S CREEK, CARROLL COUNTY; BUILT 1839-1840

Courtesy of Author.

one of the largest original arches has survived until the present day: culvert number 100, the stone arch that carried the canal over Burnett's Creek in Carroll County (Fig. 1).[26]

Nowadays the arch serves as a county road bridge and has been slightly altered and repaired, but in all major respects it stands as it did when completed in 1840.[27] It was the second largest arch built on the canal by 1847, and Williams's remarks show that he found it sound but not in perfect condition when it was seven years old. He reported that some of the ring stones on both ends were "soft" and "falling to pieces," just as they are

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[26] Burrows, Indiana, Quadrangle, 1:24,000, Universal Transverse Mercator Kilometric Grid Coordinates: 363056; located on Towpath Road, 0.33 miles northeast of Lockport, about four miles north of Rockfield on the north side of the Wabash River; Williams, "Report of the Chief Engineer," 229.

[27] "Structure Inventory and Appraisal Sheet," Carroll County Bridge Number 26, dated January 12, 1975 [?], provided by courtesy of Charles J. Ritzler, Carroll County Surveyor, Delphi, Indiana.

today, as shown in the photo of the north face (Fig. 2).[28] County workers enveloped the south face in concrete to prevent furthering weakening from the same cause (Fig. 3).[29]

The recent photographs accompanying this article, when compared with Webb's drawings (Figs. 4 and 5), and his data in Tables V and VI (unfortunately fragmentary for twenty-foot arches), show that the engineers built the Burnett's Creek arch upon the same principles and dimensions that Webb prescribed. Further explanation of these tables appears below.

The casual passerby on Towpath Road today might not even notice the arch. The great 85.5 foot length of the culvert makes it in effect a very wide bridge, and it means that a broad expanse of earth extends far from the road's edge on the south side, concealing the creek below. Only by looking down sharply on the north side of the road can one see the stream below.

FIGURE 2—CRACKED RING STONES, BURNETT'S CREEK ARCH, 1974: COMPRESSION FRACTURES ARE VISIBLE IN RING STONES ON WEST PART OF THE NORTH PORTAL

Courtesy of Author.

[28] Williams, "Report of the Chief Engineer," 229.
[29] "Structure Inventory Sheet."

TABLE V: Stone Arch

Span or Chord of Arch (ft.)	Lineal ft. under central portion of arch body. (1)	Length of timbers in col. (1) (ft.). (2)	Lineal ft. under end portions of arch body (near parapet). (3)	Length of timbers in col. (3) (ft.). (4)	Lineal ft. under wings. (5)	Length of timber in col. (5) (ft.). (6)
6	80	11	8	18	12	21
7	80	11 ½	8	19 ½	14	23 ½
8	80	12 or 12 ½	8	21	16	25
10	78	15	10	24	16	28
					18	30
10+10	80	28	8	36	18	43
12	78	17	10	28	4	28
					16	31
					20	34 ½
12+12	80	31 ½	6	37 ½	6	41 ½
					14	44 ½
14	...	...	...	...	...	...
16	74	22	14	35	24	41
18	76	24	8	31	8	38
					22	42
20	...	...	...	...	...	...
20+20	72	48	16	29	16	33
					28	12
					40	10
22	...	...	...	...	...	...
24	68	32	20	45	30	52
26	66	36	22	48	32	54
30	...	...	...	...	...	...
34	...	...	...	...	...	...

19 ¼	Cols. 1, 3, and 5 add to 120.66 feet.	±44′10″

SOURCE: Specifications for Masonry, in Whitewater Canal Papers, and Plan of Culvert . . . 12 Foot Chord, both at Indiana Commission on Public Records, Indiana State Library Building, Indianapolis.

Thickness of timber (in.). (7)	Length of ring stones (in.). (8)	Depth of ring stones (in.). (9)	Thickness of stone in wings—at ends, and next to arch (ft.). (10)	Radius of circle of wings (ft.). Cf. Fig. 4, bottom. (11)	Length of pilings (ft.). (12)
9x10 10	18	15 or 16	...	...	...
...	18	...	...	...	...
10 deep	18	16 or 17	3	...	4
10 deep	18	17 or 18	2 3	11′9″	...
...	...	18	2 2	...	...
...	21	18 or 19	2 ¼ 2 ¼	11′3″	...
9x10	...	19	2 ¼ 3 ¼	11′9″	4
...	21	19 or 20	...	...	...
...	21	20 or 21	...	...	...
10x 12	24	21 or 22	2′9″ 4′3″	...	...
...	24	22	...	...	...
10x 12	...	21	4′0″ 5′10″	19′10″	5
...	27	23	...	...	...
...	27	23 or 24	4′0″ 5′6″	25′9″	4
...	27 or 30	24 or 25	...	...	...
...	30	26 or 27	...	...	...
...	...	28 or 30	...	...	...
		Burnett's Creek Arch			
...	23 ½	...	... 2′7″	...	...

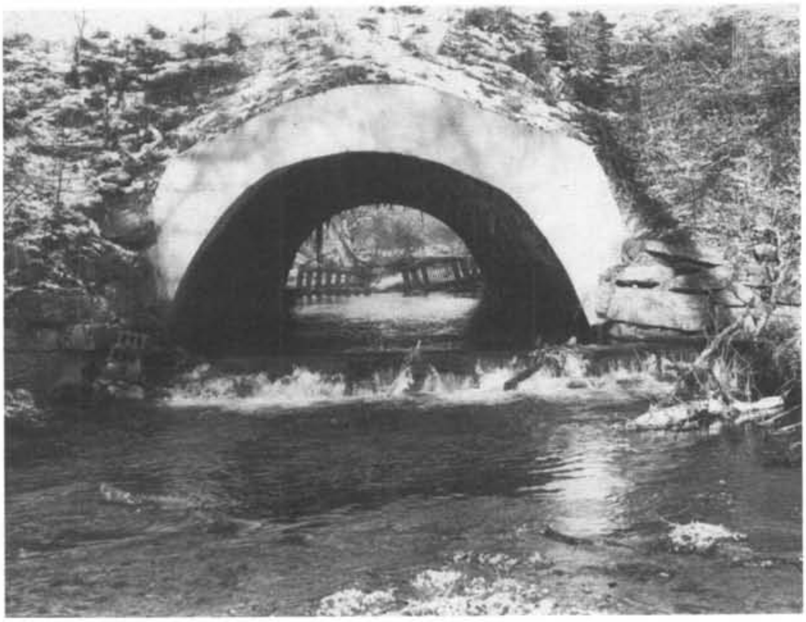

FIGURE 3—BURNETT'S CREEK ARCH, 1974: THE SOUTH PORTAL IS ENCASED IN CONCRETE. VISIBLE IN THE FOREGROUND IS THE SMALL DAM USED TO KEEP THE WATER OVER THE FOUNDATION TIMBERS UNDER THE ARCH.

Courtesy of Author.

The height of the arch in relation to the former canal prism is not easy to determine because the road has replaced the canal bed, but Webb's rule called for a minimum of two feet of earth (called puddle) between the top of the arch stones and the bottom of the canal bed, and this gives an indication of the minimum probable elevation of the canal. Note also Webb's comments in Table I, mandating an arch if the bed of the stream to be crossed lay far below the level of the canal. The site at Burnett's Creek suggests this condition. The fact that the engineer there chose a rather large twenty-foot arch, with its attendant ten-foot rise (in addition to stone thickness and puddle), indicates that the desire to gain height may have motivated him.

Canals sometimes leaked through the stone arches when the clay bed was new.[30] The winter photo (Fig. 6) showing

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[30] Williams, "Report of the Chief Engineer," 228; *re* culvert number 87, "The arch leaks considerably. . . . "

TABLE VI: Bills of Material for Stone Arch Culverts

Span or Chord of Arch in feet	Total foundation timbers (ft.³). (1)	Total two-inch oak planking (ft.²). (2)	Stone in arch body (yds.³). (3)	Stone in each wing wall (yds.³). (4)	Stone in each parapet (yds.³). (5)	Total stone: 1 arch, 2 parapets, 4 wings (yds.³). (6)	Puddle (yds.³). (7)
6	1060	350 240	...	...	...	72	...
7	1170	...	...	...	...	...	...
8	1313	420 260	72.94	5.60	2.60	100.54	...
10	1625	500 250	...	...	...	131 or 140	150
10+10	...	768 430	...	...	...	...	...
12	1912	520 310	...	...	...	160 or 190	...
12+12	...	850 252	...	...	...	...	...
14	...	...	...	...	...	226	...
16	2590	...	...	...	...	270	...
20	...	...	...	...	...	378	...
20+20	...	1420 500	...	...	...	600	...
22	...	...	...	...	...	481	...
24	4636	...	...	...	...	553	...
30	...	...	...	...	...	727	...

SOURCE: Specifications for Masonry, M.S. Webb Excavation Book, both in Whitewater Canal Papers, Indiana Commission on Public Records, Indiana State Library Building, Indianapolis.

telltale icicles under the arch proves that more than a century of settling has not eliminated this problem at Burnett's Creek.

Tables V and VI bring together large amounts of information scattered in Webb's notes and drawings. For comparative purposes data gathered in a recent survey of the accessible parts of the Burnett's Creek arch appear at the bottom of Table V.[31] The two tables possess detail that may require patience to

[31] The measurements at Burnett's Creek were made in August, 1977, and were impeded by the presence of a large coiled snake. Though it was probably a harmless black snake, the author is not herpetologist enough to know whether the creature could be safely overstepped. He wishes to thank his wife and his aunt for holding the tape even in the near presence of the reptile. Canal buff Tom Hahn has pointed out that winter is the best time to explore and photograph old canal beds; in that season one avoids snakes, poison ivy, and foliage.

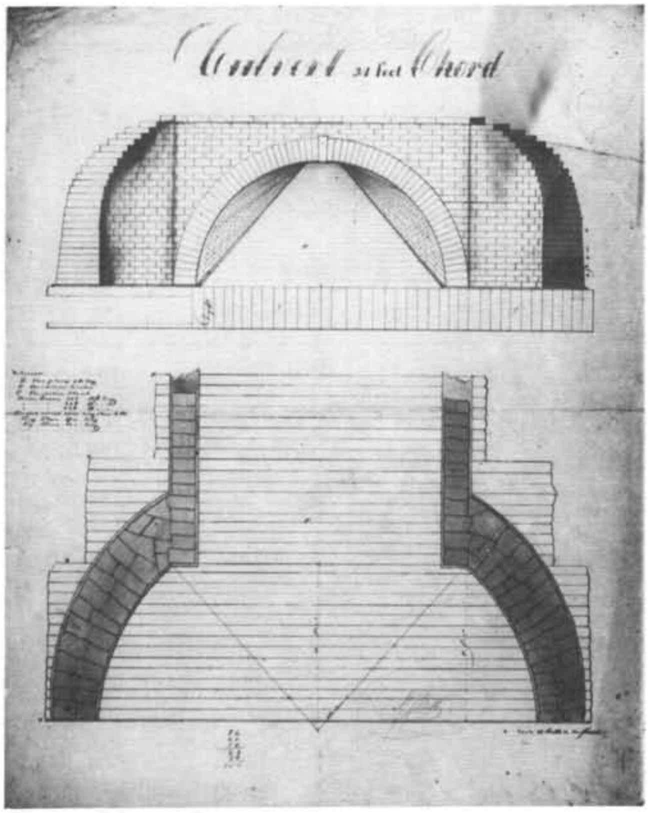

FIGURE 4—"CULVERT 24 FEET CHORD": DRAWINGS BY M.S. WEBB, WHITEWATER CANAL ENGINEER, CA. 1839

Courtesy Indiana Commission on Public Records, Indiana State Library Building, Indianapolis.

mine. Columns 1-6 of Table V are best understood in reference to Webb's overhead drawing (lower part of Fig. 4), which shows that the foundation timbers must extend ever wider as one moves out from the arch body toward the end of the spreading wing walls. Notice that in every case (except for possible scribal errors in the 12+12- and 18-foot rows), columns 1 and 3 add to 88 feet, the specified normal length for an arch body. Beyond the basic 88 feet, the extent of the timber foundation is positively correlated with the length and spread of the wing walls, which is in turn positively correlated to the span or chord of the arch.

To understand this idea, one may take as an example the data for the 12-foot arch, which are interpreted as follows: from

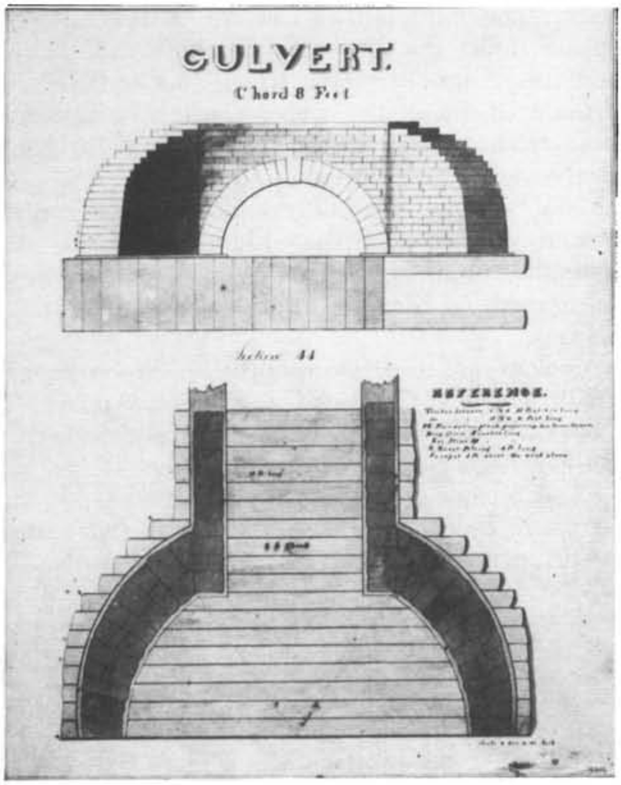

FIGURE 5—"CULVERT. CHORD 8 FEET": DRAWINGS BY M.S. WEBB, WHITEWATER CANAL ENGINEER, CA. 1839.

Courtesy Indiana Commission on Public Records, Indiana State Library Building, Indianapolis.

the inside mid-point of the culvert, 39 feet (half of 78) in each direction was undergirded by foundation timbers 17 feet long laid transversely to the arch body. Then beyond that there were 5 feet under each parapet of timbers 28 feet long, then for 2 more feet there were also 28-foot timbers where the wings began to extend from the parapet, then a further 8 feet of 31-foot timbers and finally, for the last 10 feet there were 34.5-foot beams reaching across to support the furthest extremities of the wing walls. In every case the timbers extended completely across the stream and tied together both sides of the arch and both wing walls. The overall result was a large, hourglass-shaped platform of wood supporting all the masonry.

Figure 7 shows graphically the remarkable survivability and durability of a wooden foundation like this when kept under water. The faint outlines of two intact beams (among many) appear under the water in this photograph, which looks across and down into Burnett's Creek just outside the north portal of the arch. Inside the arch a continuous timber foundation floor stretches away under the water, with beams like those faintly visible in the photograph.

Webb did not amplify certain bits of data contained in Tables V and VI. For example, builders apparently drove the pilings listed in Column 12 of Table V only near the ends of the horizontal foundation timbers. Figures 4 and 5 at least lead to that conclusion.

Also unclear are the two quantitites Webb gave for the two-inch oak planking (Table VI, column 2). Apparently these two numbers are added in each case, since elsewhere he said that a ten-foot arch required 750 square feet of oak planking. Figures 4 and 5 show that these were laid on top of the foundation beams in order to provide a perfectly flat surface from which to spring the arch and raise the wing walls.

FIGURE 6—BURNETT'S CREEK ARCH, 1974: VIEW LOOKING NORTH FROM WATER LEVEL INSIDE THE ARCH, SHOWING ICICLES AND COURSES OF STONE

Courtesy of Author.

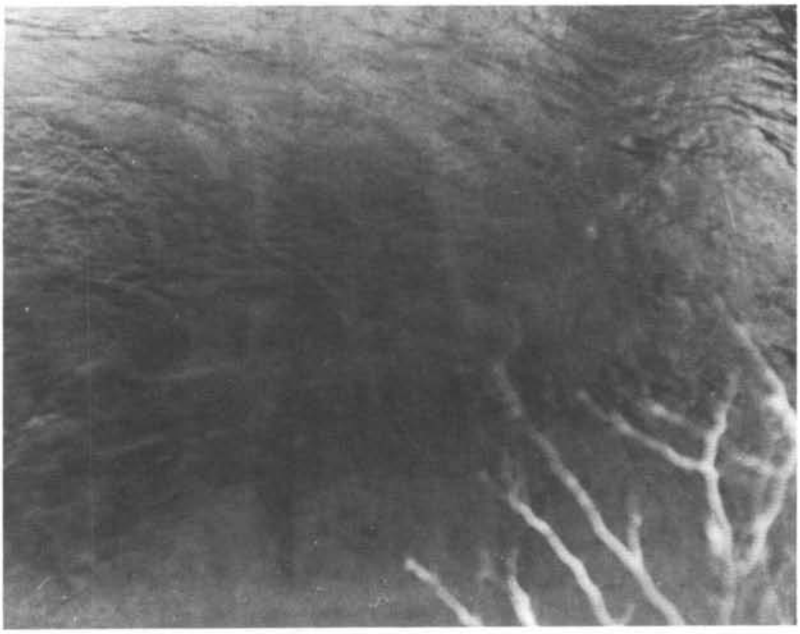

FIGURE 7—FOUNDATION TIMBERS UNDER WATER, BURNETT'S CREEK ARCH, 1974: LOOKING DOWN AND EASTWARD ACROSS BURNETT'S CREEK, ABOUT FIVE FEET NORTH OF NORTH PORTAL; THE EDGES OF TWO TIMBERS CAN BE DISCERNED

Courtesy of Author.

As is well known, the Indiana canal system was an economic failure. The large sums expended upon it were not recouped directly in tolls and fees and probably not indirectly in economic benefits, although the Wabash and Erie did for a time lower the shipping costs of Hoosier farm products headed for market. This brief period of efflorescence was from about 1847 until 1856.[32] The much shorter Whitewater provided some of the same benefits on an even more modest scale in about the same period.

The principal purpose of this paper has been to describe and summarize canal culvert technology of the mid-nineteenth century. A second purpose has been to draw attention to the historical value and aesthetic appeal of a little-known but im-

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[32] Elbert Jay Benton, *The Wabash Trade Route in the Development of the Old Northwest* (Baltimore, 1903), 76. This book's evaluation of the Wabash and Erie's economic impact has not been surpassed.

pressive monument to early Indiana engineering. The Burnett's Creek arch stands and serves—cared for by Carroll County and marked by the Carroll County Historical Society—as a valued physical reminder of early canal development in Indiana during the era of the internal improvements mania.