397

<u>Arizona State Land Department - Salt River Rebuttal:</u>
Rating Curves
Jonathan Fuller, ASLD Expert

The opposing of navigability invested considerable effort in developing alternative rating curves and criticizing the rating curves used by ASLD for the Salt River. The criticisms primarily involve differing opinions about what flow rates should be used with the rating curves, what topographic data should have been used to generate the rating curve cross section and slope, which hydraulic coefficients are most appropriate for the ordinary and natural conditions. The State's general responses to the criticisms and alternative methodologies offered by the opposing experts include the following:

- Why Now? The rating curves used by ASLD have been in the record since the original ASLD reports were completed up to 23 years ago. The rating curves had not been challenged in any previous ANSAC hearings or expert witness report. Not surprisingly, the opposing experts' new estimates are generally lower than the State's original estimates.[1]

- Right or Wrong? SRP's expert, Dr. Mussetter, was able to replicate ASLD's rating curve results for Segment 6, verifying that the State's hydraulic calculations made for Segment 6 had been done without error[2] and nullifying some of the criticisms from Mr. Gookin.

- That's it? The opposing experts seem to want to limit the discussion about the Salt River's susceptibility to navigation to just the rating curve depth estimates, in some cases to a single rating curve purported to accurately depict conditions for an entire river segment. By limiting the susceptibility investigation in this way, they ignore all of the other sources of information that can be used to estimate typical flow depths and river conditions, and that could be used to verify the relevance of the rating curve estimate(s).

- What about Seasonal High Flow? Although several of the experts explicitly mention the existence of a "boating" or "high flow" season on the Salt River, for some reason the opposing experts seem to have forgotten to apply their rating curves to flow rates that ordinarily occur during that season. Therefore, they underestimate flow depths for a significant portion of the year.

- Consensus. There are in fact several areas of agreement between the opposing experts. First, no alternative depths to those presented by ASLD were presented for Segments 1, 4 and 5.[3] The

[1] Most of the difference in flow depth estimates is due to the use of lower flow rates, not to the rating curve itself.
[2] Dr. Mussetter, like his predecessor Dr. Schumm, did not have any depth estimates or rating curves in any of his pre-hearing expert reports or in previous hearings on the Salt River, but found it necessary to add them when giving his oral testimony in 2016. Note that Dr. Mussetter, while verifying ASLD's calculations, did not concur with the ASLD's results, as discussed below.
[3] Mr. Burtell presented a rating curve based on gage data from an historical gaging station located near the upstream end of Segment 4, with no rating curve developed from data within Segment 1 or 3. However, his report and testimony appears to be limited to Segments 1 to 3. Therefore, it is assumed that he meant his rating curve based on data from the USGS Salt River at Roosevelt gage to apply to Segment 3. Regardless, it is either the ASLD rating curves for Segments 1, 3 and 5 that are unchallenged by alternative data, or the rating curves for 1, 4 and 5.

rating curve depths presented by ASLD for those segments are the only data ANSAC has to consider. Second, none of the experts' rating curves indicate that any computed velocities or flow widths existed during the ordinary and natural flow conditions that would have hindered navigation. Therefore, we can leave velocity and width out of any further discussions.

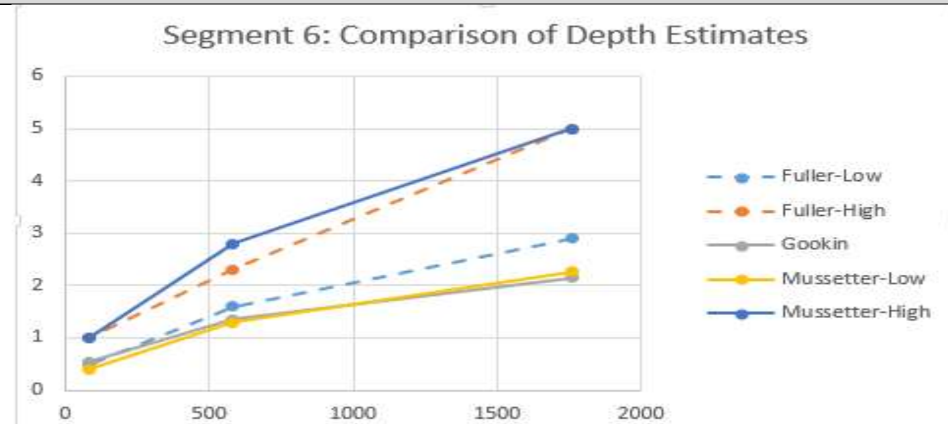
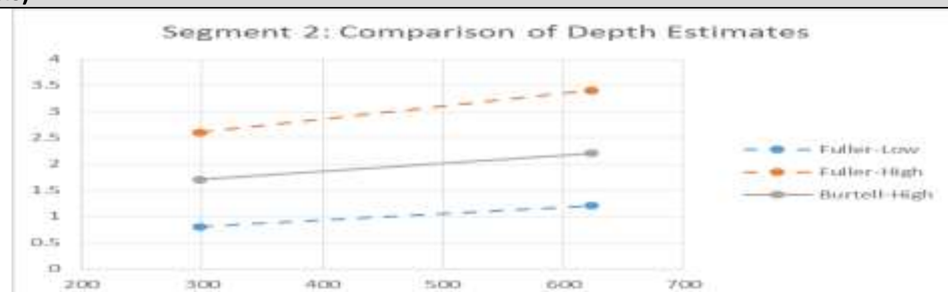
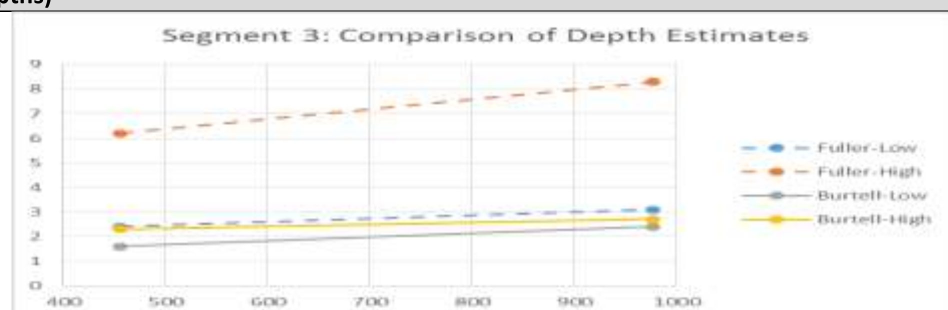
- So What? Despite all the rhetoric about topographic map accuracy, Manning's N values, single vs. multiple channels, channel slopes, and riffles vs. pool sections, the actual differences in computed depths by the various experts are insignificant relative to the navigability conditions in the river. In no case do the results indicate that the Salt River would have been conducive to deep-draft barges or large, keeled sea-going vessels. Similarly, all of the flow depth estimates indicate that the river would have been susceptible to relatively small, low-draft boats, at the very least during the ordinary high flow season. The biggest differences in rating curve results come from the flow rate estimates used to compute the depths, not from the rating cross sections or modeling techniques. This is especially significant in light of some opposing experts' failure to use ordinary and natural flow rates or to consider flows rates and depths during periods of seasonal high flow.

The bottom line is that the facts tell us that the Salt River in Segments 2 to 6 was susceptible to use by small, low-draft boats based on flow depth alone. One can argue about what types of boats could be used during some parts of some years, or if the degree of difficulty varied between some segments, but it is undeniable that small, low-draft boats could be regularly used when the river was in its ordinary (and natural) condition, at least during some parts of the year. It is the State's opinion, based on all of the available data and the extensive Salt River boating experience of the State's expert witnesses, small low-draft boats could be used during most of the year on Segments 2 to 6.

Review of Flow Depth Estimates. To determine exactly what each expert did to estimate the ordinary and natural flow depths in the Salt River, it is necessary to parse out each of their methodologies and data sources. The depths for the flow rates used by each expert are shown in Table 1 below. Clearly, there are some differences in the depth estimates when the different flow rates (as discussed early under "Hydrology") are used, so to make the comparison on an apples-to-apples basis, the depths that correspond to the same flow rates are shown in Table 2. As can be seen in Table 2, the ASLD rating curves produce depth estimates that are similar, but are both higher and lower than the estimates computed by the other experts. The magnitude of the differences do not so much affect the type of boat that could be used at those depths, but in some cases they do affect what percentage of the year those boats could be used.

Dr. Mussetter, in his oral testimony, used one of Mr. Fuller's Segment 6 rating curves to estimate flow depths in Segment 5, but used different flow rates.

Table 1. Comparison of Rating Curve Depth Estimates Made by Experts in the Salt River Navigability Case			
Expert	**Segment 6**		
	Depth Estimates	Description	
Fuller Mean Annual (1690 cfs) Median Daily (819 cfs) Minimum Flow (522 cfs)	 2.8-4.9 ft 1.9-3.2 ft 1.5-2.3 ft	6 locations in Segment 6 1903 Topographic data S = 0.0009-0.0026 N = 0.045	Double & single channels Depths from ASLD Report Appendix D Rating Curves Maximum depths listed
Gookin Mean Annual (1760 cfs) Median Daily (581 cfs) Minimum Flow (86 cfs)	 2.15 ft 1.35 ft 0.55 ft	Segment 6b, near GRIC Post-Statehood topographic data S = 0.0024 N = 0.035	Double Channel Depths from Slide 107 Maximum depths listed
Mussetter (Not Ordinary & Natural) Mean Annual (3062 cfs) Median Daily (554 cfs) Minimum Flow (277 cfs)	 Not provided 1.2-2.7 ft 0.8-1.8 ft	10 locations in Segment 6 1903 Topographic data S = 0.0009-0.0068 N = 0.035	Double and single channels Flow data from Slide 81 Depths from Slide 155 Says Maximum depths ≈ Average
	Segment 2		
Fuller Median Daily 50% (277 cfs) 75% Flow (592 cfs)	 2.2-5.1 ft 2.6-6.7 ft	Canyon & Gravel Bar Sections S = 0.003 N = 0.041-0.043	Maximum depths listed.
Burtell Median Daily 50% (<298 cfs) 75% Flow (<623 cfs)	 < 1.7 ft < 2.2 ft	Used USGS Gage Rating Section Measurements to build Rating Curve Salt River nr. Chrysotile gage	Sections located at head of riffles Average depths listed. (max depth ≈ 2 x average depth)
	Segment 3		
Fuller Median Daily 50% (405 cfs) 75% Flow (858 cfs)	 2.4-5.9 ft 2.8-6.9 ft	Canyon & Gravel Bar Sections S = 0.003 N = 0.041-0.043	Maximum depth listed
Burtell Median Daily 50% (<456 cfs) 75% Flow (< 977 cfs)	 < 1.6-2.3 ft < 2.4-2.7 ft	Used USGS Gage Rating Section Measurements to build Rating Curve Salt River at Roosevelt gage	Sections located at head of riffles Note that gage used was located in Segment 4 not Segment 3. Maximum depths listed. (Max depth ≈ 2 x average depth)
	Segments 4 & 5		
Fuller	Fuller provided the only depth estimates for Segments 4 & 5.		
Notes: (1) Dr. Mussetter provided no depth estimates in his report. Information taken from Dr. Mussetter's PowerPoint slides. (2) Mr. Burtell did not provide depth estimates for Segment 3, but did provide depth estimates for a gage station located in Segment 4. It is assumed that he meant those estimates to apply to Segment 3, since his report is limited only to Segments 1-3. (3) Mr. Fuller was the only expert to provide seasonal depth estimates. (4) Dr. Mussetter used one of Mr. Fuller's rating curves (#6) from Segment 6 to estimate depths in Segment 5. (5) Dr. Mussetter's depths are not based on ordinary and natural flow rates.			

Table 2. Comparison of Rating Curve Depth Estimates Made by Experts in the Salt River Navigability Case Using Equal Flow Rates		
Expert	**Segment 6**	
	Depths	
Fuller 1760 cfs 581 cfs 86 cfs	 2.9-5.0 ft 1.6-2.3 ft 0.5-1.0 ft	
Gookin Mean Annual (1760 cfs) Median Daily (581 cfs) Minimum Flow (86 cfs)	 2.15 ft 1.35 ft 0.55 ft	
Mussetter 1760 cfs 581 cfs 86 cfs	 Beyond Rating Curve 1.3-2.8 ft 0.4-1.0 ft	
	Segment 2 (Average Depths)	
Fuller 298 cfs 623 cfs	 0.8-2.6 ft 1.2-3.4 ft	
Burtell Median Daily 50% (<298 cfs) 75% Flow (<623 cfs)	 < 1.7 ft < 2.2 ft	
	Segment 3 (Maximum Depths)	
Fuller 456 cfs 977 cfs	 2.4-6.2 ft 3.1-8.3 ft	
Burtell Median Daily 50% (<456 cfs) 75% Flow (< 977 cfs)	 < 1.6-2.3 ft < 2.4-2.7 ft	

The biggest difference between the various testifying experts is how they considered other types of data in addition to their rating curves when reaching their opinion on the depths and subsequent navigability of the Salt River. The State's understanding from the various experts' reports and presentations of what data sources they each relied is shown in Table 3. In short, because of their limited scope of analysis or their limited areas of expertise, the non-navigability experts were forced to rely more heavily on their mathematical modeling of the river depths at individual cross sections rather than consider the segment as a whole or the wide variety of information available from which to determine typical flow depths and river conditions. Also because they did not take the opportunity to boat the river and view stream conditions firsthand, or in some cases, to even visit the river at all and take a look at it from the banks, they are unable to appreciate the difference between conditions at a single cross section versus conditions over an entire stream segment. Other opposing experts were limited in the scope of their investigation to only one or two disciplines and thus missed the benefit of considering the many types of information that could help them interpret the results of their rating curves. Still other experts only considered a single or perhaps two river segments, and missed the perspective of considering the entire Salt River as a whole. And some experts have little or no expertise with boats and clearly lack the knowledge to be able to translate a mathematical computation of depth to the practical experience of traveling down a river in a boat. The reality is that one simply cannot reach an informed opinion about the navigability of a river based solely on consideration of depths computed at a single cross section.

In fact, Tyler Williams, an expert boatman with extensive on-the-river experience on the Salt River and dozens of other Arizona streams, put it this way when asked about the "depth" of the Salt River:

> *"I mean, putting a depth on any river is sort of an amorphous sort of definition. I mean, rivers are defined by obstacles, rocks, and deep channels, shallow channels, deep channels. You know, they're dynamic animals. So to put a depth on a river, it's just really not a logical way to look at it." (376:3-8)*

For any of the testifying experts who've actually boated the Salt River, all of whom testified for the ASLD, the idea that a single depth could fully depict the river's ordinary condition at a given flow rate is overly simplistic. As Mr. Fuller stated in his direct testimony (507-508) the best way to estimate the depth of a river is to:

> *"…stick a boat in the river and paddle on down…"*

One rating curve is not sufficient. Even in navigability cases where more complex and detailed models have been used instead of the single section rating curves used for the Salt River, the modeling approach is found to be insufficient when used by itself. For example, on the recent Mosquito Fork case in Alaska, Dr. Mussetter performed some very detailed modeling on behalf of the United States which demonstrated that the river was too shallow to be boated. However, on-the-river experience indicated that the river had in fact been boated at the flow rates his model said were too shallow. In that case, after considering their evidence, the United States abandoned its claims and yielded title to the State. Therefore, it is obvious that computer-based rating curves do not tell the whole story about river depth and navigability.

Table 3. Types of Methods and Data Used by Salt River Navigability Experts to Estimate Flow Depths and Typical River Conditions						
Expert	**Segment**					
	1	**2**	**3**	**4**	**5**	**6**
Fuller	Rating Curve Field Trips	Rating Curve Field Trips Boating Trips	Rating Curve Field Trips Boating Trips	Rating Curve Field Trips Boating Trips	Rating Curve Field Trips Boating Trips	Rating Curve Field Trips Boating Trips
Williams	Boating Trip	Boating Trips	Boating Trips	NT	Boating Trips	Boating Trips
Dimock	NT	Boating Trips	Boating Trips	NT	Boating Trip	Boating Trip
Mickel	Boating Trip	Boating Trips	Boating Trips	NT	NT	NT
Gookin	NT	NT	NT	NT	X Inner tube float trip	Rating Curve Field Trips
Mussetter	X	X	X	X	X Boat trip @ 8 cfs	Rating Curve
Burtell	X	Rating Curve Field Trip – 2 Sites	Rating Curve Field Trip – 2 Sites	NT	NT	NT
Littlefield	X	X	X	X	X	X
August	X	X	X	X	X	X
Newell	X	X	X	X	X	X

Notes:
1. "X" indicates no depth estimate reported.
2. "NT" indicates expert not testifying on that segment.
3. Blue shading – expert reached conclusion of navigability.
4. Red shading – expert reached conclusion of non-navigability.
5. Yellow shading – expert not testifying on this segment.
6. SRP Experts Mussetter, Littlefield & Newell also took helicopter tours of portions of Segments 2-6 in lieu of field work or river trips. Littlefield also drove a car along the Apache Trail past portions of the Salt River reservoirs.

The following include some of the types of other information that were used by ASLD in addition to the depths calculated from the rating curves:

- Historical Descriptions. In July of 1852, Bartlett's boundary Commission described Segment 6 as being swift and clear, two to three feet deep, and 80 to 120 feet wide.[4] Given his description of the river as "clear," and the fact that it was during the lowest flow month (July), we can assume that he was describing a non-flood flow condition, probably near the annual base flow rates. Hiram Hodge and others described the river nearly the same way as Bartlett. Therefore, rating curves that indicate low flow season depths of less than two feet are probably too low.[5] Other, non-flood descriptions, during high-flow periods of the year describe the river as difficult to cross, chest- or belly-deep, or too deep to cross. Therefore, if the rating curves are accurate, the ordinary seasonal high flows should result in depths that are greater than three to five feet, or more, to be consistent with historical observations. Note that the maximum rating curve depth at any reported flow rate by any of the non-navigability experts in any segment was 2.7 feet[6] indicating that all of the rating curves underestimate typical flow depths.

- Ferry Boats. The fact that early settlers needed ferries to get across the river indicates that flow depths were regularly deeper than could be forded.[7] Horses, wagons, and people on foot could readily ford flows less than two to three feet deep, particularly at the low velocities predicted by all of the experts' rating curves. The ferries themselves were moderately sized flat boats that could carry several tons of load (e.g., automobiles, horse-drawn loaded wagons), and would likely draw at least one to two feet. History tells us that there were up to six ferry crossings operating on the lower Salt River as early as 1870 and as late as 1909, well after there were railroad bridges that could be used for emergency river crossings and well into the period when the river's natural flow had been diverted into canals. Given that a two-foot deep river could be forded relatively easily, and much less expensively than in a ferry, the rating curves should indicate depths that exceed two to three feet occurred for long enough durations to make operation of a ferry necessary. Furthermore, historical accounts of people being in danger of drowning from falling off the ferry certainly imply that the river was deep enough that one couldn't simply stand up after falling in. Therefore, the depths during times when ferries were

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[4] Incidentally, assuming a flow velocity of only 1 ft/sec, the dimensions reported by Bartlett indicate a base flow rate of 160-360 cfs.

[5] As shown in **Table 1**, Mr. Gookin's and Dr. Mussetter's estimates of ordinary flow depths at low flow conditions are 0.55 ft, and 0.8-1.8 ft, respectively, well below the known historical depth descriptions. Similar, Mr. Gookin's high flow depth estimate of 2.15 ft is well below the values obtained from the known historical (pre-diversion) descriptions.

[6] The 2.7 ft. depth was computed by Bob Mussetter for Segment 6 (high end of his 10 rating sections) for the median daily discharge. Although his rating curves stop at 600 cfs, it is likely that his high end estimates for seasonal high flows would be somewhat higher than 2.7 feet. Also, Mr. Burtell for Segment 4 at his 75% flow rate lists < 2.7 ft as his high estimate.

[7] Mr. Gookin proposes some reasons for use of ferries, none of which are supported by relevant factual evidence which include (1) ferries were only used during floods, (2) the river depths were sufficient for a ferry only in the immediate vicinity of Tempe, or (3) ferries were used to avoid quicksand in the shallow river crossings.

in use was likely much more than a few feet. Again, the maximum depths reported by the non-navigability experts are simply too shallow to be consistent with the historical use of ferries.

- Pictures of Ferries. Pictures of the Hayden Ferry in use on known dates provide the opportunity to verify the rating curve results. First, in none of the historical photographs of the Hayden Ferry does the water surface of the river around the boat indicate significant velocities, verifying the low velocities predicted by the rating curves. With respect to flow depth, the January 15, 1901 photograph provided by Dr. Littlefield (Figure 59 in his report) is of particular interest. On this day, the USGS gage stations reported a total inflow to Segment 6 of 254 cfs (Salt River at McDowell) and 250 cfs (Verde River at McDowell). Therefore, the *maximum* possible flow rate at Hayden's Ferry was 504 cfs, not accounting for upstream diversions, losses to channel infiltration, evapotranspiration, etc. theorized by the non-navigability experts that would have all combined to reduce the flow rate reaching Tempe.[8] Based on this photograph, the rating curves for a flow of about 500 cfs (or less) should indicate that depths were sufficient to float a loaded ferry (> 1-2 ft) and deep enough to necessitate its use (i.e., too deep to ford, > 2-3 ft.). Also, note that the river appears to be several hundred feet wide and in a single, non-braided channel in the photograph. This photograph clearly indicates that **all** of the rating curves are underestimating flow depths at this location in Segment 6, underscoring the State's position that consideration of more than just the mathematical results from a single rating curve is necessary when making an informed navigability decision. Furthermore, the photograph provides concrete evidence that Mr. Gookin's theory that the Arizona Dam normally diverted up to 1,000 cfs of river flow during the winter months is incorrect. Recall that Mr. Gookin speculated that the Day Brothers could not have boated the Salt River in Segment 6 because Arizona Dam would have left a dry river bed downstream if the inflow was less than 1,000 cfs.

Figure 1. Photo of Hayden's Ferry from January 15, 1901. From Littlefield, 2015, Fig. 59 & ASU Special Collections.

[8] It is not possible that ground water forced to the surface by shallow bedrock near Tempe Butte could be responsible for creating conditions that would require use of a ferry on January 15, 1901. The USGS estimated that the return flow at Tempe was less than 50 cfs, which is not enough to make a significant difference in flow depths according to any expert's rating curve for Segment 6.

- Field Observations. The importance of field verification of mathematical calculations cannot be overstated, and is the accepted standard of practice for professional civil engineers, hydrologists and geologists. Therefore, the low level and quality of field investigation by the non-navigability experts in the Arizona navigability cases is particularly disappointing. Several experts have offered testimony on the ordinary and natural flow depths for a river segment without ever visiting the segment on the ground, or choosing only to visit a river segment during a time of the year when upstream diversions have effectively shut off the river's natural flow. The lack of field investigation is particularly deficient for Segments 1, 2, and 3 which all experts agree are substantially in their ordinary and natural condition, and much could have been learned by observing each segment in its entirety. Segment 5 and the upper portion of Segment 6 retain enough of their natural character to make detailed field visits extremely valuable for verifying the accuracy of rating curves. When in the field, even if only a single cross section location were visited, a qualified expert would experience the complexity of the river's natural geometry and use that experience to place the depth estimates from a single rating section in its proper perspective.

- Boating. In a navigability study, it is inconceivable that any expert would not take the opportunity to boat the river before rendering an opinion about whether the depths are sufficient for boating. Hundreds to thousands of people manage to boat segments of the Salt River in any given year. All of the State's testifying experts have boated the river segments about which they are testifying. None of the non-navigability experts have boated the river, despite having been under contract for their work for at least two winter boating seasons when there are commercial operations that will take you boating if you lack that experience on your own. The experience of sitting in a boat and navigating the river gives an invaluable perspective on how accurately a rating curve or two depicts actual river conditions over the length of the segment, and in the various pools, riffles and rapids. The experience of boating a river is far more informative and valuable than reading about it on a website or in a boating guide.

- Historical Boating. There are numerous accounts of boats successfully travelling in Segments 1 to 6 on the Salt River. Some of these accounts occurred during very low flow conditions or during the low flow period of the year. Therefore, if the rating curves are accurate, they should indicate that depths were sufficient for the boat type used at the flow rate during the boat trip. The historical boat trips for which we know or can estimate flow rates are listed in Table 4. The historical boating data indicate that the rating curves generally underestimate the flow depths in the river segments that were boated.

Table 4. Flow Rates & Required Probable Draw for Historical Boat Trips							
Trip	**Date**	**Flow Rate**		**Boat Type**	**Draw**	**Segment**	**Statements & Notes**
		USGS Gage Records	**Median Daily Discharge Estimate**				
Logan Wooden Boat	Pre 1873	-	> 400 cfs	Rowboat	< 1 ft	1-6	Trip during spring runoff
Five Tons of Wheat	April 1873	-	2200-1350 cfs	Flatboat	2-3 ft	6	
Hayden Log Float	June 1873	-	90-220 cfs	Logs	1 ft	1?	Flow width was issue
Hamilton Jordan	Jan 1879	-	800-900 cfs	Skiff	0.5 ft	6	2 ft draw ok
Cotton & Bingham	Feb 1881	-	900-2300 cfs	Flatboat	< 1 ft	6	Very low draft
Yuma or Bust	Nov 1881	-	700-800 cfs	Flatboat	< 1.5 ft	6	Knee deep
Willcox & Andrews	Feb 1883	-	900-2300 cfs	Skiff	0.5 ft	6	
Burch	June 1885	-	500-800 cfs (Seg6) 200-450 cfs (Seg4)	Flatboat	1 ft	3-6	
Spaulding	Dec 1888	1800-1900 cfs		Canoe	0.5 ft	6	
Gentry & Cox	Jan 1889	2100 cfs		Large Ferry	2-3 ft	6	
Sykes & McLean	1890's	-	-	Canvas		6	Flow depth 1-2 ft, width 20 ft
Day Brothers	Spring 1892	-	900-2400 cfs	Wood boat	< 1 ft	6	
Hudson Res. Co.	June 1893	93-222 cfs		Canvas	0.5 ft	4	
Trappers	Jan-Feb 1894	494-617 cfs		Wood boat	< 1 ft	6	
Adams & Evans	Feb 1895	3061 cfs	900-2300 cfs	Flatboat	1 ft	6	Average Q for month
Shively & Schreiver	Mar 1905	21000 cfs		Keelboat	1-2 ft	6	High flow
Roosevelt Freight	April 1905	8,000 cfs		Boat	1-2	4	
USRS Engineers	Dec 1905	4350 cfs		Boat	1 ft	6	
Globe Power Co.	Jun-Jul 1906	385-765 cfs		Wood boat	< 1 ft	3	
Rains	Apr 1909	5,500 cfs		Boat	0.5 ft	6	
Thorpe & Crawford	June 1910	145 cfs		Rowboat	< 1 ft	4-6	
Ensign & Scott	June 1919		1350 cfs	Canoe	0.5 ft	4-6	Modern canal release for June

Notes:

1. Omitted accounts where no month and year was available.
2. Draw is estimated from boat type and load, as described in the Fuller Boating PowerPoint presentation, unless specifically given in account.
3. Median daily flows reported from this report, reconstructed as recommended above.
4. Flows reported as a range where the exact date of the trip is unknown or the trip spanned more than one day.

- Beaver. According to several sources, beaver were once abundant along the Salt River. The only qualified expert testimony about beaver submitted to ANSAC came from the State (Dave Weedman, AZGFD), and indicated that beavers would not build dams that would span the entire channel of the major rivers in Arizona, including the Salt, because of the existence of natural pools of sufficient depth and because of the flood potential of the river. Given that beavers require water depths of several feet for a river to be habitable, it is likely that large (abundant) portions of the river must have normally had flow depths greater than several feet for significant, if not all, portions of the year, a condition that is consistent with the historical descriptions of the river.[9] Alternative explanations for beaver-supporting depths that rely on beaver dams or off-channel sloughs to achieve the necessary depths contradict both the mapped channel widths and valley morphology, and the most basic principles of geomorphology. The possibility is beyond remote that beavers would have the energy or raw materials to construct enough dams to support an abundant population, when each dam would need to be hundreds of feet in length to span the channel and 3-4 feet high to sufficiently raise water depths if the river were naturally too shallow. The possibility becomes even more remote given that the dams would need to be reconstructed frequently after floods as small as a 2-year event. It is similarly a geomorphic impossibility that the depths in overbank sloughs could be deeper than the low flow channel of the river. Therefore, rating curves depicting ordinary and natural river conditions should indicate depths in pools that equal or exceed three feet. Furthermore, the presence of abundant beaver certainly contradicts the "normally dry" opinion offered by some experts.

- Fish. According to the only fish expert to offer testimony to ANSAC (Dave Weedman, AZGFD), the Salt River once supported populations of "big river" fish like the Colorado pikeminnow (a.k.a., Colorado River squawfish, Colorado salmon; 40-50 lbs, 3-4 ft long), Razorback sucker (6-13 lbs, 1.5-2.5 ft long), and Humpback and Bonytail chub (3-4 lbs, 1-1.5 ft long). These fish required flow depths of at least one foot for migration through riffles and significant pools of at least 3 to 4 feet deep to survive. Therefore, rating curves depicting ordinary and natural river conditions should indicate depths in pools that equal or exceed three feet, and minimum annual depths in riffles of about one foot. Furthermore, the presence of big river fish certainly contradicts the "normally dry" opinion offered by some experts.

- Hohokam Irrigation. The ability of the Hohokam to construct workable irrigation diversions from Segment 6 also suggests something about the ordinary widths and depths of the river in Segment 6. If the river were as wide, braided, and shallow as suggested by several experts, it would have been very difficult to construct effective diversions that would capture enough flow to irrigate more than 100,000 acres over many centuries. For example, Dr. Schumm's rating indicated Segment 6 at 20,000 cfs would average only 1.7 feet deep in a 4,200 foot wide channel, and would be much shallower during ordinary, non-flood conditions. Mr. Gookin's rating curve indicates that at seasonal low flows, when irrigation would be most needed, that the flow depths would be 0.55 ft. To effectively divert from the shallow depths suggested by

[9] Note that no historical description or photograph has been found that indicates beaver dams were present on the main channel of the Salt River, and no account of historical boating ever mentions the existence of any beaver dams on the boating channel of the river.

the non-navigability experts, the Hohokam would have needed greater flow depths and a more constrained, well defined channel, or their irrigation diversions would have needed to have been much more robust and extensive to achieve the stages needed to collect sufficient flow. Clearly, the existence of Hohokam irrigation diversions over many centuries argues for the ordinary condition of the river being deeper than indicated by the non-navigability rating curve depth estimates. The presence of multiple Hohokam canal heads[10] (and the first canal built by Euro-American settlers) in Mr. Gookin's Segment 6B (downstream of Tempe Butte), also contradicts Mr. Gookin's and Dr. August's opinions that the Salt River normally dried up in its ordinary and natural condition.

Specific Issues Raised by Opposing Experts Regarding ASLD Rating Curves. In additional to the general issues regarding rating curves discussed above, there are several specific issues that require clarification or rebuttal.

Issue #1: Channel N Value. Mr. Gookin and Dr. Mussetter testified that the ASLD rating curves were computed using too low of a Manning's N value. The N value is an empirical coefficient used in constructing a rating curve that accounts for the energy loss due to the channel roughness.[11] The standard of practice in Arizona for selecting N values is given in the following documents:

(1) "Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channels, and Vegetation Maintenance Plan Guidelines for Vegetated Channels in Central Arizona" Phillips, J.V., and Tadayon, S., USGS Scientific Investigations Report 2006-5108, 2007, or
(2) Thomsen, B.W. and Hjalmarson, H.W., 1991, Estimating Manning's Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, Arizona, Flood Control District of Maricopa County.

The factors which affect the N value in stream reaches include the flow depth (N value is higher for shallower flows), bed material size (N value is higher for larger bed material), bed forms (dunes, ripples, antidunes, etc. will increase N values), channel boundary material (size, cohesion, rock type, erodibility), channel slope (N value can increase with increased slope), channel irregularity (eroded banks, width changes, exposed tree roots, etc. can increase N values), and variations in channel cross section (flow shifts from side to side, section size changes can increase N values), obstructions (debris, boulders, bedrock blocking the flow path increases N value), and vegetation (increased vegetation density increases N values). The standard of practice is to define a base N value based on the bed material size and adjust the N values upward to reflect each of the factors listed above, as summarized in Table 5 below.

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[10] Turney's map of prehistoric canals shows at least 10 canal heads downstream of Tempe Butte, including the four canal heads at the site of the Park of the Four Waters which is at the location of the historical Swilling Ditch.
[11] Disputing N values seems to be the "go to" argument for experts in litigation regarding drainage, and considerable efforts are wasted on this matter. Lacking calibration data, the determination of N values is inherently subjective and ripe for criticism. In this case, the differences caused by use of slightly different N values are insignificant relative to the question of navigability.

As can be seen from the values listed in **Table 5**, the N values of 0.041 to 0.045 used by ASLD were well within the range of reasonable values for both pool and riffle sections in the Salt River. The opposing experts' criticisms of the N values used for the ASLD rating sections are unfounded.

Table 5. Computation of N Value		
	Riffle Section	**Pool Section**
Base Value	0.030-0.050 (gravel/cobble)	0.026-0.035 (sand/gravel)
Channel Irregularity Factor	0.001-0.005 (slightly sloughed)	0.001-0.005 (slightly sloughed)
Cross Section Variability	0.001-0.005 (occasional changes)	0.001-0.005 (occasional changes)
Obstructions	0.005-0.015 (5-15% of section)	0.000-0.004 (<5% of section)
Vegetation – channel Vegetation - banks	0.000-0.002 (negligible) 0.025-0.050 (willow, cottonwood)	0.000-0.001 (negligible) 0.025-0.050 (willow, cottonwood)
Meandering	0.000 (Sinuosity < 1.2)	0.000 (Sinuosity < 1.2)
Total N Value:	**0.037-0.077**	**0.028-0.050**

<u>Issue #2: Maximum or Average Depth</u>. For determining navigability characteristics of rivers, the maximum depth in a cross section is a better measure than the average depth. The maximum depth represents the depth at the thalweg, or the deepest part of the channel where boating would occur. The practical reason for this is that boats travel in the deepest part of river. Finding and staying in the deepest part of the river is one of the core skills of any boater. Even on major rivers like the Mississippi, finding the deepest part of the river is a valued skill of experienced river boat captains. Unless the river cross section is perfectly smooth rectangle, a phenomenon that does not occur in nature, the average depth will always be less than the maximum depth on a natural river. For complex river cross sections, like the one illustrated below, the use of the average depth can significantly underestimate the boating depth of the river. This is particularly true when considering navigability based on the use of small boats which occupy a very small part of the channel. This principal is also illustrated when considering the depths measured by Mr. Burtell at his two surveyed riffle sections, both of which had maximum depths that were twice the average depth.

Mr. Gookin appears to believe that the Utah navigability case involving the Special Master for the San Juan River demands the use of the average depth at a cross section when considering susceptibility. He seems to believe that the Utah Decision requires the use of the mean channel depth, rather than the maximum depth. It is not clear how the Utah Special Master used the various types of depths reported in that case, or how similar the cross sections used for the San Juan are to the ordinary and natural condition of the Salt River. Every river's morphology differs from other rivers to some degree and should be considered on its own merits. If the mean depth of a cross section were the standard, it would lead to scenarios as illustrated in Figure 2. The relevant depth is the depth of the boating channel, not the average depth of a single cross section. Given the narrow width of small, low-draft boats, the maximum depth is a better indication of the boating depth than the mathematical average of a single channel cross section.

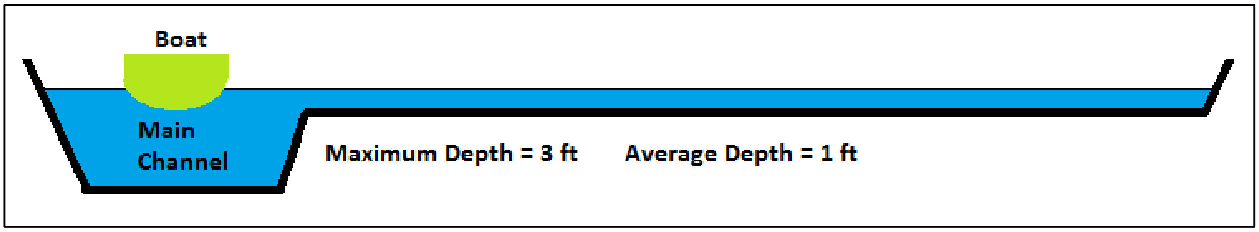

Figure 2. Illustration of maximum and average channel depth relative to the boating channel.

Another aspect of the average depth question relates to what "average" means. In the tables in the ASLD report of the upper Salt it is not clear whether the word "average" was used to depict the average at a particular rating section or the average depth over the entire length of the reach (segment) in question. Again, this is why field investigations and boating the river is particularly important when making navigability decisions.

Issue #3: Single or Multiple Channels. Mr. Gookin and Dr. Mussetter appear to believe that Segment 6 of the Salt River had a braided boating channel. They hold this belief despite the fact that no historical map or photograph of the Salt River looks anything like the examples of braided rivers provided in Dr. Mussetter's PowerPoint presentation, and that even the published sources that they rely on describe the river as having a compound channel which is not braided in the classic sense. The 1903 topographic mapping showed the low flow channel of Segment 6 as dominantly single channel, with a few split channel reaches. Therefore, it was appropriate for ASLD to model the channel cross sections as a single channel. Note that Dr. Will Graf, a former Arizona State University professor who has studied the Lower Salt River extensively and whose work is cited multiple times by Dr. Mussetter, states specifically in the cited publications that the Lower Salt River has a compound form with a single main, low flow channel. Dr. Mussetter, Mr. Gookin, and Mr. Burtell[12] all advance the opinion that a split in the low flow channel makes the depths shallower than in the single channel upstream of the split. Had either Mr. Gookin, Dr. Mussetter, or Mr. Burtell taken the time to boat the Salt River (or the Verde River or the Gila River), they would have realized that the types of split channels that occur on the Salt River do not significantly change the flow depths in the boating channel and typically make no difference to the boatability of the reach. Mr. Gookin's opinion that the river at median flows would have been braided or in multiple shallow channels lacks any credible supporting physical evidence.

Issue #4: Topographic Map Accuracy. Dr. Mussetter testified that the 5-foot contour map used by Mr. Fuller to generate the cross-sections for his rating curves was not sufficiently accurate to be used to generate the magnitudes of flow depth estimates reported by ASLD. However, the following contradict his testimony:

(1) Mr. Fuller first became aware of the 1903 5-foot contour interval topographic mapping when he was given the map by the Salt River Project in 1985 for use in generating pre-development water surface profiles for the Salt River as part of his Master's Thesis work at the University of Arizona, which was funded and approved by the Salt River Project.

[12] Mr. Burtell never took the opportunity to test his theory that split channels are always shallower and less boatable than single channels on Segments 2 and 3. Nor did he consider the fact, or attempt to speak with any of the hundreds to thousands of boaters successfully travel Segments 2 and 3 every year, throughout the year and don't seem to be at all concerned about split channels as obstacles.

(2) The 1903 mapping is the oldest, most detailed topographic mapping available for Segments 5 and 6 of the Salt River. The alternatives include: a) less detailed, more recent (circa 1914), 20-foot contour interval mapping by the US Geological Survey; b) circa 1950 4-foot contour interval mapping which post-dates much of the channelization, in-stream mining and encroachment of the river corridor; or c) the plane table survey used by Mr. Gookin which does not cover the vast majority of Segment 6 and post-dates the 1903 mapping. The topographic mapping used by the State is the best available data.

(3) Engineers, hydrologists, and river scientists routinely use topographic mapping of the same level of detail as the 1903 mapping when performing a wide variety of river studies. In fact, the Federal Emergency Management Agency (FEMA) routinely mapped floodplains using topographic maps of equivalent or less detail than the 1903 mapping used by ASLD. FEMA regulated floodplains based on such maps to +/- 0.01 foot depths.

(4) Dr. Mussetter, while criticizing the accuracy of the 1903 topographic maps for obtaining cross section data for estimating depths in Segment 6, uses the same maps to critique the State's channel slope estimates. Dr. Mussetter distinguishes channel slope differences of +/-0.0005 ft/ft. from the same mapping he believes cannot be used to generate depth estimates within +/- 0.1 feet.

<u>Issue #5: Selection of Rating Curve Cross Section Locations</u>. Dr. Mussetter and Mr. Gookin appear to suggest that ASLD selected locations preferentially to generate high flow depth estimates. This unfounded speculation is simply untrue. The cross sections were selected to be spaced throughout the entire length of Segment 6. Regardless, as discussed above, the State's depth estimates are not significantly different than any other expert's relative to the question of navigability when the same flow rates are considered.

<u>Issue #6: Are the Segment 6 Rating Curves Limiting Depths?</u> Dr. Mussetter testified that he believed that the rating curves for Segment 6 were not representative of the lowest depths in that reach, which would have occurred at steep riffles. He advocates that the ordinary depths in riffles that may have existed in Segment 6 would have been considerably shallower than shown on his rating curves. However, a number of facts contradict this aspect of Dr. Mussetter's testimony:

- No Known Rapids. Dr. Mussetter also testified that he had no evidence that any rapids existed in Segment 6 and that it was unlikely that there were any rapids there.
- Pools. It is important to remember that the vast majority of the river would have been comprised of pools and runs, which would have been much deeper than the alleged riffles postulated by Dr. Mussetter. The pool depths would been considerably deeper than indicated by any of the rating curves.
- Geomorphic Considerations. If the river was composed primarily of sandy bed material, it is unlikely that any riffles would be significantly steeper than the overall valley slope of the river, since the sand material would be unlikely to hold a steeper slope without flattening by erosion.
- Comparison to Segment 6 Above Granite Reef. The portion of Segment 6 between the Verde River and the Granite Reef backwater is largely unchanged from its pre-development condition, although it is probably somewhat more cobbly and confined by the canyon geology than the portions of Segment 6 further downstream. The riffles in that reach are not shallow and have very clear, obvious boating channels through them. It is most likely that the remainder of

Segment 6 would have been even less "limiting" than the remaining undisturbed reaches of Segment 6 above Granite Reef Dam.

- Analogy to Other Arizona Rivers. A final way to test Dr. Mussetter's hypothesis that steep, shallow, rocky riffles existed in Segment 6 of the Salt River is to look at the morphology of other (semi) free-flowing major rivers in Arizona, such as the Gila River near the New Mexico border. To a lesser degree, one can also look at the lower Colorado River outside of the bedrock gorges, the Gila River below Safford, or the Gila River between Winkelman and Kelvin. None of these rivers are characterized by steep, shallow riffles that would be obstacles to navigation.
- Other Lines of Evidence. None of the historical boat trip descriptions mention issues with shallow water at riffles. The data regarding fish and beaver populations suggest depths greater than shown by Dr. Mussetter's low flow depth estimates. None of the historical maps, photographs or survey records describe shallow riffle conditions.

Issue #7. Mr. Burtell's Rating Curves. Mr. Burtell's rating curves were derived from flow measurements made by the USGS at two gaging stations, Salt River near Chrysotile and Salt River at Roosevelt. The following is a critique of his rating curves:

1. Chrysotile Gage (Burtell, Figure 7B)
   a. Note that there is considerable scatter in the data plotted on Figure 7B. For example, for his median reconstructed flow rate of 298 cfs, the scatter of data points envelopes a range of depths from about 1.0 to 2.1 feet.
   b. Note that his rating curve is predicting the mean depth, not the maximum depth of the channel. According to Mr. Burtell's surveyed riffle sections, the maximum depths are about double the mean depths at the median flow rate.
   c. Based on the State's experts' extensive field and boating experience in this segment, Mr. Burtell's mean depth rating curve is broadly representative of the shallowest riffles in Segment 2 at the low end of the curve, but underestimates mean flow depths at the high end of the curve, even in the shallower riffles. It would be expected that the maximum depths in riffles and rapids to be double (or more) the mean depths shown on Mr. Burtell's rating curve. The pools and runs, which comprise the vast majority of the segment length are much deeper.

2. Roosevelt Gage (Burtell, Figure 9B)
   a. Note that this rating curve is based on only two years of data. It is not clear why other years of data were not considered at this gage, although it was likely because consideration of other years would have introduced too much scatter.
   b. Note that this gage is located in Segment 4 of the Salt River, but that Mr. Burtell's report and opinion on navigability are limited to Segments 1 to 3. It appears that Mr. Burtell would like to apply this Segment 4 data to Segment 3. Data from the USGS gage in Segment 3 (Salt River near Roosevelt) were not used to construct a rating curve for Segment 3 because of Mr. Burtell's untested theory that the diversion dam located approximately 4,500 feet downstream would have affected the depths within the range of ordinary flows, despite the existence of several riffle drops between the gage and the dam. The presence of the drops at the riffles would make it unlikely that backwater from the low-head diversion dam would affect stages at the USGS gage, nor is it likely

that the USGS would select a gage location that was affected by backwater from a downstream dam.

c. Although the rating curve purports to show maximum flow depths (stage), the rating curve inexplicably predicts that these maximum depths for Segment 4 (at the "at Roosevelt gage) are less than or about equal to the mean depths in Segment 2 (at the Chrysotile gage), despite the discharge being near double those of the upstream rating curve and both gauges being located in bedrock canyons with similar channel widths.
d. Based on the State's experts' field and boating experience in Segment 3 of the Salt River, Mr. Burtell's rating curve is broadly representative but slightly lower than the maximum depths in the shallow riffles in Segment 3. Obviously, the pools and runs, which comprise the vast majority of the segment length are much deeper.

Issue #8: Source Data for ASLD Rating Curves. Mr. Fuller has fully disclosed all of the data he has for the rating curves used in the original ASLD Reports. Keep in mind that these rating curves were generated 20 years ago, before there was Microsoft Windows, when modeling was done on 5.25-inch floppy disks and when there was no automated back-up to the Cloud. Some of the ratings were done using DOS-based software than can no longer be used on modern computers. The files simply don't exist anymore.

The Bottom Line: What Flow Depths Should Be Used By ANSAC? As with the discussion of flow rate estimates, to assist ANSAC's work toward a consensus position for flow depth estimates in each segment of the Salt River, the following is the State's recommended consensus position for obtaining reasonable rating curve depths:

- Flow Rates. The flow rates recommended in the Hydrology discussion above should be used for input to the rating curves.
- Maximum Depth. The maximum depth of the boating channel, not an average depth for the entire section should be used for estimating typical depths for determining navigability.
- Flow Velocity and Width. These are not limiting parameters for boating at ordinary flow rates and are not considered further.
- Segment 6. Use the 10 rating curves developed by Dr. Mussetter for Segment 6. These include the State's six original rating curves computationally verified by Dr. Mussetter. As stated, by Dr. Mussetter, these rating curves depict the range of expected flows in shallow riffles. Ordinary depths on the non-riffle portions of Segment 6 would be significantly greater.
- Segment 5: Use the Segment 6, Cross Section #6 rating curve, consistent with the computations shown by both Mr. Fuller and Dr. Mussetter. Based on the State's experts' extensive field and boating experience in this segment, this rating curve is broadly representative of the shallow riffles in the segment, but of course underestimates the overall average depths of the non-riffle portions of Segment 5.
- Segment 4. Use Mr. Burtell's (high) rating curve for the Salt River at Roosevelt gage. This curve is nearly identical to Mr. Fuller's low rating curve, as shown in **Table 2**. This rating curve significantly underestimates the typical flow depths in Segment 4, but is broadly representative of the shallow riffles and rapids that would have existed in that segment.
- Segment 3. Use Mr. Burtell's (high) rating curve for the Salt River at Roosevelt gage. This curve is nearly identical to Mr. Fuller's low rating curve, as shown in **Table 2**. This rating curve

significantly underestimates the typical flow depths in Segment 3, but is broadly representative of the shallowest riffles that would have existed in that segment.

- Segment 2. Use Mr. Burtell's mean depth rating curve from the Chrysotile gage data, but being mindful of the fact that the maximum depth is likely up to two times the mean depth shown.
- Segment 1. No party is advocating navigability, no further analysis of rating curves is needed.

Given the assumptions and criteria listed above, the recommended flow depths for the Salt River are shown in **Table 6**.

Table 6. Recommended Flow Depth Estimates by River Segment for the Ordinary & Natural Condition

Segment	**Flow Rate Type**					
	Mean Annual	Median Annual	10% (Entire Year)	Median Daily (Entire Year)	90% (Entire Year)	High-Flow Boating Season
2	2.2 ft	2.0 ft	1.2 ft	1.6 ft	3.0 ft	1.8-2.4 ft
3	2.7 ft	2.5 ft	2.0 ft	2.2 ft	3.2 ft	2.5-3.2 ft
4	2.8 ft	2.7 ft	2.0 ft	2.3 ft	3.3 ft	2.6-3.2 ft
5	2.6 ft	2.2 ft	1.1 ft	1.6 ft	3.8 ft	2.0-3.5 ft
6	2.2-4.9 ft	1.9-4.2 ft	1.2-2.5 ft	1.6-3.4 ft	3.0-5.8 ft	2.5-5.5 ft.

Notes:

1. Segments 2-4: Depths are for conditions at the head of a riffle, i.e., they are limiting depths not typical depths.
2. Segment 5: Depths shown are for non-pool sections of the river, i.e. they are limiting depths.
3. Segment 6: The low-end depths shown are for limiting conditions in shallow riffles, i.e., they are limiting depths.
4. Average depth of the rating section is shown for Segment 2.
5. Maximum depth of the rating section is shown for Segments 3, 4, 5, & 6.
6. The high-flow, or boating, season depths are based on the high and low median daily flow rates during the period from mid-February to mid-May.

The depths shown in **Table 6** can be used to determine the types of boats able to be used at various flow rates in each river segment. Given that the depths in **Table 6** are limiting depths, the rating curve data suggest that boats that draw less than 1 foot could be used more than 90% of the time on every river segment, and that boats drawing 2.0 feet could be ordinarily used during the high-flow season.