EVALUATION OF THE "MONTANA METHOD" FOR RECOMMENDING INSTREAM FLOWS IN OKLAHOMA STREAMS

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Monthly hydrographs for 24 Oklahoma streams were analyzed to determine the seasonal adjustments required for application of the "Montana method" for recommending instream flows in Oklahoma. Stream flows were recommended for 30 stream reaches. For use in Oklahoma streams, the Montana method should be modified so that the lower of two recommended base flows apply to the period from July through December, rather than that from October through March. This method should be useful for preliminary instream flow assessments in Oklahoma.

INTRODUCTION

Water flowing through natural stream channels supports a variety of needs, including habitat for fish and wildlife, outdoor recreation, hydropower generation, navigation, and waste assimilation. Construction of dams to impound water, diversion of water for irrigation, and municipal and industrial uses may deplete natural stream flows to the point where these needs are no longer met. Protection of the value of stream resources, therefore, depends upon reserving a portion of the stream flow for instream uses. Federal and state agencies are often required to recommend stream flow regimes to sustain instream uses below proposed dams or other water diversions. However, during the planning phases of these projects, time and money are usually insufficient to allow for intensive field studies upon which these recommendations can be based (1, 2, 3, 4, 5). Therefore, planners must rely on methods that require little or no field work, yet still provide reasonable flow recommendations.

The "Montana method" (6), the most widely used of the reconnaissance-level methods, is based on historical records of discharge; it has been applied to warm-and cold-water streams in the Midwest, Great Plains, and Intermountain West. This method was developed after measurements of width, average depth, and average velocity in 11 streams in Montana, Wyoming, and Nebraska indicated that the quality of instream habitat changed more rapidly from no flow to a flow of 10% of the average than in any higher range (Figure 1). As a result of these measurements, Tennant (6) concluded that 10% of the average annual flow is the minimum instantaneous flow needed to sustain short-term survival. At this flow, Tennant found that depths and velocities were significantly reduced, substrate was one-third exposed, gravel bars were dewatered, streambank cover was diminished, fish were crowded into the deeper pools, and riffles were too shallow for larger fish to pass. A flow of 30% of the average annual flow was required to maintain good habitat for aquatic life; at this flow, widths, depths, and velocities were generally satisfactory, streambanks provided some cover, and larger

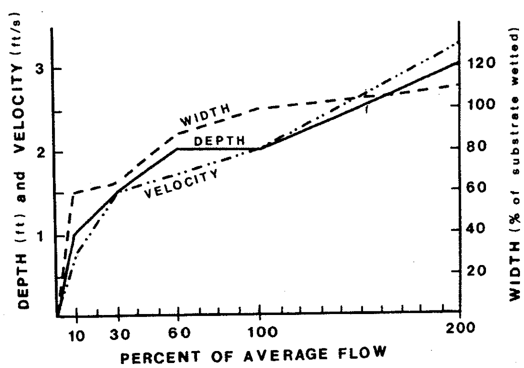

FIGURE 1. Relationships between width, depth, and velocity to percentages of the average annual flow for 11 streams in Montana, Wyoming, and Nebraska (6).

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fishes could pass most riffles. Optimum habitat was provided by flows of 60-100% of the average annual flow and flushing flows were 200% of the average annual flow. Therefore, to recommend a flow to provide habitat described as minimal, good, optimum, or flushing, a percentage of the average annual flow is selected (Table 1). The Montana method has been infrequently used outside of the western U.S., although Wood and Whelan (7) found general agreement with the recommendations made by this method in southeastern U.S. Therefore, we attempted to evaluate the applicability of this method to Oklahoma streams.

Recommended base-flow regimens for the Montana method are determined by selecting a percentage of the average annual flow (Table 1). Lower base flows are recommended for the season of lowest flow. However, before the Montana method can be applied to Oklahoma streams, the season of lowest flow must be determined, and recommended flows must meet the criterion of water availability. Therefore, the objectives of this study were: (a) to determine the season of lowest flow for Oklahoma streams; (b) to determine the availability of recommended percentages of the average annual flow recommended by the Montana method; and (c) to recommend preliminary instream flow requirements for selected Oklahoma streams.

METHODS

To determine the season of lowest flow in Oklahoma streams, we developed monthly hydrographs that depicted the flows exceeding 10, 50, and 90% of the time during the period for which gaging records were available (U.S. Geological Survey, 8). Twenty-four gaging stations were chosen based on the availability of a sufficient time series of flow data to develop monthly hydrographs (Table 2). The monthly 50-percentile flows were ranked from lowest to highest for each stream and the ranks summed over all streams. The average ranks for each month indicated the season of lowest flow under median conditions. Recommended percentages of the average annual flow (AAF) were compared with the monthly hydrographs to determine the percentage of the time that the recommended flows were equaled or exceeded.

After the season of lowest flow was determined and it was judged that the 10% AAF or 30% AAF was available in most larger streams, the Montana method was modified to take into account the different season of lowest flow. This modified Montana method was then used to make preliminary recommendations of instream flow requirements for 30 stream reaches in Oklahoma.

RESULTS AND DISCUSSION

The average rankings of the 50-percentile flows of the 24 streams studied were as follows: August, 1.6; September, 2.5; October, 3.2; November, 4.6; July 5.2; December, 5.6; January, 7.2; February, 8.5; June, 9.1; March 9.6; April 10.2; and May, 10.5 (9).

A recommended base flow of 10% of the average annual flow (AAF) was exceeded more than 50% of the time during July

TABLE 1. *Montana method for prescribing instream flow regimens for fish, wildlife, recreation and related environmental resources. For Oklahoma streams, the flows recommended (6) for Oct.-Mar. are recommended for July through December and the Apr.-Sept. flows are recommended for January through June.*

Description of flows	Recommended base flow regimens (Percent of average annual flow) Oct.-Mar.	Apr.-Sept.
Flushing or maximum	200	200
Optimum range	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	0-10	0-10

TABLE 2. *Recommended percentages of the average annual discharge for 30 Oklahoma streams. Minimum instream flows are 10% for July through December and 30% for January through June.*

Stream	County	U.S.G.S. gage	Period of Record	Average annual discharge (cfs)	Percentage of the average						
					200	60	50	40	30	20	10
Arkansas River Basin											
Chickaskia R.	Kay	071520	Oct. 1935-Sep. 1976	485	970	291	242	194	145	97	48
Crooked Cr.	Beaver	071575	Oct. 1943-Sep. 1971	45.3	91	27	23	18	14	9.1	4.5
Cimarron R.	Woods	071580	Oct. 1937-Sep. 1976	351	702	211	175	140	105	70	35
Cimarron R.	Logan	071600	Oct. 1937-Sep. 1976	889	1,778	533	444	356	267	178	89
Cimarron R.	Payne	071610	Jun. 1939-Sep. 1976	1,194	2,388	716	597	478	358	239	119
Council Cr.	Payne	071630	Mar. 1934-Sep. 1976	11.2	22	6.7	5.6	4.5	3.4	2.2	1.1
Caney R.	Osage	071720	Oct. 1939-Sep. 1974	237	474	142	118	95	71	47	24
*Caney R.	Osage	071730	Oct. 1937-Sep. 1950	413	826	248	207	165	124	83	41
*Hominy Cr.	Osage	071770	Mar. 1944-Sep. 1974	178	356	107	89	71	53	36	18
Spring R.	Ottawa	071880	Jul. 1939-Sep. 1976	1,968	3,936	1,181	984	787	590	394	197
Big Cabin Cr.	Craig	071910	Oct. 1947-Sep. 1976	331	662	199	165	132	99	66	33
Illinois R.	Cherokee	071965	Oct. 1935-Sep. 1976	915	1,830	549	457	366	274	183	91
Beaver R.	Beaver	072340	Oct. 1937-Sep. 1976	107	214	64	53	43	32	21	11
*Wolf Cr.	Woodward	072370	Oct. 1937-Sep. 1942	104	208	62	52	42	31	20	10
*North Canadian R.	Blaine	072390	Oct. 1937-Sep. 1948	256	512	154	128	102	77	51	26
Deep Fork	Okmulgee	072435	Sep. 1938-Sep. 1976	840	1,680	504	420	336	252	168	84
Sallisaw Cr.	Sequoyah	072455	Oct. 1942-Sep. 1976	202	404	121	101	81	61	40	20
Poteau R.	Scott, Ark.	072470	Feb. 1939-Sep. 1974	218	436	131	109	87	65	44	22
*Poteau R.	Leflore	072485	May 1938-Sep. 1949	1,325	2,650	795	663	530	398	265	133
Fourche Maline	Latimer	072475	Oct. 1938-Sep. 1976	131	262	79	65	52	39	26	13
Red River Basin											
Salt Fork Red R.	Greer	073005	Oct. 1937-Sep. 1976	86.8	174	52	43	35	26	17	8.7
Red R.	Jefferson	073155	Oct. 1938-Sep. 1974	2,175	4,350	1,305	1,087	870	652	435	217
*Washita R.	Custer	073250	Oct. 1936-Sep. 1960	146	292	88	73	58	44	29	15
Washita R.	Garvin	073285	Oct. 1937-Sep. 1976	699**	1,398	419	349	280	210	140	70
Washita R.	Carter	073310	Aug. 1928-Sep. 1976	1,399**	2,798	839	699	560	420	280	140
Blue R.	Bryan	073325	Jun. 1936-Sep. 1976	304	608	182	152	122	91	61	30
Muddy Boggy Cr.	Atoka	073340	Oct. 1937-Sep. 1976	915	1,830	549	457	366	274	183	91
Clear Boggy Cr.	Atoka	073350	Oct. 1942-Sep. 1976	498	996	299	249	199	149	100	50
Kiamichi R.	Pushmataha	073365	Oct. 1925-Sep. 1971	1,699	3,398	1,019	849	680	510	340	170
Glover Cr.	McCurtain	073379	Oct. 1961-Sep. 1977	456	912	274	228	182	137	91	46

*Not included in the 24 stations used to determine season of low flow.
**Includes regulated and unregulated periods.

through December in 12 of the 24 stream reaches for which hydrographs were developed. Stream reaches in which the 10% AAF was exceeded less than 50% of the time during July through December were usually in smaller streams. Median drainage size for streams where 10% AAF was not available from July to December was 1,159 km^2 compared with 10,153 km^2 for streams for which the 10% AAF was available. Therefore, in general, availability of the 10% AAF was associated with streams with larger drainage basins. However, size of the drainage area was not the only factor associated with availability of the 10% AAF. Two streams in western Oklahoma (Beaver River, Salt Fork of Red River) had large drainage areas, but low rainfall resulted in low flows during summer and fall. In spite of higher average rainfall in streams in eastern Oklahoma, steeper stream gradients and greater seasonal fluctuation in discharge (Big Cabin, Sallisaw, Poteau, Fourche Maline, Muddy Boggy, Kiamichi, Glover) also resulted in an unavailability of the 10% AAF under median summer conditions.

A base flow of 30% of the average annual flow was exceeded more than 50% of the time during January through June in almost all of the 24 streams investigated. A notable exception was Council Creek, an intermittent stream in central Oklahoma where the 50 percentile flows ranged from 5 to 15% AAF during January through June.

Based on this analysis of stream flow, we recommend a minimum instream flow of 10% of the average annual flow for July through December and 30% AAF for January through June (Table 1). Examples of the application of this methodology are presented (Table 2) for 30 stream reaches in Oklahoma. Alternative flow recommendations can also be made by using the other recommended percentages of the AAF (Tables 1, 2). Minimum instream flows (*i.e.*, 10% AAF) were compared with flow duration curves (U.S. Geological Survey, 8) for five stream reaches regulated by impoundments. The percentages of the time during which these minimum flows were exceeded were: 54% in the Caney River below Hulah Lake; 46% in Wolf Creek below Fort Supply Lake; 38% in the North Canadian River below Canton Lake; 52% in the Poteau River below Wister Lake; and 56% in the Washita River below Foss Reservoir. In the North Canadian River, the minimum instream flow was exceeded about 61% of the time before impoundment compared with 38% after impoundment. In the Washita River, the minimum instream flow was exceeded 64% of the time before impoundment compared with 56% after impoundment. In these cases minimum flow releases were probably based on the reliability of flows under drought conditions, rather than on the needs of fish.

To make preliminary flow recommendations that take into consideration the needs of fish and other aquatic life, the Montana method can be used in Oklahoma. However, it should be modified by adjusting the season of lowest flow to cover the period from July through December. We recognize that the recommendation of base flows for two 6-month periods is inadequate to closely simulate the natural stream flow regime or to provide flushing flows. A similar approach could be taken to recommend flows on a quarterly basis. However, the Montana method can still be useful, because it enables planners to obtain a preliminary estimate of the quantity of flow necessary for instream uses. With these estimates, engineers and planners can proceed with preliminary feasibility studies while taking into account the instream-flow needs of aquatic life. However, the limitations of the Montana method dictate that its use be restricted to initial planning and that it be followed by more intensive field analysis.

Flows of 10% of the average annual flow during July through December and 30% during January through June should be considered the minimum stream flows required to prevent degradation. Higher percentages of the average annual flow may be recommended for streams with greater values as fishery resources. Also, higher percentages may need to be recommended for larger, permanent streams. Recommendation of instream-flow needs for intermittent streams presents a problem, because there is no natural flow during much of the year. Further investigation is necessary to identify the value of these streams and to develop a method for deriving reasonable flow recommendations.

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