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IMPLICATIONS OF STREAM IMPOUNDMENT ON YEGUA CREEK, TEXAS

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ABSTRACT

Yegua Creek, south-central Texas, has been modified by the construction of Somerville Dam. Data are presented in this article that demonstrate changes in the characteristics of the stream. An analysis of discharge indicates that annual discharge downstream from the dam is statistically the same when pre-dam and post-dam discharge is compared. Spring high flows are decreased and early autumn low discharges are increased after dam construction. Since the construction of the dam, riparian vegetation has increased in proximity to the channel while for areas on either side of the stream the area of woodland vegetation has decreased. Increased riparian vegetation may be related to less variability in discharge, especially in the drier late summer.

INTRODUCTION

Many rivers have been greatly affected by human activity. While the modes and impacts of human activity are diverse and variable, the construction of dams has had some of the most profound impacts on riparian systems. Dams alter the characteristics of river discharge downstream from the dam. The type of flow alteration is variable depending on the purpose of the dam (e.g., hydroelectric generation or irrigation) [1, 2]. Downstream from dams the alterations of stream characteristics include changes in discharge [3], water quality [4], and sediment load [5]. These changes lead to subsequent changes in systems closely related to stream characteristics such as geomorphology [6], fisheries [7], and riparian vegetation [8]. A greater understanding of the impacts of changes in riparian systems is needed. This understanding will lead to better management of resources in riparian systems.

A study of the impact of dam construction on downstream characteristics of Yegua Creek, Texas, is presented in this article. The variability and amount of discharge for a sixty-seven year period (1924-1991) is analyzed to determine the impact of the 1966 impoundment of Lake Somerville on Yegua Creek. In order to control for climatic variability, regional average annual precipitation values are also compared for the pre- and post-dam record. Changes in vegetation near Yegua Creek are measured using maps. A pre-dam and post-dam comparison of the amount of forest cover in the vicinity of Yegua Creek is made to reveal general trends in forest cover that may be related to changes in stream discharge. Since Somerville Dam is designed for flood control, it is hypothesized that discharge in Yegua Creek will be more uniform during the course of the year. Uniformity in discharge could lead to the establishment of more riparian vegetation as a result of less disturbance and more water availability throughout the year.

IMPACTS OF DAMS ON STREAM DISCHARGE

Several types of discharge changes, related to the function of the dam, might be expected after the construction of a dam. In some cases the discharge may be reduced by the diversion of water for purposes such as irrigation. Johnson et al. found that discharge on a portion of the Snake River, Idaho, was reduced by 20 percent as a result of irrigation withdrawals [9]. In other cases, such as hydroelectric power generation or flood control, the annual discharge may be relatively unaffected, but the timing and size of peak flow or low flow may be affected. Dams can also lead to pulsed flow which is caused by periodic releases of water, resulting from specific short-term water needs [10]. After dam construction in the drainage of the McKenzie River of Oregon, peak discharges have been reduced by 50 percent [7]. A combination of hydroelectric and irrigation structures coupled with groundwater extraction on the Drava River in eastern Europe led to significant decreases in discharge [3]. Changes in stream discharge may be related to the combined withdrawal of groundwater and surface water. In addition to the impacts of navigation, flood protection, agriculture, and urbanization on the Garonne River of France, a lowering of the water table resulting from stream gravel extraction has led to a fragmentation of the riparian vegetation [11].

IMPACTS OF DAMS ON RIPARIAN VEGETATION

Rivers are highly dynamic environments where water and sediment are constantly being transferred through the fluvial system. The fluxes of material and energy can be quite variable and as a result the potential for the alteration of riparian plant communities is high. For example, changes in channel morphology as the result of lateral migration lead to a constantly changing mosaic of riparian communities [12]. The riparian zone is characterized by a highly variable environment of microtopography, soils, and water [13, 14]. In this environment, vegetation is influenced by its proximity to water and the time of inundation of features in and near the stream channel [12, 15-18]. Pautou et al. indicate that reduced variability of stream flow in the upper Rhone River has affected riparian vegetation because of the limitation of flooding and lowering of ground water [19]. This change has led to the decline of some species and the persistence of other species, at least short term. Interactions between streams and riparian vegetation that affect the distribution of riparian species include dispersal mechanisms, seedling survival, anaerobic soil conditions, and shading [20-22]. Variability in climate may also affect stream flow. Martin and Johnson were able to correlate an increase in precipitation with the expansion of riparian vegetation on the Medicine Lodge River in Kansas [23].

Although variability is common in riparian systems, the construction of dams can have a profound effect on water and sediment flows, thereby affecting riparian communities along river systems. The alteration of discharge characteristics by the construction of dams is not uniform, and as a result vegetation response is variable. Use of stream water for irrigation has led to the decline of riparian forests in southern Alberta, probably resulting from abrupt changes in warm season stream flow [24, 25]. On the Missouri River in North Dakota, Johnson projects a decline in pioneer communities of *Populus* and *Salix* with an increase in successional communities of *Fraxinus* as the result of a reduction in the rate of meandering following dam construction [26]. On the Snake River, reduced flows are hypothesized as leading to an expansion of the area of riparian vegetation [9]. Highly affected riparian systems like the Santee River of South Carolina may undergo significant changes as the result of restored flow. Much of the discharge of this river was diverted as part of a hydroelectric project. An effort to return discharge to the river may result in a large decrease in *Carya aquatica* and *Nyssa aquatica* [27]. Responses to altered riparian characteristics are highly individualistic. Some species may be affected negatively while other species may expand their distribution in response to changes in the riparian system.

METHODS

The Study Area

Yegua Creek, a tributary of the Brazos River, is located in south-central Texas. Yegua Creek drains an area to the east of Austin, southwest of College Station, and northwest of Houston (Figure 1). The focus of this study is a 27 km reach of Yegua Creek between Lake Somerville, located near the town of Somerville, Texas, and the stream's confluence with the Brazos River to the east. This reach of the stream forms the boundary between Washington County to the south and Burleson

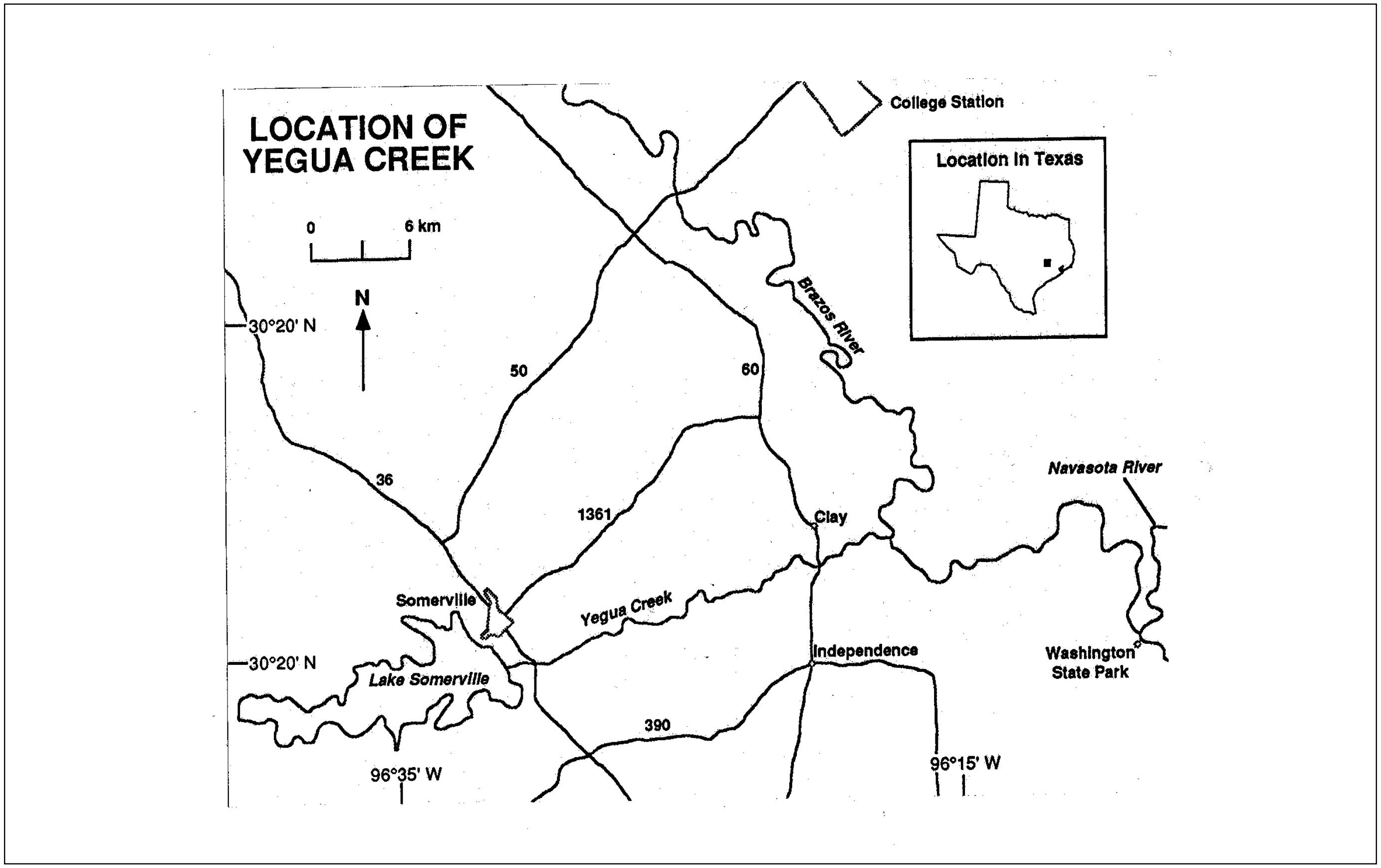

Figure 1. Map of the study area.

Highway 36 on the western side of the section and Texas State Highway 50 on the eastern side of the section. Some gravel roads allow limited access to other sections of the stream.

The drainage occupies an area of Gulf Coastal Plain composed of Tertiary marine sediments [28]. The stream forms a meandering channel through Quaternary alluvial sediment. The channel directly downstream from the dam has a broad flood plain that is subject to inundation during times of high discharge, commonly in the spring. At lower reaches the stream is more incised, with a small flood plain. This portion of Yegua Creek has no major streams contributing to its flow. Land use around the stream includes pasture, petroleum extraction, and agricultural fields. Other than the town of Somerville, located approximately 2 km north of the stream, there are no towns in the general area of this section of Yegua Creek. The upstream portion of this section of the stream tends to have more pastureland, while the downstream portion is characterized by tilled fields.

This portion of Texas is characterized by a Humid Subtropical climate. The closest weather station with a long-term record is located at Washington State Park [29]. Based on the 1961-90 record, mean annual temperature at Washington State Park is 20.2°C (Figure 2). The warmest month is July, with an average temperature of 28.6°C; the coolest is January, with an average temperature of 8.9°C. Mean annual precipitation is 1022.6 mm and is weakly bimodal, with peaks in September (121.2 mm) and May (114.1 mm). July and August experience the lowest average monthly precipitation of 57.2 mm and 70.4 mm respectively.

The natural vegetation of this area, where unaffected by agriculture or grazing, is characterized by broadleaf forest. The study area is classified as being contained in the post oak savannah vegetational area [30]. Upland forests are characterized by *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), and *Ulmus crassifolia* (cedar elm). The understory is primarily composed of grasses with some shrubs such as *Ilex vomitoria* (yaupon) and *Prosopis glandulosa* (mesquite) distributed under the canopy of larger trees and in openings [30, 31]. Riparian forests in this region of Texas are also characterized by broadleaf trees. Common riparian species include *Carya aquatica* (water hickory), *Gleditsia aquatica* (water locust), *Juniperus virginiana* (eastern red-cedar), *Planara aquatica* (water elm), and *Ulmus crassifolia* (cedar elm) [31]. The understory tends to be open with some shrubs.

Discharge Data

Discharge was recorded in acre-feet for Yegua Creek between June 1924 and September 1991 at gaging station 08110000 located in Burleson County, Texas, 12 m downstream from the centerline of State Highway 36 and reported in U.S. Geological Survey Water-Data Reports. Since February of 1966, Somerville Dam has regulated the flow of this stretch of Yegua Creek. The dam is 1.6 km upstream from the site of the gaging station. Forty-one or forty-two years of pre-dam

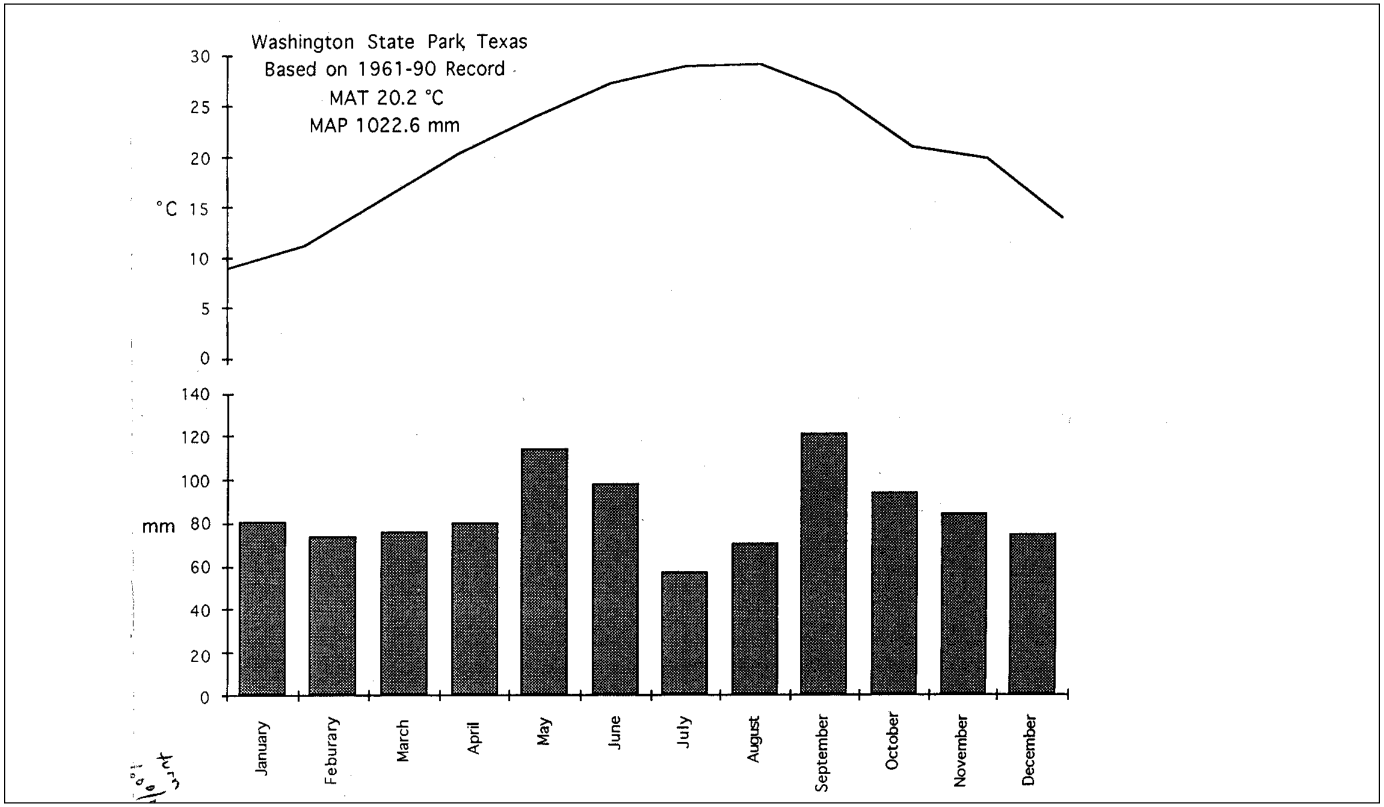

Figure 2. Climograph for Washington State Park.

discharge values are available for each month of the year and twenty-five or twenty-six years of post-dam discharge values are available for each month. Discharge data of 808 months, 500 pre-dam and 308 post-dam values, were analyzed. The pre-dam record represents 62 percent of the total record. Statistical measures, such as mean discharge and standard deviation, for the entire record, the entire pre-dam record, the entire post-dam record, and for the pre-dam and post-dam records for each month were calculated. In order to determine if there was a difference between pre-dam and post-dam discharge characteristics, pre-dam and post-dam discharge was compared for each month and for the annual total using *t*- and *F*-tests. The *t*-test was used to compare the means and the *F*-test to compare the standard deviations, both to a confidence level of 0.05. Flow duration curves were also constructed using pre-dam and post-dam monthly discharge amounts as a means of comparison.

Climatic Data

Climatic data for Texas division 7, which includes the area around the drainage of Yegua Creek, was obtained in order to analyze the relationship between precipitation and discharge. These data were selected because they would better represent the regional precipitation amounts and the amount of water available in the water shed for discharge. Precipitation values were available for the same months as the stream discharge data. Statistical measures of precipitation for the entire record, the entire pre-dam record, the entire post-dam record, and for the pre-dam and post-dam records for each month were calculated. Pre-dam and post-dam precipitation characteristics were compared for each month and for the annual total using *t*- and *F*-tests. The *t*-test was used to compare the means and the *F*-test to compare the standard deviations, both to a confidence level of 0.05. The monthly precipitation data was compared to the stream discharge using correlation in order to determine the relationship between stream discharge and precipitation.

Comparison of the Distribution of Forests for the Area

The reach of Yegua Creek between the Somerville Dam and its confluence with the Brazos River is represented on four U.S. Geological Survey 7.5' quadrangles from two dates: Somerville (1959, 1988), Gay Hill (1959, 1988), Independence (1959, 1988), and Clay (1959, 1980). Maps published in 1959 using 1958 aerial photographs were used to determine the distribution of pre-dam woodlands. Areas shaded green were inferred to represent all areas of woodland regardless of the species composition or morphology of the woodlands. The photorevised versions of these quadrangles published in the 1980s were used to determine the post-dam distribution of woodlands. The maps were photorevised using aerial photographs taken on dates between 1977 and 1982. The 1988 Gay Hill quadrangle was photorevised using 1982 aerial photographs. The Somerville and Independence 1988 quadrangles were photorevised using 1981 aerial photographs. The 1980

Clay quadrangle was photorevised using 1977 aerial photographs. It is assumed that the aerial photographs are close enough temporally so that differences in woodland distribution are limited. This assumption is supported by accurate edge matching between the quadrangles.

The distribution of woodlands represented on these maps for the two time periods was compared to determine the amount of change in woodland cover in two ways. The first was a measurement of vegetation proximal to the stream channel, which was inferred to be affected by the stream. The second was the measurement of woodland coverage for an area approximately 1.5 km on either side of the channel.

Using a planimeter, the portions of the stream in contact with the green shaded woodland symbol were measured for the entire length of the stream. These measurements were then used to determine the percentage of the streambank with an inferred riparian woodlands on them. Measurements were made from pre-dam and post-dam quadrangles and compared.

The larger area around the stream was measured using Intergraph software housed at the Mapping Sciences Laboratory on the campus of Texas A&M University. The quadrangles were scanned and converted from raster to vector data in order to use GIS to measure the distribution of woodlands. Two maps were created, one representing the pre-dam woodland distribution as represented by the 1959 maps the other representing the post-dam maps of the 1980s. The area of woodland was calculated for each of the maps to determine the amount of woodland coverage for each time period. These values were compared to determine the amount of change between the two time periods.

RESULTS

Discharge Data

Mean annual discharge is 7.95 m^3sec^{-1} (203,359.8 acre-feet). The year with the lowest discharge was 1967, with 0.008 m^3sec^{-1} (207.9 acre-feet) of discharge (Figure 3). This low flow may be related to the impoundment of Lake Somerville in 1966. The highest discharge was experienced in 1940 with a discharge of 19.65 m^3sec^{-1} (502,779.0 acre-feet). The mean annual discharge is highly variable for the entire record. The dam does not regulate the flow of Yegua Creek to the extent that annual discharge is consistent from year to year.

Mean monthly discharge for the entire record is 0.68 m^3sec^{-1} (17,313.5 acre-feet). Discharge for the entire record is highly variable: winter months generally exhibit higher discharge values, although high discharge events are found in every month. The monthly discharge ranged from 0 m^3sec^{-1}, which occurred forty-nine times, to 8.08 m^3sec^{-1} (206,800.0 acre-feet) in July of 1940. Dry events commonly occurred in late summer. Thirty-four of the months with no discharge were during August, September, or October.

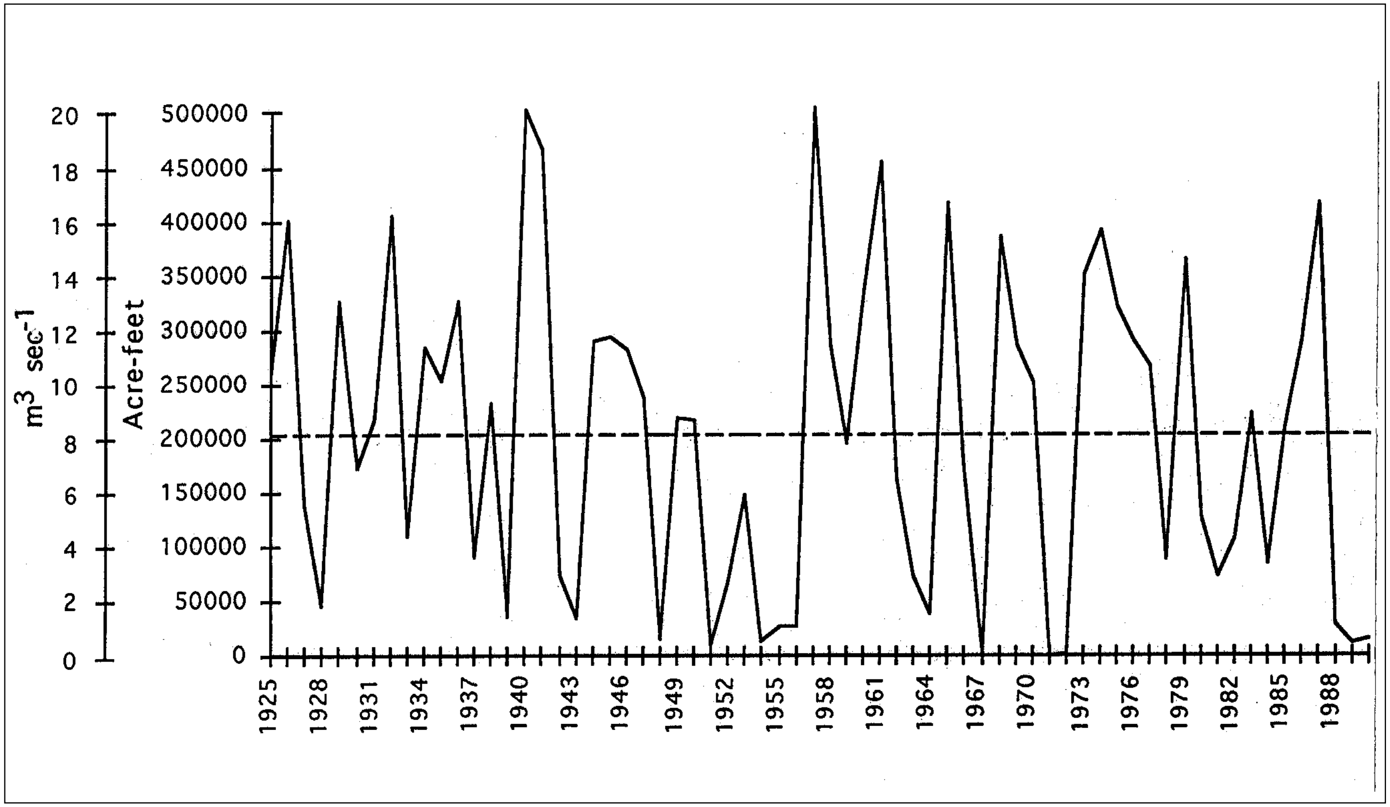

Figure 3. Annual discharge of Yegua Creek, June 1924 to September 1991.

When the pre-dam and post-dam records are compared, additional differences can be seen. The mean discharge for the 1924-1966 pre-dam period was 0.68 m^3sec^{-1} (17,434.0 acre-feet). For the 1966-91 post-dam record, the mean discharge was 0.64 m^3sec^{-1} (16,438.5 acre-feet). The pre-dam record has more variability, with a standard deviation of 1.3 m^3sec^{-1} (33,260.9 acre-feet) compared to a standard deviation of 1.00 m^3sec^{-1} (25,640.8 acre-feet) for post-dam discharge. The number of months with no discharge was most commonly found in the pre-dam record, with forty of the forty-nine months (82%) with no discharge occurring during the pre-dam period. Even taking into account the higher number of pre-dam observations, zero discharge was most commonly found during the pre-dam period.

After dam construction, monthly averages showed a slight decrease and a lag in spring discharge in comparison to pre-dam discharge (Figure 4). The month with the highest discharge for both the pre-dam and post-dam record was May, with an average discharge of 1.33 m^3sec^{-1} (33,868.0 acre-feet) and 1.19 m^3sec^{-1} (30,414.8 acre-feet) respectively. While the pre-dam discharge declined appreciably in June to an average value of 0.62 m^3sec^{-1} (15,870.7 acre-feet), the June post-dam average discharge of 1.18 m^3sec^{-1} (30,132.8 acre-feet) remained high before dropping to an average discharge of 0.89 m^3sec^{-1} (22,713.2 acre-feet) in July. Discharge was somewhat lower in the late fall after dam construction with the lowest post-dam average discharge occurring in September as compared to an August nadir for pre-dam discharge. August average pre-dam discharge was 0.15 m^3sec^{-1} (3,750.2 acre-feet) and September average post-dam discharge was 0.16 m^3sec^{-1} (4,189.6 acre-feet).

The *t*-test and *F*-test demonstrate the differences and similarities between the pre-dam and post-dam discharge amounts (Table 1). All *t*-test values for difference of means were not significant. This result indicates that the construction of the dam had no statistically testable affect on the amount of discharge on a monthly and annual basis. The *F*-test represents the differences in the variability of pre-dam and post-dam monthly and annual discharges. The *F*-test values are significant for five months and for the annual average (Table 1). The months of January, April, May, September, and October have statistically significant differences between pre-dam and post-dam discharge. April and May are months that typically have the highest average discharge, while September and October are times of low discharge. While the *t*-test indicates that there is no significant difference in the amount of discharge, the discharge is less variable after dam construction. Large and small magnitude events are limited by the presence of the dam. The high flows experienced in the winter (January) and spring (April and May) are less likely. In the early fall (September and October) the occurrence of extremely low discharge is less likely. Changes in the discharge variability are pronounced enough to affect the variability of discharge for the annual record.

The flow durations curves illustrate the changes in monthly discharge from pre-dam and post-dam conditions. Post-dam discharge is less at times of high

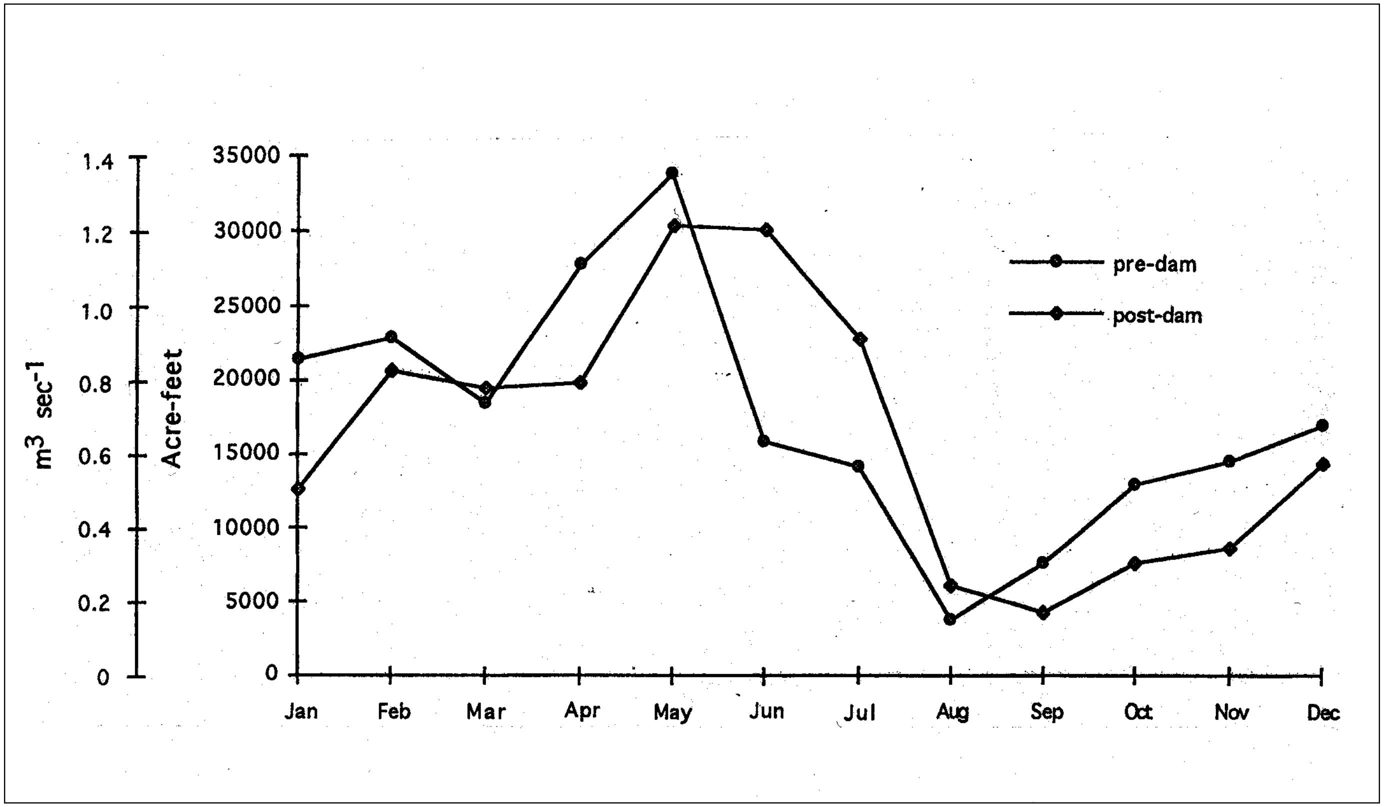

Figure 4. Average monthly discharge for Yegua Creek, June 1924 to September 1991.

Table 1. A Statistical Comparison of Pre-Dam and Post-Dam Discharge

	F-test	*t*-test
January	3.77	1.43
February	1.08	0.34
March	1.21	–0.14
April	2.81*	0.97
May	2.81*	0.35
June	1.39	–1.94
July	1.33	–0.87
August	1.48	–0.58
September	4.42	0.82
October	3.24*	0.77
November	1.66	1.04
December	1.08	0.37
Annual	1.68*	0.47

*Significant at 0.05 level

discharge and more at times of low flow when compared to the pre-dam record. Flow equaled or exceeded demonstrates the large differences between the post-dam and pre-dam discharge (Figure 5). Flow equaled or exceeded 5 percent of the time is much higher for the pre-dam record (3.39 m^3sec^{-1}; 86,650.0 acre-feet) than for the post-dam record (2.65 m^3sec^{-1}; 67,700.0 acre-feet). Flow equaled or exceeded 95 percent of the time has a less pronounced difference between pre-dam and post-dam discharge conditions. The pre-dam flow equaled or exceeded 95 percent of the time for the pre-dam record is zero, while the post-dam flow is 0.0001 m^3sec^{-1} (3.5 acre-feet). When the two curves are compared, a change in flow characteristics becomes apparent. The dam stores some of the water that would have normally flowed through the stream at periods of higher discharge. This water is released at times when there would have been less flow in the stream, therefore increasing the amount of discharge at times of low flow.

Climatic Data

Mean annual precipitation in district 7 for the entire period is 858.0 mm. The driest year was 1954, with 425.4 mm precipitation. The highest amount of precipitation was 1266.9 mm, received in 1973. These lowest and highest precipitation values do not correspond to the lowest and highest stream discharge values, but as would be expected low and high precipitation amounts are related to similar stream discharge values.

The annual district 7 precipitation pattern is similar to the precipitation record of Washington State Park (Figure 2). Average precipitation values for the district

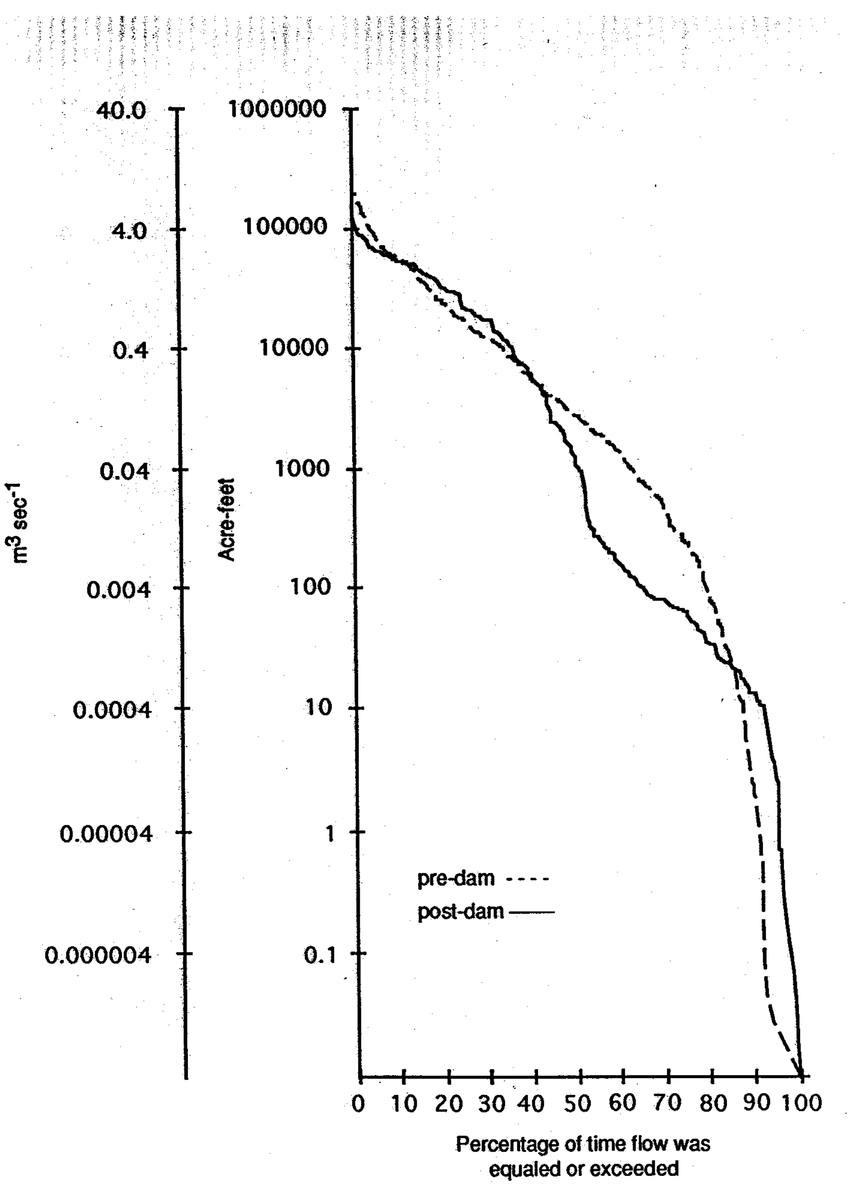

Figure 5. Flow duration curve for Yegua Creek comparing pre-dam and post-dam discharge.

are generally lower than those at Washington State Park since locations farther west receive less precipitation. Precipitation peaks during spring and fall, with summer and winter months commonly dry. Precipitation is variable, with all months of the year receiving a maximum of at least 139.1 mm precipitation and a minimum of at least 19.8 mm precipitation at some time during the 1924-1991 period.

When the mean precipitation data for the pre-dam and post-dam records are compared, there are some differences. The mean annual precipitation for the 1924-1966 pre-dam period was 832.8 mm; for the 1966-91 post-dam record the mean annual precipitation was 899.6 mm. The pre-dam precipitation record has more variability with a standard deviation of 199.6 mm compared to a standard deviation of 178.3 mm for the post-dam record. A comparison of the maximum and minimum values for the pre-dam and post-dam precipitation indicates that the post-dam record has experienced higher maximum and minimum precipitation values. For the pre-dam period, the maximum mean annual precipitation is 1190.2 mm and the minimum mean annual precipitation 425.4 mm. The maximum and minimum mean annual precipitation values for the post-dam record are 1266.9 mm and 516.8 mm respectively.

The *t*-test comparison between pre-dam and post-dam mean monthly and mean annual precipitation indicates that only the mean monthly precipitation for December is different. For all the other months and the annual record, there is no statistical difference between the pre-dam and post-dam precipitation record (Table 2). The *F*-test values are significant for three months (Table 2). The months of April, August, and September have statistically significant differences between pre-dam and post-dam mean monthly precipitation. The differences between the pre-dam and post-dam record would indicate that there has been limited changes in the precipitation pattern during the two time periods.

Of more importance to the understanding of the relationship between the amount of precipitation and stream discharge is the statistical correlation between these two variables. The correlation between annual precipitation and stream discharge is .73 for the pre-dam record and .55 for the post-dam record. As would be expected, this result indicates that precipitation is more directly associated with stream discharge before the construction of the dam than after. While the amount of precipitation has not changed enough to affect the stream discharge, there has been a change in the relationship between precipitation and stream discharge.

Comparison of the Distribution of Forests for the Area

Planimeter measurement of the pre-dam and post-dam riparian woodlands indicates a change in the amount of riparian woodlands. For the set of 1959 USGS quadrangles, based on 1958 aerial photographs, woodlands occupied approximately 47 percent of the 27 km stretch of Yegua Creek. The maps from the 1980s, based on the 1977, 1981, and 1982 aerial photographs, indicate that woodlands

Table 2. A Statistical Comparison of Pre-Dam and Post-Dam Precipitation

	F-test	*t*-test
January	1.09	–0.32
February	1.31	0.71
March	1.70	0.39
April	0.86*	0.05
May	1.41	–1.52
June	0.45	–1.13
July	1.40	–0.16
August	0.78*	–1.27
September	0.58*	–1.75
October	1.16	–0.97
November	1.07	–0.61
December	1.16	2.16*
Annual	1.25	–1.37

*Significant at 0.05 level

occupied approximately 72 percent of the same stretch of Yegua Creek. This result indicates that there had been a 25 percent increase in the amount of riparian woodland along Yegua Creek in the approximately twenty-year time span between the two sets of maps.

The measurement of the woodland areas in the vicinity of Yegua Creek indicates a decrease of woodland cover over the study period. In 1958 in the study area, 27.17 km^2 were covered with woodlands. By the post-dam period, represented by the 1977, 1981, and 1982 aerial photographs, the amount of woodland for the area had decreased by approximately 39 percent to 17.26 km^2. Woodlands were cleared for oil exploration and agriculture. This general trend of decreases in woodland cover for the area is contrary to the expansion of riparian vegetation along the banks of Yegua Creek.

CONCLUSIONS

The construction of a dam on the Yegua Creek has had mixed results. The dam has little impact on some aspects of stream discharge, but in other cases stream discharge is significantly different. Since Lake Somerville is primarily used for flood control, the total post-dam discharge is not significantly different from the pre-dam discharge, unlike other regulated streams where discharge is significantly decreased because of diversion of water [3, 11, 19]. There is no indication of a decrease or increase in the total annual discharge. This lack of change in annual discharge indicates that any changes in riparian vegetation are probably not caused by annual discharge.

While overall discharge has not been affected, there has been a definite change in the timing of water delivery during the course of a year. The slight shift of discharge from spring and early summer to later summer and early fall has had an effect on the amount of time, on average, that the stream channel contains water. Flooding still occurs, but discharge is more constant with a decrease in very low flow events. The data analyzed does not have the resolution to indicate that Yegua Creek experiences pulsed flow [10], but it is not likely that this has occurred since the dam is not used for hydroelectric generation. Yegua Creek appears to be similar to the MacKenzie River [7], with a reduction of peak discharge.

While flooding can disrupt riparian plant communities, it appears that in the case of Yegua Creek the availability of water throughout the year may have more of an affect on the viability of riparian plant communities. The 25 percent increase in riparian communities after the construction of Somerville Dam, in spite of a 39 percent decrease in woodland vegetation for the area around Yegua Creek, indicates that the riparian zone is being affected by a set of controls different from those in areas away from the stream.

The post-dam stream discharge regime may be less disruptive to riparian communities, not because of reduced flooding but because of more favorable summer conditions. The alteration of stream discharge may have given an advantage to newly established seedlings. Both flooding and summer drought can cause mortality of young individuals [20-22]. In the post-dam period, both flooding and dry channel conditions were greatly decreased which could lead to the persistence of seedlings. The riparian environment of Yegua Creek has probably become less dynamic and more favorable for the establishment and expansion of riparian forests. The response of these riparian communities is different from those seen when discharge is reduced [24, 25] or increased [27] on other streams. Unlike other streams where the construction of a dam has affected stream channel morphology [9, 26], there is little evidence of channel change in the case of Yegua Creek. The increased amount of water in the channel appears to favor the growth of riparian trees, while decreased flooding limits the disruption of riparian communities.

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