ADJUSTMENTS BETWEEN HISTORICAL FLOW AND SEDIMENTS IN A RIVER BASIN USING GENETICS ALGORITHS

Preciado, J. M, Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor., preciado@tlaloc.imta.mx,; Arganis, J. M. L., Instituto de Ingeniería, Universidad Nacional Autónoma de México, and PUMAGUA, Universidad Nacional Autónoma de México, MArganisJ@iingen.unam.mx; Ocón G.A., Instituto Mexicano de Tecnología del Agua, Jiutepec, Mor., acon@tlaloc.imta.mx; Val, S. R., PUMAGUA, Universidad Nacional Autónoma de México, RValS@iingen.unam.mx.

INTRODUCTION

Abstract Suspended materials in rivers are closely related to currents as well as to sediments transported by surface flows during storm periods (Ogardi, 1978). Sediments transported by the channels also come from other erosive processes in the drainage network of the river basins. Thus suspended sediment in channels results from erosion within the channel and on adjacent slopes.

In Mexico, the principal federal office in charge of the hydrometric stations ceased collecting measurements of sediments. Thus genetic algorithms are very important to sediment modeling. This paper presents preliminary results of investigations using the data of the hydrometric stations of the river basin of the Apatlaco River. Correlations between annual and monthly data to were sought, in order to investigate the viability of applying techniques of evolutionary calculation to obtain models of adjustment between flow and sediments.

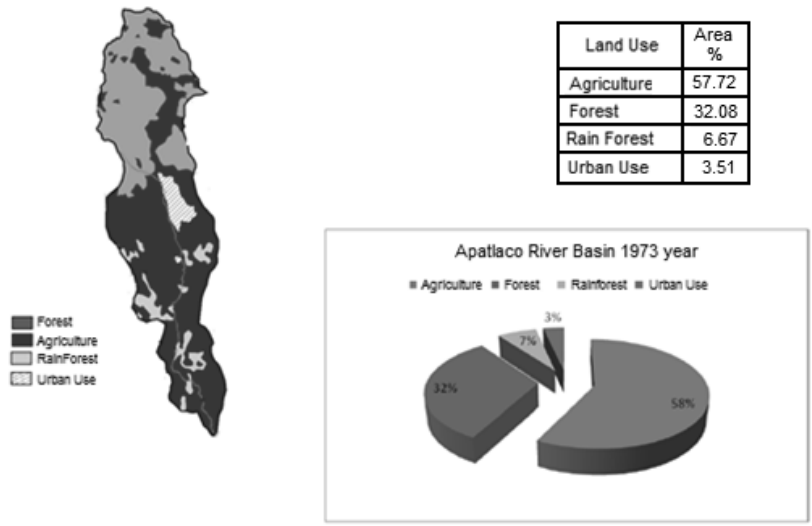
SITE OF STUDY

The Apatlaco River basin is located in the northwest portion of the state of Morelos, bounded on the north by the Federal District, to the north and the northwest by the State of Mexico, to the west by the Tembembe River basin, and to the east and the south by the Yautepec River. The Apatlaco River originates in the stream denominated Chalchihuapan, to the northwest of Cuernavaca and southwest of the Municipality of Huitzilac, and ends at the Yautepec River, a tributary of the Amacuzac River that finally joins the Balsas River. Three large cities are located within the river basin: Cuernavaca, Jiutepec and Temixco. Also located there are municipalities with a great rate of growth in the State, which can group in two nuclei: Cuernavaca, Jiutepec, Temixco and Xochitepec, on the one hand, and Jojutla, Zacatepec and Tlaltizapán, on the other. The area of the river basin is 750,660 km^2. Within the river basin are 3 hydrometric stations with sediment data: Temixco (18271), Tetlama (18323) and Zacatepec (18264). In Figures 1 and 2 the changes in the land use in this basin are indicated, comparing years 1973 and 2000. In Figure 3 the digital elevations model, the different soil types appear as well as the slope of the main channel.

METHODOLOGY

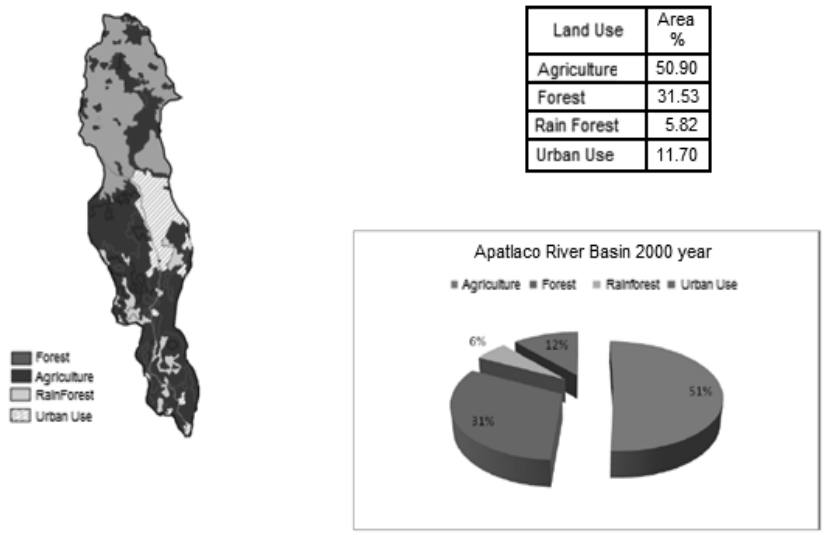
Genetic algorithms Within the evolutionary calculation the genetic algorithms are emphasized (Goldberg, 1989). These algorithms are based on the way on which the nature is able to cause more and more adaptation to surroundings, that is to say, evolution. Year 1975 is taken as a datum point from the origin of the studies on genetic algorithms and, from then until now, these

algorithms have been improving. They have been used in the last few years to solve problems within hydrology and hydraulics. In Figure 4 the sequence of a simple genetic algorithm is indicated.



Land Use	Area %
Agriculture	57.72
Forest	32.08
Rain Forest	6.67
Urban Use	3.51

Figure 1. Land Use 1973 year. Apatlaco River Basin



Land Use	Area %
Agriculture	50.90
Forest	31.53
Rain Forest	5.82
Urban Use	11.70

Figure 2 Land Use 2000 year. Apatlaco River Basin.

Coefficient of correlation The correlation coefficient allows identifying the existing relation between series of time. In the present study it was used to demonstrate the possible existing dependency between the sediment transport and the runoff volumes. The coefficient is considered in agreement with equation 1.

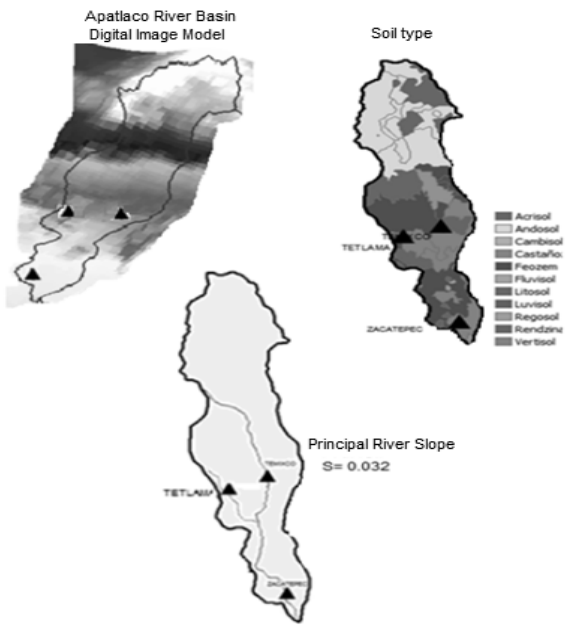


Figure 3 Apatlaco River Basin Characteristics.

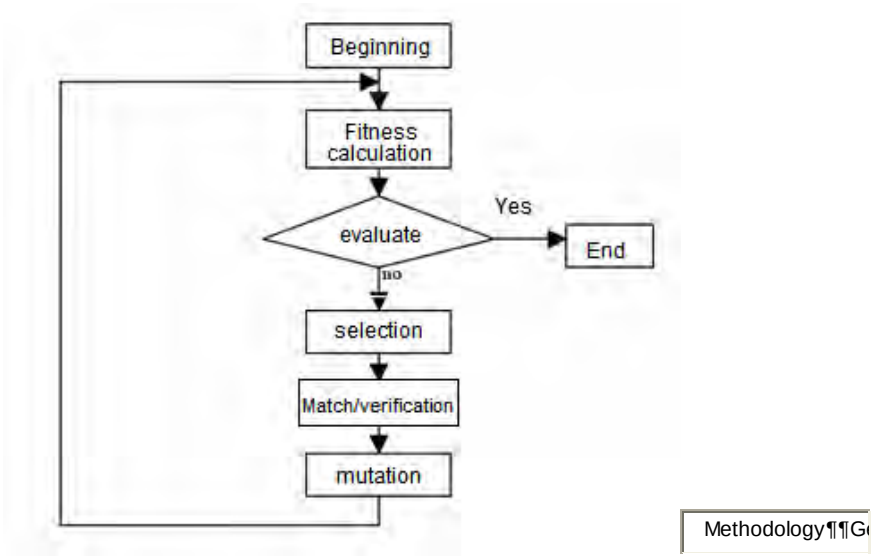


Figure 4 Simple Genetic algorithm.

$$r_{V,A} = \frac{Cov(V,A)}{\sigma_V \sigma_A} \tag{1}$$

Data available The Water National Commission (Conagua) counts on an installed network of 2339 hydrometric stations. At the moment 865 stations are operating. There are 415 hydrometric stations in the sediment data base. Station 26424 counts on a registry of 71620 days. Station 19016 has an historical data base from the 01-01-1975 until 01-04-2008 (Table 1).

Table 1 Evolution of the hydrometric stations operated by the Water National Commission (CONAGUA).

Year	Hydrometric Stations	Year	Hydrometric Stations	Year	Hydrometric Stations
1926	41	1954	612	1982	1176
1927	63	1955	622	1983	1214
1928	87	1956	669	1984	1239
1929	82	1957	708	1985	1240
1930	100	1958	716	1986	1156
1931	113	1959	769	1987	1150
1932	135	1960	755	1988	1148
1933	141	1961	807	1989	1145
1934	141	1962	832	1990	1145
1935	169	1963	866	1991	1067
1936	199	1964	915	1992	1068
1937	175	1965	1024	1993	1067
1938	182	1966	1068	1994	1077
1939	194	1967	1086	1995	1055
1940	205	1968	113	1996	960
1941	219	1969	1129	1997	844
1942	230	1970	1141	1998	774
1943	235	1971	1149	1999	779
1944	244	1972	1157	2000	780
1945	275	1973	1164	2001	780
1946	316	1974	1164	2002	811
1947	389	1975	1164	2003	865
1948	410	1976	1180	2004	862
1949	454	1977	1207	2005	864
1950	475	1978	1224	2006	863
1951	500	1979	1241	2007	865
1952	507	1980	1257	2008	865
1953	641	1981	1147	2009	860

RESULTS

From the records of the National Bank of Superficial Water Data (BANDAS), annual volumes and transports were determined. The coefficient of correlation for the Temixco, Tetlama and Zacatepec stations was determined. Figures 5 to 10 show the obtained results.

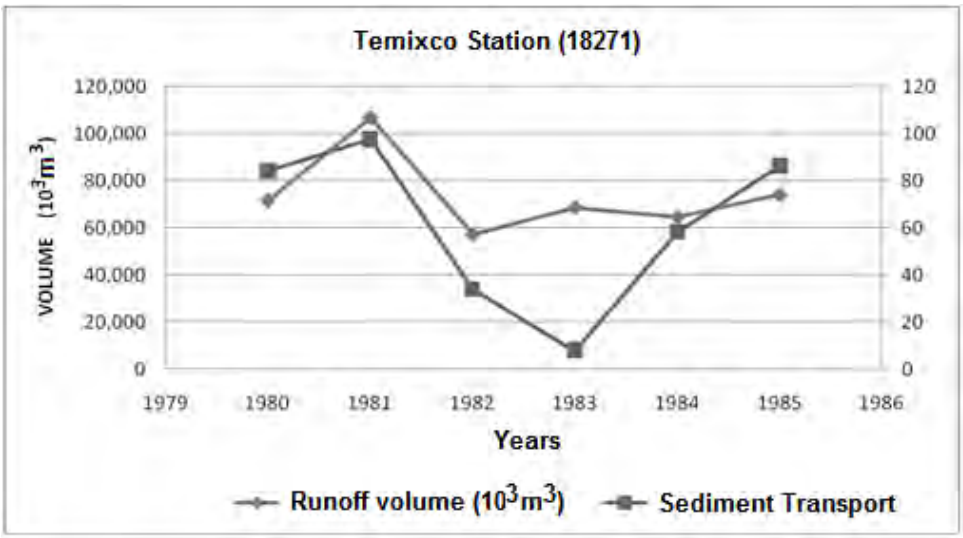


Figure 5 Historical record runoff volume and sediment transport, Temixco Station.

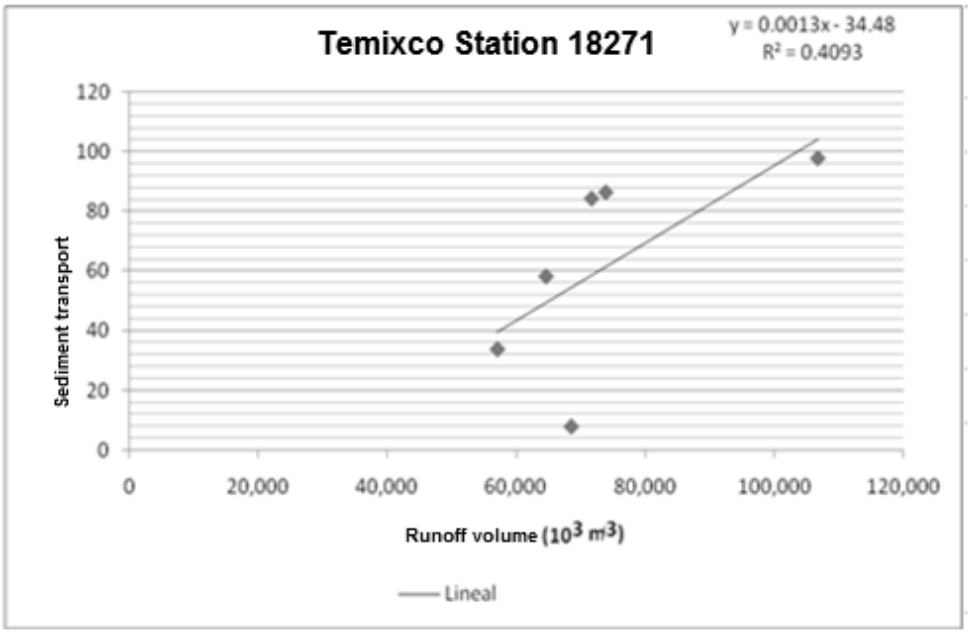


Figure 6 Runoff volume vs sediment transport, Temixco Station.

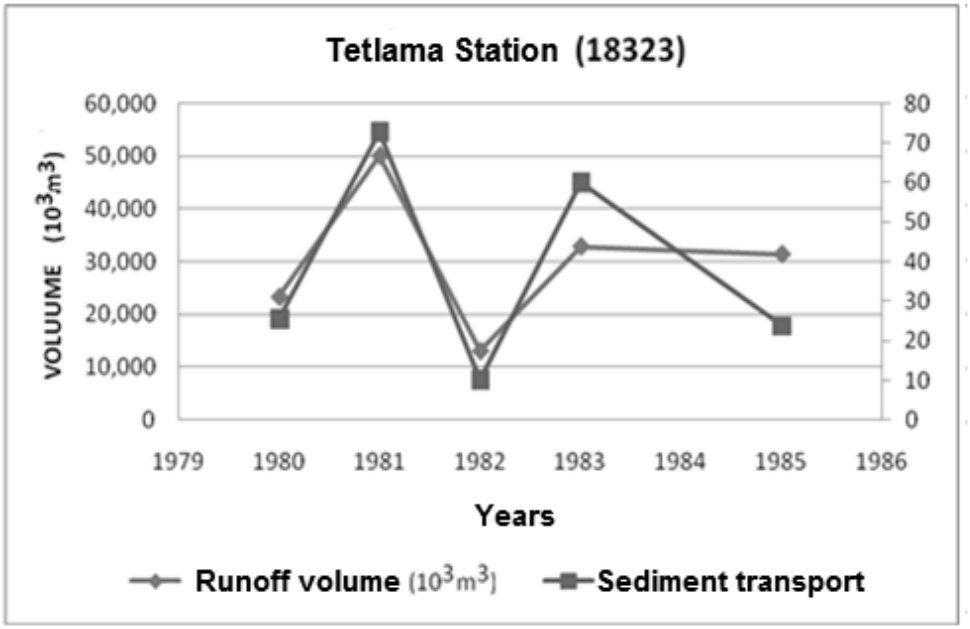


Figure 7 Historical record runoff volume and sediment transport, Tetlama Station.

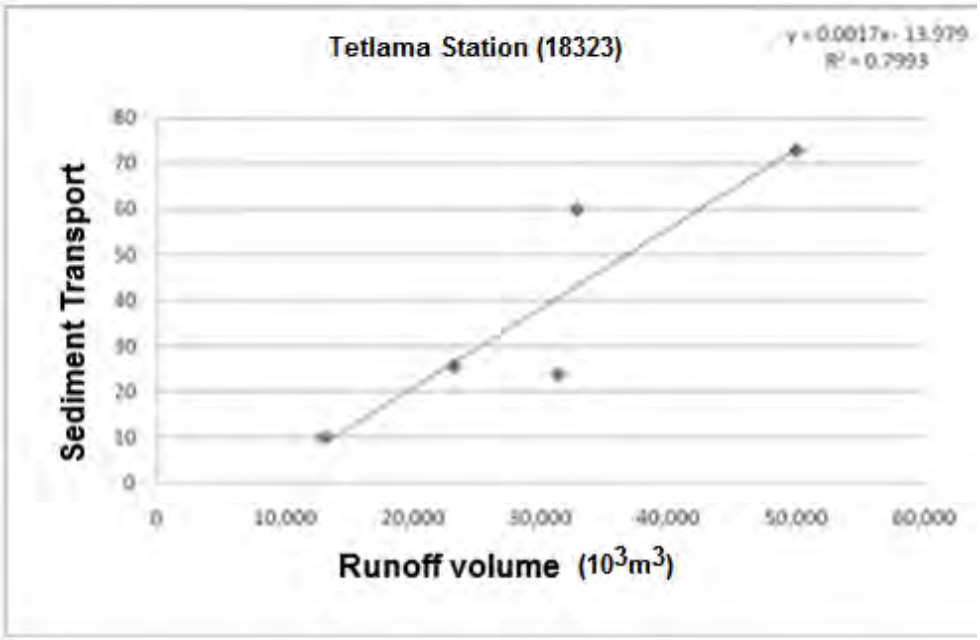


Figure 8 Runoff volume vs sediment transport, Tetlama Station.

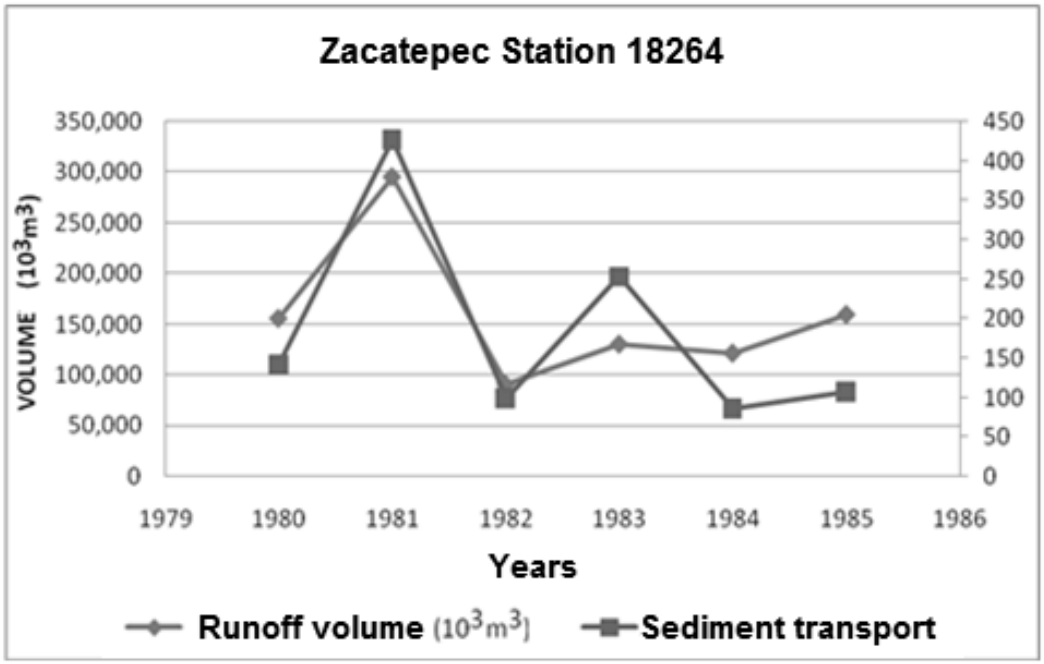


Figure 9 Historical record runoff volume and sediment transport, Zacatepec Station.

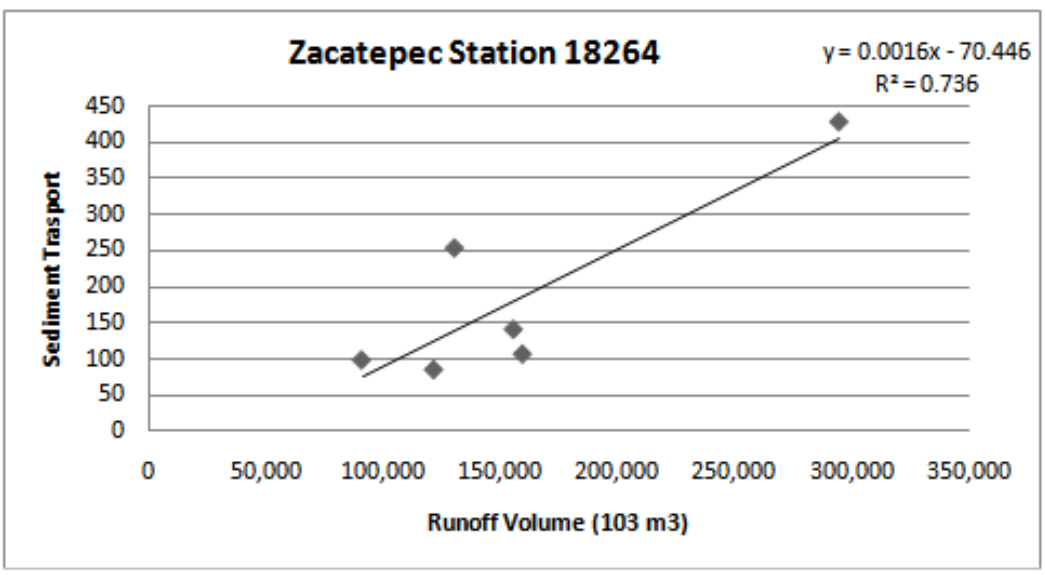


Figure 10 Runoff volume vs sediment transport, Zacatepec Station.

In Figure 6 we can see a clear correlation between the runoff and the sediment transport for the Temixco Station, possibly attributable to an important variation in the slope of the channel when being the affluent or by the variation in the land use. In this case the correlation is of 0.639. For the Tetlama Station (Figure 8) the opposite happens; the correlation is 0.89. Something similar happens to the Zacatepec Station (Figure 10), where the correlation is 0.86. Due to the important variability in the runoff at different times of the year, it was decided to investigate the behavior of the runoff and the sediment transport on a monthly basis. For the case of the Tetlama Station

there was the highest correlation at annual level. Figures 11 and 12 are graphs of the behavior of the runoff and the sediment transport in the time and with respect to the identity function, to identify these correlations.

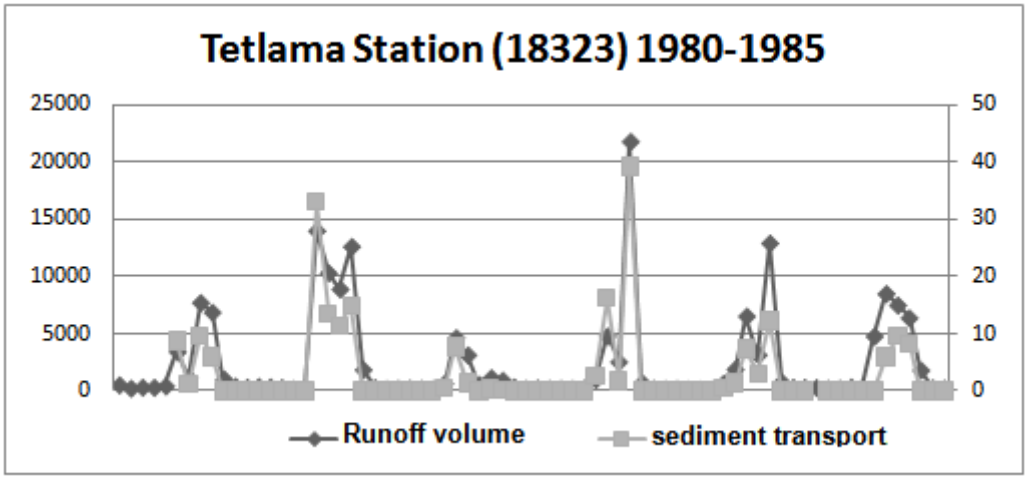


Figure 11 Runoff volume vs sediment transport, Tetlama Station, monthly Data.

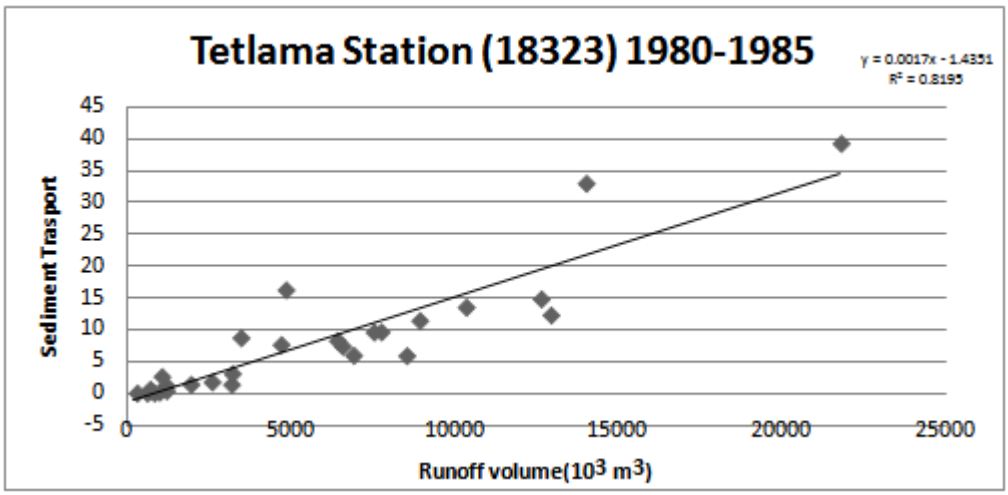


Figure 12 Runoff volume vs sediment transport, Tetlama Station, monthly Data.

When dropping the period of time to the monthly level, forts is observed correlations between the sediment transport and the runoff volume, the correlation is 0.91. For the case of the Tetlama Station, that had more information at monthly level, two models were applied, one with variation nonlinear with algebraic operators and another one with an exponential variation of the sediment transport with respect to the volume. The parameters of these models were determined using a simple genetic algorithm; the models correspond to equations 2 and 3. In Figure 13 we compare the results.

$$A = -6963.918V^{-1600.5269} - 1537.2173V^{0.9156} + 8.2340 \quad (2)$$

$$A = 183.4162e^{(-v/7738.5784)} - 233.4666e^{(-v/10000)} + 50.3555 \quad (3)$$

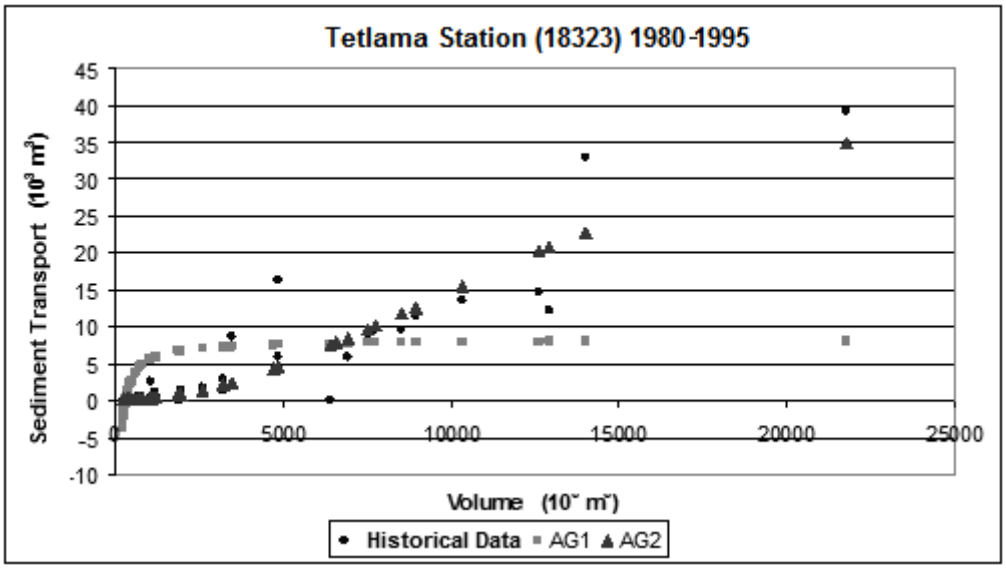


Figure 13 Comparison of measured and calculated data. Tetlama Station.

CONCLUSIONS

Due to the strong correlations it is feasible to think about models that associate runoff with the sediment transport. An alternative is the technique of evolutionary calculations, such as genetic algorithms, to consider the parameters of a proposed model or genetic programming. Both these techniques allow the obtaining of the mathematical model, for data at annual level or in periods of shorter time, like monthly data, or for grouping months according to the time of the year (low water, avenues or by stations of the year). The graphs of the runoff volume in the time and of the sediments transport in the time for the three stations, and the sum, allow us to see that the behavior of each with time is random, given the little correlation as a reason why an analysis with models for annual series of time is possible also. The application of genetic algorithms to the monthly data of the Tetlama Atation allowed obtaining a curve of exponential type that manages to consider the value of the sediment transport based on the narrow-hipped volumes. It is advisable to apply this curve to another group of measured data to verify its applicability for the case of months without information on the sediment transport.

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