Rates of Channel Migration on the Brazos River

FINAL REPORT
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October 2011

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Submitted to the Texas Water Development Board

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Project TASKS

For this project four (4) tasks were developed and agreed to by the Texas Water Development Board (TWDB) contract person and the investigators. The four tasks are:

1) Calculate rates of channel migration along selected reaches
2) Categorize channel banks for erosion occurrence/potential
3) Develop estimated sediment budget for selected reaches
4) Determine and classify behavior of channel movement

Introduction to Problem

Channel migration is a natural phenomenon presenting challenges for engineers, scientists, and managers on how to best accommodate societal needs with the structure and processes of nature. The Texas Instream Flow Program has identified the major objective concerning geomorphic processes for Texas rivers, as the "interrelationships among flows, bank stability, channel maintenance, and alluvial and associated aquifers (TFIP, 2009)".

Briefly, from our study, we can say that indicators of stability include rates of lateral channel migration and the nature of bank erosion. Lateral channel migration and bank erosion are influenced by a number of variables including land cover, hydrologic regime, bank composition and underlying geology, among others.

The fluvial system, of which the main channel is a part of, is a physical system with a memory (Schumm, 1977). This memory is represented by the template of various landforms and geologic deposits on which contemporary processes operate. By examining this memory, we examined channel movements patterns in relation to hydrologic characteristics to understand the effect of changes in hydrologic discharge regime on the rates and styles of lateral channel migration.

Rates of lateral channel migration along a 203 km reach of the middle Brazos River (Fig. 1) range from 1.09 to 13.01 meter/year from 1929 to 2010. Taking into account effects of impoundment from several large reservoirs constructed after 1951 (Table 1) upstream of the study reach migration rates average 1.09 to 5.18 meters/year since 1955.

The maximum monthly discharge and total surface discharge within the channel have the strongest correlation (R^2 = 0.55 and R^2 = 0.4397, respectively), following a second-order polynomial function. We determined the highest migration rate occurs when the total discharge was lowest; suggesting discharge is one of several factors that need to be considered in determining migration rates. Other factors shown to influence migration along the Brazos River include the presence or absence of established vegetation along the banks and the influence of groundwater, which causes saturation and failure at the river-aquifer interface and results in bank failure.

Background Studies

The migration of large alluvial rivers has received a great deal of attention in the fields of geomorphology, geology, hydrology and engineering (Dunne and Leopold, 1978). The range of work covers from the early definitions of channel-forming, or "bankfull", discharges discussed by Wolman and Leopold (1957) to complex modeling of meander characteristics for predictive purposes (Lancster and Bras, 2002; Guneralp and Rhoads, 2010) Of particular interest is understanding the processes and associated rates that lead to the formation of the numerous features and forms found in fluvial environments.

Briaud et al. (2007) presents an overview on meander migration predictions, flume tests, risk analysis and various software to address migration. Briaud et al. (2002) presents the three commonly used approaches when predicting meander migration, with specific focus on the magnitude of channel movement. These methods are 1) empirical approach, 2) time-sequence maps and extrapolation approach, and 3) a fundamental modeling approach. The first approach uses correlation equations built using observed meander data, whereas the second uses observed movement of a given meander to predict subsequent migration. The third approach relies on modeling erosion processes at the soil-water interface and making future projections using recent hydrographs.

Two general types of meanders have been proposed by Kinoshita (1961); symmetric, low amplitude meanders that migrate in a consistent pattern downstream, and high amplitude where different shifting at points along the bends creates a complex planform pattern. This relates to the importance of geometric properties, especially the radius of curvature, in understanding channel migration. Spatial lag is attributed to the development of asymmetric meanders because the migration rate is related to the curvature at a point upstream (Ferguson, 1984). Numerous workers have shown the relationship between channel migration rates and channel curvature. Early efforts by Hickon and Nanson (1975, 1984) demonstrated that a radius of curvature where $2< r_c/w < 3$ gives the maximum value of rates of migration, with decreases on either side of this limit.

The distinction should be made between channel migration and meander migration. For the purpose of this study, rates of migration were concerned with using the channel, rather than discrete meanders. Previous work on river migration along the Brazos (Gillespie, 1997) is concerned with rates of migration in discrete meanders, of which were defined by changes in inflection along the channel.

Study Area

The Brazos River has a drainage area of approximately 137,000 km^2 and a length of 2,060 kilometers. The study reach is defined from just below the last major reservoir, Lake Waco, to near the Brazos County line (Fig. 1). Three gaging stations (Waco, Highbanks, and Highway 21) along the main channel provide the hydrologic data used in this study. The southern extent of the reach was selected based on the stage-discharge relationship presented in Fig. 3. The river channel downstream of the Highway 21 gauging station is incised up to 20-30 meters with little lateral migration.

A geologic map including the middle portion of the Brazos River basin is displayed in Figure 2. The middle and lower alluvial floodplain is ~ 12.8 km wide near the Brazos County line. Horizontal layers of clay and silt overlain by overbank deposits constitute the majority of materials forming the alluvial valley (Waters, 1995). Upland areas of Eocene age confine the broad alluvial valley (Phillips, 2006).

Figure 2 displays the various geologic units within the Brazos River basin. The study reach extends from just south of the city of Waco to approximately the northern Brazos County line. It is within this reach that the Brazos River floodplain expands to its full extent within the drainage basin.

Strata striking northeast to southwest underlie the study area. Outcrops consist of indurated sedimentary layers. Several major and minor aquifers underlie the floodplain area. The Texas Board of Water Engineers (2007) describes the northern aquifers north of the Falls County line as having negligible contributions to the Brazos River base flow; whereas the region between the northern Falls County line and the city of Bryan, which encompasses the majority of the study reach, appears to have a significant contribution to the baseflow discharge.

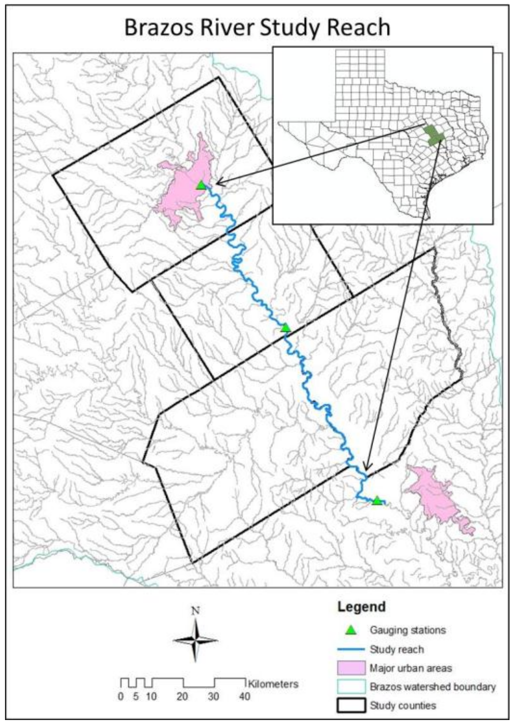

Figure 1. Map of the study reach along main channel of the Brazos River from southern Waco (Waco gaging station) to near the Brazos County line (Highbank gaging station). Total length is approximately 200 kilometers.

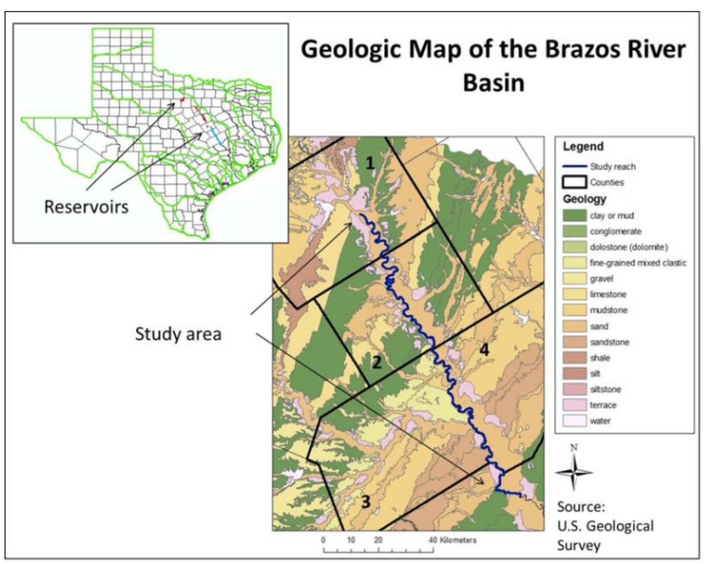

Figure 2. Brazos River basin geology. The study reach is between the city of Waco and the northern Brazos County line. The major Brazos River reservoirs are outlined in the inset. The inset numbers represent counties; 1) McLennan, 2) Falls, 3) Milam & 4) Robertson.

<u>Task 1 - Calculate rates of channel migration along selected reaches</u>

The following is a succinct summary for Task 1.

Task 1:
1) Calculate rates of meander migration along selected reaches of the Brazos River and correlate values to varying discharges. Determine mechanism of channel migration for temporal intervals (i.e., 1950s, 1960s, etc).

Results for Task 1:
The rates of lateral channel migration for entire time period (1929-2010) average 1.09-13.01 meters/year. Rates of lateral channel migration after completion of reservoirs average 1.09-4.6 meters/year.

Methods Employed to Accomplish Task 1

The major data components utilized in this study include vertical aerial photographs, planimetric maps, regional geologic and hydrogeologic data, digital elevation models (DEMs), hydrologic data from surface gauging stations, and field surveys. These data were integrated into a Geographic Information System (GIS) for compilation and analysis. This is a common data processing procedure used in a number of river morphology studies (Shields, 2000; Buckingham, 2007; Rhoades, 2009).

Hydrology

The majority of hydrologic analysis data was based on data from the Waco gauging station. It was selected because it covered the entire time period (1929-2010) for the study area. Because hydrologic records have been kept since 1898, covering the entire time period under investigation, the collection of data from the Waco gaging station was utilized. The Highbank gaging station is located at the entrance of a major tributary along the main river channel.

A second gaging station located at the bridge crossing of Highway 21 was used to represent the southern extent of the study reach.

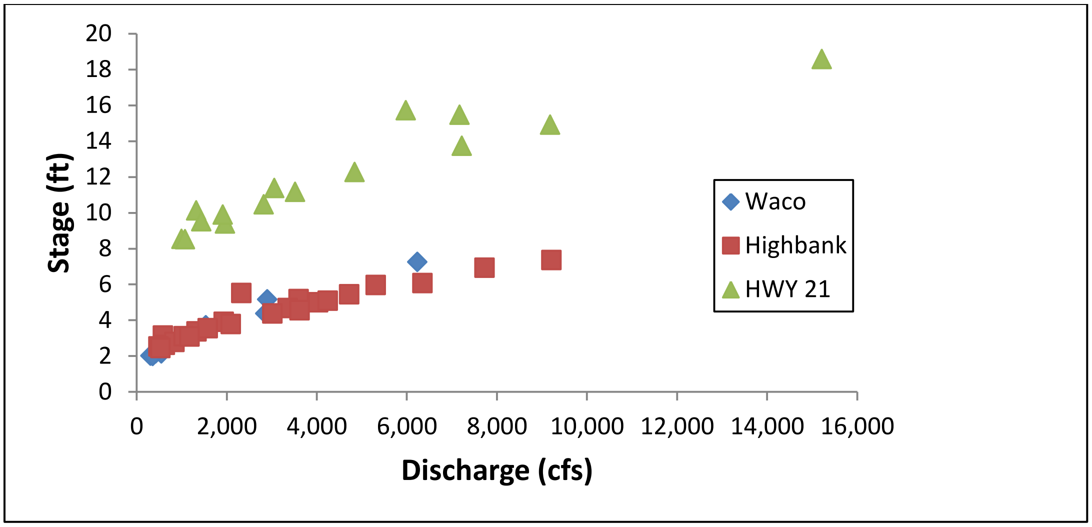

Figure 3. Brazos river incision increases downstream. The Waco gaging station is at the upper portion of the study reach. The Highbank gaging station is approximate midpoint of the study reach, while the Highway 21 gaging station is a short distance downstream of the southern extent of the study reach.

Figure 3 shows a threefold increase in stage with an equivalent discharge between the two upstream gauge stations, Waco and Highbank, and the downstream gauge, Highway 21 gauge. Deepening of the main river channel at the Brazos County line increases the stage height for an equivalent discharge. The Highway 21 forms the southern limit of the study reach. The amount of channel migration differs between the study and subsequent downstream reaches. Migration is neither as frequent nor as high downstream of the Highway 21 gaging station. Because of the relatively homogenous composition of the Brazos floodplain within the study reach changes in channel geometry most often occur lateral, or across valley, rather than vertical incision or accretion.

Surface hydrologic data gathered from the Waco gaging station along the main Brazos River channel were analyzed to determine discharge patterns affecting channel migration. Important flows incorporated into our evaluation of migration-discharge include the yearly maximum, mean and total channel discharge. These flow variables describe the hydrologic characteristics of the river channel for each particular time period. All hydrologic values are presented in units of cubic meter per second (cms). Figure 4 displays changes in the overall channel discharge from 1910 to 2010. The pre-reservoir period, 1910-1950, shows greater discharge than the post-reservoir, 1950-2010, period.

Several major reservoirs (Table 1), including Possum Kingdom (1941), Lake Whitney (1951), Lake Granbury (1969) and Waco Lake (1965) constructed along the Brazos River significantly alter the overall hydrologic regime of the river and affect channel response to discharge. Channel discharge at the Waco gaging station averaged 75 cms/month prior to 1950 and 61 cms/month after 1950. Figures 4 and 5 display changes in the mean and total discharge for 10-year increments at the Waco gaging station with significant decrease of 0.4 cms/month in discharge after 1950. It is apparent there is a change in overall hydrology pre- and post-1950. The discharge has a relatively uniform flow pre-1950 but post-1950 there is high fluctuation in the values. The pattern for discharge between the average and total is nearly identical.

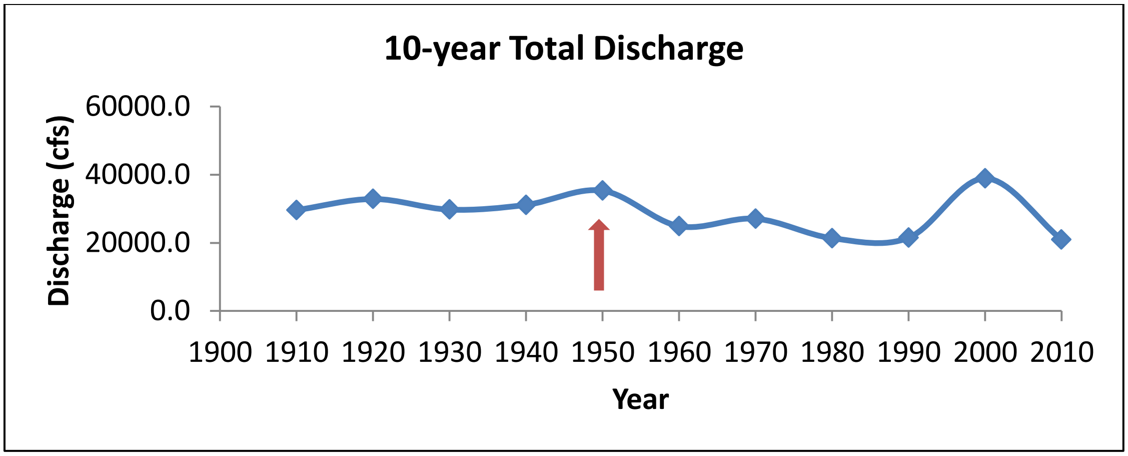

Figure 4. Total discharge at the Waco gaging station for ten year intervals. Discharge has a marked decrease after 1949. The red arrow points to the first data point after the completion of several large reservoirs on the upper portions of the Brazos River.

Table 1 presents the dates of major impoundments and the storage in acre-feet. The most significant reservoirs are Possum Kingdom (1941) and Whitney (1951). These reservoirs are used to divide the study into pre- and post-reservoir construction. Possum Kingdom has the largest storage at 750,000 acre-ft, with Whitney having significant storage at 380,000 acre-ft.

Table 1. Major reservoirs constructed upstream of the study reach.

Reservoir	Impoundment date	Approximate Storage (cu. m)
Possum Kingdom	1941	92,511,000 acre-feet
Whitney	1951	46,872,240 acre-feet
Waco	1965	9,744,492 acre-feet
Granbury	1969	16,898,676 acre-feet

Channel Migration

Methods for measuring channel migration are well documented in the scientific literature (Shields, 2000; Urban and Rhoads, 2004). Typically, aerial photography, satellite imagery, topographic maps and other planimetric data are integrated into a GIS for measurement and analysis. This present study is based primarily on aerial photography, including black and white, color, and false-color images to analyze channel movement. Including all sources of data, the channel coverage dates are 1929, 1941, 1951, 1955, 1958, 1960, 1965, 1968, 1972, 1974, 1978, 1982, 1988, 1993, 1995, 2004, 2008, and 2010, respectively. The data for all channel coverages preceding 1995 are not continuous along the study reach, but rather cover portions of the study reach throughout the counties of McLennan, Falls, Milam and Robertson. The coverage dates of 1995, 2004, 2005 and 2008 are continuous along the entire study reach. The southern two counties, Milam and Robertson, share the Brazos River as the county border.

Additional data sources were used, including topographic maps, engineering survey maps, and digital elevation models. Survey maps produced by the Texas State Reclamation Department dating from the late 1920s were obtained from the Texas General Land Office. United State Geological Survey topographic maps dated from 1978 were used for channel locations for Falls County only to provide an additional time period between 1968 and 1995.

Measurements were made for 1968-1978, 1978-1995, and 1968-1995 to eliminate any spatial error from topographic maps.

Historic and contemporary aerial photographs, including the years 1941, 1951, 1955, 1958, 1960, 1965, 1968, 1972, 1974, 1982, 1988, 1993, 1995, 2004, 2008, and 2010, form the majority of channel migration values presented in this work; scales range from 1:20,000 to 1:60,000. The river channel positions were digitized using editing tools available in the ArcGIS® software. A scale of 1:4,000 was used to digitize channel features. This scale provides sufficient spatial separation between terrestrial and aquatic areas. The majority of images are black-and-white photographs held by the US Department of Agriculture Farm Service Agency and the National Agricultural Imagery Program for recent images.

All pre-1996 aerial photographs lacked spatial coordinates and had to be georeferenced in the GIS. In total, 419 separate aerial photographs were georeferenced using ArcGIS® software. In addition, the Texas GLO reclamation maps were georeferenced by converting the lat-long coordinate system into Universal Transverse Mercator (UTM) system.

Georeferencing images require both a transformation and resampling of the pixel data. Hughes (2006) recommends using a second-order polynomial transformation for orthorectification and a cubic convolution for pixel resampling. The transformation of a second-order quadratic applies a least-squares function between the ground control points (GCP) selected on the image and the coordinates present on the base image. The 2004 Natianal Agricultural Imagery Program (NAIP) provided the base layer for ground control point (GCP) selection.

Ground control points are assigned to locations in the unregistered photograph to known locations on the georegistered photograph .The imagery is in false-color format whereby areas of heavy vegetation have a more intense red hue and water shows especially dark as compared to the surrounding landscape. These data are especially useful for delineating different geometries such as bank boundaries. The spatial resolution for all aerial photographs range between 1 and 3 meters. *Time frame* refers to an individual photograph year, i.e., 1974; whereas *time period* refers to an interval between photograph years, i.e., 1968-1974, from which migration was measured.

The methodology for measuring total channel migration between years is similar to that presented in Hughes (2006) and Shields (2000). Channel boundaries were manually digitized using the editing tools available in ArcGIS®. Bank lines were drawn between the edge of vegetation and the exposed channel bank during high/low water periods (Richard et al., 2005). In locations where the water level was lower than expected, usually along large, sandy point bars, the channel boundary was delineated as the interface between established vegetation and dominantly sandy areas. Where tree crowns overhang banks the bankline was drawn through the crown center (Winterbottom, 2000). The separate left and right bankline shapefiles were merged into a single shapefile; a centerline for each time frame was calculated using automatic tools in ArcGIS®. The resultant centerline shapefile was adjusted for errant channel center locations that may have been generated from the merged banklines shapefile. The centerlines for respective years were overlayed and 'migration' polygons were generated between adjacent and sequential centerlines.

The respective total area of a migration polygon was divided by half the perimeter of that polygon, or the length of the migration polygon centerline (Fig. 5). Values below four meters of migration were eliminated because of potential spatial error in both the georeferencing of images and manual digitizing.

The migration rate was calculated using the following equation:

$$R_m = \frac{A}{L} / y \qquad (1)$$

where: R_m is the migration rate; A is the area of the polygon; L is the length of centerline Time 1 for each polygon; and y is the number of years between sequential channel centerlines.

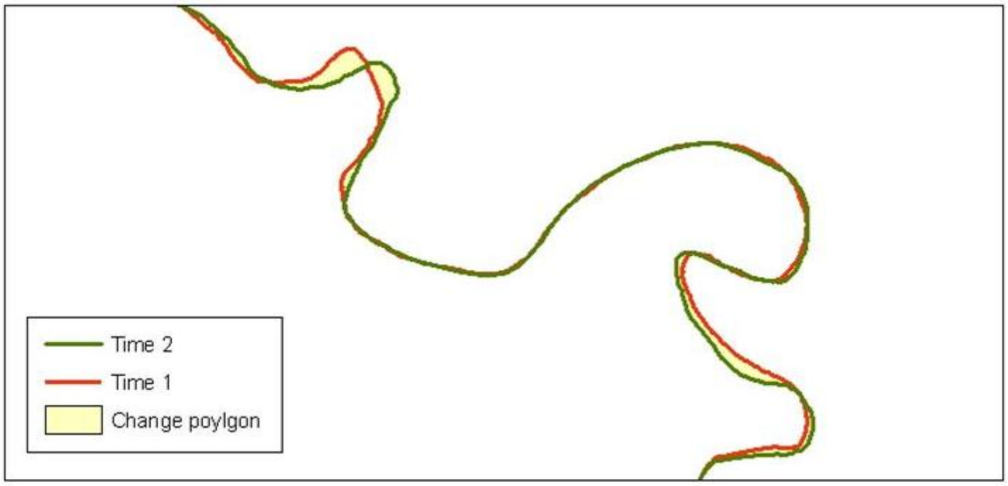

Figure 5. Method for measuring channel migration amounts. Time 1 and Time 2 lines represent channel centerlines for a particular year.

A migration value represents the average for a particular migration polygon and takes into account both narrowing and widening of the migration polygon. The extreme values, both high and low, for each individual polygon are not represented. It is important to note that this has the effect of smoothing the data. The migration value measured along a particular bend during a time period describes neither the smallest nor the largest amount of migration at that location, but rather the average migration for the lateral movement polygon.

To assess pre- and post-reservoir effects on channel migration and channel width an alternate migration method was employed for the entire study reach (Fig. 6). We used the method used by Leopold (1973) and others (Gurnell, 1994) to analyze the 1929, 1950s, and 2004 planimetric data.

The method involves delineating a series of transects perpendicular to the river floodplain and measuring the distance between the points of intersection between the channel centerline and transect for subsequent time frames. We generated 180 migration values for the 1929 to 1950s and the 1950s to 2004 datasets, respectively. The migration distance for pre- and post-reservoir time periods was calculated using the following equation:

$$D_m = T_1 - T_2 \qquad (2)$$

Where: D_m is the distance the channel migrated, and T_1 and T_2 are the time periods of subsequent channel migration.

Time periods between the 1950s and 2004, i.e., 1972, 1988, etc., were not used in the analysis of channel migration differences between the major pre- and post-reservoir construction time periods. Transects were placed one kilometer apart. This method eliminates bias in selecting migration locations, but features of particular interest, such as avulsions or abrupt changes in a small area, may not be recorded.

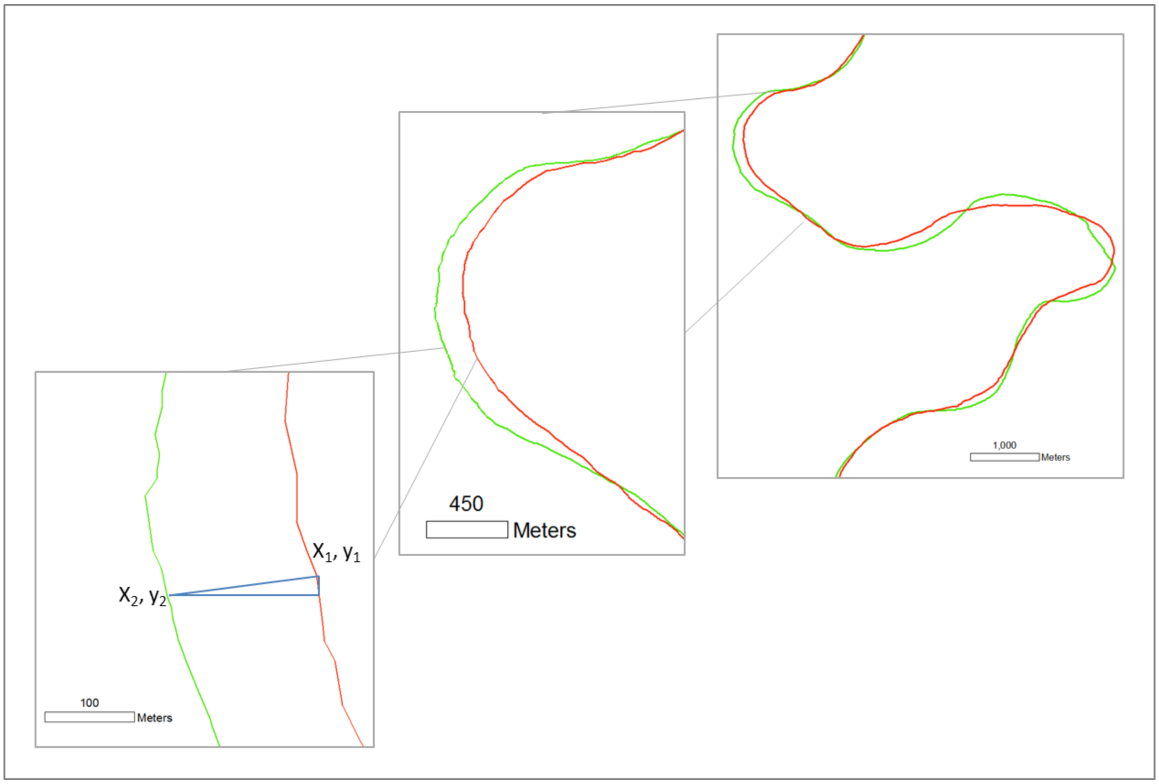

Figure 6. Secondary method for measuring channel migration used to determine pre- and post-reservoir magnitude and rate of migration. Red line represents channel position pre-reservoir, while the green line represents the channel position post-reservoir.

The geospatial coordinates for the inflection point along the meander bend were captured for each time period. Using the right triangle we could quickly determine the distance between subsequent inflection points. The following formula calculates the distance between inflection points:

$$D_t = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2]} \qquad (3)$$

Where: D_t is the distance between inflection points; x_1, y_1 are the coordinates of the earlier time period; and x_2, y_2 are the coordinates of the later time period. The initial values are kept positive to give a magnitude of migration. This method for calculating these pre- and post-reservoir values is displayed in Fig. 6.

Geospatial Error

There is an inherent amount of spatial error within the measures of channel movement using the two methods. If total migration from one temporal period to the next was less than four meters, the measurement was not included in the analysis. Average geospatial error and the number of frames georeferenced are presented in Table 2. In addition, data values less than 12 meters generated from the Texas GLO 1929, and the topographic map data were not considered in this analysis because these values are below the spatial resolution of the maps. This step was undertaken to eliminate error present within those data sources.

Table 2. Planform data, including aerial photographs and maps, used in this study. Average geospatial error values for determining migration.

Time period	# of frames	Average spatial error (m)	Transformation
Texas GLO 1929	10	1.59	2nd order
McLennan 1958	24	3.16	2nd order
McLennan 1972	8	2.62	2nd order
McLennan 1982	30	2.68	2nd order
McLennan 1988	15	2.82	2nd order
McLennan 1993	14	2.82	2nd order
Falls 1955	48	3.18	2nd order
Falls 1960	45	2.88	2nd order
Falls 1968	65	2.96	2nd order
Milam/Robertson 1941	30	2.98	2nd order
Milam/Robertson 1951	28	2.76	2nd order
Milam/Robertson 1958	44	2.95	2nd order
Milam/Robertson 1965	27	2.50	2nd order
Milam/Robertson 1974	18	3.91	2nd order
All counties 1995*	39	2.00	2nd order
All counties 2004*	39	1.00	2nd order
All counties 2008*	39	1.00	2nd order
All counties 2010*	39	1.00	2nd order

*** Previously georeferenced by National Agricultural Imagery Program**

Appendix B lists individual frames used in the analysis, along with the spatial root mean square error, number of ground control points used in rectifying the photograph and order of transformation. The hydrologic regime of the Brazos River is highly variable, particularly across the decades (1929-2010) encompassing the study time period. Figures 9 and 10 display the total annual, average, and median discharge patterns from 1900 through the summer of 2010.

Results for Task 1

The results are presented in the following categories: hydrology, channel migration, and pre/post reservoir channel changes.

Hydrology

The discharge values presented in Fig. 8 correspond to the total annual values to the total annual discharge (Fig. 7). The trend for individual yearly flows can be seen in both graphs. Prior to 1950 channel discharge often averaged from 37 cms to 127 cms. After 1950 discharge averaged from 34 cms to 85 cms, representing the change in hydrologic regime impacted by the construction of large reservoirs. Major drought occurred in the 1950s (Reynolds, 1999), accounting for the unusually low discharge values. For example, one can see a decrease of 11 cms in the discharge.

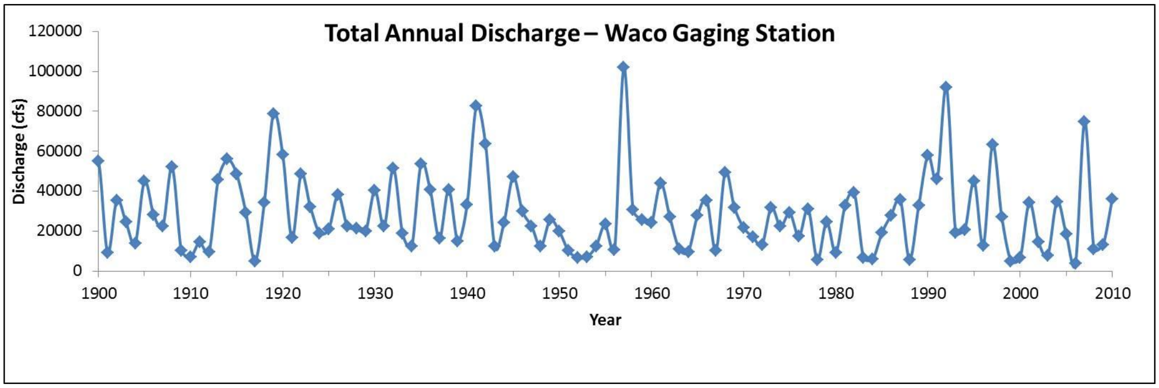

Figure 7. Total sum discharge at the Waco gaging station from 1900 through 2010. Notice range of flow values prior to 1949, as compared to subsequent years.

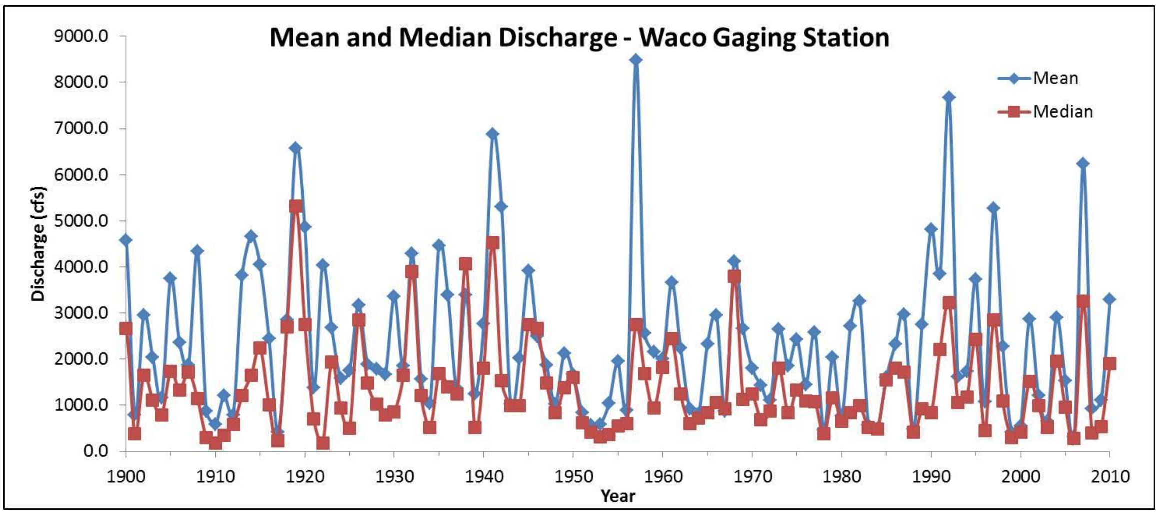

Figure 8. Mean and median yearly discharges at the Waco gaging station. Note difference in vertical scale as compared to total annual discharge.

Channel Migration

The lateral migration distances and rates of migration were divided by the number of years between sequential migration centerlines, or photograph coverage dates. Table 3 displays mean and median migration rates for the 21 time periods measured. Average rates of lateral migration range from 1.09 to 11.53 (m/yr), and median rates range from 0.69 to 12.3 4 (m/yr) for the years 1929-2010.

Values of particular interest in those measured are the GLO 1929 data representing migration rates from 6.64 to 11.53 (m/yr), respectively. These data represent channel positions prior to major flow regulation on the Brazos River and show the large variation in migration rates. These migration values are subsequently higher by 5.55 to 8.83 meters than those of other time periods. Overall, average migration rates range from greater than 1.0 (m/yr) to slightly greater than 11 (m/yr). Standard deviations are high in some time periods representing great spread among the migration values within those time periods. From this analysis we suggest migration rates were highest on the Middle Brazos River prior to construction of the major reservoirs upstream.

It is important to understand that although the migration periods are listed by county, many of the channel lengths overlaps into adjacent counties. Also, the migration rate from 1968-1995 is lower than both migration rates from 1968-1978 and 1978-1995, which represent data from topographic maps. We suggest this discrepancy may be the results of variability in the topographic spatial reference and difficulty in identifying the correct channel boundary on the topographic map. Nevertheless, the data are useful for approximating trends.

A large variation in migration rates for each county (Fig. 11) exists. The ranges observed in the rates of lateral migration are quite large with values ranging from ~ 2 m/yr to 50 m/yr. The range in rates is greatest for early time periods (i.e., 1929-1958) and the 2008-2010 time period for McLennan and Falls Counties. The 2008-2010 maximum includes three meander bends experiencing avulsion (Fig. 9).

Table 3. Time periods and measured channel migration values.

County	Time period	Channel length (km)	# of migration points (n)	Mean migration rate (m/yr)	Median migration rate (m/yr)	Standard deviation
McLennan	1929-1958	34.5	17	6.64	6.14	3.14
	1958-1972	37.1	43	2.05	0.93	2.25
	1972-1982	34.1	35	1.60	1.44	1.25
	1982-1988	35.1	46	2.13	1.61	1.82
	1988-1993	35.9	51	2.58	1.99	2.22
	1993-1995	38.5	46	5.25	3.72	4.26
Falls	1929-1955	77.1	34	7.23	6.4	4.95
	1955-1960	77.3	69	5.18	4.02	4.03
	1960-1968	75.3	70	3.46	2.22	3.67
	1968-1978*	19.0	13	2.82	2.41	1.37
	1978*-1995	26.4	19	1.29	1.23	0.6
	1968-1995	78.42	69	1.09	0.92	0.88
Milam/Robertson**	1929-1941	76.4	29	11.53	10.39	7.12
	1941-1951	54.9	63	3.15	1.45	4.15
	1951-1958	63.6	74	2.47	1.59	2.4
	1958-1965	83.1	89	2.55	1.4	2.67
	1965-1974	55.8	39	3.08	1.85	3.02
	1974-1995	59.8	48	1.55	1.14	1.42
All counties	1995-2004	197.2	229	1.11	0.69	1.01
	2004-2008	185.2	208	2.12	1.51	1.72
	2008-2010	186.4	102	4.6	2.91	4.22

***Migration measurements based on values obtained from topographic maps for the years 1968-1978 and 1978-1995.**
**** Milam & Robertson counties share the Brazos River as an eastern/western border.**

The migration values for the individual counties should be compared to the geology presented in Fig. 1. The northeast to southwest trend of the bedrock, combined with lithology, may affect the differences in migration occurring among the counties. McLennan and Falls County consist predominantly of clay, conglomerate and mudstone lithologies; whereas Milam/Robertson Counties consists of shales and sandstones. This difference in lithology may explain some of the range in migration values.

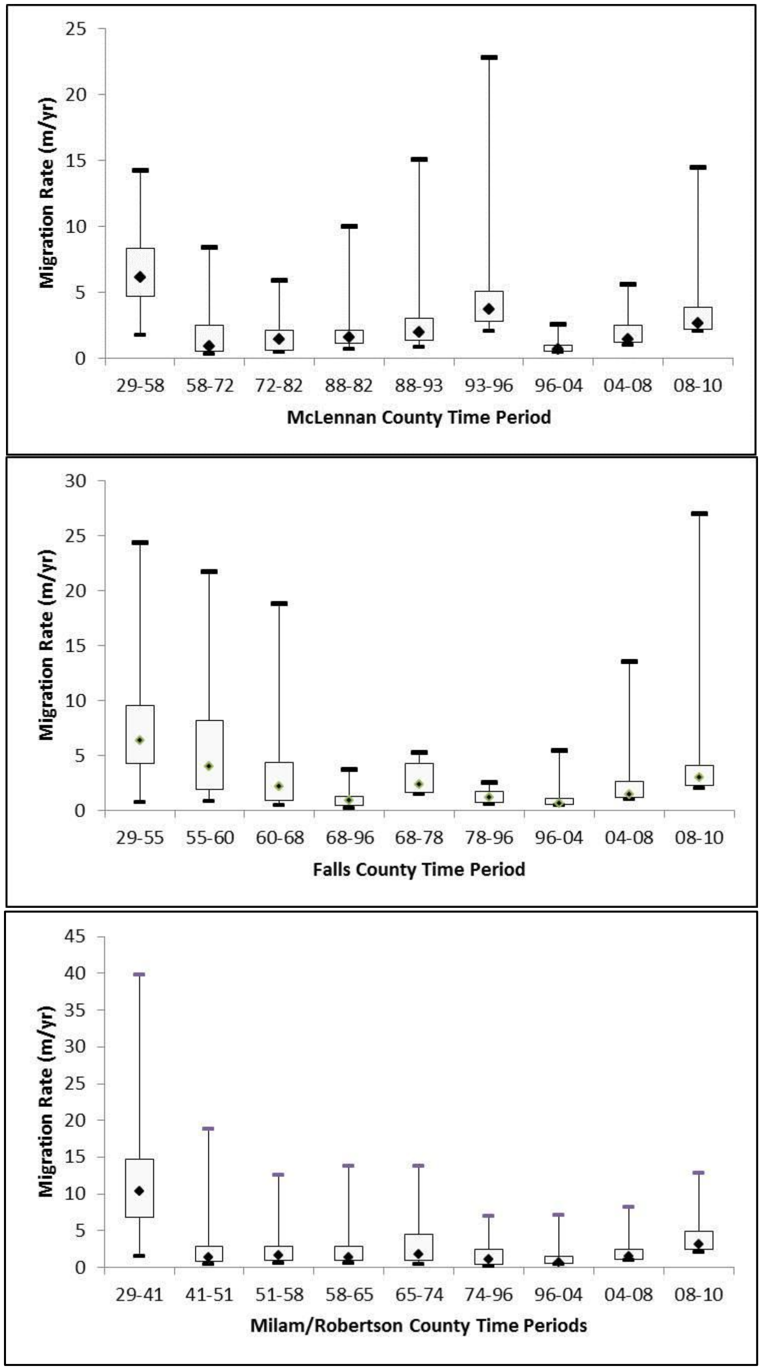

Figure 9. Migration rates for each county. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

Table 4 summarizes the mean, monthly, maximum, total and mean yearly discharge values for each time period, which in turn represents channel migration between sequential digitized channel lines. Monthly discharge values are relatively consistent with values ranging between 28 cms to slightly greater than 85 cms.

Maximum yearly Q represents the maximum discharge experienced by a particular year within the time period (i.e., 1995-2004). A greater range in the value than mean monthly discharge with lows near 283 cms and highs around 1,048 cms is seen in the data. Total discharge for a given time period represents the highest range between any particular flow measure with values ranging from ~1,698 cms to greater than 25,470 cms.

The average yearly discharges for a particular time period are presented (Table 3). The range for these values is relatively small, considering the difference in the number of years within each time period. Lows range in the low 566 cms with the high in the low 1,132 cms. Thus, the average yearly discharge maintains a relatively constant value, despite differences in the extreme high and low discharges among time periods.

Discharge values are often correlated with an average migration rate with discharge as one factor in explaining migration rates (Winterbottom, 2000; Hooke, 2008). To better understand the effect of different flow values on the range of migration rates within a particular time period, we utilized boxplots similar to other fluvial studies (O'Connor, 2003; Richardson, 2010). O'Conner (2003) compared channel migration rates and channel widths for three separate rivers in the Pacific Northwest whereas Richardson (2010) presents a similar approach using width/swath (active channel divided by floodplain distance) and active channel values from 1949-2007 for a New Zealand river. Thus, boxplots are an efficient way to present the range of migration values for each time period.

Figure 10 represents the range of migration rates for each time period categorized by their representative discharge measure. Figure 10 shows the range of migration rates in relation to both increasing average monthly discharge and average yearly discharge.

Table 4. Time periods for discharge values used to characterize surface hydrology for the study reach. Presented are the average monthly, maximum monthly, total sum and average yearly discharges.

Time interval	Mean monthly Q (cms)	Maximum monthly Q (cms)	Effective erosion Q_a	Total Q (cms)	Mean yearly Q (cms)	Effective erosion Q_b
1929-1958	71	1,051	-76	25,684	856	-271
1958-1972	60	434	-693	10,733	716	-411
1972-1982	55	351	-776	7,240	658	-469
1982-1988	47	390	-737	3,964	566	-561
1988-1993	100	807	-320	7,183	1197	70
1993-1995	67	282	-845	2,406	802	-325
1929-1955	67	636	-491	21,631	801	-326
1955-1960	85	1,051	-76	6,127	1021	-106
1960-1968	63	434	-693	6,760	751	-376
1968-1978	58	418	-709	7,654	696	-431
1978-1995	69	807	-320	14,880	827	-300
1968-1995	67	807	-320	22,375	799	-328
1929-1941	81	626	-501	12,650	973	-154
1941-1951	75	636	-491	9,905	900	-227
1951-1958	60	1,051	-76	5,750	719	-408
1958-1965	59	434	-693	5,665	708	-419
1965-1974	62	434	-693	7,384	738	-389
1974-1995	67	807	-320	17,704	805	-322
1995-2004	59	482	-645	7,110	711	-416
2004-2008	67	750	-377	4,041	808	-319
2008-2010	50	239	-888	1,710	570	-557

a: This column represents the effective erosion discharge from the maximum monthly discharge.
b: This column represents the effective erosion discharge from the mean yearly discharge.

Migration rates in relation to increasing total discharge for the time periods are presented in Fig. 11. The rates show moderately large ranges in migration (<5 - >20 m/yr) with lower discharge and very large ranges in lateral migration rates (<5 - >45 m/yr) near the highest total discharges within a time period. The time periods with the largest range in migration values, which are generally those in the pre-dam period, also have nearly the highest total time-period discharge with values ranging from ~9,905 to ~25,470 total cms. In general, as the number of years increases for a given time period, the range of migration rates also increases. Thus, the greater total discharge and longer time provide increase the probability the river channel may avulse or erode its banks rapidly.

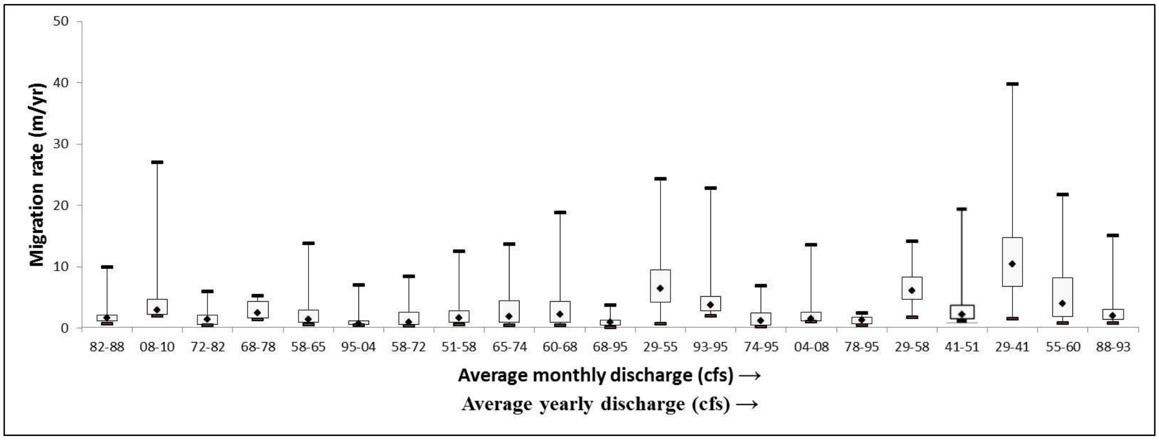

Figure 10. Boxplot of migration rates as average monthly and average yearly discharge increase at the Waco gauging station. Intervals along x-axis represent year time periods, i.e., 1982-1988, etc. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

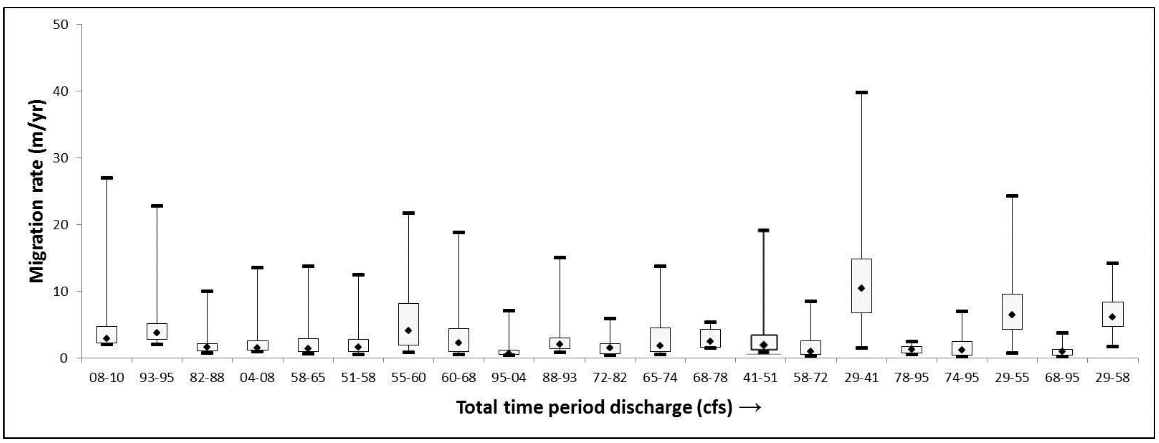

Figure 11. Boxplot of migration rates as the total discharge for a time period increases. Intervals along x-axis represent year time periods, i.e., 2008-2010. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

We related the average rates of lateral channel migration to the four discharge variables from Table 3, and these are shown in Fig. 12 (a-d). Poor correlations of R^2 = 0.1392 and R^2 = 0.0189, exist for Fig. 12a and 12b, of the influence of average monthly discharge and average yearly discharge, respectively. Some generalized trends, appropriate to the scale at which the variables were measured, are apparent in Fig. 12c and 12d. The relationship between migration rates and maximum monthly discharge (Fig. 12c) is correlated at R^2 = 0.5494, whereas the migration rate versus total discharge within a time period is correlated at R^2 = 0.4397. These figures omit migration values obtained from the 1929 datasets. From these values we suggest the maximum monthly and total discharge have the greatest effect on rates of lateral migration.

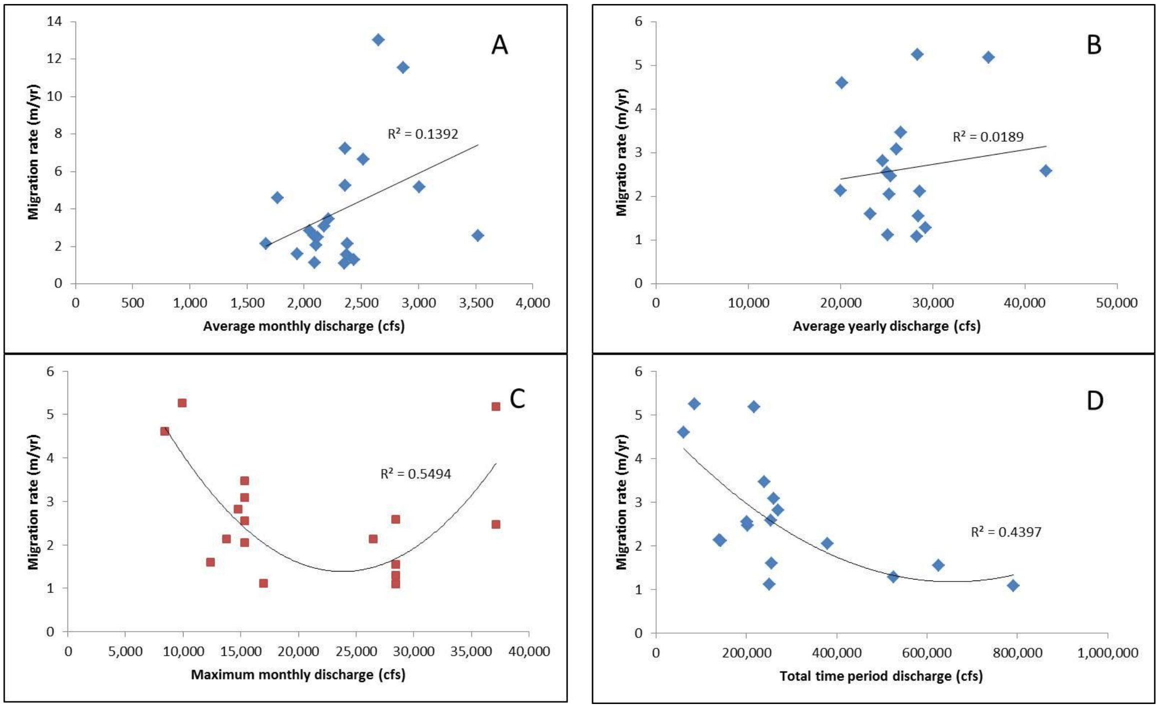

Figure 12. Relationships between rates of lateral channel migration and a) average monthly discharge; b) average yearly discharge; c) maximum monthly discharge; and d) total time period discharge.

Figure 12b relates the average monthly discharge to average migration rates. The data cluster towards the middle of the graph with most values falling below 4 m/yr and between 51 and 71 cms.

Figure 12b displays average yearly discharge, within a time period, to average migration rate. More spread is apparent among the data points, but they continue to cluster within the same ranges as the above graph. We suggest that the average yearly discharge has a greater effect on migration rates versus the variation in average monthly flows.

Figures 12c and d present average migration rates as a function of maximum monthly discharge and total time period discharge, respectively. In Fig. 12c, the values cluster around ~340 -453 cms and 736-821 cms. As seen in Fig. 12d, migration rates follow a first-order polynomial trend with decreasing migration rates as the total discharge within a time period decreases. The trend has a poor correlation with an R^2 = 0.4397. But, it is important to understand it explains the variations of channel migration values better than other discharge characteristics.

It was suggested to analyze the migration data using the effective erosion discharge, which represents the average discharge (monthly, yearly, decadal, etc.) minus the critical discharge (defined as the main channel forming discharge). This was attempted but because only one gauging station, the Waco station, was used in this work and we are only concerned with the Brazos River, the results were the same as using the standard discharge.

Pre- and Post-Reservoir Changes

The second migration method (Leopold, 1973; Gurnell, 1994) was used to examine migration rates for pre- and post-reservoir construction periods (Figures 13 and 14). It Analysis of segmented photographs show that impoundment of the upstream reach of the Brazos River has decreased channel migration (Fig. 13) by ~ 200-300 meters and the width of the channel by 100-200 meters in some localities (Fig. 14). The amount of migration is based on the period 1929-1950s and the period 1950s-2004, whereas channel width is for both the period 1950s and the year 2004.

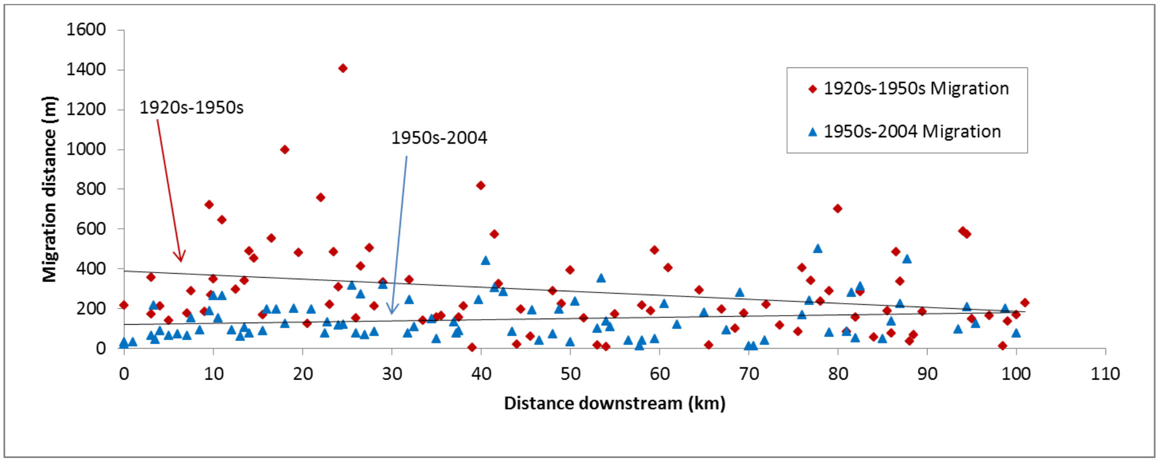

Figure 13. Migration amounts for pre (1929-1950s) and post (1950s-2004) reservoir time periods. A marked decrease in migration is observed between the pre and post reservoir time periods. The pre reservoir migration values are overall higher than the pre time period. Also, the trend is to decrease in migration distance moving downstream. The linear trendline shows an overall decrease in channel migration for the post reservoir with the values relatively constant. The beginning location is at State Highway 77 in southeastern Waco, Texas.

The largest changes in both amount of migration and width of the channel are in the upstream reaches where the channel is most sinuous. The trendline for pre reservoir migration shows values decreasing in the downstream direction, but still overall higher than those of the post reservoir period. After completion of the reservoir, the values of migration-distance values range from 50 to ~1,500 meters, whereas channel width ranges from ~30 to 1,200 meters. After several decades of impoundment, migration distances reaches 500 meters maximum, and channel width is generally less than 250 meters. These values are important to understand the impact that reservoirs have had on the Brazos River.

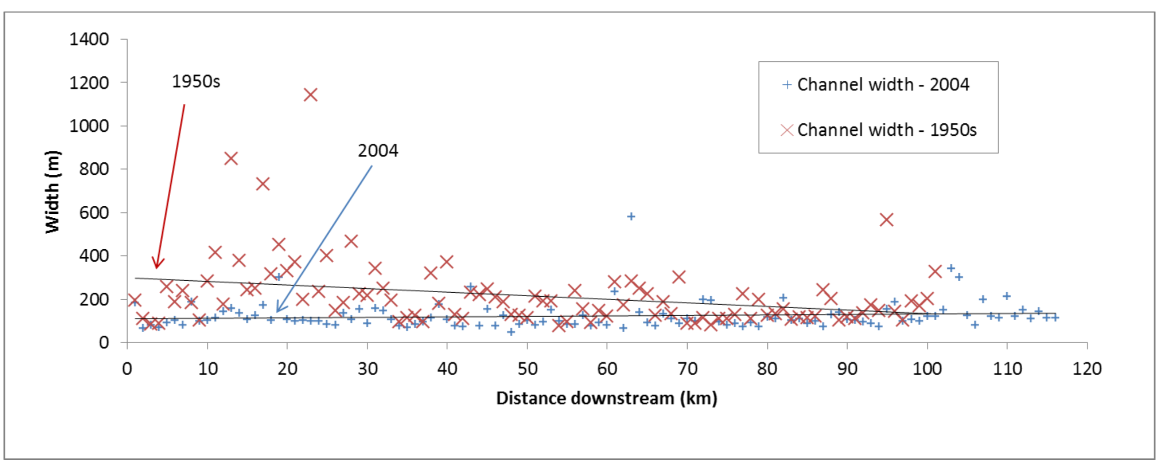

Figure 14. Channel width for pre (1929-1950s) and post (1950s-2004) reservoir time periods. A marked decrease in channel width is observed between the pre and post reservoir time periods.

The trendline for the 1950s shows a steady decrease in channel width moving downstream but the overall values are higher than those of the 2004 channel widths, which show a slight increase in channel width moving downstream. The distance downstream is measured from the State Highway 77 bridge in southeastern Waco, Texas.

Analysis and Interpretation for Task 1

The analysis and interpretation are presented in the following categories: meander and channel migration.

Meander and Bend Migration

Gillespie and Giardino (1997) looked at migration characteristics along a longer reach and found poor correlations with independent variables affecting migration rates. Migration amounts, and subsequent rates, decreased markedly after construction of the last major reservoir (Fig. 13). Gillespie and Giardino (1997) also showed that the relatively homogenous material of the Brazos floodplain allows one to assume a constant effect of material type on the bank stability. If this variable was neglected, a direct correlation between lateral migration rates and surface discharge at the scales explored in this study would not exist.

Migration rates for the study reach in the present study are representative of those observed in the middle section of other alluvial rivers (Lawler, 1992). The middle section, termed the sediment transfer zone (Schumm, 1977), has the combination of slope, floodplain material and morphology, and discharge to provide higher stream power relative to upstream or downstream reaches. The concept of high stream power in the middle section helps to explain why rates of migration along this section are greater than those in the deltaic portion of the river (Phillips, 2006).

The clustering of migration rates (Fig. 12c) detailing maximum monthly discharge may represent the "average" flow conditions in those reaches. The high end values may represent extreme hydrologic events where much geomorphic work takes place.

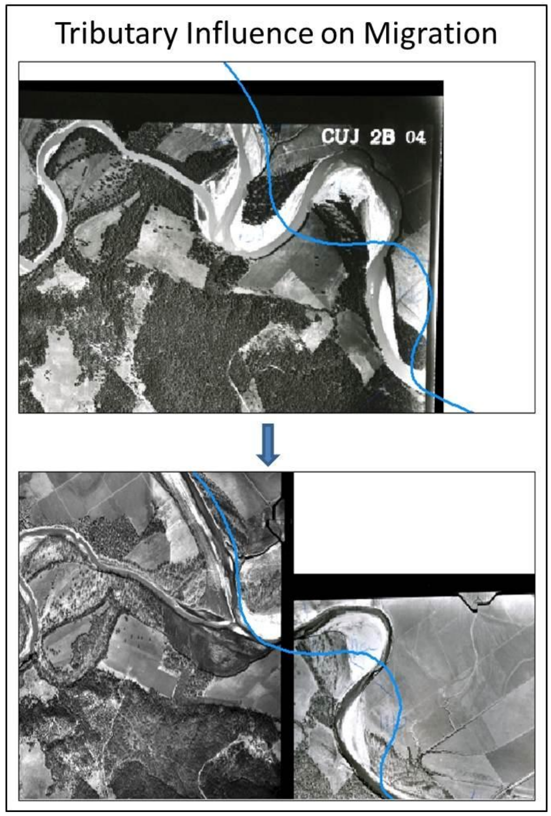

Figure 15. Example of tributary effect on lateral migration with large change in channel postion (>20 m) during a ten year period. Top photo is dated 1941 and bottm is 1951. The blue line in both photographs represents represents the 2004 channel position. Location is central Milam and Robertson counties. Scale is 1:24,000.

Several tributaries enter the study reach in this area may impact the style and rate of channel migration (Asahi, 2003). These tributaries transport a significant volume of water and sediment to the main Brazos channel and have an impact on the style and nature of migration in the Brazos Valley. For example (Fig. 15), several channel locations in Milam and Robertson counties have experienced significant migration (> 10 meters) during the 1941-1951 time period. Though 1941 had a high discharge (Fig. 7), the ten year period does not have an abnormally high rate for the number of years within the time period (Table 3). In addition, the tributary seen in Fig. 15 may have contributed to the avulsion of the main channel that can be seen in the confluence of the lower photograph.

The main focus of this study was to calculate rates of lateral channel migration along the Middle Brazos River and to understand the effect of surface discharge variations on this migration. Rates of lateral migration from the late 1920s to 2010 were found to range from ~ 1 m/yr to ~ 50 m/yr.

Lateral migration rates have been calculated for several time periods covering the entire study reach. In general, migration rates are at the high end for alluvial river migration. Knighton (1998) has shown that generally the larger the drainage basin, and the longer the period of measurement, the higher the migration rate, values generally range from nearly zero to ten meters of lateral migration a year. The Middle Brazos River follows this trend with migration values across the study reach ranging from 1.0 to ~11.0 meters/yr.

<u>Task 2 - Categorize channel banks for erosion occurrence/potential</u>

The following is a succinct summary for Task 2.

> Task 2
> 2) Categorize channel banks for erosion occurrence/potential by examining hydrologic shear stress, and associated flow, along banks.
>
> Results for Task 2:
> Previous studies have shown the Brazos River exhibits uniform erosion potential along the main banks. The majority of the channel is comprised of a silt/sand mixture susceptible to erosion. Large meander bends with a radius of curvature (r_c/w) between 2 and 3 experienced the most frequent and highest erosion (> 10 meters per 20 years) during the study period. This erosion occurs along the outer channel bank on the downstream half of the meander bend.

Methods Employed to Accomplish Task 2

The results are presented in the following categories: field surveys.

Field Surveys

Field sites were selected to observe meander characteristics (Fig. 16). Data collected at these sites include bank heights for the outer (cut) bank, photographs of bank conditions and geometry, and tree cores for dating of scroll bar sequences. The tree cores were collected from *Populus deltoides* (eastern cottonwood) along scroll bar topography sequences on point bars in an attempt to correlate tree-ring age with scroll bar position and calculate approximate migration rates for channel locations prior to the earliest planimetric map data. The method of calculating channel migration rates from tree ages and scroll topography has been used with success on Canadian rivers (Hickin, 1974), but the data are not included in this report because of various problems encountered with poor tree-ring records in the cottonwood tree species along the this section of Brazos River.

For tree coring data the largest and most mature trees, almost always *Populus deltoides* (eastern cottonwood), were selected for coring. Trees were selected in scroll bar sequences older than the GLO maps to obtain dates of channel positions prior to 1929. The data proved unreliable and are not included for a number of reasons noted by Everitt (1968) and include difficulty in reading the rings of a diffuse-porous wood and a low climate stress, or extreme variation, in the Brazos River valley at this location. All of these factors appear to which cause tree ring series to become dormant in annual growth rings.

Figure 16. Large meander bend along middle of study reach looking towards outer bend. Note shear bank wall.

Bank height and bank characteristics were observed to understand mechanisms for bank failure and erosion. The height data for the field sites was compared to the values obtained from the 10-meter DEM, which was used for calculating deposition and erosion along the entire study reach for the multiple time periods.

Results for Task 2

Two sites were measured to determine the height of channel bank and the sediment volume in an individual slump toe. The sites are presented in Fig. 17. Both sites are characterized by a lack of vegetation along the outer cutbank. In addition, site two has a large tributary immediately upstream, adding the overall sediment and water discharge along the bend.

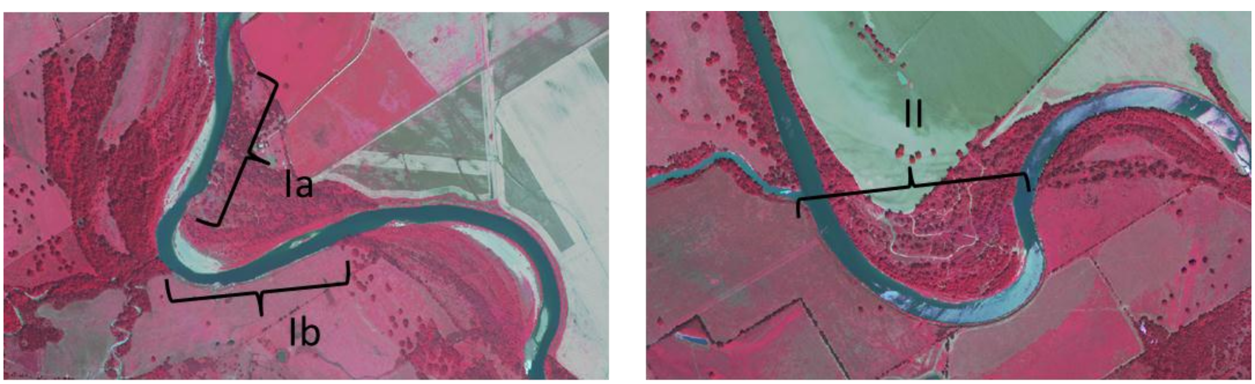

Figure 17. Three field sites where cutbank height and slump toe sediment volume were measured.

Table 5 presents the measured bank heights and sediment volume along the slump toe of the outer cutbank. All sites are characterized by high, vertical bank walls and recently deposited material comprising the slump toe.

Table 5. Outer bank characteristics and slump toe sediment volume for three sites. As evident the values are relatively consistent, with the greater channel length contributing to overall greater sediment volume in the slump toe at the base of the bank.

Site	Cutbank height (m)	Cutbank length (m)	Slump toe height (m)	Slump toe width (m)	Slump toe volume (m^3)
Ia	7.7	627	3	0.15	141.1
Ib	8.2	709	4	0.16	226.8
II	7.6	1347	6	0.14	565.7

Analysis and Interpretation for Task 2

Figure 18 displays various types of outer cut-bank erosion encountered along the main channel. In the upper portion of a large meander bend, bank morphology is a sloped or slumped bank with vegetative cover (Fig. 20). Moving downstream along the meander bend the outer banks transition to a shear or vertical channel wall where the bank toe is more readily eroded away.

Changes in channel geometry along meander bends was observed in field surveys (Fig. 19). As the channel migrates laterally across the floodplain, the upper portion of the bank collapses and is deposited along the base of the bend wall. The eroded bank material is then available for further transport downstream with the majority of the material (89-97%) as suspended or dissolved load (Epps, 1973).

Figure 20 displays effects of forest clearing on the geometry of banks with a shear bank wall and slump toe. The slump toe is unstable and readily eroded during higher flows. This locality is along the inner bank of a meander bend. As one can see, there is a marked lack of tree roots for bank stability.

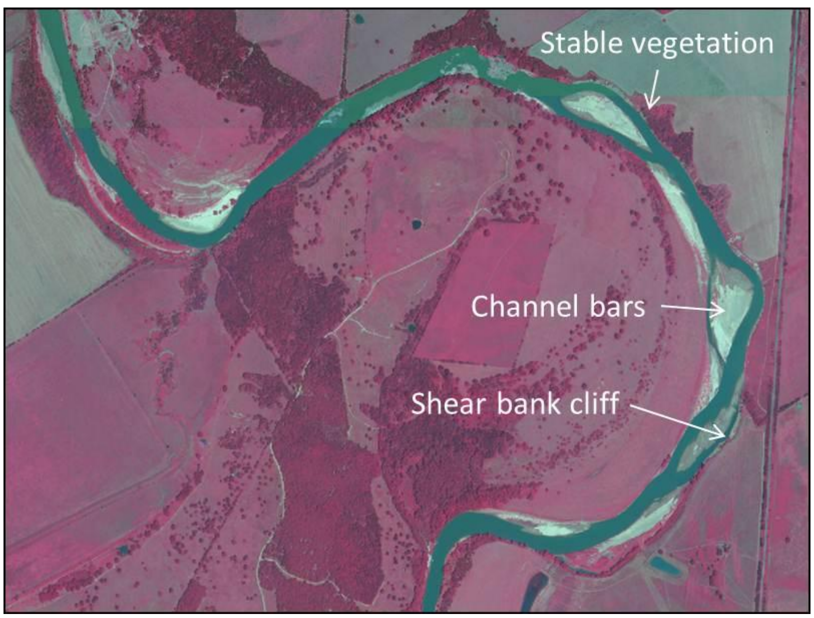

Figure 18. Typical large meander bend displaying stable outer banks, with vegetation, in upstream and relatively unstable outer downstream outer banks. Scale is 1:14,500. (Photograph is 2004 NAIP image).

Bank erosion rates are affected by a variety of other factors. After especially high flows, especially those close to bankfull discharge, begin to recede the banks are saturated and water begins to flow towards the river channel. The pressure change in the channel walls causes slumping and piling of bank material (Fig.19) and is made available for transport during the next high flow (Leopold, 1994).

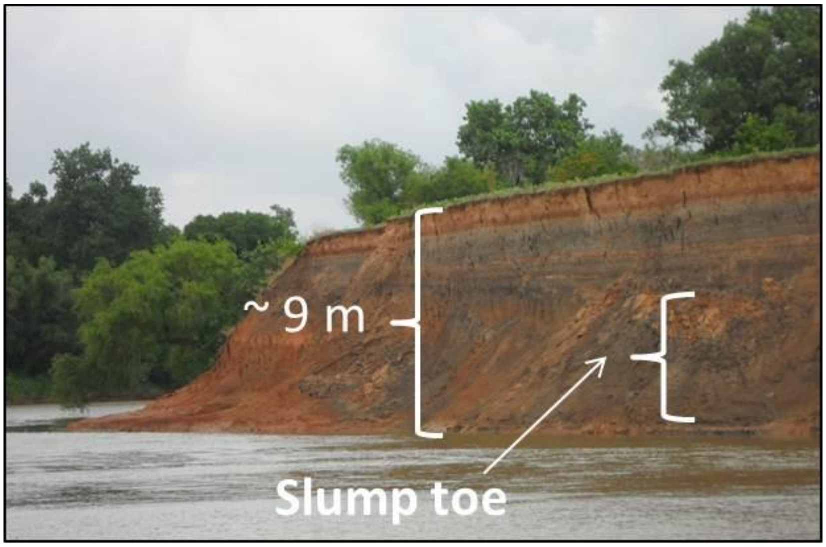

Figure 19. Typical outer bank morphology along meanders, including high cliff wall with slump toe at base. Notice high black soil content mixed into the slump toe. Height is approximately 9 meters. Location is central Falls County.

Figure 20. Inner bank with slump toe. The vegetation is not extensive along the bank and the area has experienced deforestation since the 1995 time frame.

The longitudinal profile presented below (Fig. 22) displays the highly sinuous character and large meander bends of the Brazos River. Present in the profile is back-water effects as elevations fluctuate within relatively short distances. The large changes in elevation within the short distance may influence the nature of bank erosion along the length of a particular meander bend with a lower stream energy along meanders with a radius to width ratio greater than three (Knighton, 1998).

Gillespie (1992) found little correlation between the silt-clay composition and migration values found along the Brazos River from Waco to Richmond. Rather, he suggests, the alluvial sediments may be interspersed with layers of resistant rock and paleosediment, negating the effect of bank composition on overall channel migration along the Brazos River.

<u>Task 3 - Develop estimated sediment budget for selected reaches</u>

The following is a succinct summary for Task 1.

Task 3
3) Develop sediment budget for selected reaches based on various flow regimes.

Results for Task 3:

A sediment budget was developed for thirty three freely migrating meanders on the study reach. Overall, a net deposition of 5,580,161 metric meters of material was deposited in the reach through the study time period. This component focuses on the material eroded and deposited from areas visible in the aerial photograph set.

Methods Employed to Accomplish Task 3

Channel Sediment Estimate & Budget

The sediment budget for the Brazos River focused on the sediment deposition and erosion along the main channel. The sediment inputs and outputs along tributaries and overland sources were not accounted.

A budget concerning only freely migrating meanders is calculated. Freely migrating meanders are defined as those meanders that are not immediately adjacent to the upland terraces that bound the valley floor. An exception is made to also include those meanders that while adjacent to the upland terrace are actively migrating in a direction towards the center of the valley floor for a sufficient amount of time to build an extensive bar complex (Appendix D).

The method used involved creating a series of overlay polygons along specific delineated bends to include all bankline movements within the time series analyzed. The polygon ends were drawn perpendicular to the channel centerline. The total number of freely migrating meanders covered in the sediment budget is thirty three.

A number of assumptions were made to develop this sediment budget. Bends directly adjacent to the valley wall were not measured because the influence of stable geologic formations may influence the style and rate of sediment in the main channel. Those meanders analyzed were freely meandering across the floodplain, specifically as the main channel transitions to and from either side of the river valley. Exceptions to this were made where the river channel is actively migrating away from the valley wall.

Deposition was calculated following a slightly different methodology. The 2004-2008 channel deposition was overlayed atop the 10-meter DEM to provide the most recent significant coverage of meander migration. The deposition amount was calculated by determining the elevation difference between the land surface adjacent to the cut bank and the depositional point bar.

Several assumptions were made. First, the plane of the deposition is held as level. Second, the rate of vertical deposition has remained constant throughout the study time period. Last, all movement of the Brazos River has been lateral, with no vertical change channel depth.

A final sediment budget assessment involved examining several meander bends in the field. These sites are located along the channel section in southern McLennan and northern Falls counties. A stadia rod and tape measure were used to estimate bank sediment volumes on the near bank of the channel. The measurements recorded include the height of the bank, height and width of the slumped material. To gather data on the far side of the bank measurements were taken using an inclinometer. Assuming a vertical cutbank, a measurement was taken at the bank top and bottom. Two right triangles can then be used to estimate the total bank height, and therefore, the slump toe height.

Results for Task 3

Sediment Budget

The sediment erosion and deposition values for the freely migrating meanders are presented in table 6. The overall net sediment change is a deposition of 5,580,161 m^3. These values are from the thirty three freely migrating meanders along the study reach. Appendix D displays the location of the meanders along the entire study reach, along with their location relative to the watershed uplands. The sediment balance in the last column is calculated by the sediment erosion minus sediment deposition.

Table 6. Sediment budget for selected meanders. The time period column is arranged that sediment balance for the erosion portion is listed first; the time period for deposition listed second.

Time Period	County	Total Erosion (m^3)	Total Deposition (m^3)	Sediment Balance (m^3)
1972-1952/1952-1972	McLennan	13,932,007	19,237,438	-5,305,431
1982-1972/1972-1982	McLennan	4,630,388	16,783,450	-12,153,062
1988-1982/1982-1988	McLennan	3,953,306	6,115,613	-2,162,307
1993-1988/1988-1993	McLennan	10,128,158	2,730,314	7,397,844
1995-1993/1993-1995	McLennan	3,255,091	3,322,823	-67,732
2004-1995/1995-2004	McLennan	382,851	2,551,067	-2,168,216
2008-2004/2004-2008	McLennan	1,869,758	522,258	1,347,500
1960-1955/1955-1960	Falls	24,201,666	4,965,994	19,235,672
1968-1960/1960-1968	Falls	9,755,788	20,095,351	-10,339,563
1995-1968/1968-1995	Falls	9,953,652	15,493,720	-5,540,068
2004-1995/1995/2004	Falls	1,976,270	4,838,540	-2,862,270
2008-2004/2004-2008	Falls	3,056,565	1,674,800	1,381,765
1958-1951/1951-1958	Milam-Robertson	38,355,314	4,471,661	33,883,653
1965-1958/1958-1965	Milam-Robertson	12,530,507	13,682,469	-1,151,962
1974-1965/1965-1974	Milam-Robertson	7,437,067	30,803,595	-23,366,528
1995-1974/1974-1995	Milam-Robertson	14,325,420	7,830,521	6,494,899
2004-1995/1995-2004	Milam-Robertson	4,768,757	6,063,567	-1,294,810
2008-2004/2004-2008	Milam-Robertson	5,442,182	3,191,405	2,250,777
			Total Net Sediment	**5,580,161**

Analysis and Interpretation for Task 3

The overall trend for sediment dynamics in the (Lauer, 2008) is deposition of eroded material a short distance downstream. The majority of material building bar sequences is sourced from in-channel erosion upstream (Dunn, 2001).Comparison of the change in net sediment, total erosion minus total deposition for a time period, shows a relatively equal distribution of net erosion or net deposition for each of the time periods. McLennan and Falls counties display overall greater sediment deposition throughout the study, while the Milam-Robertson display a balance of erosion and deposition.

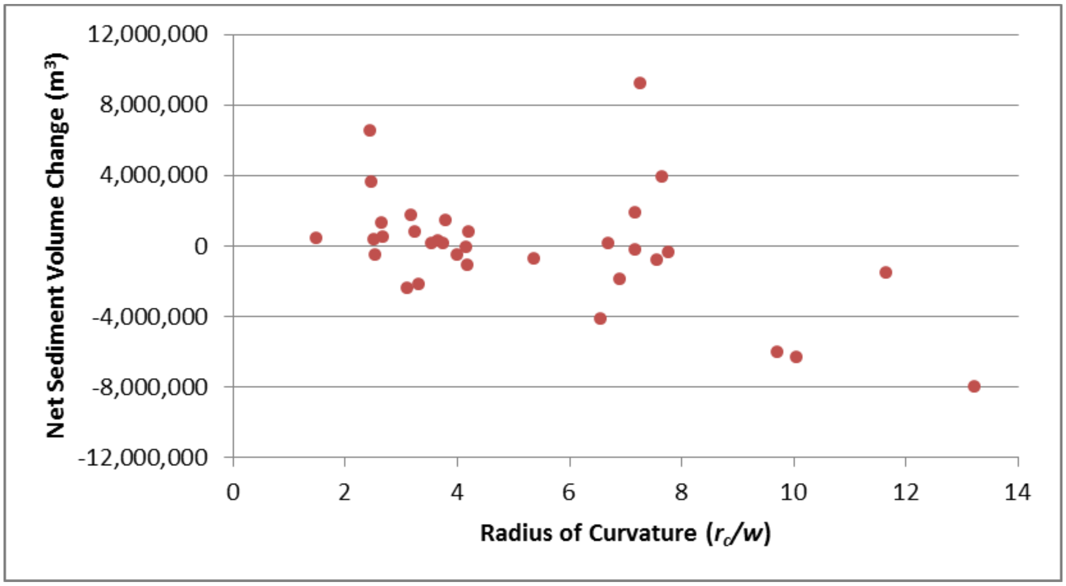

Figure 21. Radius of curvature on net sediment change for freely migrating meanders. Each data point represents the total net sediment change for all time periods. Positive values denote overall erosion, negative values denote overall deposition.

Radius of curvature (r_c/w), where the radius of a circle adjacent to the meander bend is divided by the channel width, has shown to be a predictable indicator of channel migration, and subsequently, bank movement and sediment deposition (Knighton, 1998). Generally, values are highest at ~ 3with values lowering on either side. The data in Fig. 21 generally portrays this relationship. Many of the freely migrating meanders analyzed exhibit a radius of curvature of ~3 but high sediment loads also occur at r_c/w values between 6 and 8.

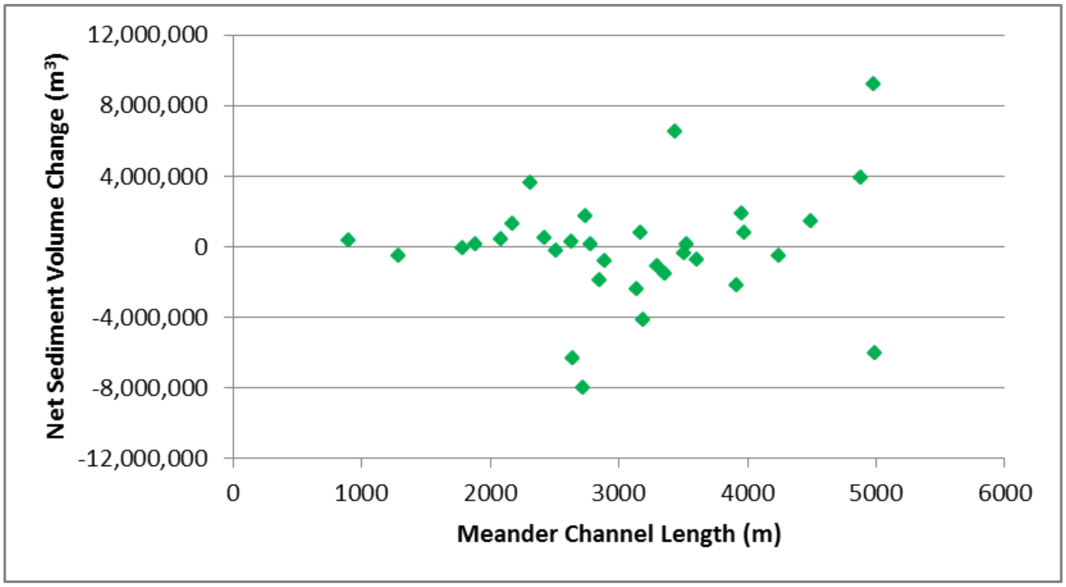

Figure 22. Meander channel length and net sediment change for freely migrating meanders. Each data point represents the total net sediment change for all time periods. Positive values denote overall erosion, negative values denote overall deposition.

Figure 22 displays the relationship between the channel length, determined from the 2004 dataset, and change in net sediment volume. Generally, as the length of channel increases in a particular freely migrating meander, the overall difference in net sediment increases. This suggests there is greater variability in erosion and deposition among meander bends with longer channel between inflection points. In addition, as the spatial scale increases, other factors such as bank composition, contact with local bedrock layers, or discharge dynamics may play a greater role in causing a disparity between the balance of erosion and deposition.

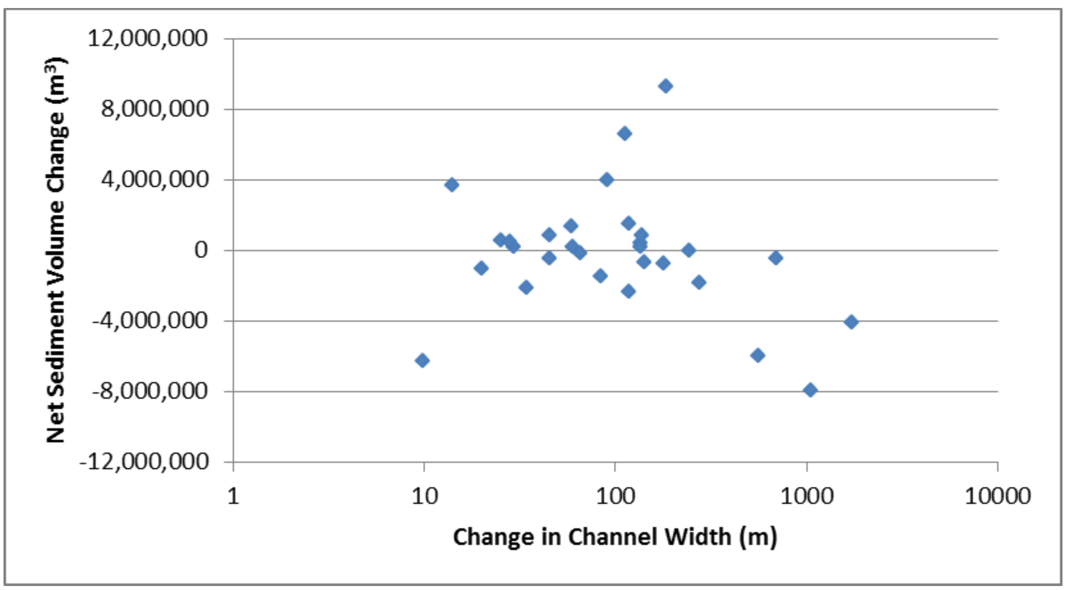

Figure 23. Change in channel width from 1950s to 2004 and net change in sediment. The channel width is expressed as a magnitude in order for all values to be positive. Each data point represents the total net sediment change for all time periods. Positive values denote overall erosion, negative values denote overall deposition. The change in channel width is log-scale.

Figure 23 displays the relationship between the change in channel width during the study period and the change in net sediment volume. The change in channel width is denoted as the width of the channel in the 1950s minus the 2004 channel width. Because the 1950s channel is generally greater the majority of the values are positive. In those few instances where the 2004 channel width is greater the magnitude of change was used to avoid negative values. From Fig. 23 we can see most of the values cluster near zero with higher values of net sediment volume near the lower and upper ends of change in channel width. This is an interesting observation. It is expected, similar to the length of channel shown in Fig. 22, that a greater change in channel width may introduce more variability into the system, causing wide fluctuations in erosion and deposition, but it is interesting to note the small values also generate large disparities between erosion and deposition. One data point lists approx. 4,000,000 (m3) of erosion and another is at approx.. 5,000,000 (m3) of deposition; both for a relatively small amount of change in channel width. This may be explained by changes in land use along the adjacent floodplain. It is important to remember that positive change in net sediment equals erosion, while negative values represents deposition.

<u>Task 4 – Determine and classify behavior of channel movement</u>

The following is a succinct summary for Task 1.

> Task 4
> 4) Determine and classify response of the channel movement within the river valley.
>
> Results for Task 4:
> The Brazos River along this section generally flows against the western side of the Brazos River valley. This affects the rates and style of migration as the main river channel has to migrate in an easterly direction. The longitudinal profile of the channel was classified at locations where the channel elevation decreased significantly (2-5 m) in a short distance downstream (<5 m), creating ten channel gradient classes. The rates of channel migration increase as the channel sinuosity, obtained for each gradient class, increases.

Methods Employed to Accomplish Task 4

Longitudinal profile – gradient and sinuosity classification

A classification system to segment channel susceptibility to bank failure and movement was developed to segment the migration rates into different groups based on the physical properties of the channel. This classification system is based on dividing the channel longitudinal profile into various segments based on significant changes in gradient. The longitudinal profiles are termed *slope classes*. Ten slope classes were developed from the longitudinal profile. The boundaries of each gradient class are shown in Figure 24.

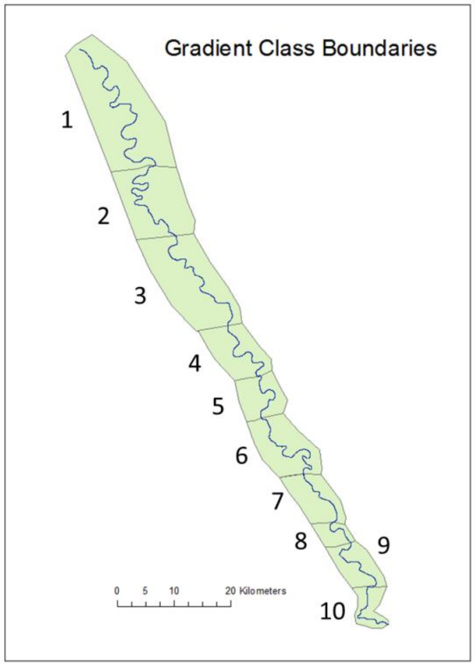

Figure 24. Boundaries for ten gradient classes. Division of channel was done through the natural breaks in longitudinal gradient.

The longitudinal profile was generated by extracting point values along the 2004 channel centerline from a U.S. Geological Survey 30-meter DEM. The 2004 channel centerline was used because it corresponds most closely to the date the DEM was generated. Because of the raster data structure within the DEM, the resulting points were spatially joined to points spaced every thirty meters along the 2004 channel centerline. This step was used to smooth the profile and reduce duplicate elevation values not immediately positioned along the centerline. The lateral rates of channel migration for all years were then grouped and stratified into their respective gradient classes to gain an understanding of the role of gradient and sinuosity serve in impacting migration rates.

The 2004 channel centerline was corrected for compatibility issues with the 10-meter DEM. The revised channel centerline was used to extract the elevation values from the 10-m DEM. The extracted raster was converted to a point shapefile using the center of the raster cell as the individual point location. The channel centerline was divided into 10 meter segments. The center point of these segments was converted to a point shapefile. The point shapefile was joined to the elevation (raster DEM) shapefile.

Two measures of gradient, or slope, are presented. First, channel gradient whereby the elevation difference between the upstream and downstream channel end points is divided by the channel distance between the two points to give a slope value along the main river channel. Alternately, the change in upper and lower channel bed elevation is divided by the length of the channel to give a channel slope value. The second gradient measure, valley gradient, represents the difference in elevation between upstream and downstream end points divided by the length of the floodplain in the downstream direction.

Results for Task 4

Longitudinal profile and channel classification

The longitudinal profile of the Brazos River from the southern edge of the City of Waco to the northern Brazos County line is show in Fig. 25. The profile is separated into ten slope classes. In addition to joining the DEM values to the centerline, as described previously, the data were not smoothed so as to capture the geometry of the large meanders occurring along the study reach. Examination of the profile shows nine substantial breaks in the profile. Evident in the graph are areas of high sinuosity (i.e., slope classes 6 and 7). The slope class segments and their respective channel and valley gradients, sinuosity values are presented in Table 7.

Examination of the data suggests there are definitive sections within the study reach that have distinct gradients. For example, section 2 has a distinct change in elevation at 43.4 km upstream and at 72.0 km downstream. Because channel slope influences stream power (Bagnold, 1980), changes in slope values along the study reach may translate into changes in lateral channel migration rates.

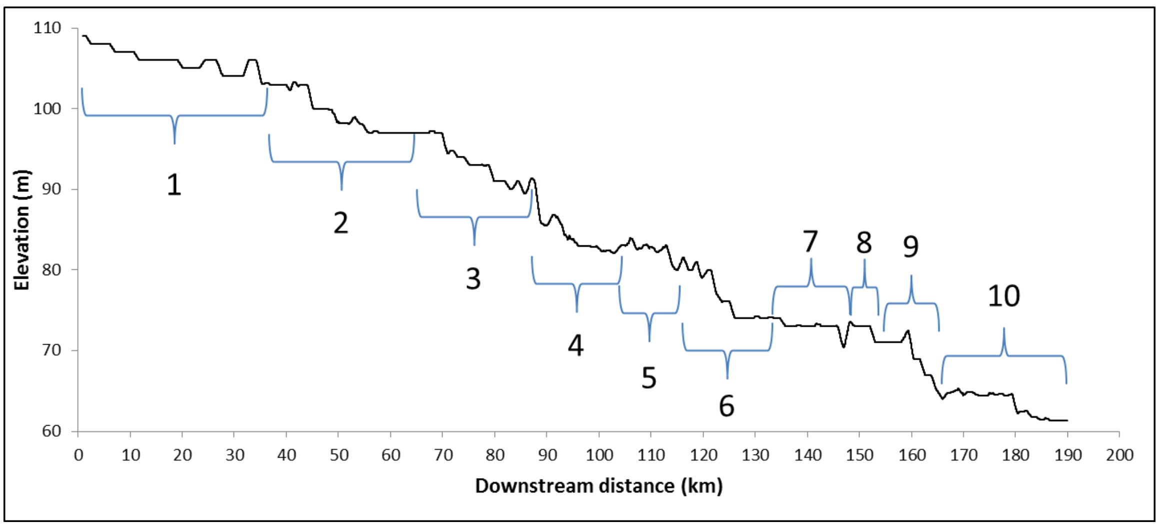

Figure 25. Longitudinal profile for the study reach with different slope classes delineated. The distance downstream orginates from the State Highway 77 bridge in southeastern Waco, TX. The line is the moving average of the profile generated using a 10-meter dataset.

A trendline using a moving average with a period of 100 was used to smooth the overall longitudinal trend. The individual classes presented in Fig. 25 and Table 7 were delineated using the natural breaks in the original raw data from the DEM. Refer to Figure 24 for the location of the individual channel units.

Table 7. Channel gradient, valley gradient and sinuosity for the ten slope classes.

Class	Length (km)	Channel gradient (m/m)	Valley gradient (m/m)	Sinuosity
1-A	43.4	0.000138	0.000254	1.839
2-B	28.6	0.000210	0.000455	2.166
3-C	27.0	0.000407	0.000567	1.392
4-D	17.3	-0.000173	-0.000286	1.649
5-E	11.7	0.000684	0.001194	1.746
6-F	23.5	0.000171	0.000313	1.833
7-G	12.0	0.000250	0.000294	1.176
8-H	6.84	0.000439	0.000714	1.629
9-I	14.1	0.000711	0.001124	1.581
10-J	8.57	0.000162	0.000294	1.821

All migration totals, those post reservoir construction and equal to or larger than the four meter error allowance, are stratified by the different slope/gradient classes (Fig. 26 and 27). The graph does not include measurements collected from topographic maps, i.e., the 1968-1978 or 1978-1995 data from Falls County because of the low number of data points that exist and the overlapping coverage associated with the 1968-1995 data for Falls County.

The following Figures (26, 27 and 28) were constructed using the entire migration dataset divided into its respective channel class. The values presented show the minimum, 25th percentile, mean, 75th percentile, and maximum. The migration values were stratified among the slope classes (Fig. 26). Examination of the trend suggests that migration rates have a greater range as channel length increases, the slope decreases and the sinuosity increases, though there are irregularities. For example, as sinuosity increases, within a given slope class, the difference between channel and valley gradient increases as well. Irregularities may be explained by additional factors including influence of groundwater and vegetation along the channel banks.

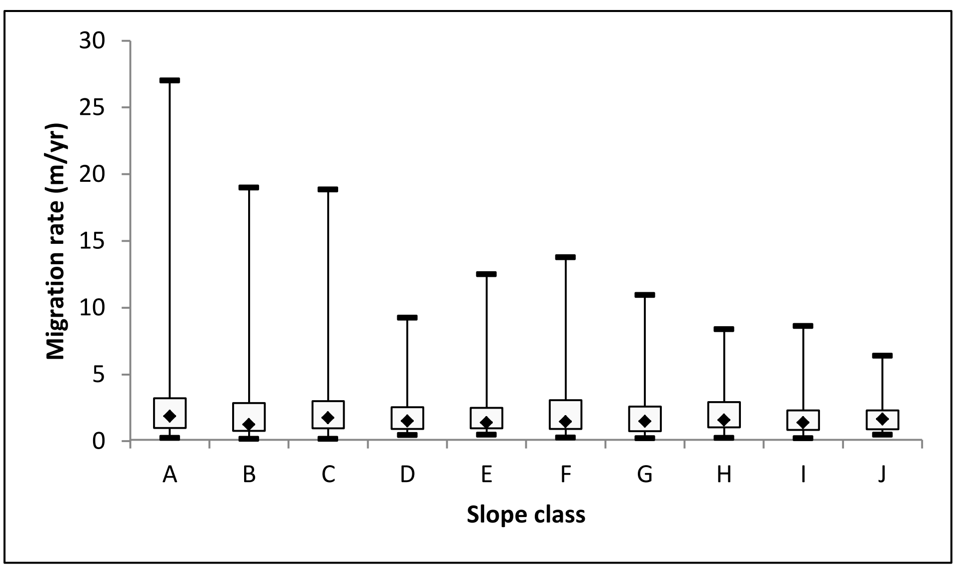

Figure 26. Boxplot for total migration values for each slope class. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

Figure 27 displays total migration rates according to increasing sinuosity. Again, it is important to understand sinuosity increases the range of values for lateral migration rates increases as well. The most sinuous portion of the main channel is located in McLennan County at the upper end of the study reach. This reach also contains the highest migration rates from 2 to 28 meters.

The range of values for migration rates is shown in Fig. 28 in order of increasing channel gradient. The channel gradient experiences a range of migration rates from 2-7 m for the 10-J slope class to 2-28m for the 1-A slope class. The largest migration rate generally occurs around the profile classes having the largest slope and sinuosity, for example slope class B and C (Fig. 28).

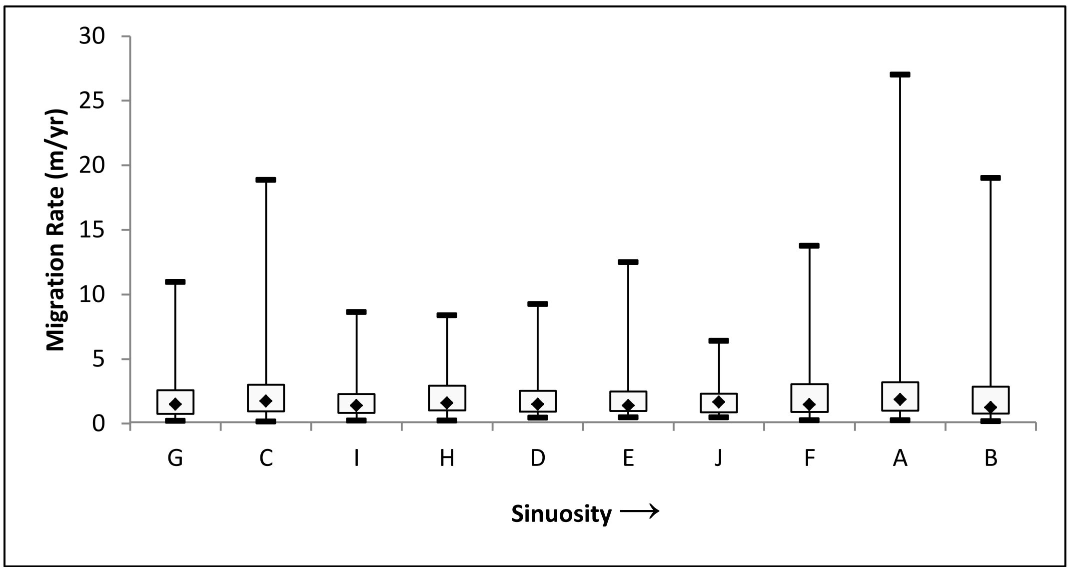

Figure 27. Boxplot for migration rates with increasing channel sinuosity. The letters along the x-axis correspond to the slope classes from Table 4. Letters were assigned to the different slope classes to more readily differentiate the individual classes. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

Examination of the migration values between the Texas GLO images and earliest (1941, 1955 and 1958) aerial photographs shows the highest migration rates (i.e., ~ 10 meters or greater). High migration rates for the earliest time periods are expected as major channel impoundments had not been fully constructed yet, allowing greater discharges. It is fundamental to realize that these values, though, do not differentiate between lateral channel migration that occurs as the meander bend erodes along the outer bank and any major channel avulsions or cutoffs that may have occurred.

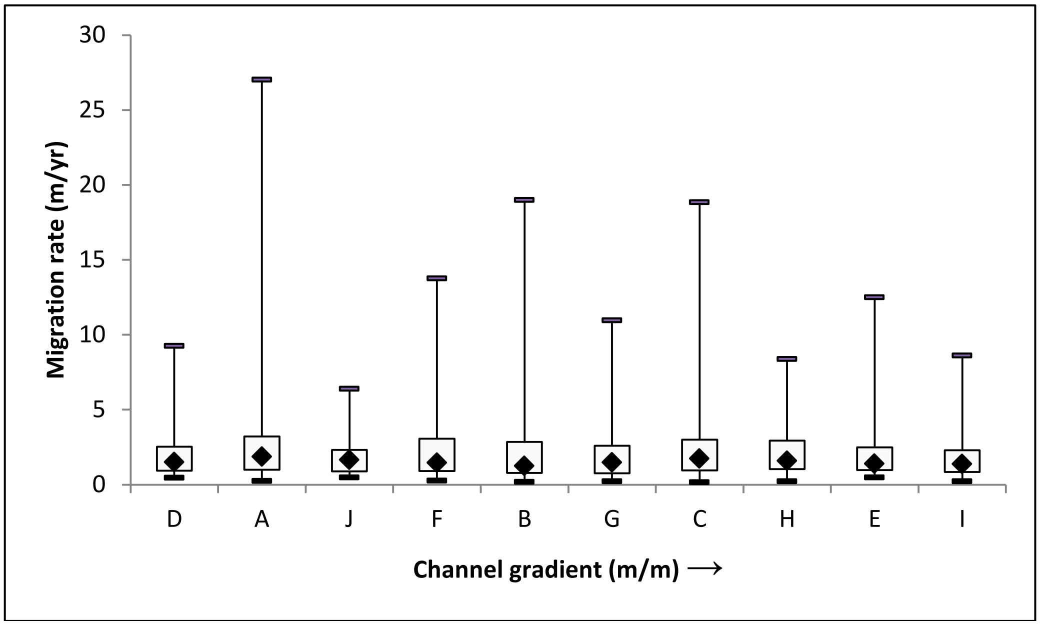

Figure 28. Boxplot for migration rates with increasing channel gradient. The dot in the center of each rectangle represents the mean value for each time period. The upper and lower edges of the rectangle represent the 25th and 75th percentiles, respectively. The upper and lower bars are the highest and lowest values for a given time period.

The lateral migration values in locations where major avulsions or cutoffs may skew the migration rates towards abnormally high values within the pre-reservoir datasets. The larger meander bends commonly consist of a long, low point bar with a large sand bar exposed along the inner channel bend. Many of these features are susceptible to avulsions with some supporting isolated stands of vegetation.

Analysis and Interpretation for Task 4

Gaining and Losing Segments

Turco and others (2007) present data mapping losing and gaining channel sections of the Brazos River based on analysis of hydrograph separation using point data generated along specific sections of the main channel. The mapped reaches of losing or gaining sections are presented in Fig. 29. By comparing the county migration rates presented in Fig. 9 with those reaches experience losing or gaining one can map the effect of surface-groundwater connectivity with rates of lateral migration. Examination of this data shows that stable or losing reaches have greater rates of channel migration, especially southern McLennan County and northern Falls County.

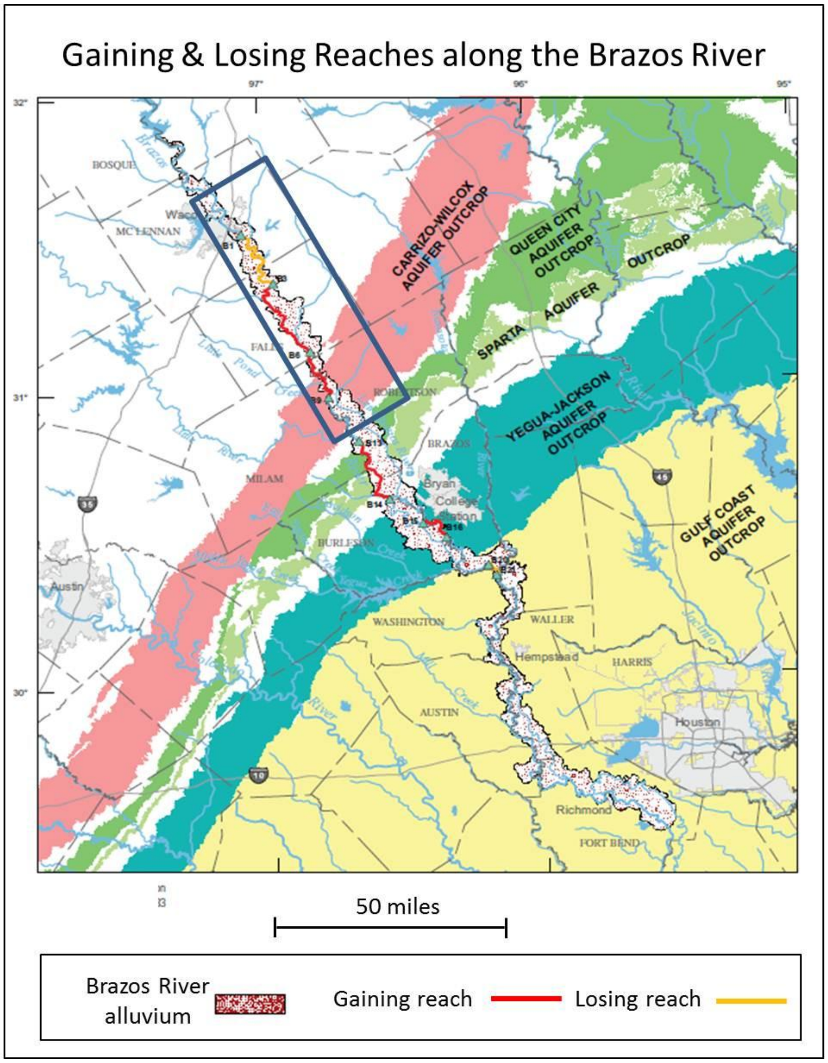

Figure 29. Gaining and losing streams along Middle Brazos River (After Turco, 2007). The blue box outlines the present study reach.

Migration rates are generally highest in losing or stable reaches, whereas reaches experiencing gaining are relatively stable. As the main channel loses water to underground areas, migration rate increases. The lateral migration of the main channel may occur as water flowing out of the channel bank dislodges sediment and results in bank slumping (Fig. 19).

Floodplain Position

The position of the main channel within the floodplain appears to have an effect on the style and magnitude of lateral channel migration. Here we define the floodplain as the relatively level surface with a slope of less than 1.5 degrees. For much of its length through the study area, the main channel flows close to the major watershed terrace, with several large meander loops extending across the middle of the floodplain. Analysis of the proximity of the channel to upland valley walls and the direction of migration we suggest the main channel is attempting to migrate back to the eastern portion of the floodplain (Fig. 30).

Nicoll (2010) presents data on confined meanders along the Canadian prairies in which small differences are noted among channel width and bend curvature. Similar to that work, we little correlation between discharge and migration rates for the Brazos River, with a wide range within the migration rates, similar for other rates of freely meandering rivers (Nanson and Hickin, 1986; Williams, 1986). The total volume of water and the maximum monthly discharge for a given time period best explain the variation in channel migration.

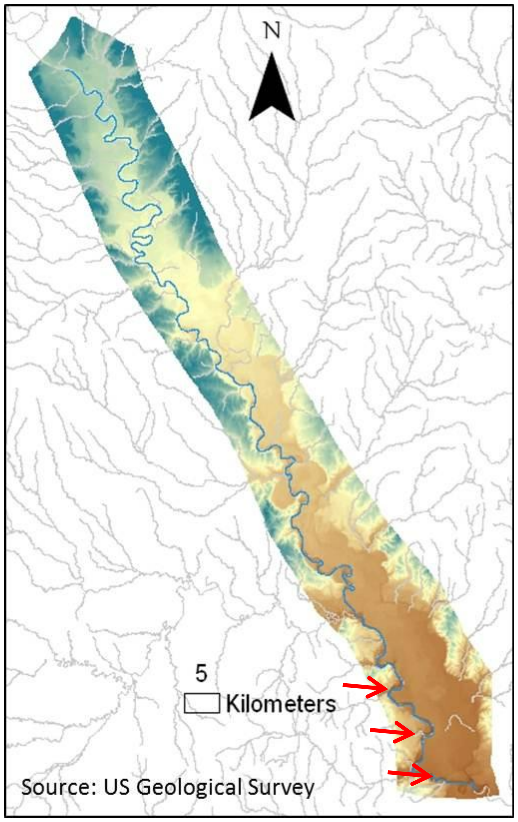

Figure 30. Hillshade of Brazos River alluvial valley. The main channel flows along the western valley wall for much of its length through the study reach. Red arrows represent areas of relatively large bank erosion and direction of migration, towards east.

Vegetation

A factor not analyzed, but examined in this work, is the effect of vegetation on bank stability. Many studies have addressed the effect of presence or absence of different types of vegetation on bank stability (Beeson and Doyle, 1995; Micheli, 2004; Esfahani, 2010). Vegetative coverage, whether it consists primarily of grassland or large woody plants, may be an underlying factor in the relationship between hydrologic regime and migration rates. Observations of numerous bends along the study reach showed areas that have been cleared of vegetation mainly for increased agricultural area (Fig. 31).

The meander bends presented in Fig. 31 show examples of the effect of cleared vegetation on channel migration. As one can see, the presence or lack of vegetation, specifically forest or shrub cover, has a strong impact on the magnitude of migration. For example, if one compares (A) to (F) on can see distinct styles of migration. The meanders generally migrate in the direction of areas containing no tree cover. Because of the position of the channel within the valley many of the bends are forced to migrate in one direction and take on an irregular appearance. This channel geometry is exacerbated by the lack of vegetation along many of the outer cut banks.

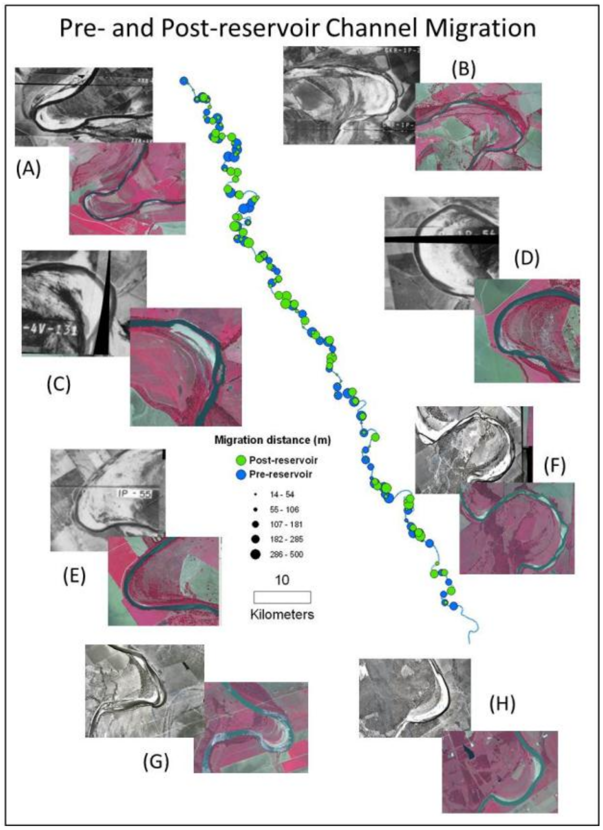

Figure 31. Examples of migration magnitude in locations lacking adequate large woody plants. Proportional symbols display migration magnitude post- and pre-reservoir construction.

The main focus of this study was to calculate rates of lateral channel migration along the Middle Brazos River and to understand the effect of surface discharge variations on this migration. Four tasks were established for this project. These tasks were:

1) Calculate rates of meander migration along selected reaches of the Brazos River and correlate values to varying discharges. Determine mechanism of channel migration for temporal intervals (i.e., 1950s, 1960s, etc);

2) Categorize channel banks for erosion occurrence/potential by examining hydrologic shear stress, and associated flow, along banks;

3) Develop sediment budget for selected reaches based on various flow regimes;

4) Determine and classify response of the channel movement within the river valley.

We found that migration values range from ~1 m/yr to ~50 m/yr from 1929 to 2010. The majority of migration values fall within a range from ~2 m/yr to ~10 m/yr.

In generally, as channel gradient and channel sinuosity increased the range of migration values increased as well, similar to other large alluvial rivers. The ten slope classes present a framework for classifying the migration potential within this section of the Brazos River.

The Middle Brazos River generally flows along the western side of the floodplain valley. This characteristic affects channel migration in that the channel is migrating towards the eastern side of the valley. This easterly migration direction creates irregular channel meanders with channel erosion concentrated along the outer bank.

After considerable analysis, we believe the evidence is inconclusive as the effect of changes in discharge on lateral channel migration along the Middle Brazos River. Discharge does have an impact on migration magnitude, but at the scale measured within this study it is difficult to determine with both the volume and timing of water needed to initiate a specific amount of channel migration. We were unable to determine the exact relationship between surface discharge and channel migration. The two variables quantified in this study, the influence of groundwater and the presence or lack or forest cover, were observed to affect the magnitude of lateral channel migration.

Lateral migration rates have been calculated for several time periods covering the entire study reach. In general, migration rates are at the high end for alluvial river migration. Knighton (1998) has shown that generally the larger the drainage basin, and the longer the period of measurement, the higher the migration rate, values generally range from nearly zero to ten meters of lateral migration a year. The Middle Brazos River follows this trend with migration values across the study reach ranging from 1.0 to ~11.0 meters/yr.

Overall sediment balance for the freely migrating meanders is a net positive deposition of 5,580,161 m^3 located predominantly along point bar complexes.

Observed in this dataset is the effect of land use and management on the magnitude of migration. The presence, or lack thereof, of large woody plants, namely trees, assists in creating conditions favorable for high bank erosion rates. Across the study reach areas lacking adequate vegetated cover, especially those areas along large meander bends, experienced the highest bank erosion rates. Establishment of large woody vegetation along these bends, in particular the outer banks, would be difficult.

Foundational Findings

The following is a bulleted list of the significant findings for this study:

- Rates of lateral channel migration range from 1.09 to 11.53 m/yr, with an average of 3.28 m/yr for the study reach.

- The maximum monthly discharge and the total time period discharge display the greatest effect on migration rates. Lateral migration rates cluster at 340 cms to 453 max monthly cms. As the total time period discharge increases migration rates decrease.

- Milam/Robertson Counties experience the greatest single range in migration with values from ~1 m/yr to ~40 m/yr for the time period 1929-1941. McLennan County is shown to have a greater range over all time periods with large migration rates between ~2 m/yr and ~23 m/yr.

- The third quartile of lateral rates of migration generally do not exceed 10 m/yr. The 1929-1941 time period for Milam/Robertson Counties shows the only migration rate greater than 10 m/yr for the thrid quartile, with a value of ~ 15 m/yr.

- The range of migration rates increases as average monthly discharge and average yearly discharges increase.

- The range of migration rates generally decrease as the total time period discharge decreases.

- The longitudinal profile of the study reach was divided into ten classes. As sinuosity increases the range of lateral channel migration increases.

- The largest range in migration rates (~ 1 m/yr to ~ 20 m/yr) occurs with channel gradients of 0.000210 and 0.000407 (m/m). These channel gradients are near the median for channel gradients along the study reach.

- Pre-reservoir migration distance is significantly greater (50 to 1,500 m) than post-reservoir migration distances ((10 to 500 m). Channel width for pre-reservoir ranges from 30 to 1,200 meters and post-reservoir width is 50 to 250 m.

- The total net change in sediment balance was 5,580,161 m^3 in deposition along point bar sequences for thirty three freely migrating meanders.

- Segments of losing and gaining reaches correspond with migration rates with losing and stable reaches corresponding to greater migration rates.

- Outer meander bends lacking forest cover typically show vertical cut banks and are prone to higher rates of migration with values ranging from ~2 m/yr to ~5 m/yr.

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Appendix A

Channel Migration

The following tables list the individual migration values at the county level. Listed are the area (m2) and perimeter (m) for each migration unit. The migration amount is calculated by dividing the area by the perimeter. The migration rate is then calculated by dividing the migration amount by the number of years in the time period for a particular aerial photograph set.

The location of each migration unit is listed using the X-Y coordinates. The XY location coordinates denote the center of the migration polygon. These coordinates are plotted on the Universal Transverse Mercator coordinate system using zone 13. The distance downstream column lists the downstream distance of the centroid of the migration unit from the State Highway 77 bridge crossing the channel in east Waco.

McLennan

Area (m2)	Perimeter (m)	Years	Migration amount (m)	Migration rate (m/yr)	X Coordinate	Y Coordinate	Distance downstream (km)
202289.00	2104.92	1929-1958	192.21	6.63	684691.33	3489281.75	6.00
159999.00	2350.52	1929-1958	136.14	4.69	685343.22	3489051.28	7.00
789.88	346.40	1929-1958	4.56	0.16	685881.00	3487904.03	8.00
13150.00	1048.37	1929-1958	25.09	0.87	685778.71	3488402.66	8.00
2127.64	547.86	1929-1958	7.77	0.27	685801.11	3487442.14	9.00
188069.00	3360.80	1929-1958	111.92	3.86	685668.10	3487245.23	9.00
1161840.00	13056.40	1929-1958	177.97	6.14	687153.72	3485775.78	13.00
442.96	186.60	1958-1972	4.75	0.34	687718.18	3485280.80	14.00
150984.00	1860.39	1929-1958	162.31	5.60	686402.36	3482899.47	17.00
1246390.00	8237.38	1929-1958	302.62	10.44	688997.04	3482684.83	21.00
158198.00	2192.17	1929-1958	144.33	4.98	689890.01	3481390.39	23.00
408928.00	3389.58	1929-1958	241.29	8.32	690741.48	3480915.92	24.00
431470.00	2785.78	1929-1958	309.77	10.68	689811.29	3479052.09	27.00
404768.00	3783.08	1929-1958	213.99	7.38	688854.85	3478650.33	28.00

113526.00	2455.10	1929-1958	92.48	3.19	688377.59	3477968.65	29.00
80965.10	2032.72	1929-1958	79.66	2.75	689190.62	3476422.95	31.00
611557.00	4343.79	1929-1958	281.58	9.71	690470.52	3476622.39	32.00
1434440.00	6968.44	1929-1958	411.70	14.20	689254.24	3474686.85	35.00
206605.00	2409.15	1929-1958	171.52	5.91	688972.69	3473395.87	37.00
374866.00	3888.44	1929-1958	192.81	6.65	690186.18	3472601.25	38.00
39808.50	1592.76	1929-1958	49.99	1.72	690489.82	3472419.58	39.00
9784.41	1623.84	1958-1972	12.05	0.86	681868.40	3491801.20	1.00
1633.09	433.86	1958-1972	7.53	0.54	682395.53	3491231.50	2.00
6062.91	1138.18	1958-1972	10.65	0.76	682530.15	3491070.51	2.00
9911.13	1278.31	1958-1972	15.51	1.11	683052.99	3490136.93	3.00
1438.20	431.41	1958-1972	6.67	0.48	683242.81	3489445.63	4.00
5379.44	1117.13	1958-1972	9.63	0.69	683093.53	3490025.28	4.00
11586.50	1328.22	1958-1972	17.45	1.25	683285.49	3489210.38	4.00
3701.29	549.25	1958-1972	13.48	0.96	684031.88	3488930.71	5.00
326.44	135.95	1958-1972	4.80	0.34	684379.58	3489017.33	6.00
2967.89	523.13	1958-1972	11.35	0.81	684264.25	3488986.71	6.00
1539.71	235.99	1958-1972	13.05	0.93	684483.89	3489074.51	6.00
2636.56	467.32	1958-1972	11.28	0.81	685278.04	3489113.00	7.00
13877.30	978.91	1958-1972	28.35	2.03	685073.40	3489226.49	7.00
32081.90	1942.55	1958-1972	33.03	2.36	685483.42	3488939.06	7.00
2865.45	650.44	1958-1972	8.81	0.63	685805.42	3488285.89	8.00
17294.70	2367.25	1958-1972	14.61	1.04	685883.46	3487874.14	8.00
2112.39	712.14	1958-1972	5.93	0.42	685378.03	3486948.05	9.00
11592.60	1217.16	1958-1972	19.05	1.36	685013.09	3486335.30	10.00
9966.48	1171.84	1958-1972	17.01	1.22	685156.35	3485697.84	11.00

61881.00	3252.60	1958-1972	38.05	2.72	687153.72	3485775.78	13.00
597.51	225.81	1958-1972	5.29	0.38	687559.72	3485569.34	14.00
667.73	225.04	1958-1972	5.93	0.42	687680.05	3485362.07	14.00
5825.50	660.81	1958-1972	17.63	1.26	687529.80	3485621.28	14.00
195487.00	6829.96	1958-1972	57.24	4.09	687528.13	3483744.88	16.00
118214.00	2728.82	1958-1972	86.64	6.19	686330.24	3482241.17	18.00
3270.25	763.75	1958-1972	8.56	0.61	689056.27	3482693.47	21.00
93925.30	2511.77	1958-1972	74.79	5.34	688671.90	3482650.61	21.00
157565.00	3734.51	1958-1972	84.38	6.03	689780.60	3481740.57	23.00
114413.00	2262.46	1958-1972	101.14	7.22	689998.01	3481290.99	23.00
1531.12	376.59	1958-1972	8.13	0.58	690952.78	3480761.72	25.00
162118.00	4348.91	1958-1972	74.56	5.33	690965.13	3480643.46	25.00
1099.10	278.20	1958-1972	7.90	0.56	689697.55	3479016.18	27.00
11643.00	1169.00	1958-1972	19.92	1.42	689440.01	3478937.76	27.00
457.83	168.52	1958-1972	5.43	0.39	689024.77	3478773.54	28.00
600.65	182.24	1958-1972	6.59	0.47	688975.54	3478739.35	28.00
834.91	193.11	1958-1972	8.65	0.62	688878.52	3478668.75	28.00
441790.00	7491.99	1958-1972	117.94	8.42	688461.00	3478092.53	29.00
46984.30	1529.12	1958-1972	61.45	4.39	690252.37	3476540.35	32.00
525.73	134.36	1958-1972	7.83	0.56	690802.97	3475959.50	33.00
474.88	109.66	1958-1972	8.66	0.62	690814.21	3476017.79	33.00
517794.00	10280.70	1958-1972	100.73	7.20	689952.40	3474835.11	35.00
100215.00	3288.29	1958-1972	60.95	4.35	692040.93	3472842.48	40.00
23356.20	1950.70	1972-1982	23.95	2.39	680865.99	3492222.61	0.00
21390.70	2818.10	1972-1982	15.18	1.52	681601.14	3491992.30	1.00
32068.70	4058.31	1972-1982	15.80	1.58	682530.15	3491070.51	2.00

5956.88	1042.98	1972-1982	11.42	1.14	683285.49	3489210.38	4.00
1180.57	389.39	1972-1982	6.06	0.61	683874.88	3488848.55	5.00
7316.33	997.70	1972-1982	14.67	1.47	684264.25	3488986.71	6.00
535.51	191.84	1972-1982	5.58	0.56	685552.25	3488881.44	7.00
75088.40	2530.09	1972-1982	59.36	5.94	684992.21	3489264.98	7.00
2145.60	706.86	1972-1982	6.07	0.61	685713.74	3488601.49	8.00
6722.37	1624.19	1972-1982	8.28	0.83	685893.14	3487784.71	8.00
7430.07	1412.36	1972-1982	10.52	1.05	685771.94	3488431.86	8.00
10569.10	1794.14	1972-1982	11.78	1.18	685468.11	3487027.21	9.00
1430.20	513.90	1972-1982	5.57	0.56	685013.09	3486335.30	10.00
7250.53	864.73	1972-1982	16.77	1.68	684955.65	3486074.39	10.00
1670.78	529.53	1972-1982	6.31	0.63	685244.37	3485618.10	11.00
23423.40	3045.05	1972-1982	15.38	1.54	685749.03	3485194.93	12.00
7328.94	977.85	1972-1982	14.99	1.50	687102.61	3485746.86	13.00
6116.58	770.77	1972-1982	15.87	1.59	687637.40	3485441.20	14.00
721.07	325.72	1972-1982	4.43	0.44	687480.92	3483670.01	16.00
18382.90	2553.37	1972-1982	14.40	1.44	687276.80	3483380.64	16.00
20872.10	2296.55	1972-1982	18.18	1.82	687556.63	3483797.57	16.00
276.08	129.09	1972-1982	4.28	0.43	686315.80	3482823.86	18.00
1757.46	821.37	1972-1982	4.28	0.43	686275.96	3482779.62	18.00
5425.27	1523.09	1972-1982	7.12	0.71	686348.69	3482217.52	18.00
24795.10	1301.06	1972-1982	38.12	3.81	687418.82	3482289.06	19.00
83728.70	5781.03	1972-1982	28.97	2.90	689173.24	3482717.83	21.00
300.74	135.77	1972-1982	4.43	0.44	689913.59	3481372.78	23.00
5110.24	1284.92	1972-1982	7.95	0.80	689998.01	3481290.99	23.00
10185.20	817.68	1972-1982	24.91	2.49	689780.60	3481740.57	23.00

17859.90	1253.76	1972-1982	28.49	2.85	690546.68	3480993.95	24.00
4827.84	1362.60	1972-1982	7.09	0.71	690891.76	3480386.47	25.00
39797.80	3354.83	1972-1982	23.73	2.37	690710.01	3479728.40	26.00
121453.00	8668.68	1972-1982	28.02	2.80	689353.52	3478914.05	27.00
124033.00	5435.42	1972-1982	45.64	4.56	690822.15	3476046.47	33.00
1335.52	558.60	1972-1982	4.78	0.48	689728.17	3474750.14	35.00
14471.20	2601.26	1982-1988	11.13	1.85	681601.14	3491992.30	1.00
5457.05	895.64	1982-1988	12.19	2.03	681160.60	3492174.87	1.00
6943.90	1891.31	1982-1988	7.34	1.22	682530.15	3491070.51	2.00
64860.80	3611.04	1982-1988	35.92	5.99	683228.15	3489534.24	4.00
1504.67	414.71	1982-1988	7.26	1.21	684459.16	3489057.98	6.00
7465.21	1023.06	1982-1988	14.59	2.43	684632.61	3489215.73	6.00
1226.38	428.78	1982-1988	5.72	0.95	685129.29	3489207.20	7.00
1441.00	309.53	1982-1988	9.31	1.55	684965.56	3489278.65	7.00
4569.89	947.56	1982-1988	9.65	1.61	685483.42	3488939.06	7.00
4241.21	880.99	1982-1988	9.63	1.60	685805.42	3488285.89	8.00
1792.30	365.59	1982-1988	9.80	1.63	685771.94	3488431.86	8.00
32842.30	2838.51	1982-1988	23.14	3.86	685885.39	3487844.20	8.00
5840.71	1125.13	1982-1988	10.38	1.73	685104.46	3486522.76	10.00
3359.52	592.26	1982-1988	11.34	1.89	684960.90	3486014.67	10.00
8680.80	1415.32	1982-1988	12.27	2.04	685131.45	3485714.38	11.00
8908.79	2254.52	1982-1988	7.90	1.32	687153.72	3485775.78	13.00
435.45	158.43	1982-1988	5.50	0.92	687352.60	3485811.47	14.00
1077.35	360.80	1982-1988	5.97	1.00	687545.60	3485595.78	14.00
64946.70	4186.95	1982-1988	31.02	5.17	687803.78	3484332.06	15.00
762.04	287.21	1982-1988	5.31	0.88	687327.47	3483454.47	16.00

62331.90	2077.40	1982-1988	60.01	10.00	687260.95	3483355.23	16.00
176903.00	7437.52	1982-1988	47.57	7.93	686402.36	3482899.47	17.00
4911.62	655.65	1982-1988	14.98	2.50	689173.24	3482717.83	21.00
498.58	233.91	1982-1988	4.26	0.71	689789.81	3481769.10	23.00
1242.23	363.47	1982-1988	6.84	1.14	689849.29	3481433.84	23.00
9073.52	1443.84	1982-1988	12.57	2.09	689890.01	3481390.39	23.00
19789.80	2011.99	1982-1988	19.67	3.28	689819.12	3481853.66	23.00
3320.25	1049.00	1982-1988	6.33	1.06	690546.68	3480993.95	24.00
516.77	221.67	1982-1988	4.66	0.78	690871.88	3480299.47	25.00
895.96	376.23	1982-1988	4.76	0.79	690968.15	3480673.22	25.00
2537.29	688.41	1982-1988	7.37	1.23	690855.48	3480180.83	25.00
2809.79	498.46	1982-1988	11.27	1.88	690937.97	3480527.87	25.00
656.23	298.87	1982-1988	4.39	0.73	690653.06	3479623.13	26.00
947.76	454.40	1982-1988	4.17	0.70	690117.41	3479168.81	27.00
1893.75	572.78	1982-1988	6.61	1.10	689894.29	3479086.39	27.00
1404.15	338.53	1982-1988	8.30	1.38	689239.84	3478876.36	27.00
7153.36	1125.14	1982-1988	12.72	2.12	689640.45	3478998.15	27.00
24320.80	2939.85	1982-1988	16.55	2.76	689048.73	3478791.51	28.00
2838.72	731.06	1982-1988	7.77	1.29	688238.60	3477379.69	29.00
3140.05	528.15	1982-1988	11.89	1.98	688308.86	3477059.29	30.00
10230.50	1695.91	1982-1988	12.06	2.01	688582.91	3476709.94	30.00
5294.72	582.44	1982-1988	18.18	3.03	688259.95	3477231.86	30.00
44142.20	5593.15	1982-1988	15.78	2.63	690822.15	3476046.47	33.00
5032.08	1848.72	1982-1988	5.44	0.91	690038.21	3474859.82	34.00
1732.50	445.85	1982-1988	7.77	1.30	689201.46	3474659.55	35.00
817.22	171.79	1982-1988	9.51	1.59	688781.65	3474136.84	36.00

7890.85	984.95	1988-1993	16.02	3.20	680689.99	3492241.86	0.00
4976.38	1081.23	1988-1993	9.21	1.84	681845.48	3491820.55	1.00
15064.20	2181.74	1988-1993	13.81	2.76	681131.40	3492181.76	1.00
9537.32	2156.49	1988-1993	8.85	1.77	682280.19	3491369.37	2.00
3004.56	983.34	1988-1993	6.11	1.22	682908.65	3490466.41	3.00
7230.19	1133.54	1988-1993	12.76	2.55	683139.12	3489882.56	4.00
5308.37	1072.13	1988-1993	9.90	1.98	683638.20	3488854.44	5.00
1565.38	569.85	1988-1993	5.49	1.10	684379.58	3489017.33	6.00
8524.12	905.98	1988-1993	18.82	3.76	684883.99	3489311.21	6.00
1153.65	266.22	1988-1993	8.67	1.73	684965.56	3489278.65	7.00
22923.40	3320.69	1988-1993	13.81	2.76	685256.16	3489133.44	7.00
786.32	340.05	1988-1993	4.62	0.92	685537.08	3487084.83	9.00
5877.10	1176.62	1988-1993	9.99	2.00	685852.67	3487550.41	9.00
5962.75	1073.93	1988-1993	11.10	2.22	685422.36	3486988.44	9.00
4680.44	1183.09	1988-1993	7.91	1.58	685104.46	3486522.76	10.00
3686.77	1205.84	1988-1993	6.11	1.22	685131.45	3485714.38	11.00
6411.25	678.45	1988-1993	18.90	3.78	684995.51	3485870.22	11.00
23958.10	2800.63	1988-1993	17.11	3.42	686939.65	3485614.91	13.00
22959.00	2321.48	1988-1993	19.78	3.96	687153.72	3485775.78	13.00
657.59	294.28	1988-1993	4.47	0.89	687848.45	3484505.91	15.00
2999.49	754.77	1988-1993	7.95	1.59	687199.71	3483252.68	16.00
4943.88	1053.39	1988-1993	9.39	1.88	687675.98	3484039.35	16.00
5284.33	633.73	1988-1993	16.68	3.34	687513.62	3483718.67	16.00
14702.80	1210.50	1988-1993	24.29	4.86	686629.63	3482928.08	17.00
16082.20	2252.77	1988-1993	14.28	2.86	686260.33	3482338.57	18.00
16409.60	1495.07	1988-1993	21.95	4.39	686227.67	3482421.94	18.00

122303.00	3246.42	1988-1993	75.35	15.07	687971.19	3482660.59	20.00
35310.80	2488.20	1988-1993	28.38	5.68	689173.24	3482717.83	21.00
1841.70	740.15	1988-1993	4.98	1.00	689807.02	3481826.53	23.00
17464.10	2222.98	1988-1993	15.71	3.14	689769.30	3481594.19	23.00
1489.25	683.72	1988-1993	4.36	0.87	690855.48	3480180.83	25.00
355.65	144.05	1988-1993	4.94	0.99	690945.99	3480556.39	25.00
1341.51	485.87	1988-1993	5.52	1.10	690960.12	3480732.65	25.00
1546.11	356.55	1988-1993	8.67	1.73	690882.82	3480358.00	25.00
3357.68	620.48	1988-1993	10.82	2.16	690710.01	3479728.40	26.00
75681.60	3840.09	1988-1993	39.42	7.88	690535.53	3479491.57	26.00
772.61	302.39	1988-1993	5.11	1.02	688854.85	3478650.33	28.00
18598.30	3047.16	1988-1993	12.21	2.44	688604.73	3478353.68	28.00
3197.31	657.82	1988-1993	9.72	1.94	688308.86	3477059.29	30.00
34649.20	3536.44	1988-1993	19.60	3.92	688582.91	3476709.94	30.00
511.74	150.13	1988-1993	6.82	1.36	690300.22	3476574.10	32.00
5779.73	878.93	1988-1993	13.15	2.63	690354.44	3476597.87	32.00
1795.66	410.97	1988-1993	8.74	1.75	690806.22	3475989.29	33.00
1581.02	291.97	1988-1993	10.83	2.17	690856.55	3476191.28	33.00
12108.00	2432.58	1988-1993	9.95	1.99	690617.03	3475392.21	34.00
2631.73	726.59	1988-1993	7.24	1.45	689924.42	3474824.33	35.00
3798.31	848.34	1988-1993	8.95	1.79	689784.96	3474769.49	35.00
4930.55	869.72	1988-1993	11.34	2.27	689341.26	3474707.20	35.00
790.90	385.33	1988-1993	4.11	0.82	689041.51	3474526.66	36.00
481.73	219.52	1988-1993	4.39	0.88	688896.52	3474375.42	36.00
2227.58	436.86	1988-1993	10.20	2.04	688810.74	3474220.29	36.00
752.57	336.90	1993-1995	4.47	2.23	681131.40	3492181.76	1.00

5753.43	1580.34	1993-1995	7.28	3.64	681845.48	3491820.55	1.00
4615.46	1545.49	1993-1995	5.97	2.99	682280.19	3491369.37	2.00
2838.38	1356.15	1993-1995	4.19	2.09	682750.39	3490787.93	3.00
11227.50	1653.96	1993-1995	13.58	6.79	683139.12	3489882.56	4.00
357.87	152.76	1993-1995	4.69	2.34	684691.33	3489281.75	6.00
600.81	224.85	1993-1995	5.34	2.67	684653.10	3489237.25	6.00
265.00	88.56	1993-1995	5.98	2.99	684483.89	3489074.51	6.00
7905.10	2187.68	1993-1995	7.23	3.61	684175.73	3488970.70	6.00
29425.80	4058.40	1993-1995	14.50	7.25	684883.99	3489311.21	6.00
315.34	154.87	1993-1995	4.07	2.04	685491.96	3487045.40	9.00
6409.03	1206.85	1993-1995	10.62	5.31	685852.67	3487550.41	9.00
1083.60	478.23	1993-1995	4.53	2.27	684960.60	3486103.73	10.00
2628.66	975.20	1993-1995	5.39	2.70	685317.99	3486881.67	10.00
23120.00	4212.63	1993-1995	10.98	5.49	684995.51	3485870.22	11.00
3525.35	968.53	1993-1995	7.28	3.64	686988.36	3485649.92	13.00
40157.30	2822.59	1993-1995	28.45	14.23	687153.72	3485775.78	13.00
5742.01	1735.75	1993-1995	6.62	3.31	687828.24	3484418.32	15.00
2557.47	890.71	1993-1995	5.74	2.87	687199.71	3483252.68	16.00
615.13	227.59	1993-1995	5.41	2.70	686629.63	3482928.08	17.00
1394.82	372.08	1993-1995	7.50	3.75	686427.21	3482914.78	17.00
4616.75	922.57	1993-1995	10.01	5.00	687123.81	3483124.78	17.00
3408.42	922.49	1993-1995	7.39	3.69	686198.23	3482656.73	18.00
1181.22	247.30	1993-1995	9.55	4.78	686227.67	3482421.94	18.00
73948.00	7677.96	1993-1995	19.26	9.63	689173.24	3482717.83	21.00
1891.42	384.45	1993-1995	9.84	4.92	689889.73	3482405.21	22.00
7185.17	1457.52	1993-1995	9.86	4.93	689819.12	3481853.66	23.00

19562.40	2532.13	1993-1995	15.45	7.73	689762.57	3481623.34	23.00
535.86	243.84	1993-1995	4.40	2.20	690876.38	3480851.85	24.00
1885.95	400.60	1993-1995	9.42	4.71	690960.12	3480732.65	25.00
11262.20	2238.68	1993-1995	10.06	5.03	690937.97	3480527.87	25.00
1967.38	514.71	1993-1995	7.64	3.82	690535.53	3479491.57	26.00
57776.60	2532.82	1993-1995	45.62	22.81	690196.74	3479210.85	26.00
1515.31	504.11	1993-1995	6.01	3.01	688748.18	3478545.11	28.00
4978.45	1016.18	1993-1995	9.80	4.90	688577.35	3478300.35	28.00
1030.71	427.06	1993-1995	4.83	2.41	688242.63	3477706.17	29.00
5572.16	1850.94	1993-1995	6.02	3.01	688241.82	3477526.84	29.00
2498.36	653.07	1993-1995	7.65	3.83	688624.46	3476667.49	30.00
86330.50	5336.59	1993-1995	32.35	16.18	690828.70	3476075.67	33.00
14591.40	1811.81	1993-1995	16.11	8.05	690227.36	3474947.26	34.00
2614.24	969.55	1993-1995	5.39	2.70	689128.39	3474608.11	35.00
4292.53	1395.81	1993-1995	6.15	3.08	688766.03	3473845.14	36.00
3605.56	872.74	1993-1995	8.26	4.13	688757.40	3473904.51	36.00
61419.50	3953.06	1993-1995	31.07	15.54	689333.97	3473149.16	37.00
240.16	107.09	1995-2004	4.49	0.50	680895.40	3492218.74	0.00
1143.48	492.99	1995-2004	4.64	0.52	680984.44	3492207.49	0.00
595.07	272.01	1995-2004	4.38	0.49	681982.54	3491704.37	2.00
4750.58	1630.09	1995-2004	5.83	0.65	683065.00	3490109.47	4.00
12786.60	1101.34	1995-2004	23.22	2.58	683285.49	3489210.38	4.00
1547.68	486.17	1995-2004	6.37	0.71	683638.20	3488854.44	5.00
3361.83	1133.25	1995-2004	5.93	0.66	684483.89	3489074.51	6.00
5993.42	1797.99	1995-2004	6.67	0.74	684739.36	3489316.24	6.00
2126.19	545.83	1995-2004	7.79	0.87	684669.81	3489261.50	6.00

1490.09	513.42	1995-2004	5.80	0.64	685483.42	3488939.06	7.00
4560.03	1791.73	1995-2004	5.09	0.57	685867.99	3487992.96	8.00
2639.96	672.76	1995-2004	7.85	0.87	684968.44	3485955.50	11.00
17834.20	2156.06	1995-2004	16.54	1.84	686939.65	3485614.91	13.00
6558.85	2780.40	1995-2004	4.72	0.52	687482.92	3485698.11	14.00
11240.70	2441.77	1995-2004	9.21	1.02	687740.37	3484198.62	15.00
23357.60	3046.66	1995-2004	15.33	1.70	687135.22	3483152.16	17.00
5165.90	1202.80	1995-2004	8.59	0.95	686276.91	3482313.63	18.00
189.98	86.13	1995-2004	4.41	0.49	687186.37	3482163.21	19.00
265.93	104.32	1995-2004	5.10	0.57	686789.01	3482074.56	19.00
585.42	151.08	1995-2004	7.75	0.86	687255.31	3482214.93	19.00
2096.37	538.96	1995-2004	7.78	0.86	687078.08	3482115.95	19.00
2739.48	559.14	1995-2004	9.80	1.09	687447.68	3482296.99	19.00
6722.30	851.81	1995-2004	15.78	1.75	687804.30	3482600.26	20.00
30129.50	5849.20	1995-2004	10.30	1.14	689173.24	3482717.83	21.00
3666.04	1488.52	1995-2004	4.93	0.55	689998.01	3481290.99	23.00
652.95	249.99	1995-2004	5.22	0.58	689913.59	3481372.78	23.00
379.07	189.05	1995-2004	4.01	0.45	690919.70	3480810.72	25.00
569.64	268.93	1995-2004	4.24	0.47	690960.12	3480732.65	25.00
3379.24	1183.74	1995-2004	5.71	0.63	690937.97	3480527.87	25.00
4382.28	826.06	1995-2004	10.61	1.18	690603.19	3479548.48	26.00
2150.36	941.80	1995-2004	4.57	0.51	689811.29	3479052.09	27.00
3173.11	1289.26	1995-2004	4.92	0.55	688568.81	3478272.16	28.00
2618.93	578.04	1995-2004	9.06	1.01	688238.85	3477556.61	29.00
1702.66	714.27	2004-2008	4.77	1.19	680895.40	3492218.74	0.00
3657.00	1419.35	2004-2008	5.15	1.29	684116.98	3488959.39	6.00

16130.80	1445.16	2004-2008	22.32	5.58	684739.36	3489316.24	6.00
385.77	172.27	2004-2008	4.48	1.12	685104.46	3486522.76	10.00
2319.88	948.13	2004-2008	4.89	1.22	684955.65	3486074.39	10.00
1915.17	943.51	2004-2008	4.06	1.01	686643.78	3485283.50	13.00
16813.50	1587.10	2004-2008	21.19	5.30	687206.46	3485803.37	13.00
423.87	184.18	2004-2008	4.60	1.15	687351.59	3483507.57	16.00
1065.66	402.54	2004-2008	5.29	1.32	687480.92	3483670.01	16.00
528.42	262.63	2004-2008	4.02	1.01	687166.43	3483203.01	17.00
14054.60	1454.80	2004-2008	19.32	4.83	687077.74	3483051.07	17.00
2203.86	600.65	2004-2008	7.34	1.83	686193.90	3482627.40	18.00
2599.71	537.90	2004-2008	9.67	2.42	686355.84	3482865.98	18.00
816.59	272.95	2004-2008	5.98	1.50	686671.20	3482069.66	19.00
3918.79	1050.15	2004-2008	7.46	1.87	687282.07	3482228.36	19.00
9573.37	1663.44	2004-2008	11.51	2.88	688052.33	3482694.04	20.00
2736.04	1362.45	2004-2008	4.02	1.00	688997.04	3482684.83	21.00
7595.91	1613.70	2004-2008	9.41	2.35	689527.39	3482718.23	22.00
562.49	264.07	2004-2008	4.26	1.07	689791.08	3481538.40	23.00
353.71	122.85	2004-2008	5.76	1.44	689913.59	3481372.78	23.00
5307.50	1010.30	2004-2008	10.51	2.63	689928.89	3482119.33	23.00
5190.16	1028.84	2004-2008	10.09	2.52	690164.95	3481164.92	24.00
874.19	370.22	2004-2008	4.72	1.18	690952.78	3480761.72	25.00
7594.96	1276.50	2004-2008	11.90	2.97	690535.53	3479491.57	26.00
1676.12	581.75	2004-2008	5.76	1.44	689894.29	3479086.39	27.00
219.85	87.16	2004-2008	5.04	1.26	688248.28	3477407.63	29.00
1195.79	525.96	2008-2010	4.55	2.27	682718.54	3490838.76	3.00
16611.90	1147.09	2008-2010	28.96	14.48	684739.36	3489316.24	6.00

2889.01	1362.77	2008-2010	4.24	2.12	684975.85	3486222.47	10.00
688.41	317.29	2008-2010	4.34	2.17	686963.91	3485632.56	13.00
15545.30	1472.82	2008-2010	21.11	10.55	687206.46	3485803.37	13.00
2037.78	956.98	2008-2010	4.26	2.13	687803.78	3484332.06	15.00
375.89	112.28	2008-2010	6.70	3.35	687707.98	3484152.85	15.00
604.97	269.98	2008-2010	4.48	2.24	687424.87	3483601.62	16.00
278.01	123.26	2008-2010	4.51	2.26	687351.59	3483507.57	16.00
1832.01	663.19	2008-2010	5.52	2.76	687651.10	3483984.85	16.00
168.63	82.44	2008-2010	4.09	2.05	687123.81	3483124.78	17.00
965.64	327.81	2008-2010	5.89	2.95	686864.26	3482951.45	17.00
1564.49	440.81	2008-2010	7.10	3.55	686402.36	3482899.47	17.00
1888.01	333.01	2008-2010	11.34	5.67	686601.45	3482920.42	17.00
23098.60	2451.02	2008-2010	18.85	9.42	686208.06	3482684.92	18.00
3706.60	1109.03	2008-2010	6.68	3.34	686789.01	3482074.56	19.00
6026.35	1273.85	2008-2010	9.46	4.73	688317.71	3482693.60	20.00
271.39	103.00	2008-2010	5.27	2.63	689527.39	3482718.23	22.00
2973.74	1094.21	2008-2010	5.44	2.72	689879.41	3482462.14	22.00
269.62	130.90	2008-2010	4.12	2.06	689903.66	3482009.27	23.00
414.08	188.89	2008-2010	4.38	2.19	690952.78	3480761.72	25.00
13286.70	1687.86	2008-2010	15.74	7.87	690561.26	3479506.26	26.00
646.00	258.00	2008-2010	5.01	2.50	689811.29	3479052.09	27.00
1713.30	799.21	2008-2010	4.29	2.14	688671.56	3478453.19	28.00

Falls

Area (m2)	Perimeter (m)	Years	Migration amount (m)	Migration rate (m/yr)	X Coordinate	Y Coordinate	Distance downstream (km)

130749.00	1970.07	1929-1955	132.74	5.11	689934.06	3481351.46	23.00
340527.00	3159.26	1929-1955	215.57	8.29	690741.48	3480915.92	24.00
494167.00	2935.01	1929-1955	336.74	12.95	689811.29	3479052.09	27.00
392452.00	3384.28	1929-1955	231.93	8.92	688767.88	3478567.74	28.00
198579.00	3417.59	1929-1955	116.21	4.47	688344.13	3477918.93	29.00
41448.70	1414.65	1929-1955	58.60	2.25	689190.62	3476422.95	31.00
503077.00	4025.79	1929-1955	249.93	9.61	690300.22	3476574.10	32.00
1677660.00	7660.58	1929-1955	438.00	16.85	690038.21	3474859.82	34.00
206722.00	2121.88	1929-1955	194.85	7.49	688784.64	3474077.45	36.00
501984.00	3950.24	1929-1955	254.15	9.78	690251.83	3472539.73	38.00
78731.00	1661.56	1929-1955	94.77	3.64	690577.68	3472400.70	39.00
1107840.00	8078.95	1929-1955	274.25	10.55	691659.37	3472558.70	40.00
395553.00	4333.72	1929-1955	182.55	7.02	692794.31	3470702.51	46.00
114514.00	1798.41	1929-1955	127.35	4.90	691611.70	3470024.45	47.00
1944560.00	6148.63	1929-1955	632.52	24.33	692522.46	3468714.89	52.00
764593.00	6328.35	1929-1955	241.64	9.29	691431.21	3467502.71	54.00
455152.00	3103.59	1929-1955	293.31	11.28	690645.15	3467843.94	55.00
1622230.00	15997.20	1929-1955	202.81	7.80	693976.75	3461997.92	66.00
5980.55	460.42	1929-1955	25.98	1.00	694390.01	3461515.49	67.00
543793.00	6133.68	1929-1955	177.31	6.82	694842.68	3462088.48	68.00
973.59	308.76	1929-1955	6.31	0.24	696536.39	3460153.04	71.00
317546.00	5657.83	1929-1955	112.25	4.32	697978.18	3458779.99	73.00
413405.00	5635.37	1929-1955	146.72	5.64	696578.56	3456529.07	76.00
498.22	234.60	1929-1955	4.25	0.16	696968.68	3455690.58	77.00
1283.19	588.07	1929-1955	4.36	0.17	697045.17	3455598.82	77.00
414.50	175.57	1929-1955	4.72	0.18	696841.56	3455893.38	77.00

1157.11	454.99	1929-1955	5.09	0.20	696870.43	3455840.84	77.00
2266.14	656.10	1929-1955	6.91	0.27	696742.19	3456110.92	77.00
967937.00	4666.04	1929-1955	414.89	15.96	698611.28	3455301.09	79.00
248358.00	1859.52	1929-1955	267.12	10.27	699471.34	3454226.91	81.00
498530.00	4851.33	1929-1955	205.52	7.90	700935.89	3453125.42	84.00
274175.00	4252.10	1929-1955	128.96	4.96	702302.44	3452057.54	86.00
130928.00	3295.79	1929-1955	79.45	3.06	702056.74	3450393.36	88.00
1287660.00	16904.60	1929-1955	152.34	5.86	702254.21	3449808.77	89.00
10913.50	764.59	1929-1955	28.55	1.10	707687.83	3445021.26	97.00
1766.40	465.08	1929-1955	7.60	0.29	707138.54	3444247.25	98.00
18976.90	1340.48	1929-1955	28.31	1.09	707202.82	3444306.76	98.00
7608.40	1237.61	1929-1955	12.30	0.47	707058.31	3443545.66	99.00
4714.14	503.30	1929-1955	18.73	0.72	708713.74	3440199.84	103.00
39402.50	1289.37	1929-1955	61.12	2.35	708944.89	3440680.29	103.00
577529.00	7455.48	1929-1955	154.93	5.96	708862.75	3440805.56	103.00
148550.00	2709.92	1929-1955	109.63	4.22	708467.73	3439937.82	104.00
37071.20	1695.00	1955-1960	43.74	8.75	689834.16	3481459.69	23.00
1333.33	498.00	1955-1960	5.35	1.07	690964.73	3480703.01	25.00
3855.36	1096.00	1955-1960	7.04	1.41	690919.70	3480810.72	25.00
226730.00	4173.00	1955-1960	108.67	21.73	690891.76	3480386.47	25.00
29971.40	2871.00	1955-1960	20.88	4.18	689382.54	3478921.32	27.00
18551.90	2002.00	1955-1960	18.53	3.71	688344.13	3477918.93	29.00
1735.00	365.00	1955-1960	9.51	1.90	688273.24	3477173.46	30.00
32138.30	1518.00	1955-1960	42.34	8.47	688562.82	3476731.34	30.00
163737.00	5473.00	1955-1960	59.83	11.97	690762.89	3475815.23	33.00
117877.00	5422.00	1955-1960	43.48	8.70	690227.36	3474947.26	34.00

14088.20	1400.00	1955-1960	20.13	4.03	689388.64	3473124.60	37.00
6421.06	1188.00	1955-1960	10.81	2.16	689785.12	3472913.72	38.00
17251.00	1789.00	1955-1960	19.29	3.86	690117.17	3472658.98	38.00
49024.80	2560.00	1955-1960	38.30	7.66	692186.62	3472993.40	41.00
63264.60	2938.00	1955-1960	43.07	8.61	692144.63	3472950.55	41.00
62531.30	2425.00	1955-1960	51.57	10.31	694226.25	3472277.85	43.00
1743.02	434.00	1955-1960	8.03	1.61	693415.26	3471631.88	44.00
5695.30	641.00	1955-1960	17.77	3.55	693711.56	3471640.10	44.00
15528.20	1326.00	1955-1960	23.42	4.68	693355.77	3471627.72	44.00
4819.65	928.00	1955-1960	10.39	2.08	692842.10	3470844.11	45.00
2128.18	517.00	1955-1960	8.23	1.65	692785.39	3470673.94	46.00
170.27	85.00	1955-1960	4.01	0.80	691999.49	3470042.96	47.00
4988.56	1169.00	1955-1960	8.53	1.71	691611.70	3470024.45	47.00
17481.50	1341.00	1955-1960	26.07	5.21	692057.50	3470055.88	47.00
136867.00	4127.00	1955-1960	66.33	13.27	691026.94	3469827.63	48.00
178.31	64.00	1955-1960	5.57	1.11	690831.99	3468582.57	50.00
298.76	100.00	1955-1960	5.98	1.20	690891.87	3468585.17	50.00
11026.30	965.00	1955-1960	22.85	4.57	691219.91	3468607.84	50.00
6726.20	830.00	1955-1960	16.21	3.24	692942.20	3468233.86	52.00
84787.80	3954.00	1955-1960	42.89	8.58	692578.28	3468736.36	52.00
277.14	118.00	1955-1960	4.70	0.94	691992.87	3467365.50	54.00
15883.50	1835.00	1955-1960	17.31	3.46	692199.97	3467468.76	54.00
10501.70	1031.00	1955-1960	20.37	4.07	691431.21	3467502.71	54.00
34719.60	1968.00	1955-1960	35.28	7.06	690645.15	3467843.94	55.00
167081.00	6451.00	1955-1960	51.80	10.36	691656.86	3466450.40	58.00
155026.00	7333.00	1955-1960	42.28	8.46	690952.87	3465684.40	60.00

5921.40	697.00	1955-1960	16.99	3.40	692988.71	3463764.23	64.00
16632.30	1319.00	1955-1960	25.22	5.04	693174.85	3463508.75	64.00
2663.50	748.00	1955-1960	7.12	1.42	693976.75	3461997.92	66.00
85834.70	3906.00	1955-1960	43.95	8.79	695627.60	3462029.15	69.00
20347.70	1825.00	1955-1960	22.30	4.46	696781.23	3460029.22	71.00
71293.70	4205.00	1955-1960	33.91	6.78	696546.02	3460094.23	71.00
4496.00	1026.00	1955-1960	8.76	1.75	697758.04	3459473.50	72.00
2741.94	791.00	1955-1960	6.93	1.39	698029.09	3458612.26	73.00
17016.90	1800.00	1955-1960	18.91	3.78	698102.88	3458266.11	74.00
3427.91	620.00	1955-1960	11.06	2.21	697201.90	3457654.63	75.00
50318.20	4263.00	1955-1960	23.61	4.72	697056.48	3457619.32	75.00
196603.00	5360.00	1955-1960	73.36	14.67	698997.90	3455307.48	79.00
171202.00	4965.00	1955-1960	68.96	13.79	700117.02	3453929.39	82.00
896.34	214.00	1955-1960	8.38	1.68	700292.75	3453959.67	83.00
46557.80	2338.00	1955-1960	39.83	7.97	701000.48	3452958.11	84.00
53643.90	2035.00	1955-1960	52.72	10.54	700935.89	3453125.42	84.00
37804.20	3066.00	1955-1960	24.66	4.93	702302.44	3452057.54	86.00
8571.65	1346.00	1955-1960	12.74	2.55	702755.80	3451215.73	87.00
1452.65	519.00	1955-1960	5.60	1.12	702120.15	3450456.13	88.00
32005.30	1515.00	1955-1960	42.25	8.45	702025.63	3450342.87	88.00
13408.60	1207.00	1955-1960	22.22	4.44	704229.24	3448764.06	91.00
93882.70	4585.00	1955-1960	40.95	8.19	703802.14	3449087.82	91.00
60632.80	3851.00	1955-1960	31.49	6.30	705071.19	3447668.50	93.00
25761.10	2423.00	1955-1960	21.26	4.25	706772.51	3447631.56	94.00
24773.40	3314.00	1955-1960	14.95	2.99	707620.55	3446028.41	96.00
4346.50	759.00	1955-1960	11.45	2.29	707761.97	3445478.06	97.00

41832.50	1721.00	1955-1960	48.61	9.72	707700.90	3445048.26	97.00
903.27	249.00	1955-1960	7.26	1.45	707180.18	3444287.98	98.00
9557.01	1643.00	1955-1960	11.63	2.33	707138.54	3444247.25	98.00
14887.30	1911.00	1955-1960	15.58	3.12	706979.96	3442676.77	100.00
28639.80	3147.00	1955-1960	18.20	3.64	708692.15	3441050.59	102.00
8711.02	1980.00	1955-1960	8.80	1.76	708527.62	3440004.88	104.00
5994.78	1526.00	1955-1960	7.86	1.57	707919.05	3438946.37	105.00
75851.50	2193.78	1960-1968	69.15	8.64	690044.78	3481253.85	24.00
57789.50	5439.87	1960-1968	21.25	2.66	690939.63	3480788.34	25.00
28265.00	1758.35	1960-1968	32.15	4.02	690279.05	3476552.98	32.00
279600.00	8773.18	1960-1968	63.74	7.97	690137.55	3476509.72	32.00
344.08	129.52	1960-1968	5.31	0.66	690743.26	3475727.55	33.00
389.08	131.46	1960-1968	5.92	0.74	690762.89	3475815.23	33.00
13656.10	1648.98	1960-1968	16.56	2.07	690570.37	3475315.46	34.00
9029.42	1118.59	1960-1968	16.14	2.02	690117.17	3472658.98	38.00
325548.00	6914.76	1960-1968	94.16	11.77	689679.93	3472971.09	38.00
28511.40	2224.87	1960-1968	25.63	3.20	690489.82	3472419.58	39.00
5487.75	793.41	1960-1968	13.83	1.73	691907.65	3472724.08	40.00
40414.40	3528.19	1960-1968	22.91	2.86	692186.62	3472993.40	41.00
11430.70	1112.39	1960-1968	20.55	2.57	693776.64	3472876.73	42.00
147962.00	3556.64	1960-1968	83.20	10.40	693385.29	3471632.52	44.00
5704.09	1695.85	1960-1968	6.73	0.84	692854.74	3470902.66	45.00
47684.20	2840.21	1960-1968	33.58	4.20	692842.10	3470844.11	45.00
239429.00	5850.45	1960-1968	81.85	10.23	691640.96	3470030.30	47.00
7023.05	1161.76	1960-1968	12.09	1.51	691503.47	3468525.10	50.00
1160.98	475.06	1960-1968	4.89	0.61	691766.61	3468474.47	51.00

813.22	263.04	1960-1968	6.18	0.77	692392.11	3468643.93	51.00
1107.93	355.50	1960-1968	6.23	0.78	691974.21	3468485.56	51.00
3099.10	540.67	1960-1968	11.46	1.43	692337.57	3468619.18	51.00
44589.30	5125.73	1960-1968	17.40	2.17	692664.96	3468760.36	52.00
6977.23	1547.25	1960-1968	9.02	1.13	690763.85	3467834.43	55.00
202210.00	5346.30	1960-1968	75.64	9.46	691627.08	3466453.85	58.00
138552.00	2064.05	1960-1968	134.25	16.78	691859.18	3466264.69	59.00
108602.00	5504.59	1960-1968	39.46	4.93	692187.74	3464800.98	62.00
55732.30	2202.81	1960-1968	50.60	6.33	692247.48	3464795.71	63.00
1709.31	415.46	1960-1968	8.23	1.03	692988.71	3463764.23	64.00
6454.11	1630.61	1960-1968	7.92	0.99	693492.25	3463117.72	65.00
8036.36	1665.40	1960-1968	9.65	1.21	693788.69	3462502.43	65.00
24473.70	2391.78	1960-1968	20.46	2.56	694044.84	3461832.05	66.00
69684.00	2544.92	1960-1968	54.76	6.85	694842.68	3462088.48	68.00
4002.46	959.50	1960-1968	8.34	1.04	696210.27	3461479.40	69.00
36614.70	1911.35	1960-1968	38.31	4.79	696443.21	3461062.11	70.00
1092.34	542.91	1960-1968	4.02	0.50	696926.04	3459991.79	71.00
4040.72	423.31	1960-1968	19.09	2.39	696546.02	3460094.23	71.00
1500.24	557.72	1960-1968	5.38	0.67	697356.19	3459732.58	72.00
1025.14	500.38	1960-1968	4.10	0.51	697932.77	3458949.00	73.00
3422.46	599.32	1960-1968	11.42	1.43	698090.37	3458415.45	73.00
1044.23	427.47	1960-1968	4.89	0.61	697114.44	3457634.33	75.00
31359.50	1924.67	1960-1968	32.59	4.07	697172.54	3457648.47	75.00
59638.30	2579.66	1960-1968	46.24	5.78	696486.07	3456869.74	76.00
1903.84	837.26	1960-1968	4.55	0.57	696841.56	3455893.38	77.00
1241.85	501.27	1960-1968	4.95	0.62	696755.94	3456084.25	77.00

67228.20	3816.85	1960-1968	35.23	4.40	698611.28	3455301.09	79.00
294511.00	3907.67	1960-1968	150.74	18.84	698938.03	3455308.04	79.00
42356.80	1752.22	1960-1968	48.35	6.04	699318.41	3453880.79	82.00
95001.10	3216.61	1960-1968	59.07	7.38	700935.89	3453125.42	84.00
75413.90	3287.63	1960-1968	45.88	5.73	701731.46	3452371.96	85.00
57586.90	3658.60	1960-1968	31.48	3.94	702471.11	3451888.01	86.00
1370.02	475.80	1960-1968	5.76	0.72	702025.63	3450342.87	88.00
3062.65	886.09	1960-1968	6.91	0.86	702062.95	3450174.50	88.00
6927.27	2067.44	1960-1968	6.70	0.84	702763.45	3449451.84	89.00
1661.14	430.94	1960-1968	7.71	0.96	703212.48	3449297.40	90.00
3448.19	529.76	1960-1968	13.02	1.63	703497.71	3449210.62	90.00
15726.30	1250.93	1960-1968	25.14	3.14	703968.80	3448962.34	91.00
26119.80	2055.91	1960-1968	25.41	3.18	704678.65	3448123.72	92.00
23267.20	2264.94	1960-1968	20.55	2.57	705505.41	3447570.58	93.00
24193.90	2586.77	1960-1968	18.71	2.34	706772.51	3447631.56	94.00
725.61	356.36	1960-1968	4.07	0.51	707365.21	3446846.81	95.00
4356.00	659.98	1960-1968	13.20	1.65	707267.63	3447148.00	95.00
4215.74	463.30	1960-1968	18.20	2.27	707271.40	3447029.81	95.00
5032.92	816.19	1960-1968	12.33	1.54	707577.85	3446140.37	96.00
6084.93	985.43	1960-1968	12.35	1.54	707402.23	3446551.33	96.00
440.37	189.85	1960-1968	4.64	0.58	707732.77	3445594.31	97.00
71197.30	2745.15	1960-1968	51.87	6.48	707755.02	3445507.19	97.00
20881.10	1426.36	1960-1968	29.28	3.66	707117.26	3444227.05	98.00
2703.59	721.68	1960-1968	7.49	0.94	708692.15	3441050.59	102.00
69339.40	6736.30	1960-1968	20.59	2.57	708354.71	3441572.05	102.00
24709.20	2047.06	1968-1978	24.14	2.41	690849.62	3480864.68	24.00

11551.10	1458.33	1968-1978	15.84	1.58	690836.95	3480062.44	25.00
2558.94	756.26	1968-1978	6.77	0.68	690535.53	3479491.57	26.00
88765.20	4133.93	1968-1978	42.94	4.29	692580.90	3473174.35	41.00
1886.94	578.29	1968-1978	6.53	0.65	694247.46	3472256.67	43.00
2518.91	435.55	1968-1978	11.57	1.16	693927.20	3472738.58	43.00
38188.00	2966.66	1968-1978	25.74	2.57	694313.06	3472126.73	43.00
425.80	201.62	1968-1978	4.22	0.42	692864.03	3470931.12	45.00
789.53	335.75	1968-1978	4.70	0.47	693103.55	3471438.92	45.00
1197.81	303.94	1968-1978	7.88	0.79	693177.44	3471532.33	45.00
15112.10	1600.82	1968-1978	18.88	1.89	690795.53	3466607.62	57.00
35463.60	2598.55	1968-1978	27.29	2.73	691627.08	3466453.85	58.00
1498.25	331.79	1968-1978	9.03	0.90	691333.75	3465856.39	60.00
12464.80	1712.96	1968-1978	14.55	1.46	690952.87	3465684.40	60.00
24658.80	2601.19	1968-1978	18.96	1.90	691211.68	3464859.44	61.00
753.03	272.10	1968-1978	5.53	0.55	691860.40	3464770.14	62.00
68641.50	3040.61	1968-1978	45.15	4.51	692187.74	3464800.98	62.00
4021.82	557.46	1968-1978	14.43	1.44	692991.90	3463734.43	64.00
776.36	295.73	1968-1978	5.25	0.53	697056.48	3457619.32	75.00
4204.72	516.05	1968-1978	16.30	1.63	696826.40	3457484.14	75.00
85657.10	3222.84	1968-1978	53.16	5.32	699146.31	3455325.23	80.00
13260.20	2324.90	1968-1978	11.41	1.14	699341.26	3453825.95	82.00
1194.05	418.02	1968-1978	5.71	0.57	700888.62	3453235.07	84.00
1301.15	367.14	1968-1978	7.09	0.71	700959.88	3453070.50	84.00
58024.00	2349.40	1968-1978	49.39	4.94	700858.02	3453377.42	84.00
72602.00	3562.23	1968-1995	40.76	1.51	690519.58	3481006.81	24.00
2483.24	777.63	1968-1995	6.39	0.24	690808.41	3479946.63	25.00

4115.19	834.83	1968-1995	9.86	0.37	690968.15	3480673.22	25.00
63473.20	3563.34	1968-1995	35.63	1.32	689555.32	3478970.31	27.00
5536.16	752.75	1968-1995	14.71	0.54	688524.27	3478194.38	28.00
35600.00	2230.85	1968-1995	31.92	1.18	688878.52	3478668.75	28.00
87925.00	5359.42	1968-1995	32.81	1.22	688697.88	3476617.55	30.00
184252.00	7910.76	1968-1995	46.58	1.73	690038.21	3474859.82	34.00
89084.80	3913.75	1968-1995	45.52	1.69	689388.64	3473124.60	37.00
8897.41	1412.71	1968-1995	12.60	0.47	689758.92	3472928.31	38.00
194697.00	4381.94	1968-1995	88.86	3.29	690251.83	3472539.73	38.00
47751.00	3417.63	1968-1995	27.94	1.03	693112.37	3473132.84	42.00
53400.80	1567.80	1968-1995	68.12	2.52	693873.13	3472805.65	42.00
36161.70	2640.83	1968-1995	27.39	1.01	693415.26	3471631.88	44.00
34165.30	1989.91	1968-1995	34.34	1.27	693020.64	3471314.65	45.00
40988.30	3594.46	1968-1995	22.81	0.84	691611.70	3470024.45	47.00
655.59	284.61	1968-1995	4.61	0.17	691421.93	3468562.08	50.00
44769.40	5796.85	1968-1995	15.45	0.57	691011.42	3468591.55	50.00
22983.90	2561.18	1968-1995	17.95	0.66	691503.47	3468525.10	50.00
90503.10	5573.88	1968-1995	32.47	1.20	692782.39	3468754.70	52.00
100140.00	4137.42	1968-1995	48.41	1.79	690063.20	3467065.52	56.00
22171.50	1135.37	1968-1995	39.06	1.45	690622.01	3466768.03	57.00
329.28	103.53	1968-1995	6.36	0.24	691737.87	3466417.83	58.00
376.36	99.79	1968-1995	7.54	0.28	691784.37	3466386.97	58.00
69219.90	1960.83	1968-1995	70.60	2.61	690947.47	3466472.34	58.00
9004.50	949.40	1968-1995	18.97	0.70	691392.36	3465868.22	59.00
32767.40	1763.24	1968-1995	37.17	1.38	691896.71	3466124.78	59.00
5752.53	882.78	1968-1995	13.03	0.48	690952.87	3465684.40	60.00

52333.30	4045.02	1968-1995	25.88	0.96	690530.26	3465231.45	61.00
121946.00	2812.53	1968-1995	86.72	3.21	692187.74	3464800.98	62.00
13604.60	852.64	1968-1995	31.91	1.18	693001.84	3463706.33	64.00
1555.73	520.74	1968-1995	5.98	0.22	693422.48	3463214.46	65.00
22348.70	1770.89	1968-1995	25.24	0.93	694937.81	3462203.37	68.00
75828.10	5026.33	1968-1995	30.17	1.12	694812.68	3462036.56	68.00
5592.87	1757.00	1968-1995	6.37	0.24	696150.68	3461546.81	69.00
1015.18	447.47	1968-1995	4.54	0.17	696371.17	3461226.61	70.00
26666.50	1812.21	1968-1995	29.43	1.09	696492.56	3460920.75	70.00
7948.70	1208.21	1968-1995	13.16	0.49	696781.23	3460029.22	71.00
4076.63	506.66	1968-1995	16.09	0.60	697116.69	3459905.94	71.00
7484.49	1272.18	1968-1995	11.77	0.44	697401.38	3459693.52	72.00
234.85	115.22	1968-1995	4.08	0.15	697965.90	3458837.00	73.00
3026.52	983.69	1968-1995	6.15	0.23	697882.48	3459273.71	73.00
1181.99	330.69	1968-1995	7.15	0.26	697978.89	3458750.48	73.00
10776.70	2028.13	1968-1995	10.63	0.39	696877.09	3457514.88	75.00
47717.30	3172.34	1968-1995	30.08	1.11	697346.77	3457692.95	75.00
9063.12	1907.26	1968-1995	9.50	0.35	696615.80	3456447.40	76.00
9753.02	924.83	1968-1995	21.09	0.78	698668.63	3455314.58	79.00
72376.90	4271.92	1968-1995	33.88	1.25	698527.41	3455270.77	79.00
149078.00	3851.79	1968-1995	77.41	2.87	699293.59	3455352.26	80.00
28585.10	1607.45	1968-1995	35.57	1.32	700089.04	3453918.58	82.00
100324.00	2185.80	1968-1995	91.80	3.40	700174.36	3453946.58	83.00
7859.70	1174.73	1968-1995	13.38	0.50	701011.77	3452930.32	84.00
9042.43	1336.55	1968-1995	13.53	0.50	701265.68	3452474.17	85.00
171210.00	5851.05	1968-1995	58.52	2.17	702147.56	3450467.60	88.00

39672.10	3648.27	1968-1995	21.75	0.81	703096.69	3449326.66	90.00
17899.90	1436.03	1968-1995	24.93	0.92	703354.64	3449250.20	90.00
9725.32	955.19	1968-1995	20.36	0.75	704034.22	3448901.35	91.00
44757.40	1248.51	1968-1995	71.70	2.66	704453.40	3448625.23	91.00
77351.50	4705.33	1968-1995	32.88	1.22	706306.19	3447582.52	94.00
561.74	249.90	1968-1995	4.50	0.17	707332.64	3446928.15	95.00
97205.30	1914.49	1968-1995	101.55	3.76	707271.40	3447029.81	95.00
2482.60	761.10	1968-1995	6.52	0.24	707577.85	3446140.37	96.00
5428.20	1421.52	1968-1995	7.64	0.28	707434.48	3446436.75	96.00
111790.00	3284.58	1968-1995	68.07	2.52	707732.77	3445594.31	97.00
20245.10	1412.39	1968-1995	28.67	1.06	707096.34	3444206.18	98.00
35150.60	1746.58	1968-1995	40.25	1.49	707060.19	3443515.72	99.00
23249.20	3397.12	1968-1995	13.69	0.51	708180.48	3441735.39	102.00
10242.60	1170.36	1968-1995	17.50	0.65	708431.02	3441479.95	102.00
11335.10	1139.62	1968-1995	19.89	0.74	708726.93	3441001.93	102.00
8792.60	929.56	1978-1995	18.92	1.11	690960.12	3480732.65	25.00
84768.50	6899.04	1978-1995	24.57	1.45	692580.90	3473174.35	41.00
59398.60	3116.94	1978-1995	38.11	2.24	693672.38	3472935.09	42.00
6298.01	1376.59	1978-1995	9.15	0.54	694077.26	3471767.66	44.00
38757.80	2867.30	1978-1995	27.03	1.59	693245.41	3471589.17	45.00
375.43	115.99	1978-1995	6.47	0.38	692286.60	3467481.09	53.00
9217.21	1465.72	1978-1995	12.58	0.74	692662.20	3467725.58	53.00
752.11	217.23	1978-1995	6.92	0.41	692178.16	3467450.24	54.00
66181.00	3008.05	1978-1995	44.00	2.59	690814.29	3466585.20	57.00
3003.78	333.63	1978-1995	18.01	1.06	691866.04	3465980.48	59.00
5769.69	584.42	1978-1995	19.75	1.16	691630.19	3465861.48	59.00

10876.50	1373.55	1978-1995	15.84	0.93	690846.69	3465629.64	60.00
83775.10	5035.64	1978-1995	33.27	1.96	690660.24	3465535.51	60.00
57313.70	2254.95	1978-1995	50.83	2.99	692519.11	3464675.48	63.00
1513.08	295.66	1978-1995	10.24	0.60	696826.40	3457484.14	75.00
3160.52	603.06	1978-1995	10.48	0.62	697114.44	3457634.33	75.00
30177.90	1438.63	1978-1995	41.95	2.47	699293.59	3455352.26	80.00
2135.11	453.87	1978-1995	9.41	0.55	699555.64	3454779.34	81.00
44345.30	1989.64	1978-1995	44.58	2.62	699547.99	3454630.37	81.00
22833.80	1771.19	1978-1995	25.78	1.52	700145.19	3453939.66	82.00
45005.80	1496.74	1978-1995	60.14	3.54	700442.03	3453972.62	83.00
8921.70	1289.27	1978-1995	13.84	0.81	701011.77	3452930.32	84.00
164807.00	4866.83	1978-1995	67.73	3.98	711270.93	3438321.03	110.00
1829.50	677.41	1978-1995	5.40	0.32	711923.50	3437048.77	111.00
51083.60	2110.81	1978-1995	48.40	2.85	711804.08	3437041.86	111.00
7278.53	902.07	1978-1995	16.14	0.95	712364.22	3437126.25	112.00
70345.00	2573.13	1978-1995	54.68	3.22	712824.89	3437250.75	112.00
1763.75	422.36	1978-1995	8.35	0.49	712871.26	3436284.41	114.00
412.98	194.00	1995-2004	4.26	0.47	689160.63	3476422.17	31.00
2826.26	623.06	1995-2004	9.07	1.01	690354.44	3476597.87	32.00
12981.40	1578.70	1995-2004	16.45	1.83	690850.21	3476310.20	33.00
1042.07	452.49	1995-2004	4.61	0.51	689341.26	3474707.20	35.00
3471.80	1366.27	1995-2004	5.08	0.56	689784.96	3474769.49	35.00
1815.15	675.87	1995-2004	5.37	0.60	689128.39	3474608.11	35.00
1791.11	569.37	1995-2004	6.29	0.70	688776.35	3473817.12	36.00
4107.61	991.62	1995-2004	8.28	0.92	688882.68	3474348.83	36.00
1001.66	441.00	1995-2004	4.54	0.50	689070.65	3473286.34	37.00

1611.79	603.89	1995-2004	5.34	0.59	689333.97	3473149.16	37.00
578.79	191.82	1995-2004	6.03	0.67	688859.54	3473562.76	37.00
2311.14	920.84	1995-2004	5.02	0.56	691181.38	3472397.24	39.00
10750.00	2364.59	1995-2004	9.09	1.01	690548.01	3472405.05	39.00
1036.42	406.53	1995-2004	5.10	0.57	692101.89	3472908.44	40.00
1596.30	569.20	1995-2004	5.61	0.62	691907.65	3472724.08	40.00
24293.20	2148.83	1995-2004	22.61	2.51	692819.06	3473184.72	41.00
3593.21	1471.41	1995-2004	4.88	0.54	693513.37	3473016.99	42.00
1404.05	386.04	1995-2004	7.27	0.81	694221.70	3471914.00	43.00
40791.20	1662.48	1995-2004	49.07	5.45	694038.95	3472542.38	43.00
5134.15	1740.57	1995-2004	5.90	0.66	693296.82	3471618.32	45.00
12127.30	1430.16	1995-2004	16.96	1.88	693245.41	3471589.17	45.00
2910.19	1189.51	1995-2004	4.89	0.54	692057.50	3470055.88	47.00
655.02	288.14	1995-2004	4.55	0.51	690229.26	3468849.47	49.00
2872.47	1022.60	1995-2004	5.62	0.62	690413.78	3469308.27	49.00
1515.68	466.74	1995-2004	6.49	0.72	690298.31	3468685.68	49.00
3105.62	1255.05	1995-2004	4.95	0.55	691279.35	3468606.47	50.00
3856.84	1328.87	1995-2004	5.80	0.64	692337.57	3468619.18	51.00
1236.44	486.13	1995-2004	5.09	0.57	692950.28	3468262.67	52.00
1714.10	699.69	1995-2004	4.90	0.54	692864.51	3467975.95	53.00
19604.20	3603.78	1995-2004	10.88	1.21	692440.87	3467571.28	53.00
1897.48	899.60	1995-2004	4.22	0.47	690306.70	3467725.35	56.00
539.93	243.69	1995-2004	4.43	0.49	690038.41	3467455.85	56.00
286.17	117.20	1995-2004	4.88	0.54	690063.20	3467065.52	56.00
921.71	409.67	1995-2004	4.50	0.50	690459.59	3466895.69	57.00
1296.51	567.36	1995-2004	4.57	0.51	690643.76	3466749.07	57.00

219.74	85.63	1995-2004	5.13	0.57	690856.46	3466545.58	57.00
495.29	185.46	1995-2004	5.34	0.59	690106.52	3467027.16	57.00
1763.73	438.08	1995-2004	8.05	0.89	690178.42	3466978.48	57.00
198.82	80.11	1995-2004	4.96	0.55	691509.61	3466447.89	58.00
1986.45	545.99	1995-2004	7.28	0.81	691537.33	3466459.24	58.00
791.74	189.09	1995-2004	8.37	0.93	691784.37	3466386.97	58.00
5858.23	1062.25	1995-2004	11.03	1.23	690995.50	3466438.12	58.00
430.64	210.80	1995-2004	4.09	0.45	691630.19	3465861.48	59.00
933.67	360.09	1995-2004	5.19	0.58	691451.92	3465867.60	59.00
599.38	187.73	1995-2004	6.39	0.71	691719.45	3465868.70	59.00
4738.98	981.88	1995-2004	9.65	1.07	691845.56	3466291.40	59.00
1611.68	538.84	1995-2004	5.98	0.66	690611.67	3465500.75	60.00
4753.90	1185.48	1995-2004	8.02	0.89	691333.75	3465856.39	60.00
274.86	112.39	1995-2004	4.89	0.54	690591.27	3465097.16	61.00
581.59	209.85	1995-2004	5.54	0.62	690537.39	3465202.41	61.00
3944.85	1010.35	1995-2004	7.81	0.87	690750.91	3464977.60	61.00
1438.01	688.69	1995-2004	4.18	0.46	691268.73	3464841.59	62.00
3562.46	1227.81	1995-2004	5.80	0.64	691890.37	3464771.38	62.00
5279.57	591.76	1995-2004	17.84	1.98	693027.18	3463653.19	64.00
46339.80	2743.33	1995-2004	33.78	3.75	692986.75	3464118.54	64.00
9922.30	4108.81	1995-2004	4.83	0.54	693954.41	3462053.54	66.00
15916.40	1744.34	1995-2004	18.25	2.03	694336.07	3461541.65	67.00
18279.00	1881.43	1995-2004	19.43	2.16	695044.34	3462257.20	68.00
590.11	176.85	1995-2004	6.67	0.74	695645.15	3462004.84	69.00
23832.40	4621.81	1995-2004	10.31	1.15	696569.56	3460478.91	70.00
1244.96	444.19	1995-2004	5.61	0.62	696840.19	3460018.52	71.00

1280.26	599.47	1995-2004	4.27	0.47	697170.78	3459880.71	72.00
8839.24	1830.71	1995-2004	9.66	1.07	698062.32	3458039.49	74.00
3101.44	1065.03	1995-2004	5.82	0.65	697346.77	3457692.95	75.00
3151.57	659.02	1995-2004	9.56	1.06	696826.40	3457484.14	75.00
4630.65	463.39	1995-2004	19.99	2.22	696980.85	3457573.08	75.00
2761.32	840.92	1995-2004	6.57	0.73	696732.01	3456139.05	77.00
13290.50	1680.12	1995-2004	15.82	1.76	697385.24	3455362.11	78.00
6976.28	744.46	1995-2004	18.74	2.08	697669.37	3455279.48	78.00
1239.28	594.30	1995-2004	4.17	0.46	698611.28	3455301.09	79.00
3786.90	832.08	1995-2004	9.10	1.01	698277.39	3455185.81	79.00
25058.80	1380.17	1995-2004	36.31	4.03	699293.59	3455352.26	80.00
34527.60	1515.26	1995-2004	45.57	5.06	699506.15	3455274.84	80.00
1333.23	514.06	1995-2004	5.19	0.58	699552.13	3454720.09	81.00
12699.10	1420.90	1995-2004	17.87	1.99	699552.26	3454451.72	81.00
8299.28	1810.59	1995-2004	9.17	1.02	700117.02	3453929.39	82.00
39438.90	1864.61	1995-2004	42.30	4.70	700471.90	3453974.77	83.00
2379.53	853.80	1995-2004	5.57	0.62	700935.89	3453125.42	84.00
1863.98	628.67	1995-2004	5.93	0.66	701061.45	3452789.00	84.00
688.88	326.86	1995-2004	4.22	0.47	701190.80	3452523.74	85.00
1962.64	920.74	1995-2004	4.26	0.47	701496.79	3452418.98	85.00
3434.45	925.06	1995-2004	7.43	0.83	702654.55	3451616.82	86.00
1392.98	425.56	1995-2004	6.55	0.73	702731.96	3451422.60	87.00
2706.72	1105.36	1995-2004	4.90	0.54	702120.15	3450456.13	88.00
19235.00	2185.47	1995-2004	17.60	1.96	702346.99	3450525.00	88.00
442.49	214.30	1995-2004	4.13	0.46	702211.91	3449849.91	89.00
32396.60	5598.02	1995-2004	11.57	1.29	704479.92	3448612.13	91.00

1432.92	438.77	1995-2004	6.53	0.73	705683.35	3447548.52	93.00
2228.10	959.44	1995-2004	4.64	0.52	706306.19	3447582.52	94.00
1137.42	343.33	1995-2004	6.63	0.74	706515.09	3447582.99	94.00
2056.32	369.77	1995-2004	11.12	1.24	706772.51	3447631.56	94.00
22587.10	1667.81	1995-2004	27.09	3.01	706888.10	3447655.18	94.00
1969.43	928.49	1995-2004	4.24	0.47	707344.49	3446901.02	95.00
2350.54	898.56	1995-2004	5.23	0.58	707724.27	3445623.08	97.00
9594.71	1235.06	1995-2004	15.54	1.73	707744.21	3445159.82	97.00
11594.30	1205.19	1995-2004	19.24	2.14	707398.92	3444443.85	98.00
8989.83	1421.51	1995-2004	12.65	1.41	707055.25	3443426.05	99.00
13079.60	1603.70	1995-2004	16.31	1.81	707017.57	3444015.72	99.00
211.92	103.11	2004-2008	4.11	1.03	690279.05	3476552.98	32.00
56958.00	2103.86	2004-2008	54.15	13.54	690850.21	3476310.20	33.00
3794.02	1635.36	2004-2008	4.64	1.16	689341.26	3474707.20	35.00
9031.79	1714.56	2004-2008	10.54	2.63	689060.45	3474549.90	36.00
2659.70	923.83	2004-2008	5.76	1.44	689172.33	3473226.01	37.00
682.38	115.00	2004-2008	11.87	2.97	688867.77	3473536.93	37.00
511.36	144.46	2004-2008	7.08	1.77	690829.21	3472369.98	39.00
16933.50	1591.16	2004-2008	21.28	5.32	692580.90	3473174.35	41.00
990.34	400.65	2004-2008	4.94	1.24	694282.87	3472016.16	43.00
6860.75	1308.72	2004-2008	10.48	2.62	694038.95	3472542.38	43.00
1335.52	254.43	2004-2008	10.50	2.62	693939.42	3472683.07	43.00
1268.95	567.23	2004-2008	4.47	1.12	693296.82	3471618.32	45.00
15093.40	2896.57	2004-2008	10.42	2.61	692864.03	3470931.12	45.00
2415.13	1198.04	2004-2008	4.03	1.01	691640.96	3470030.30	47.00
1283.08	552.03	2004-2008	4.65	1.16	690239.19	3468997.36	49.00

2650.86	934.13	2004-2008	5.68	1.42	690298.31	3468685.68	49.00
3148.14	988.74	2004-2008	6.37	1.59	692724.66	3468765.39	52.00
1070.41	330.96	2004-2008	6.47	1.62	692578.28	3468736.36	52.00
6275.58	1288.91	2004-2008	9.74	2.43	692792.10	3467845.87	53.00
2727.34	1204.29	2004-2008	4.53	1.13	691684.10	3467412.55	54.00
301.35	129.54	2004-2008	4.65	1.16	692078.04	3467393.01	54.00
315.13	115.32	2004-2008	5.47	1.37	692178.16	3467450.24	54.00
576.29	282.24	2004-2008	4.08	1.02	690049.73	3467483.62	56.00
5095.59	775.21	2004-2008	13.15	3.29	690004.85	3467372.67	56.00
153.40	71.32	2004-2008	4.30	1.08	690643.76	3466749.07	57.00
1089.48	497.47	2004-2008	4.38	1.10	690431.87	3466906.53	57.00
194.51	84.29	2004-2008	4.62	1.15	690376.37	3466921.83	57.00
3829.88	458.22	2004-2008	16.72	4.18	690106.52	3467027.16	57.00
308.46	137.10	2004-2008	4.50	1.12	691656.86	3466450.40	58.00
5229.44	1107.94	2004-2008	9.44	2.36	691537.33	3466459.24	58.00
3382.31	593.29	2004-2008	11.40	2.85	691712.27	3466429.96	58.00
1039.95	420.98	2004-2008	4.94	1.24	691888.87	3466213.90	59.00
6738.17	1316.76	2004-2008	10.23	2.56	691333.75	3465856.39	60.00
870.55	350.29	2004-2008	4.97	1.24	690528.17	3465319.02	61.00
994.59	278.16	2004-2008	7.15	1.79	690635.23	3465060.96	61.00
4137.99	932.48	2004-2008	8.88	2.22	690977.77	3464900.51	61.00
3204.69	1396.89	2004-2008	4.59	1.15	691620.73	3464774.50	62.00
11170.70	964.30	2004-2008	23.17	5.79	692896.58	3464301.88	63.00
2154.91	802.71	2004-2008	5.37	1.34	693042.82	3463627.59	64.00
4443.84	465.30	2004-2008	19.10	4.78	692995.50	3463823.37	64.00
9875.67	2520.76	2004-2008	7.84	1.96	694044.84	3461832.05	66.00

989.97	419.31	2004-2008	4.72	1.18	695490.59	3462183.49	68.00
2527.42	1208.61	2004-2008	4.18	1.05	695789.14	3461901.98	69.00
238.93	101.17	2004-2008	4.72	1.18	695604.78	3462046.58	69.00
411.53	169.35	2004-2008	4.86	1.22	695645.15	3462004.84	69.00
737.42	268.25	2004-2008	5.50	1.37	696558.85	3460420.74	71.00
214.88	96.42	2004-2008	4.46	1.11	697958.61	3458865.69	73.00
1275.44	469.97	2004-2008	5.43	1.36	697965.90	3458837.00	73.00
2494.09	951.27	2004-2008	5.24	1.31	698062.32	3458039.49	74.00
3299.15	1541.07	2004-2008	4.28	1.07	697150.87	3455493.43	77.00
5125.77	924.65	2004-2008	11.09	2.77	697442.78	3455347.09	78.00
500.19	247.45	2004-2008	4.04	1.01	698611.28	3455301.09	79.00
1777.96	797.75	2004-2008	4.46	1.11	698698.57	3455315.03	79.00
42204.80	1564.40	2004-2008	53.96	13.49	698527.41	3455270.77	79.00
9105.43	1663.17	2004-2008	10.95	2.74	699431.75	3455322.36	80.00
3503.07	629.35	2004-2008	11.13	2.78	699293.59	3455352.26	80.00
884.41	342.96	2004-2008	5.16	1.29	699549.10	3454600.59	81.00
4291.58	1289.41	2004-2008	6.66	1.66	699544.30	3454422.94	81.00
280.19	112.74	2004-2008	4.97	1.24	699564.39	3453705.15	82.00
1460.24	445.25	2004-2008	6.56	1.64	699341.26	3453825.95	82.00
3334.71	999.43	2004-2008	6.67	1.67	699867.68	3453827.98	82.00
1195.76	459.58	2004-2008	5.20	1.30	700203.79	3453951.92	83.00
21298.10	1383.83	2004-2008	30.78	7.70	700471.90	3453974.77	83.00
1669.10	736.23	2004-2008	4.53	1.13	700921.75	3453574.80	84.00
11531.50	1982.79	2004-2008	11.63	2.91	702756.16	3451245.67	87.00
2028.12	584.03	2004-2008	6.95	1.74	702062.95	3450174.50	88.00
8054.61	1843.62	2004-2008	8.74	2.18	702346.99	3450525.00	88.00

4947.79	1329.10	2004-2008	7.45	1.86	702655.36	3449503.40	89.00
3134.96	762.59	2004-2008	8.22	2.06	703125.46	3449318.36	90.00
625.88	194.59	2004-2008	6.43	1.61	704479.92	3448612.13	91.00
1634.35	719.81	2004-2008	4.54	1.14	704753.17	3447931.29	92.00
10673.90	1312.33	2004-2008	16.27	4.07	704590.82	3448435.70	92.00
1340.07	668.24	2004-2008	4.01	1.00	706515.09	3447582.99	94.00
619.19	293.82	2004-2008	4.21	1.05	706160.15	3447561.13	94.00
26848.00	1741.05	2004-2008	30.84	7.71	706947.46	3447649.80	94.00
2346.07	834.71	2004-2008	5.62	1.41	707288.07	3447004.94	95.00
4126.08	1419.96	2004-2008	5.81	1.45	707724.27	3445623.08	97.00
15672.80	2976.64	2004-2008	10.53	2.63	707373.89	3444427.34	98.00
7401.12	1806.76	2004-2008	8.19	2.05	707056.04	3443575.55	99.00
59673.40	2209.41	2008-2010	54.02	27.01	690834.36	3476105.13	33.00
46929.70	2730.56	2008-2010	34.37	17.19	688757.40	3473904.51	36.00
282.79	134.63	2008-2010	4.20	2.10	688855.62	3473591.67	37.00
193.43	88.79	2008-2010	4.36	2.18	689045.83	3473303.19	37.00
366.57	93.83	2008-2010	7.81	3.91	688867.77	3473536.93	37.00
7823.36	1019.30	2008-2010	15.35	7.68	690548.01	3472405.05	39.00
6644.09	1214.95	2008-2010	10.94	5.47	692729.38	3473189.76	41.00
287.30	115.58	2008-2010	4.97	2.49	693917.51	3472766.01	42.00
1075.06	333.54	2008-2010	6.45	3.22	693939.42	3472683.07	43.00
1859.32	918.20	2008-2010	4.05	2.02	690742.21	3468581.41	50.00
1087.00	534.22	2008-2010	4.07	2.03	692003.52	3468491.94	51.00
889.67	381.90	2008-2010	4.66	2.33	691618.09	3468490.46	51.00
1094.53	363.87	2008-2010	6.02	3.01	692284.39	3468591.61	51.00
473.76	234.37	2008-2010	4.04	2.02	692942.20	3468233.86	52.00

4348.22	1107.98	2008-2010	7.85	3.92	692879.66	3468688.05	52.00
396.90	190.15	2008-2010	4.17	2.09	692893.07	3468061.23	53.00
4378.70	1210.87	2008-2010	7.23	3.62	692792.10	3467845.87	53.00
867.89	337.50	2008-2010	5.14	2.57	691516.04	3467473.26	54.00
235.41	75.63	2008-2010	6.23	3.11	691760.69	3467379.47	54.00
400.40	123.36	2008-2010	6.49	3.25	691684.10	3467412.55	54.00
340.18	96.44	2008-2010	7.06	3.53	691788.30	3467370.58	54.00
19266.10	2825.43	2008-2010	13.64	6.82	690528.93	3467814.29	55.00
173.82	86.75	2008-2010	4.01	2.00	690814.29	3466585.20	57.00
5661.96	882.51	2008-2010	12.83	6.42	690346.61	3466922.85	57.00
458.05	212.59	2008-2010	4.31	2.15	691451.87	3466445.36	58.00
39580.90	2348.07	2008-2010	33.71	16.86	691656.86	3466450.40	58.00
14228.40	3038.19	2008-2010	9.37	4.68	690555.80	3465145.39	61.00
1075.77	450.80	2008-2010	4.77	2.39	691268.73	3464841.59	62.00
1396.86	688.57	2008-2010	4.06	2.03	692640.45	3464587.57	63.00
28752.30	1513.78	2008-2010	37.99	18.99	692845.70	3464374.38	63.00
1195.19	487.55	2008-2010	4.90	2.45	693284.19	3463408.14	64.00
993.88	310.54	2008-2010	6.40	3.20	693042.82	3463627.59	64.00
5008.65	2194.71	2008-2010	4.56	2.28	693910.18	3462165.03	66.00
2755.72	671.57	2008-2010	8.21	4.10	695604.78	3462046.58	69.00
2498.86	1041.68	2008-2010	4.80	2.40	697607.96	3459571.79	72.00
372.01	142.08	2008-2010	5.24	2.62	697944.05	3458891.18	73.00
1884.05	509.08	2008-2010	7.40	3.70	697975.81	3458808.68	73.00
2940.97	1221.89	2008-2010	4.81	2.41	696652.76	3457283.07	75.00
3073.91	1074.87	2008-2010	5.72	2.86	697882.37	3455205.28	78.00
2441.31	726.57	2008-2010	6.72	3.36	697498.25	3455324.56	78.00

928.60	266.84	2008-2010	6.96	3.48	697833.22	3455237.11	78.00
1606.16	400.83	2008-2010	8.01	4.01	699591.14	3455190.57	80.00
2528.27	1119.44	2008-2010	4.52	2.26	699548.19	3454660.24	81.00
463.51	199.28	2008-2010	4.65	2.33	699349.35	3453993.50	81.00
1473.00	506.30	2008-2010	5.82	2.91	699434.52	3454145.45	81.00
5927.46	851.20	2008-2010	13.93	6.96	699329.50	3453853.54	82.00
20824.40	1458.79	2008-2010	28.55	14.28	700471.90	3453974.77	83.00
17467.50	1451.06	2008-2010	24.08	12.04	702721.05	3450812.97	87.00
368.07	178.12	2008-2010	4.13	2.07	702120.15	3450456.13	88.00
360.02	129.20	2008-2010	5.57	2.79	704497.02	3448587.94	91.00
9432.15	1300.01	2008-2010	14.51	7.26	704708.55	3448009.25	92.00
2082.83	929.85	2008-2010	4.48	2.24	707267.96	3447118.44	95.00
311.10	133.75	2008-2010	4.65	2.33	707288.07	3447004.94	95.00

Milam-Robertson

Area (m2)	Perimeter (m)	Years	Migration amount (m)	Migration rate (m/yr)	X Coordinate	Y Coordinate	Distance downstream (km)
224905.00	3608.82	1929-1941	124.64	10.39	731446.17	3396888.05	17.00
1814400.00	18479.30	1929-1941	196.37	16.36	730303.53	3400466.55	23.00
317338.00	5225.12	1929-1941	121.47	10.12	727278.62	3404281.22	30.00
1171960.00	11956.10	1929-1941	196.04	16.34	725053.20	3407696.37	38.00
791059.00	14298.30	1929-1941	110.65	9.22	725398.33	3408930.37	39.00
268632.00	2333.78	1929-1941	230.21	19.18	725345.42	3408904.73	39.00
332226.00	4909.45	1929-1941	135.34	11.28	722568.23	3414378.74	47.00
25658.10	1175.12	1929-1941	43.67	3.64	721864.94	3415163.50	48.00
224200.00	6462.65	1929-1941	69.38	5.78	720598.53	3416516.47	50.00

293762.00	2867.18	1929-1941	204.91	17.08	720957.87	3418608.31	53.00
324881.00	4470.78	1929-1941	145.34	12.11	721124.43	3419073.22	55.00
494294.00	7396.57	1929-1941	133.65	11.14	716379.50	3422330.46	68.00
11524.80	916.25	1929-1941	25.16	2.10	714447.21	3425003.27	71.00
342427.00	6763.06	1929-1941	101.26	8.44	713079.62	3427144.87	74.00
335948.00	6669.70	1929-1941	100.74	8.39	712778.13	3427988.03	75.00
17855.00	659.57	1929-1941	54.14	4.51	714219.16	3430480.22	78.00
186426.00	3022.45	1929-1941	123.36	10.28	714357.91	3430574.62	79.00
547745.00	7866.95	1929-1941	139.25	11.60	714324.53	3432327.61	82.00
3950.07	911.98	1929-1941	8.66	0.72	712543.14	3433331.92	85.00
159388.00	4008.38	1929-1941	79.53	6.63	712534.20	3433876.63	86.00
60060.30	1473.09	1929-1941	81.54	6.80	712420.66	3435895.32	89.00
165347.00	1848.13	1929-1941	178.93	14.91	712955.14	3436369.85	89.00
933339.00	3908.87	1929-1941	477.55	39.80	713189.74	3437021.74	90.00
430850.00	4858.89	1929-1941	177.35	14.78	712190.97	3437081.54	91.00
186706.00	2334.72	1929-1941	159.94	13.33	711270.93	3438321.03	93.00
915893.00	8096.48	1929-1941	226.24	18.85	710116.13	3438795.61	95.00
208741.00	3773.76	1929-1941	110.63	9.22	708990.38	3440570.82	100.00
600285.00	6866.07	1929-1941	174.86	14.57	708685.47	3441079.42	101.00
12521.60	1370.25	1929-1941	18.28	1.52	707056.04	3443575.55	104.00
12867.40	2131.53	1929-1941	12.07	1.01	707157.29	3444269.54	105.00
66773.90	1867.01	1929-1941	71.53	5.96	707687.83	3445021.26	106.00
1554.49	740.57	1941-1951	4.20	0.42	728793.70	3402016.75	26.00
898.82	376.01	1941-1951	4.78	0.48	729031.90	3402043.95	26.00
1726.49	493.64	1941-1951	6.99	0.70	728234.82	3401915.55	27.00
26950.60	2753.44	1941-1951	19.58	1.96	727947.11	3401983.68	27.00

8363.51	1510.05	1941-1951	11.08	1.11	726905.99	3403801.59	29.00
12281.60	1697.53	1941-1951	14.47	1.45	726639.35	3403318.32	29.00
111108.00	3735.38	1941-1951	59.49	5.95	727308.04	3404283.24	30.00
1558.36	425.64	1941-1951	7.32	0.73	728376.43	3405586.71	33.00
8936.91	1675.71	1941-1951	10.67	1.07	727923.61	3406215.30	33.00
3026.72	770.13	1941-1951	7.86	0.79	727694.28	3406528.65	34.00
6792.29	1097.82	1941-1951	12.37	1.24	727515.05	3407128.90	34.00
7519.04	1111.10	1941-1951	13.53	1.35	727539.12	3406981.12	34.00
1803.92	758.83	1941-1951	4.75	0.48	727014.95	3407803.52	35.00
2075.58	574.40	1941-1951	7.23	0.72	727148.04	3407736.52	35.00
4358.48	862.66	1941-1951	10.10	1.01	726267.92	3407751.04	36.00
4295.91	690.52	1941-1951	12.44	1.24	726028.15	3407526.64	36.00
48860.90	1127.80	1941-1951	86.65	8.66	725827.83	3407352.16	37.00
62802.20	2765.20	1941-1951	45.42	4.54	725425.46	3408942.55	39.00
221173.00	2920.47	1941-1951	151.46	15.15	725192.80	3408762.03	39.00
36638.40	3774.28	1941-1951	19.41	1.94	726165.73	3410273.17	41.00
7039.98	3074.57	1941-1951	4.58	0.46	725079.10	3412509.32	43.00
848.75	350.09	1941-1951	4.85	0.48	724347.45	3412893.93	44.00
251.10	122.68	1941-1951	4.09	0.41	723666.16	3413097.31	45.00
62261.90	2777.30	1941-1951	44.84	4.48	723030.67	3413413.32	46.00
193399.00	3664.66	1941-1951	105.55	10.55	721992.11	3414557.13	48.00
180402.00	1914.56	1941-1951	188.45	18.85	722031.02	3414511.89	48.00
727.61	361.89	1941-1951	4.02	0.40	720957.83	3416118.73	50.00
7311.07	868.53	1941-1951	16.84	1.68	721181.85	3415969.64	50.00
16961.30	2166.75	1941-1951	15.66	1.57	720500.60	3416666.86	51.00
22377.20	2573.04	1941-1951	17.39	1.74	720260.17	3417870.76	52.00

16398.50	1723.45	1941-1951	19.03	1.90	720957.87	3418608.31	53.00
29280.40	1276.66	1941-1951	45.87	4.59	720387.20	3419838.37	56.00
156958.00	1923.03	1941-1951	163.24	16.32	714898.10	3423184.66	69.00
56014.30	1415.89	1941-1951	79.12	7.91	714291.35	3423863.62	70.00
5442.94	847.80	1941-1951	12.84	1.28	713253.47	3428840.36	76.00
13070.40	1277.91	1941-1951	20.46	2.05	712988.72	3428701.65	76.00
468.04	219.36	1941-1951	4.27	0.43	713877.44	3429238.43	77.00
3719.96	1023.41	1941-1951	7.27	0.73	713491.94	3428964.39	77.00
1639.90	718.93	1941-1951	4.56	0.46	714031.49	3429545.93	78.00
13736.80	2127.48	1941-1951	12.91	1.29	714171.63	3430309.08	78.00
255511.00	5005.63	1941-1951	102.09	10.21	714598.43	3432215.40	81.00
1344.03	343.68	1941-1951	7.82	0.78	714381.85	3432311.34	82.00
10585.20	1746.41	1941-1951	12.12	1.21	714213.23	3432324.71	82.00
5201.25	718.63	1941-1951	14.48	1.45	713544.93	3431886.50	83.00
15722.50	1365.75	1941-1951	23.02	2.30	712931.52	3431906.30	83.00
6568.87	1047.56	1941-1951	12.54	1.25	712774.01	3432193.15	84.00
12350.10	1967.96	1941-1951	12.55	1.26	712640.86	3432743.41	84.00
14862.70	993.69	1941-1951	29.91	2.99	712514.57	3433854.00	86.00
392239.00	5484.33	1941-1951	143.04	14.30	711245.77	3437759.18	93.00
18995.00	1452.06	1941-1951	26.16	2.62	708356.80	3439837.29	99.00
207517.00	8006.28	1941-1951	51.84	5.18	708292.50	3439774.46	99.00
1805.97	476.23	1941-1951	7.58	0.76	708990.38	3440570.82	100.00
26585.30	1962.09	1941-1951	27.10	2.71	708685.47	3441079.42	101.00
11734.40	1487.66	1941-1951	15.78	1.58	708010.23	3441858.21	102.00
28142.60	2965.27	1941-1951	18.98	1.90	707690.16	3442080.42	102.00
30707.60	2313.31	1941-1951	26.55	2.65	707056.04	3443575.55	104.00

1262.15	376.28	1941-1951	6.71	0.67	707225.64	3444325.52	105.00
6163.85	929.76	1941-1951	13.26	1.33	707157.29	3444269.54	105.00
51590.00	2486.19	1941-1951	41.50	4.15	707717.80	3445652.31	106.00
6385.61	1158.29	1941-1951	11.03	1.10	707365.21	3446846.81	108.00
6958.43	673.34	1941-1951	20.67	2.07	707265.63	3447058.79	108.00
22388.90	1058.66	1941-1951	42.30	4.23	707267.63	3447148.00	108.00
3497.25	949.42	1951-1958	7.37	1.05	728793.70	3402016.75	26.00
547.48	188.04	1951-1958	5.82	0.83	727678.60	3402301.03	27.00
12984.10	1598.22	1951-1958	16.25	2.32	727922.29	3402000.38	27.00
3362.51	1107.61	1951-1958	6.07	0.87	727237.15	3402704.99	28.00
8350.34	982.49	1951-1958	17.00	2.43	726894.30	3402993.49	28.00
918.29	330.62	1951-1958	5.55	0.79	726921.98	3403826.85	29.00
7855.99	1379.61	1951-1958	11.39	1.63	726639.35	3403318.32	29.00
1250.02	507.14	1951-1958	4.93	0.70	727204.35	3404238.61	30.00
24714.20	2320.86	1951-1958	21.30	3.04	727364.53	3404264.90	30.00
9795.15	1199.19	1951-1958	16.34	2.33	728553.67	3404670.43	32.00
1091.45	463.25	1951-1958	4.71	0.67	727884.89	3406261.06	33.00
5537.02	1165.30	1951-1958	9.50	1.36	728267.65	3405689.22	33.00
64113.20	4530.90	1951-1958	28.30	4.04	727694.28	3406528.65	34.00
2822.39	653.25	1951-1958	8.64	1.23	726267.92	3407751.04	36.00
94046.10	4486.78	1951-1958	41.92	5.99	726028.15	3407526.64	36.00
3730.63	682.96	1951-1958	10.92	1.56	725511.93	3408955.70	39.00
25005.30	2063.93	1951-1958	24.23	3.46	726198.66	3409855.40	40.00
5375.24	952.75	1951-1958	11.28	1.61	726185.27	3410094.39	41.00
76783.90	7731.68	1951-1958	19.86	2.84	726076.38	3410743.64	41.00
15433.50	1914.08	1951-1958	16.13	2.30	723341.24	3413245.35	45.00

61084.00	1594.69	1951-1958	76.61	10.94	722892.42	3414371.37	47.00
2616.16	979.21	1951-1958	5.34	0.76	720598.53	3416516.47	50.00
91843.50	4901.79	1951-1958	37.47	5.35	721181.85	3415969.64	50.00
8651.61	1722.07	1951-1958	10.05	1.44	720328.56	3417316.46	51.00
41916.90	2549.90	1951-1958	32.88	4.70	720898.60	3418603.40	53.00
536.94	230.59	1951-1958	4.66	0.67	720197.15	3420175.85	56.00
1653.33	363.70	1951-1958	9.09	1.30	720209.96	3420148.79	56.00
32938.80	1984.18	1951-1958	33.20	4.74	720340.45	3419914.77	56.00
58628.30	3882.68	1951-1958	30.20	4.31	718389.95	3420536.37	63.00
686.94	343.08	1951-1958	4.00	0.57	717039.20	3420658.95	64.00
284.14	129.88	1951-1958	4.38	0.63	717239.02	3420595.32	64.00
38741.60	2376.21	1951-1958	32.61	4.66	716590.63	3421115.81	65.00
79337.60	3444.36	1951-1958	46.07	6.58	715053.82	3423099.97	69.00
4082.66	990.68	1951-1958	8.24	1.18	714370.52	3424530.69	71.00
1485.79	437.21	1951-1958	6.80	0.97	714460.54	3425122.42	72.00
6366.63	1485.61	1951-1958	8.57	1.22	714409.47	3425651.77	72.00
10581.60	2143.39	1951-1958	9.87	1.41	713969.42	3426658.67	73.00
8216.35	1158.57	1951-1958	14.18	2.03	713624.81	3427088.99	74.00
7160.01	1413.24	1951-1958	10.13	1.45	712803.49	3427689.98	75.00
24186.50	3663.70	1951-1958	13.20	1.89	712778.87	3428107.75	75.00
456.28	224.98	1951-1958	4.06	0.58	713723.45	3429149.46	77.00
896.21	403.07	1951-1958	4.45	0.64	714184.05	3430367.64	78.00
3352.92	890.13	1951-1958	7.53	1.08	714040.86	3429605.15	78.00
62098.40	1419.74	1951-1958	87.48	12.50	714219.16	3430480.22	78.00
659.30	235.90	1951-1958	5.59	0.80	715306.72	3431273.84	80.00
1686.70	437.64	1951-1958	7.71	1.10	715283.88	3431547.77	80.00

6407.49	1174.65	1951-1958	10.91	1.56	715288.57	3431095.65	80.00
15029.10	2035.26	1951-1958	14.77	2.11	714626.89	3432206.35	81.00
5476.73	570.34	1951-1958	19.21	2.74	714381.85	3432311.34	82.00
34441.40	3135.29	1951-1958	21.97	3.14	714213.23	3432324.71	82.00
12257.70	1864.55	1951-1958	13.15	1.88	712814.48	3432113.81	84.00
844.17	320.17	1951-1958	5.27	0.75	712555.92	3433153.04	85.00
1388.42	383.14	1951-1958	7.25	1.04	712501.44	3433827.28	85.00
20741.70	1116.20	1951-1958	37.16	5.31	712534.20	3433876.63	86.00
343.05	130.69	1951-1958	5.25	0.75	711539.55	3437046.88	92.00
804.25	197.54	1951-1958	8.14	1.16	711410.14	3437096.93	92.00
10508.10	1164.39	1951-1958	18.05	2.58	711245.77	3437759.18	93.00
55700.70	1720.58	1951-1958	64.75	9.25	711254.67	3437847.98	93.00
22319.70	1826.06	1951-1958	24.45	3.49	709854.88	3438594.54	95.00
67843.40	2391.21	1951-1958	56.74	8.11	709879.07	3438612.28	95.00
25582.60	4290.77	1951-1958	11.92	1.70	707919.05	3438946.37	98.00
18507.50	2147.88	1951-1958	17.23	2.46	708270.64	3439753.95	99.00
26170.80	3446.41	1951-1958	15.19	2.17	708692.15	3441050.59	101.00
4480.91	1180.63	1951-1958	7.59	1.08	707690.16	3442080.42	102.00
462.28	228.20	1951-1958	4.05	0.58	707292.70	3442398.94	103.00
11051.60	1798.58	1951-1958	12.29	1.76	706979.96	3442676.77	103.00
1910.06	865.20	1951-1958	4.42	0.63	707058.31	3443545.66	104.00
1300.84	393.38	1951-1958	6.61	0.94	707225.64	3444325.52	105.00
12668.10	1689.77	1951-1958	14.99	2.14	707138.54	3444247.25	105.00
68292.30	2941.21	1951-1958	46.44	6.63	707672.54	3445825.67	106.00
2035.21	587.12	1951-1958	6.93	0.99	707620.55	3446028.41	107.00
454.29	199.96	1951-1958	4.54	0.65	707321.44	3446955.73	108.00

1427.20	425.74	1951-1958	6.70	0.96	707271.40	3447029.81	108.00
4365.42	674.61	1951-1958	12.94	1.85	707370.53	3446817.36	108.00
1816.96	540.28	1958-1965	6.73	0.96	731633.41	3397577.28	17.00
108766.00	6941.79	1958-1965	31.34	4.48	731828.90	3399721.89	21.00
3601.42	739.24	1958-1965	9.74	1.39	730840.12	3400209.41	22.00
11264.40	2111.69	1958-1965	10.67	1.52	731437.91	3399872.86	22.00
140546.00	4828.69	1958-1965	58.21	8.32	730194.51	3400562.18	23.00
3599.48	1013.80	1958-1965	7.10	1.01	729031.90	3402043.95	26.00
7931.18	1068.57	1958-1965	14.84	2.12	727922.29	3402000.38	27.00
20842.20	1745.38	1958-1965	23.88	3.41	727678.60	3402301.03	27.00
4282.85	720.57	1958-1965	11.89	1.70	726894.30	3402993.49	28.00
1355.31	451.35	1958-1965	6.01	0.86	726921.98	3403826.85	29.00
7619.99	1563.86	1958-1965	9.75	1.39	726639.35	3403318.32	29.00
568.59	279.01	1958-1965	4.08	0.58	727336.86	3404275.42	30.00
1095.42	461.24	1958-1965	4.75	0.68	727278.62	3404281.22	30.00
2882.40	1195.34	1958-1965	4.82	0.69	727992.04	3406116.93	33.00
13266.80	1832.21	1958-1965	14.48	2.07	727521.82	3407069.28	34.00
27837.80	2556.53	1958-1965	21.78	3.11	726843.99	3407859.11	35.00
2110.72	602.60	1958-1965	7.01	1.00	726226.56	3407708.68	36.00
1049.11	287.57	1958-1965	7.30	1.04	726338.49	3407804.13	36.00
130722.00	4460.24	1958-1965	58.62	8.37	726006.55	3407505.86	36.00
4130.90	1139.19	1958-1965	7.25	1.04	725511.93	3408955.70	39.00
4366.57	1268.67	1958-1965	6.88	0.98	726195.27	3409735.76	40.00
3376.93	937.14	1958-1965	7.21	1.03	726178.11	3410153.92	41.00
74446.40	8136.01	1958-1965	18.30	2.61	726076.38	3410743.64	41.00
3522.70	793.94	1958-1965	8.87	1.27	723341.24	3413245.35	45.00

838.04	398.39	1958-1965	4.21	0.60	723070.35	3413371.38	46.00
5797.24	1093.70	1958-1965	10.60	1.51	723030.67	3413413.32	46.00
503.33	200.38	1958-1965	5.02	0.72	722776.32	3414392.21	47.00
6389.87	959.92	1958-1965	13.31	1.90	722746.42	3414391.67	47.00
12652.00	998.10	1958-1965	25.35	3.62	722834.00	3414382.01	47.00
711.22	290.35	1958-1965	4.90	0.70	721918.52	3414718.86	48.00
1355.29	510.32	1958-1965	5.31	0.76	721908.24	3414837.64	48.00
1350.61	431.51	1958-1965	6.26	0.89	722031.02	3414511.89	48.00
2564.66	406.40	1958-1965	12.62	1.80	721947.65	3414634.90	48.00
4154.62	1283.01	1958-1965	6.48	0.93	721259.78	3415924.77	49.00
4626.75	1043.28	1958-1965	8.87	1.27	721647.93	3415554.12	49.00
5707.03	895.98	1958-1965	12.74	1.82	720598.53	3416516.47	50.00
63926.30	4876.47	1958-1965	26.22	3.75	720339.08	3417463.89	51.00
17522.00	1253.51	1958-1965	27.96	3.99	721075.94	3418594.02	53.00
2790.16	667.47	1958-1965	8.36	1.19	721406.03	3418974.93	55.00
69518.50	3836.68	1958-1965	36.24	5.18	720197.15	3420175.85	56.00
82668.00	3525.37	1958-1965	46.90	6.70	720205.26	3420653.70	57.00
76048.50	7428.75	1958-1965	20.47	2.92	718790.25	3421018.62	62.00
1549.66	562.41	1958-1965	5.51	0.79	718339.62	3420503.88	63.00
1094.79	344.56	1958-1965	6.35	0.91	718459.31	3420593.61	63.00
16716.90	2246.26	1958-1965	14.88	2.13	717763.30	3420474.47	64.00
1287.37	395.26	1958-1965	6.51	0.93	716873.21	3420724.08	65.00
128739.00	4739.66	1958-1965	54.32	7.76	716574.24	3421058.27	65.00
86881.40	1876.21	1958-1965	92.61	13.23	715661.25	3422461.13	68.00
84846.50	1762.21	1958-1965	96.30	13.76	715661.25	3422461.13	68.00
52596.30	2309.51	1958-1965	45.55	6.51	715027.34	3423113.99	69.00

2143.28	577.42	1958-1965	7.42	1.06	714254.84	3424037.43	70.00
5816.26	1605.09	1958-1965	7.25	1.04	714435.24	3424914.55	71.00
3030.16	621.70	1958-1965	9.75	1.39	714473.25	3425241.40	72.00
1916.31	834.52	1958-1965	4.59	0.66	713928.04	3426770.53	73.00
3143.48	1291.56	1958-1965	4.87	0.70	714239.13	3426001.72	73.00
736.87	346.59	1958-1965	4.25	0.61	713224.33	3427115.59	74.00
1023.91	480.50	1958-1965	4.26	0.61	713853.96	3426899.01	74.00
214.18	88.45	1958-1965	4.84	0.69	713372.63	3427135.15	74.00
202.74	82.89	1958-1965	4.89	0.70	713491.45	3427150.52	74.00
706.98	192.68	1958-1965	7.34	1.05	713431.76	3427145.14	74.00
1459.34	266.97	1958-1965	10.93	1.56	713624.81	3427088.99	74.00
5638.97	922.43	1958-1965	12.23	1.75	713031.61	3427180.54	74.00
10433.40	2142.99	1958-1965	9.74	1.39	712779.60	3427958.06	75.00
186949.00	8233.21	1958-1965	45.41	6.49	713148.30	3428783.44	76.00
9827.30	1447.48	1958-1965	13.58	1.94	714960.78	3432043.93	81.00
16886.00	2400.16	1958-1965	14.07	2.01	714024.92	3432234.14	82.00
8044.02	1029.52	1958-1965	15.63	2.23	713026.89	3431792.15	83.00
7598.73	739.30	1958-1965	20.56	2.94	713569.10	3431903.62	83.00
26297.80	2818.23	1958-1965	18.66	2.67	712762.29	3432220.56	84.00
5447.40	1194.86	1958-1965	9.12	1.30	712489.09	3433769.49	85.00
46917.50	2073.90	1958-1965	45.25	6.46	712647.69	3434789.29	87.00
79541.00	2585.74	1958-1965	61.52	8.79	712185.49	3435763.40	88.00
48436.70	2470.40	1958-1965	39.21	5.60	712793.30	3436193.40	89.00
668.28	224.16	1958-1965	5.96	0.85	713133.31	3436475.40	90.00
2286.90	715.66	1958-1965	6.39	0.91	712072.12	3437066.49	91.00
9228.86	929.38	1958-1965	19.86	2.84	712072.12	3437066.49	91.00

330.06	108.98	1958-1965	6.06	0.87	711539.55	3437046.88	92.00
1122.60	258.54	1958-1965	8.68	1.24	711656.70	3437042.37	92.00
17409.60	1346.20	1958-1965	25.86	3.69	711249.49	3437729.49	93.00
127247.00	4248.04	1958-1965	59.91	8.56	711245.88	3437788.68	93.00
73233.10	7107.00	1958-1965	20.61	2.94	709879.07	3438612.28	95.00
6125.38	1463.72	1958-1965	8.37	1.20	708672.75	3440156.10	99.00
6717.47	2034.12	1958-1965	6.60	0.94	708692.15	3441050.59	101.00
3405.25	903.14	1958-1965	7.54	1.08	708431.02	3441479.95	101.00
25810.90	3606.82	1958-1965	14.31	2.04	706979.96	3442676.77	103.00
2530.22	691.65	1958-1965	7.32	1.05	707138.54	3444247.25	105.00
2085.52	898.31	1958-1965	4.64	0.66	707402.23	3446551.33	107.00
70581.70	3925.01	1958-1965	35.97	5.14	707620.55	3446028.41	107.00
3118.37	539.91	1958-1965	11.55	1.65	707370.53	3446817.36	108.00
484.80	199.21	1965-1974	4.87	0.54	731788.10	3397659.06	17.00
296068.00	13850.30	1965-1974	42.75	4.75	730162.22	3400703.31	23.00
1758.36	508.20	1965-1974	6.92	0.77	729599.64	3402044.35	25.00
685.34	218.56	1965-1974	6.27	0.70	727878.22	3402040.68	27.00
6633.49	1095.70	1965-1974	12.11	1.35	727947.11	3401983.68	27.00
950.20	295.54	1965-1974	6.43	0.71	726759.47	3403612.26	29.00
2308.98	603.61	1965-1974	7.65	0.85	726954.00	3403877.52	29.00
88589.20	4023.85	1965-1974	44.03	4.89	726639.35	3403318.32	29.00
17211.00	1941.18	1965-1974	17.73	1.97	727810.85	3406355.17	34.00
213850.00	7836.78	1965-1974	54.58	6.06	727528.45	3407040.03	34.00
8384.26	2120.83	1965-1974	7.91	0.88	725511.93	3408955.70	39.00
10679.90	1151.51	1965-1974	18.55	2.06	726136.02	3409444.89	40.00
56200.50	4300.29	1965-1974	26.14	2.90	726178.11	3410153.92	41.00

47756.60	5745.15	1965-1974	16.63	1.85	725340.27	3412262.77	43.00
119042.00	2788.93	1965-1974	85.37	9.49	722776.32	3414392.21	47.00
2599.15	663.72	1965-1974	7.83	0.87	722101.39	3414458.19	48.00
15397.30	1220.16	1965-1974	25.24	2.80	721908.24	3414837.64	48.00
93255.40	7796.86	1965-1974	23.92	2.66	720469.26	3416717.89	51.00
80626.90	3468.83	1965-1974	46.49	5.17	721432.14	3418960.78	55.00
4428.04	930.92	1965-1974	9.51	1.06	720554.50	3420505.26	57.00
5778.22	674.73	1965-1974	17.13	1.90	720321.40	3420639.09	57.00
190271.00	4440.06	1965-1974	85.71	9.52	720205.26	3420653.70	57.00
37893.20	2768.61	1965-1974	27.37	3.04	721425.74	3421060.29	59.00
22822.70	2943.77	1965-1974	15.51	1.72	720201.38	3421792.29	61.00
10602.80	2010.81	1965-1974	10.55	1.17	719267.43	3421425.85	62.00
9658.73	1923.40	1965-1974	10.04	1.12	718389.95	3420536.37	63.00
3415.92	1249.02	1965-1974	5.47	0.61	717267.69	3420586.46	64.00
2639.60	807.36	1965-1974	6.54	0.73	716574.24	3421058.27	65.00
2184.62	440.90	1965-1974	9.91	1.10	716873.21	3420724.08	65.00
140768.00	3496.93	1965-1974	80.51	8.95	716817.35	3421745.02	66.00
147065.00	2379.23	1965-1974	123.63	13.74	715762.73	3422399.17	68.00
56263.30	2435.48	1965-1974	46.20	5.13	715436.77	3422740.49	69.00
235814.00	8588.15	1965-1974	54.92	6.10	714523.53	3423480.74	70.00
3171.67	652.07	1965-1974	9.73	1.08	713031.61	3427180.54	74.00
3519.60	516.94	1965-1974	13.62	1.51	713520.28	3427144.64	74.00
4921.39	690.76	1965-1974	14.25	1.58	713372.63	3427135.15	74.00
60556.20	3230.38	1965-1974	37.49	4.17	712779.60	3427958.06	75.00
77629.40	4234.40	1965-1974	36.67	4.07	713590.30	3429029.38	77.00
338.46	158.67	1965-1974	4.27	0.47	714299.11	3430564.76	79.00

81689.40	4548.92	1974-1995	35.92	1.71	732642.30	3397613.47	18.00
2580.57	772.20	1974-1995	6.68	0.32	732614.78	3399298.34	20.00
94709.60	5545.83	1974-1995	34.16	1.63	730159.25	3400673.51	23.00
909.33	411.02	1974-1995	4.42	0.21	728322.94	3401929.33	26.00
86843.30	5283.83	1974-1995	32.87	1.57	729031.90	3402043.95	26.00
105491.00	4898.11	1974-1995	43.07	2.05	726668.32	3403267.18	29.00
20528.70	1659.73	1974-1995	24.74	1.18	727389.94	3404249.04	30.00
1239.74	529.66	1974-1995	4.68	0.22	727754.58	3406425.27	34.00
225274.00	6614.65	1974-1995	68.11	3.24	727810.85	3406355.17	34.00
187449.00	5266.82	1974-1995	71.18	3.39	727498.68	3407217.38	34.00
112366.00	5582.66	1974-1995	40.26	1.92	725345.42	3408904.73	39.00
120268.00	7089.44	1974-1995	33.93	1.62	725709.61	3411721.06	42.00
2188.62	620.56	1974-1995	7.05	0.34	724768.45	3412740.19	44.00
4578.46	1159.36	1974-1995	7.90	0.38	725056.77	3412529.34	44.00
4181.26	1047.45	1974-1995	7.98	0.38	724260.88	3412917.67	44.00
6713.98	1464.78	1974-1995	9.17	0.44	723618.34	3413131.33	45.00
63633.70	2232.43	1974-1995	57.01	2.71	722863.80	3414380.11	47.00
59678.10	2501.01	1974-1995	47.72	2.27	721908.24	3414837.64	48.00
86528.00	2665.25	1974-1995	64.93	3.09	721682.43	3415505.46	49.00
15837.30	1412.49	1974-1995	22.42	1.07	720744.01	3416326.95	50.00
409.99	187.75	1974-1995	4.37	0.21	720454.29	3416743.85	51.00
1440.66	587.78	1974-1995	4.90	0.23	720469.26	3416717.89	51.00
318.33	121.08	1974-1995	5.26	0.25	720370.69	3418388.46	52.00
24516.10	2959.02	1974-1995	16.57	0.79	720257.80	3417929.87	52.00
38698.10	1718.93	1974-1995	45.03	2.14	720409.33	3418432.45	52.00
56512.70	1366.55	1974-1995	82.71	3.94	721406.03	3418974.93	55.00

133770.00	1835.48	1974-1995	145.76	6.94	721487.77	3418939.69	55.00
1725.13	464.37	1974-1995	7.43	0.35	720321.40	3420639.09	57.00
89518.90	3535.01	1974-1995	50.65	2.41	720205.26	3420653.70	57.00
1590.85	364.99	1974-1995	8.72	0.42	721425.99	3421176.56	59.00
89638.50	3376.84	1974-1995	53.09	2.53	721427.39	3421030.50	59.00
4912.73	911.63	1974-1995	10.78	0.51	719764.75	3421692.66	61.00
32481.90	2621.09	1974-1995	24.78	1.18	720201.38	3421792.29	61.00
5433.99	1612.90	1974-1995	6.74	0.32	719074.54	3421284.66	62.00
10103.00	1727.45	1974-1995	11.70	0.56	718681.27	3420875.69	63.00
8427.71	1369.84	1974-1995	12.30	0.59	717705.11	3420489.04	64.00
20854.00	1215.89	1974-1995	34.30	1.63	716659.72	3421466.61	65.00
32393.30	1852.59	1974-1995	34.97	1.67	716574.24	3421058.27	65.00
3644.52	447.16	1974-1995	16.30	0.78	716817.35	3421745.02	66.00
203759.00	5858.14	1974-1995	69.56	3.31	717079.46	3422405.65	67.00
83612.50	1383.17	1974-1995	120.90	5.76	717133.52	3422381.52	67.00
3088.96	489.08	1974-1995	12.63	0.60	713624.81	3427088.99	74.00
5572.01	696.99	1974-1995	15.99	0.76	713283.92	3427122.04	74.00
220740.00	8156.95	1974-1995	54.12	2.58	713743.37	3426997.85	74.00
7871.40	883.64	1974-1995	17.82	0.85	712883.05	3427401.77	75.00
40633.80	2792.58	1974-1995	29.10	1.39	712779.60	3427958.06	75.00
45755.00	3951.84	1974-1995	23.16	1.10	713543.23	3428992.83	77.00
7508.66	751.58	1974-1995	19.98	0.95	714273.28	3430549.81	79.00
57408.10	3984.21	1995-2004	28.82	3.20	732614.78	3399298.34	20.00
3361.67	1641.28	1995-2004	4.10	0.46	731885.73	3399702.66	21.00
818.79	295.22	1995-2004	5.55	0.62	732421.40	3399439.02	21.00
724.55	213.48	1995-2004	6.79	0.75	730213.87	3400540.43	23.00

766.80	360.85	1995-2004	4.25	0.47	730213.81	3400874.35	24.00
13319.70	1941.37	1995-2004	13.72	1.52	730177.72	3401768.17	25.00
4643.51	2046.66	1995-2004	4.54	0.50	729211.22	3402057.34	26.00
2239.75	984.21	1995-2004	4.55	0.51	728793.70	3402016.75	26.00
1955.79	780.53	1995-2004	5.01	0.56	727922.29	3402000.38	27.00
1520.84	524.41	1995-2004	5.80	0.64	727617.31	3402366.62	27.00
1122.35	378.44	1995-2004	5.93	0.66	727773.90	3402186.03	27.00
7588.40	1564.58	1995-2004	9.70	1.08	727027.24	3402873.92	28.00
4480.54	1517.25	1995-2004	5.91	0.66	726954.00	3403877.52	29.00
1846.16	486.11	1995-2004	7.60	0.84	727103.31	3404132.29	30.00
12347.10	2324.98	1995-2004	10.62	1.18	727251.05	3404271.45	30.00
2620.88	688.48	1995-2004	7.61	0.85	728535.84	3404646.58	32.00
18724.30	2284.68	1995-2004	16.39	1.82	728355.52	3405608.23	33.00
613.72	294.33	1995-2004	4.17	0.46	727069.48	3407779.11	35.00
1963.97	744.10	1995-2004	5.28	0.59	727373.12	3407552.06	35.00
2629.87	1036.84	1995-2004	5.07	0.56	726434.81	3407872.35	36.00
852.58	221.16	1995-2004	7.71	0.86	726338.49	3407804.13	36.00
27723.60	4022.63	1995-2004	13.78	1.53	724956.14	3408153.32	38.00
3052.48	884.38	1995-2004	6.90	0.77	725036.13	3408583.14	39.00
35153.70	4049.03	1995-2004	17.36	1.93	726195.28	3409974.92	41.00
4278.84	2004.01	1995-2004	4.27	0.47	725419.14	3412172.51	43.00
3677.94	1274.22	1995-2004	5.77	0.64	724318.42	3412901.35	44.00
208.82	102.10	1995-2004	4.09	0.45	723666.16	3413097.31	45.00
2370.92	1085.55	1995-2004	4.37	0.49	723740.51	3413048.41	45.00
2243.98	1057.86	1995-2004	4.24	0.47	723121.98	3413340.93	46.00
29901.70	2481.71	1995-2004	24.10	2.68	722863.80	3414380.11	47.00

17955.10	2137.25	1995-2004	16.80	1.87	721936.04	3414662.30	48.00
3363.70	1585.56	1995-2004	4.24	0.47	721732.93	3415431.15	49.00
1072.85	531.47	1995-2004	4.04	0.45	720348.08	3417019.30	51.00
1981.19	985.76	1995-2004	4.02	0.45	720370.69	3418388.46	52.00
496.23	214.99	1995-2004	4.62	0.51	721132.69	3418575.42	53.00
6086.79	1420.53	1995-2004	8.57	0.95	720898.60	3418603.40	53.00
64205.00	2018.10	1995-2004	63.63	7.07	721624.38	3418828.93	54.00
53398.00	2786.74	1995-2004	38.32	4.26	720544.29	3419620.20	56.00
2771.21	1178.31	1995-2004	4.70	0.52	720077.30	3420416.55	57.00
773.28	299.92	1995-2004	5.16	0.57	720110.00	3420586.66	57.00
16289.80	2016.32	1995-2004	16.16	1.80	721400.26	3420497.91	58.00
6917.72	1047.87	1995-2004	13.20	1.47	721237.19	3421509.00	60.00
1599.42	661.17	1995-2004	4.84	0.54	719707.22	3421675.73	61.00
1644.23	775.65	1995-2004	4.24	0.47	716591.81	3420971.44	65.00
1354.67	634.82	1995-2004	4.27	0.47	716897.98	3420707.23	65.00
565.60	251.06	1995-2004	4.51	0.50	716600.84	3421174.65	65.00
9765.46	908.52	1995-2004	21.50	2.39	716771.21	3421707.17	66.00
16452.00	1142.63	1995-2004	28.80	3.20	716905.56	3422412.86	67.00
53993.40	2097.39	1995-2004	51.49	5.72	717079.46	3422405.65	67.00
1034.55	496.00	1995-2004	4.17	0.46	716170.19	3422335.92	68.00
2935.61	840.54	1995-2004	6.99	0.78	715562.56	3422573.35	68.00
7900.16	929.17	1995-2004	17.00	1.89	714922.62	3423167.48	69.00
6178.48	1458.48	1995-2004	8.47	0.94	714418.49	3423626.33	70.00
1319.17	640.11	1995-2004	4.12	0.46	713743.37	3426997.85	74.00
1828.27	762.55	1995-2004	4.80	0.53	713283.92	3427122.04	74.00
1829.88	908.98	1995-2004	4.03	0.45	712893.33	3427373.68	75.00

663.65	304.74	1995-2004	4.36	0.48	712988.72	3428701.65	76.00
3037.62	1225.01	1995-2004	4.96	0.55	712836.24	3428519.29	76.00
256.77	112.43	1995-2004	4.57	0.51	713723.45	3429149.46	77.00
4375.35	1786.02	1995-2004	4.90	0.54	714102.70	3429927.27	78.00
302.83	129.25	1995-2004	4.69	0.52	714677.93	3430505.57	79.00
5163.11	1185.52	1995-2004	8.71	0.97	715167.46	3430831.56	80.00
26405.90	3209.01	1995-2004	16.46	1.83	715283.88	3431547.77	80.00
1501.29	351.94	1995-2004	8.53	0.95	714598.43	3432215.40	81.00
1393.70	427.43	1995-2004	6.52	0.72	714213.23	3432324.71	82.00
24596.00	2274.86	1995-2004	21.62	2.40	713451.80	3431813.46	83.00
8542.93	2606.70	1995-2004	6.55	0.73	712630.75	3432771.65	84.00
1608.29	414.05	1995-2004	7.77	0.86	712489.09	3433769.49	85.00
1286.19	568.88	1995-2004	4.52	0.50	712894.85	3434429.65	86.00
2776.71	700.52	1995-2004	7.93	0.88	712677.42	3434790.63	87.00
43000.20	2128.74	1995-2004	40.40	4.49	712500.49	3434778.58	87.00
2960.69	968.91	1995-2004	6.11	0.68	712263.81	3435807.58	88.00
6320.49	2078.70	1995-2004	6.08	0.68	712665.47	3436067.49	89.00
18897.00	2051.29	1995-2004	18.42	2.05	712767.56	3437237.51	91.00
32393.00	2046.62	1995-2004	31.66	3.52	712996.42	3437203.04	91.00
2298.64	938.63	1995-2004	4.90	0.54	711251.44	3437404.67	93.00
650.82	213.78	1995-2004	6.09	0.68	711258.54	3437492.96	93.00
4708.19	1188.42	1995-2004	7.92	0.88	711259.46	3437996.88	93.00
2840.23	637.07	1995-2004	8.92	0.99	711182.57	3438633.40	94.00
1366.56	338.56	1995-2004	8.07	0.90	710459.21	3438972.88	95.00
3501.69	710.38	1995-2004	9.86	1.10	710487.48	3438982.42	95.00
6377.12	827.25	1995-2004	15.42	1.71	710267.33	3438891.37	95.00

3159.71	1427.21	1995-2004	4.43	0.49	709717.29	3438478.69	96.00
1570.57	722.78	1995-2004	4.35	0.48	708139.12	3438236.22	97.00
19769.70	3978.01	1995-2004	9.94	1.10	708134.89	3439596.43	99.00
1178.04	582.56	1995-2004	4.04	0.45	708808.70	3440877.41	100.00
745.71	352.60	1995-2004	4.23	0.47	706943.71	3442724.01	103.00
8989.83	1421.51	1995-2004	12.65	1.41	707030.70	3443218.10	104.00
13079.60	1603.70	1995-2004	16.31	1.81	707013.14	3443869.80	104.00
34381.40	2693.42	2004-2008	25.53	6.38	733059.22	3398603.15	20.00
2575.76	1238.17	2004-2008	4.16	1.04	731800.89	3399732.33	21.00
6995.07	1886.04	2004-2008	7.42	1.85	732471.51	3399406.52	21.00
3814.89	941.46	2004-2008	8.10	2.03	732421.40	3399439.02	21.00
8970.17	1454.04	2004-2008	12.34	3.08	730865.88	3400194.12	22.00
787.55	255.94	2004-2008	6.15	1.54	730167.18	3400614.41	23.00
19425.50	2980.73	2004-2008	13.03	3.26	729944.73	3401951.70	25.00
1674.87	692.90	2004-2008	4.83	1.21	727878.22	3402040.68	27.00
1143.61	558.56	2004-2008	4.09	1.02	727098.80	3402819.58	28.00
1182.34	566.19	2004-2008	4.18	1.04	726871.68	3403013.19	28.00
1894.60	886.69	2004-2008	4.27	1.07	727489.65	3402493.39	28.00
531.81	254.60	2004-2008	4.18	1.04	726668.32	3403267.18	29.00
1017.40	459.41	2004-2008	4.43	1.11	726649.86	3403434.91	29.00
24310.20	2101.18	2004-2008	23.14	5.78	727251.05	3404271.45	30.00
941.72	272.85	2004-2008	6.90	1.73	728535.12	3405451.27	32.00
12952.70	1936.71	2004-2008	13.38	3.34	728624.96	3405335.73	32.00
1522.67	693.90	2004-2008	4.39	1.10	728145.38	3405859.63	33.00
3228.41	1271.64	2004-2008	5.08	1.27	727439.04	3407417.84	35.00
873.95	422.73	2004-2008	4.13	1.03	726434.81	3407872.35	36.00

244.36	104.13	2004-2008	4.69	1.17	726294.75	3407764.45	36.00
428.20	134.66	2004-2008	6.36	1.59	726639.20	3407889.38	36.00
5305.76	1524.39	2004-2008	6.96	1.74	726247.71	3407729.82	36.00
3491.39	949.95	2004-2008	7.35	1.84	726697.00	3407880.58	36.00
1010.60	474.49	2004-2008	4.26	1.06	724992.19	3407832.38	38.00
4756.62	1386.13	2004-2008	6.86	1.72	725108.66	3407590.17	38.00
1633.17	441.90	2004-2008	7.39	1.85	725589.21	3408989.01	39.00
5261.23	915.42	2004-2008	11.49	2.87	725345.42	3408904.73	39.00
6480.14	2219.03	2004-2008	5.84	1.46	726199.31	3409825.41	40.00
8782.52	3298.43	2004-2008	5.33	1.33	725655.53	3411827.88	43.00
1842.53	624.86	2004-2008	5.90	1.47	723714.11	3413062.67	45.00
877.72	322.22	2004-2008	5.45	1.36	723142.34	3414030.69	46.00
5419.99	897.03	2004-2008	12.08	3.02	723124.23	3413885.15	46.00
2539.27	493.09	2004-2008	10.30	2.57	723040.26	3414273.94	47.00
5587.26	883.49	2004-2008	12.65	3.16	722538.27	3414377.77	47.00
5946.15	888.87	2004-2008	13.38	3.34	721960.82	3414607.99	48.00
10114.70	2871.13	2004-2008	7.05	1.76	721284.54	3415907.92	49.00
4316.04	2023.30	2004-2008	4.27	1.07	720454.29	3416743.85	51.00
491.47	225.24	2004-2008	4.36	1.09	720260.17	3417870.76	52.00
1954.41	639.83	2004-2008	6.11	1.53	720305.44	3417668.79	52.00
2103.97	836.64	2004-2008	5.03	1.26	720554.51	3418513.44	53.00
3668.19	954.11	2004-2008	7.69	1.92	720898.60	3418603.40	53.00
40174.30	2439.17	2004-2008	32.94	8.24	721159.82	3418562.70	53.00
32163.40	2918.52	2004-2008	22.04	5.51	720945.73	3419182.86	55.00
1650.21	767.29	2004-2008	4.30	1.08	720205.26	3420653.70	57.00
1491.91	681.34	2004-2008	4.38	1.09	720141.77	3420282.10	57.00

457.14	198.38	2004-2008	4.61	1.15	720073.55	3420475.25	57.00
9192.45	1253.73	2004-2008	14.66	3.67	720554.50	3420505.26	57.00
616.08	187.89	2004-2008	6.56	1.64	721123.41	3420207.15	58.00
7017.45	1152.17	2004-2008	12.18	3.05	721443.68	3420672.36	59.00
7910.01	1477.35	2004-2008	10.71	2.68	721237.19	3421509.00	60.00
6301.01	2829.67	2004-2008	4.45	1.11	719623.95	3421641.99	61.00
1348.80	638.69	2004-2008	4.22	1.06	717182.16	3420614.38	64.00
1148.39	382.21	2004-2008	6.01	1.50	716952.22	3420681.85	64.00
3674.07	1212.43	2004-2008	6.06	1.52	717501.08	3420534.22	64.00
2546.28	521.92	2004-2008	9.76	2.44	716662.90	3421496.38	65.00
4594.97	823.22	2004-2008	11.16	2.79	716604.18	3420944.47	65.00
3982.51	649.54	2004-2008	12.26	3.07	716625.71	3421260.84	65.00
19406.20	1828.28	2004-2008	21.23	5.31	717272.02	3422073.37	66.00
165.48	66.51	2004-2008	4.98	1.24	716492.32	3422298.07	67.00
15669.40	1993.33	2004-2008	15.72	3.93	716905.56	3422412.86	67.00
1026.06	413.85	2004-2008	4.96	1.24	716170.19	3422335.92	68.00
273.09	123.56	2004-2008	4.42	1.11	715205.90	3423009.14	69.00
3800.94	1346.89	2004-2008	5.64	1.41	715436.77	3422740.49	69.00
4778.24	1407.04	2004-2008	6.79	1.70	714774.36	3423268.87	70.00
1658.14	785.50	2004-2008	4.22	1.06	714322.12	3425842.35	72.00
2601.70	1031.16	2004-2008	5.05	1.26	714460.54	3425122.42	72.00
740.27	304.44	2004-2008	4.86	1.22	713743.37	3426997.85	74.00
2166.43	625.68	2004-2008	6.93	1.73	713853.96	3426899.01	74.00
11889.50	2841.01	2004-2008	8.37	2.09	712780.81	3427928.12	75.00
558.11	223.49	2004-2008	4.99	1.25	712942.98	3428663.11	76.00
5997.45	2758.10	2004-2008	4.35	1.09	713825.72	3429209.60	77.00

1132.36	429.50	2004-2008	5.27	1.32	714171.63	3430309.08	78.00
5499.00	1082.53	2004-2008	10.16	2.54	714328.08	3430571.55	79.00
7989.81	874.69	2004-2008	18.27	4.57	714946.40	3430551.69	79.00
21913.20	3594.35	2004-2008	12.19	3.05	715296.56	3431154.63	80.00
2617.08	1062.81	2004-2008	4.92	1.23	714024.92	3432234.14	82.00
3424.79	1107.55	2004-2008	6.18	1.55	714300.13	3432344.10	82.00
2615.06	752.21	2004-2008	6.95	1.74	713732.00	3432033.58	82.00
544.22	270.93	2004-2008	4.02	1.00	713026.89	3431792.15	83.00
792.55	376.45	2004-2008	4.21	1.05	713451.80	3431813.46	83.00
1374.15	599.47	2004-2008	4.58	1.15	712854.07	3432033.30	84.00
4224.31	1133.21	2004-2008	7.46	1.86	712630.75	3432771.65	84.00
3414.93	1407.48	2004-2008	4.85	1.21	712526.07	3433570.31	85.00
1529.20	655.66	2004-2008	4.66	1.17	712819.06	3434172.81	86.00
2184.84	791.84	2004-2008	5.52	1.38	712810.31	3434675.24	86.00
8857.42	1772.12	2004-2008	10.00	2.50	712500.49	3434778.58	87.00
5392.48	1294.38	2004-2008	8.33	2.08	711950.33	3435499.75	88.00
30031.10	5158.67	2004-2008	11.64	2.91	712420.66	3435895.32	89.00
7103.03	1755.61	2004-2008	8.09	2.02	712767.56	3437237.51	91.00
596.20	259.17	2004-2008	4.60	1.15	711568.61	3437039.44	92.00
485.85	240.64	2004-2008	4.04	1.01	711252.62	3437434.32	93.00
685.62	229.05	2004-2008	5.99	1.50	711258.53	3437671.26	93.00
13299.20	1930.04	2004-2008	13.78	3.45	711262.66	3438380.31	94.00
816.37	322.70	2004-2008	5.06	1.26	710401.39	3438957.71	95.00
1574.62	418.77	2004-2008	7.52	1.88	710213.98	3438864.60	95.00
1826.01	771.86	2004-2008	4.73	1.18	707881.53	3438626.38	98.00
3995.86	676.46	2004-2008	11.81	2.95	707922.90	3438976.09	98.00

2447.43	566.43	2004-2008	8.64	2.16	708228.39	3439712.05	99.00
2335.00	931.91	2004-2008	5.01	1.25	708921.12	3440414.77	100.00
1760.18	550.55	2004-2008	6.39	1.60	708623.51	3441213.43	101.00
1438.63	710.09	2004-2008	4.05	1.01	707690.16	3442080.42	102.00
7401.12	1806.76	2004-2008	8.19	2.05	707030.70	3443218.10	104.00
15672.80	2976.64	2004-2008	10.53	2.63	707013.14	3443869.80	104.00
5367.39	1118.36	2008-2010	9.60	4.80	730345.26	3401525.81	24.00
279.52	125.76	2008-2010	4.45	2.22	727204.35	3404238.61	30.00
406.92	164.40	2008-2010	4.95	2.48	727278.62	3404281.22	30.00
912.08	455.33	2008-2010	4.01	2.00	728492.05	3404568.84	31.00
15609.40	1812.86	2008-2010	17.22	8.61	728119.73	3404151.83	31.00
254.07	113.36	2008-2010	4.48	2.24	728669.43	3404903.10	32.00
1729.44	350.23	2008-2010	9.88	4.94	728575.51	3405408.52	32.00
430.52	135.55	2008-2010	6.35	3.18	725569.85	3408966.60	39.00
361.29	112.82	2008-2010	6.40	3.20	725611.54	3409007.09	39.00
792.58	153.70	2008-2010	10.31	5.16	725482.77	3408958.37	39.00
597.45	241.96	2008-2010	4.94	2.47	721246.35	3418380.56	53.00
3705.96	710.48	2008-2010	10.43	5.22	721674.85	3418755.04	54.00
16860.50	1308.80	2008-2010	25.76	12.88	721732.96	3418557.92	54.00
558.16	271.43	2008-2010	4.11	2.06	716924.61	3420693.42	64.00
4781.04	1646.21	2008-2010	5.81	2.90	716692.34	3421580.15	66.00
2407.71	893.22	2008-2010	5.39	2.70	716629.69	3422310.92	67.00
23214.50	2295.87	2008-2010	20.22	10.11	717180.82	3422344.75	67.00
3407.40	866.98	2008-2010	7.86	3.93	715205.90	3423009.14	69.00
930.45	369.38	2008-2010	5.04	2.52	714387.78	3430572.37	79.00
221.77	108.46	2008-2010	4.09	2.04	715131.28	3430784.19	80.00

9057.84	905.01	2008-2010	20.02	10.01	715313.36	3431501.08	80.00
570.21	235.06	2008-2010	4.85	2.43	714626.89	3432206.35	81.00
1621.43	376.44	2008-2010	8.61	4.31	714768.24	3432174.69	81.00
2306.00	619.45	2008-2010	7.45	3.72	713261.50	3431680.61	83.00
6041.51	2298.13	2008-2010	5.26	2.63	711992.54	3435579.03	88.00

Appendix B

Aerial Photographs

This appendix lists the aerial photographs used to collect channel migration data. The county and year are listed with the corresponding photograph and frame numbers. The aerial photographs were received as a mosaic consisting of dozens of photographs covering large sections of a particular county. The mosaic was produced by manually overlaying the photographs and scanning the large mosaic. This process introduces a large amount of spatial error because of the offset between individual frames. Mosaic was divided into the individual frames using cut and crop tools in Adobe Photoshop to georeference the images to a common spatial coordinate system.

The “# of GCP” column displays the number of ground control points (GCP) selected in an individual frame to properly align the frame to an existing georeferenced image. A minimum of ten points were selected to adequately cover extent of the frame.

The “Total RMS error” column displays the root mean square (RMS) error of an individual frame. The acceptable maximum error, based on previous channel migration studies, was 4.0 meters. Dashes in both the “# of GCP” and “Total RMS error” columns represent overlapping frames and were not georeferenced.

County & Year	Photo #	Frame #	# of GCP	Total RMS error
McLennan 1958	4	1	10	3.63
		2	12	1.86
		3	11	3.30
		4	10	3.64
		5	10	2.75
		6	11	2.79
		7	-	3.86
		8	-	-
McLennan 1958	5	1	-	-
		2	11	3.48
		3	10	1.10
		4	10	3.79
		5	12	3.26
		6	13	2.55
		7	12	3.03
		8	10	3.37
		9	10	1.98
		10	10	3.65
		11	15	2.83
		12	13	3.15
		13	10	3.63
		14	15	3.17
		15	13	3.99
		16	14	2.64

McLennan 1958	7	1	-	-
		2	-	-
		3	-	-
		4	-	-
		5	-	-
McLennan 1972	1	1	10	3.06
		2	10	1.66
		3	10	2.12
		4	10	1.95
		5	10	3.40
		6	10	2.93
		7	10	2.84
		8	12	2.99
McLennan 1982	1	1	11	2.82
		2	10	1.96
		3	13	2.86
		4	12	3.50
		5	10	2.59
		6	11	3.23
		7	11	2.24
		8	11	2.24
		9	11	2.79
		10	15	3.40
		11	12	3.00
		12	10	3.63
		13	10	2.96
		14	10	0.95
		15	10	2.08
McLennan 1988	1	1	13	2.91
		2	10	2.88
		3	11	2.27
		4	13	2.62
		5	11	2
		6	13	3.36
		7	12	2.46
		8	11	3.88
		9	11	3.24
		10	10	3.35
		11	13	3.44
		12	11	3.32
		13	12	2.98
		14	13	2.24
		15	10	2.09
McLennan 1993	1	1	11	3.02
		2	13	3.9
		3	10	3.72
		4	13	2.58
		5	10	3.97

		6	10	2.54
		7	10	2.84
		8	11	2.5
		9	10	3.25
		10	11	3.07
		11	10	2.29
		12	11	3.96
		13	12	2.37
		14	10	3.38
Falls 1955	1	1	10	2.90
		2	12	3.59
		3	12	3.49
		4	13	3.30
		5	11	2.38
		6	10	1.83
		7	10	2.70
		8	12	3.44
		9	11	2.96
		10	10	3.30
		11	10	3.77
		12	11	3.10
		13	10	3.18
		14	11	3.16
		15	11	2.82
		16	12	2.23
		17	14	3.74
		18	13	3.77
		19	13	3.96
		20	15	3.27
		21	13	3.42
		22	13	3.50
		23	12	2.80
		24	-	-
		25	-	-
		26	-	-
	2	1	-	-
		2	-	-
		3	-	-
		4	-	-
	3	1	-	-
		2	12	4.88
		3	14	3.22
		4	11	3.39
		5	13	3.72
		6	12	3.66
		7	11	2.71
		8	14	3.34

		9	11	2.98
		10	12	0.87
		11	11	3.48
		12	11	3.19
		13	-	-
		14	11	1.76
		15	11	3.83
		16	10	3.12
		17	12	3.34
		18	10	2.93
Falls 1960	2	1	10	2.88
		2	10	3.22
		3	10	2.83
		4	10	2.44
		5	10	3.09
		6	10	2.86
		7	10	2.50
		8	10	3.79
		9	12	3.83
		10	11	1.44
		11	10	3.59
		12	10	1.68
		13	10	3.61
		14	10	2.33
		15	-	-
		16	14	2.94
		17	10	2.23
		18	12	3.10
		19	10	3.54
		20	12	3.73
		21	12	2.84
		22	11	3.10
		23	10	2.49
		24	11	3.01
		25	-	-
	5	1	-	-
		2	-	-
		3	-	-
		4	-	-
		5	10	3.21
		6	10	2.93
		7	12	3.40
		8	13	2.27
		9	10	3.47
		10	10	2.64
		11	10	1.48
		12	10	3.10
		13	10	1.75

		14	10	3.58
		15	13	3.20
		16	11	2.88
		17	10	2.67
		18	12	1.89
		19	10	3.90
		20	10	3.27
Falls 1968	1	1	10	2.68
		2	10	3.16
		3	11	3.43
		4	10	2.25
		5	10	3.84
		6	-	-
		7	12	3.34
		8	12	3.43
		9	10	2.99
		10	11	3.92
		11	10	1.96
		12	10	3.60
		13	10	3.04
		14	10	3.11
		15	10	3.30
	2	1	-	-
		2	-	-
		3	-	-
		4	-	-
		5	10	2.61
		6	10	1.83
		7	10	3.20
		8	11	3.59
		9	13	3.65
		10	14	3.13
		11	13	2.17
		12	12	3.35
		13	10	2.92
		14	15	3.06
		15	13	2.71
	3	1	-	-
		2	10	2.31
		3	11	1.80
		4	10	3.29
		5	10	3.60
		6	10	3.04
		7	10	2.21
		8	10	1.44
		9	10	2.55
		10	10	3.31
		11	11	3.99

		12	10	3.66
		13	10	1.54
		14	12	2.26
		15	-	-
		16	-	-
		17	11	3.21
		18	10	3.51
	4	1	-	-
		2	-	-
		3	-	-
		4	-	-
		5	-	-
		6	-	-
		7	-	-
		8	-	-
		9	-	-
		10	-	-
		11	-	-
		12	-	-
		13	10	3.53
		14	11	3.66
		15	-	-
		16	-	-
		17	10	2.24
Milam 1951	1	1	10	1.81
		2	13	2.65
		3	11	1.80
		4	-	-
		5	-	-
		6	-	-
		7	10	2.31
		8	10	3.40
		9	11	2.48
		10	10	2.76
		11	10	2.83
		12	10	2.82
		13	10	2.45
		14	-	-
		15	11	3.09
		16	10	3.44
		17	10	3.07
		18	-	-
		19	-	-
		20	10	1.94
		21	-	-
		22	10	3.42
		23	-	-

		24	-	-
		25	11	2.94
		26	10	3.43
		27	10	2.11
		28	11	3.63
Robertson 1941	1	51	-	-
		52	-	-
		53	10	2.61
		54	12	3.12
		55	10	2.57
		56	11	2.19
		57	11	3.73
		58	14	3.94
		59	13	3.68
		60	10	3.38
		61	10	3.14
		62	-	-
		63	14	2.04
		64	11	2.66
		65	12	3.49
		66	10	1.83
		67	13	3.95
		68	15	3.64
		69	-	-
		70	15	3.12
		71	-	-
		72	-	-
		73	13	3.13
		74	14	3.45
		75	12	1.99
		76	14	3.03
		77	13	2.87
		78	-	
		79	13	-
		80	10	3.31
		81	10	2.77
Robertson 1958	2	1	10	3.35
		2	10	2.68
		3	11	3.36
		4	10	2.48
		5	10	3.06
		6	10	2.43
		7	10	2.32
		8	10	2.65
		9	10	2.64
		10	10	3.70
		11	10	3.51

		12	10	2.74
		13	10	2.72
		14	10	2.20
		15	10	3.40
		16	10	3.35
	4	1	11	3.49
		2	-	-
		3	-	-
		4	10	3.20
		5	10	2.58
		6	11	2.40
		7	10	3.14
		8	10	2.88
		9	13	3.58
		10	10	2.77
		11	10	2.43
		12	10	1.91
		13	10	3.52
		14	10	3.09
		15	10	3.12
		16	11	2.93
		17	11	3.33
		18	10	3.68
		19	10	3.15
		20	10	2.35
		21	10	2.68
		22	10	3.74
		23	10	2.90
		24	10	3.60
		25	10	2.93
		26	11	2.34
		27	11	2.30
		28	10	3.45
Robertson 1965	1	29	11	2.28
		30	-	-
		31	11	2.75
		32	10	2.53
		33	10	2.42
		34	12	3.44
		35	11	2.88
		36	-	-
		37	10	2.72
		38	10	1.83
		39	11	2.78
		40	10	2.63
		41	11	2.95
		42	10	1.73
		43	10	2.59

		44	-	-
		45	12	1.88
		46	11	2.80
		47	10	1.83
		48	10	3.66
		49	11	1.42
		50	12	3.79
Robertson 1965	3	8	10	2.17
Robertson 1965	4	6	13	2.30
		7	10	3.12
Robertson 1965	5	1	10	1.99
Robertson 1965	8	8	10	0.95
		1	5	3.06
Roberston 1974	4	2	5	3.18
		3	6	3.93
		4	5	3.06
		5	5	3.35
		6	5	2.54
		7	5	3.50
		8	5	2.40
		9	6	3.59
		10	5	2.34
		11	5	3.62
		12	6	3.63
		13	5	3.18
		14	5	3.57
		15	5	3.82

Appendix C

Sediment Budget

The following tables contain erosion volumes calculated along the main channel. The values were obtained by subtracting the channel polygon of the older time frame from the channel polygon of the younger time frame. The resulting polygon represents areas of erosion.

The “meander” column lists the corresponding meander bend where erosion was calculated.

McLennan Sediment Erosion

Time period	Meander	Area (m^2)	Bank height (m)	Sediment volume (m^3)
1972-1952	0	25001.3	8	200010.4
1972-1952	1	13907.6	8	111260.8
1972-1952	2	36774.1	8	294192.8
1972-1952	3	103742.0	8	829936.0
1972-1952	4	62265.9	8	498127.2
1972-1952	5	42043.3	8	336346.4
1972-1952	6	98767.1	8	790136.8
1972-1952	7	41499.8	8	331998.4
1972-1952	8	114512.0	8	916096.0
1972-1952	9	62841.3	8	502730.4
1972-1952	10	71869.5	8	574956.0
1972-1952	11	487620.0	8	3900960.0
1972-1952	12	303023.0	8	2424184.0
1972-1952	13	277634.0	8	2221072.0
1982-1972	0	18415.6	8	147324.8
1982-1972	1	20582.6	8	164660.8
1982-1972	2	29224.0	8	233792.0
1982-1972	3	26314.7	8	210517.6
1982-1972	4	22721.0	8	181768.0
1982-1972	5	24669.6	8	197356.8
1982-1972	6	29925.4	8	239403.2
1982-1972	7	1744.5	8	13955.9
1982-1972	8	35738.8	8	285910.4
1982-1972	9	339622.0	8	2716976.0
1982-1972	10	29840.3	8	238722.4
1988-1982	0	51565.3	8	412522.4
1988-1982	1	31384.5	8	251076.0
1988-1982	2	43285.2	8	346281.6
1988-1982	3	52214.4	8	417715.2
1988-1982	4	31582.9	8	252663.2
1988-1982	5	150180.0	8	1201440.0
1988-1982	6	22252.0	8	178016.0
1988-1982	7	8101.9	8	64815.0
1988-1982	8	100558.0	8	804464.0

1988-1982	9	3039.1	8	24312.4
1988-1993	0	38570.8	8	308566.4
1988-1993	1	50662.9	8	405303.2
1988-1993	2	46197.6	8	369580.8
1988-1993	3	121280.0	8	970240.0
1988-1993	4	83908.9	8	671271.2
1988-1993	5	77791.5	8	622332.0
1988-1993	6	67926.3	8	543410.4
1988-1993	7	16093.8	8	128750.4
1988-1993	8	136583.0	8	1092664.0
1988-1993	9	231678.0	8	1853424.0
1988-1993	10	282035.0	8	2256280.0
1988-1993	11	113292.0	8	906336.0
1993-1995	0	28704.5	8	229636.0
1993-1995	1	44469.0	8	355752.0
1993-1995	2	39384.9	8	315079.2
1993-1995	3	42393.8	8	339150.4
1993-1995	4	46666.9	8	373335.2
1993-1995	5	25657.7	8	205261.6
1993-1995	6	16839.3	8	134714.4
1993-1995	7	8837.3	8	70698.6
1993-1995	8	62907.7	8	503261.6
1993-1995	9	28434.7	8	227477.6
1993-1995	10	62590.6	8	500724.8
1995-2004	0	2573.3	8	20586.2
1995-2004	1	5699.3	8	45594.6
1995-2004	2	7674.0	8	61391.6
1995-2004	3	6151.5	8	49211.7
1995-2004	4	9002.5	8	72019.9
1995-2004	5	2522.6	8	20180.9
1995-2004	6	10806.9	8	86455.2
1995-2004	7	489.3	8	3914.3
1995-2004	8	2937.0	8	23496.1
2008-2004	0	50993.2	8	407945.6
2008-2004	1	37633.8	8	301070.4
2008-2004	2	18238.2	8	145905.6
2008-2004	3	45198.6	8	361588.8
2008-2004	4	43811.3	8	350490.4
2008-2004	5	6542.9	8	52343.3
2008-2004	6	19893.5	8	159148.0
2008-2004	7	4730.7	8	37845.8
2008-2004	8	6677.6	8	53420.6

Falls Sediment Erosion

Time period	Meander	Area (m^2)	Bank height (m)	Sediment volume (m^3)
1960-1955	6	54000.3	8	432002.4
1960-1955	7	110463.0	8	883704.0
1960-1955	8	401660.0	8	3213280.0
1960-1955	9	182669.0	8	1461352.0
1960-1955	10	137603.0	8	1100824.0
1960-1955	11	353645.0	8	2829160.0
1960-1955	12	70565.8	8	564526.4
1960-1955	13	319970.0	8	2559760.0
1960-1955	14	94757.3	8	758058.4
1960-1955	15	90784.1	8	726272.8
1960-1955	16	313607.0	8	2508856.0
1960-1955	17	20447.8	8	163582.4
1960-1955	18	93290.6	8	746324.8
1960-1955	19	75975.0	8	607800.0
1960-1955	20	411560.0	8	3292480.0
1960-1955	21	133277.0	8	1066216.0
1960-1955	22	71962.5	8	575700.0
1960-1955	23	88970.8	8	711766.4
1960-1968	6	7167.3	8	57338.2
1960-1968	7	13812.0	8	110496.0
1960-1968	8	49325.5	8	394604.0
1960-1968	9	188045.0	8	1504360.0
1960-1968	10	13625.5	8	109004.0
1960-1968	11	46702.0	8	373616.0
1960-1968	12	19172.3	8	153378.4
1960-1968	13	34364.2	8	274913.6
1960-1968	14	48919.2	8	391353.6
1960-1968	15	140451.0	8	1123608.0
1960-1968	16	139850.0	8	1118800.0
1960-1968	17	48518.0	8	388144.0
1960-1968	18	61683.6	8	493468.8
1960-1968	19	13712.6	8	109700.8
1960-1968	20	184637.0	8	1477096.0
1960-1968	21	83997.7	8	671981.6
1960-1968	22	51281.7	8	410253.6
1960-1968	23	74208.9	8	593671.2
1995-1968	7	12692.6	8	101540.8
1995-1968	8	70599.2	8	564793.6
1995-1968	9	31028.7	8	248229.6
1995-1968	10	131824.0	8	1054592.0
1995-1968	11	61229.9	8	489839.2
1995-1968	12	16271.4	8	130171.2
1995-1968	13	38327.2	8	306617.6

1995-1968	14	118516.0	8	948128.0
1995-1968	15	78423.6	8	627388.8
1995-1968	16	68206.4	8	545651.2
1995-1968	17	67617.8	8	540942.4
1995-1968	18	20842.3	8	166738.4
1995-1968	19	36202.4	8	289619.2
1995-1968	20	137982.0	8	1103856.0
1995-1968	21	132878.0	8	1063024.0
1995-1968	22	118350.0	8	946800.0
1995-1968	23	103215.0	8	825720.0
2004-1995	8	2825.9	8	22607.3
2004-1995	9	13017.1	8	104136.8
2004-1995	10	15089.4	8	120715.2
2004-1995	11	19170.0	8	153360.0
2004-1995	12	28016.4	8	224131.2
2004-1995	13	4034.6	8	32276.9
2004-1995	14	7295.8	8	58366.7
2004-1995	15	9447.5	8	75580.3
2004-1995	16	12572.1	8	100576.8
2004-1995	17	12253.5	8	98028.0
2004-1995	18	14032.6	8	112260.8
2004-1995	19	6064.6	8	48516.6
2004-1995	20	47003.5	8	376028.0
2004-1995	21	10552.7	8	84421.6
2004-1995	22	27844.7	8	222757.6
2004-1995	23	17813.3	8	142506.4
2008-2004	8	5803.8	8	46430.2
2008-2004	9	12522.1	8	100176.8
2008-2004	10	11115.4	8	88923.2
2008-2004	11	53508.1	8	428064.8
2008-2004	12	4977.1	8	39817.2
2008-2004	13	16701.5	8	133612.0
2008-2004	14	27582.4	8	220659.2
2008-2004	15	33846.5	8	270772.0
2008-2004	16	23778.9	8	190231.2
2008-2004	17	31774.2	8	254193.6
2008-2004	18	12154.1	8	97232.8
2008-2004	19	22887.0	8	183096.0
2008-2004	20	30014.7	8	240117.6
2008-2004	21	52322.6	8	418580.8
2008-2004	22	24391.0	8	195128.0
2008-2004	23	18691.2	8	149529.6

Milam-Robertson Sediment Erosion

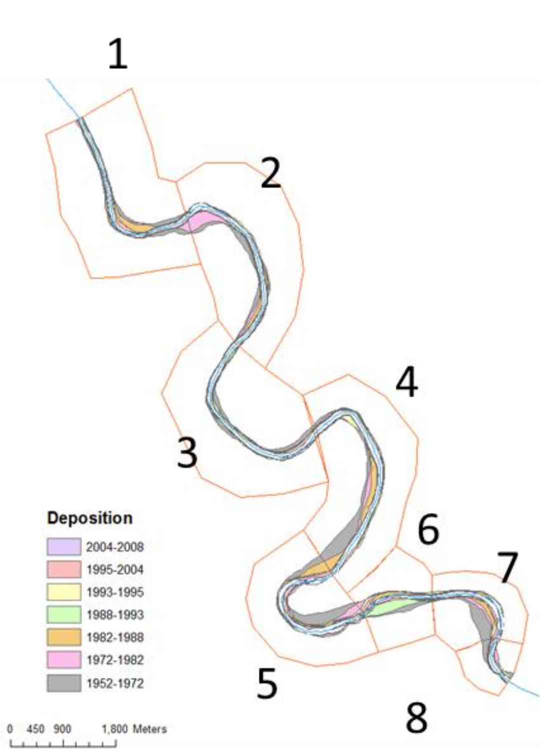
Time period	Meander	Area (m^2)	Bank height (m)	Sediment volume (m^3)
1958-1951	22	282857.0	12	3394284.0
1958-1951	23	71651.2	12	859814.4
1958-1951	24	276810.0	12	3321720.0
1958-1951	25	662953.0	12	7955436.0
1958-1951	26	205595.0	12	2467140.0
1958-1951	27	331508.0	12	3978096.0
1958-1951	28	340834.0	12	4090008.0
1958-1951	29	104565.0	12	1254780.0
1958-1951	30	25969.0	12	311628.0
1958-1951	31	132093.0	12	1585116.0
1958-1951	32	761441.0	12	9137292.0
1958-1965	22	22162.2	12	265946.4
1958-1965	23	50586.7	12	607040.4
1958-1965	24	32910.9	12	394930.8
1958-1965	25	141355.0	12	1696260.0
1958-1965	26	43277.0	12	519324.0
1958-1965	27	295496.0	12	3545952.0
1958-1965	28	130431.0	12	1565172.0
1958-1965	29	66716.8	12	800601.6
1958-1965	30	76653.0	12	919836.0
1958-1965	31	118807.0	12	1425684.0
1958-1965	32	65813.3	12	789759.6
1974-1965	27	158338.0	12	1900056.0
1974-1965	28	55421.2	12	665054.4
1974-1965	29	74936.1	12	899233.2
1974-1965	30	78965.3	12	947583.6
1974-1965	31	102854.0	12	1234248.0
1974-1965	32	149241.0	12	1790892.0
1995-1974	27	284452.0	12	3413424.0
1995-1974	28	142014.0	12	1704168.0
1995-1974	29	124283.0	12	1491396.0
1995-1974	30	215214.0	12	2582568.0
1995-1974	31	238865.0	12	2866380.0
1995-1974	32	188957.0	12	2267484.0
2004-1995	24	10970.2	12	131642.4
2004-1995	25	31394.1	12	376729.2
2004-1995	26	20572.6	12	246871.2
2004-1995	27	74765.0	12	897180.0
2004-1995	28	38520.0	12	462240.0
2004-1995	29	4316.9	12	51802.8
2004-1995	30	107309.0	12	1287708.0
2004-1995	31	48339.3	12	580071.6
2004-1995	32	61209.3	12	734511.6

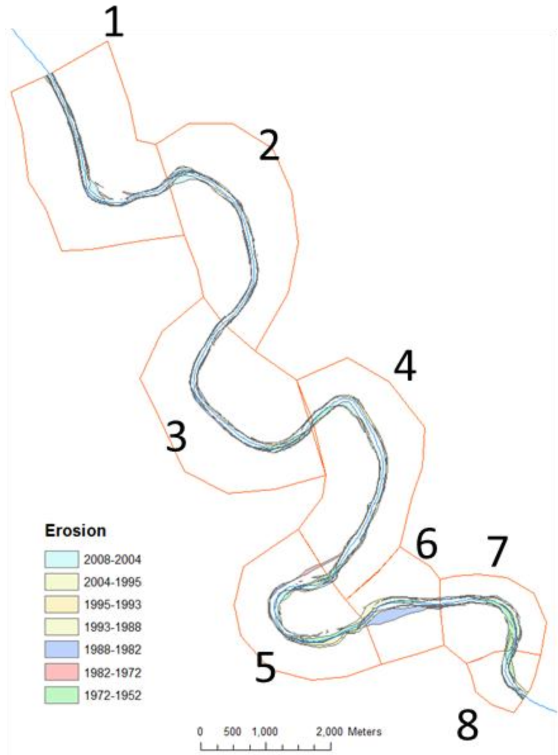
2008-2004	24	18652.8	12	223833.6
2008-2004	25	51688.9	12	620266.8
2008-2004	26	17508.2	12	210098.4
2008-2004	27	72726.0	12	872712.0
2008-2004	28	31324.0	12	375888.0
2008-2004	29	8504.2	12	102050.3
2008-2004	30	148037.0	12	1776444.0
2008-2004	31	32344.9	12	388138.8
2008-2004	32	72729.2	12	872750.4

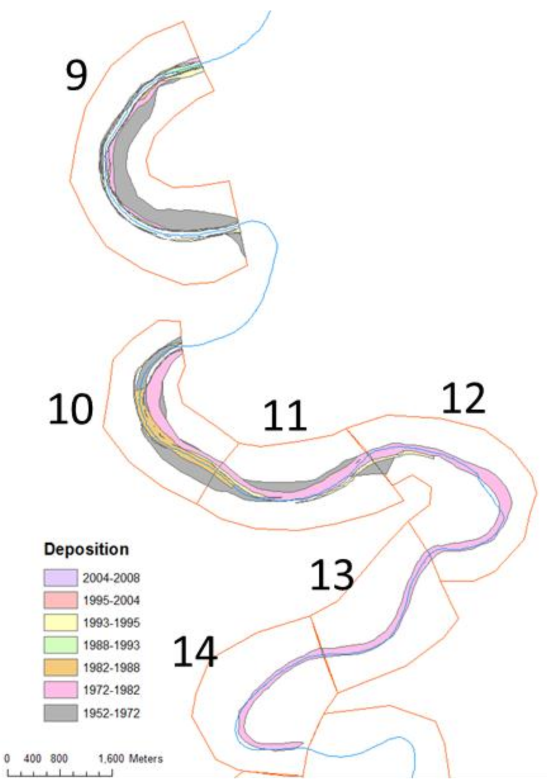
Appendix D

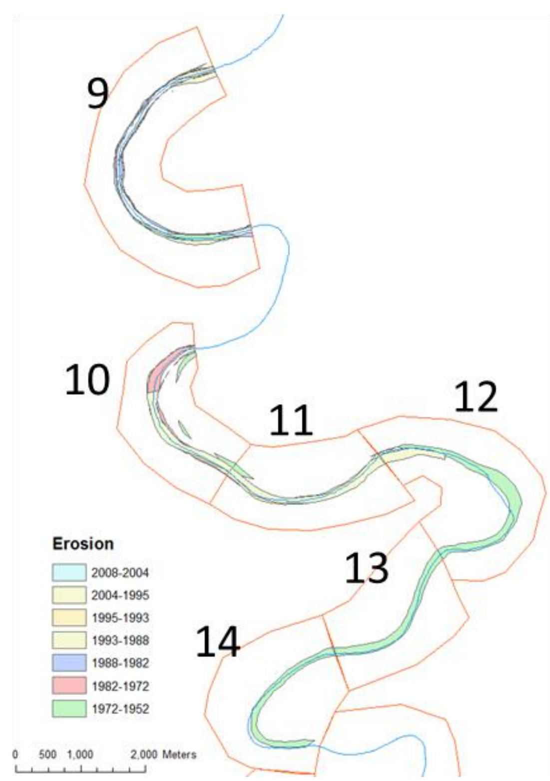
Sediment Budget – Meander Maps

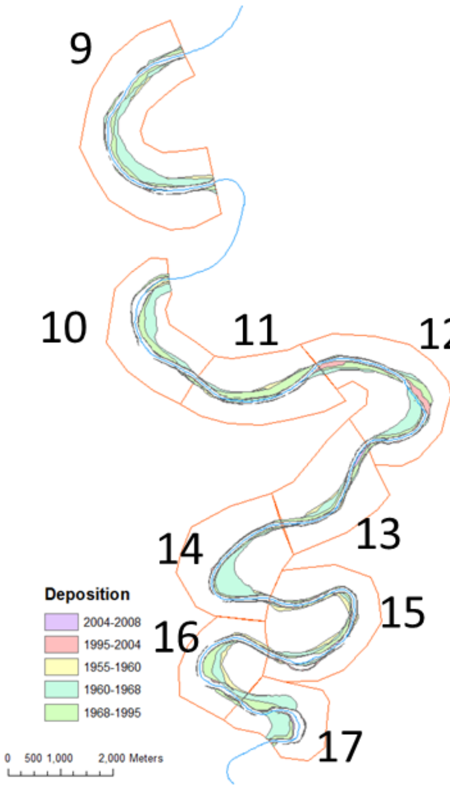
The following maps depict areas of erosion and deposition along the thirty three freely migrating meanders. Each image denotes the areal extent for a particular time period. The polygon enclosing each meander is shown only to delineate the boundaries of an individual meander. The deposition values show the data as the older year *minus* the younger year, while the erosion is shown as the younger year *minus* the older year.

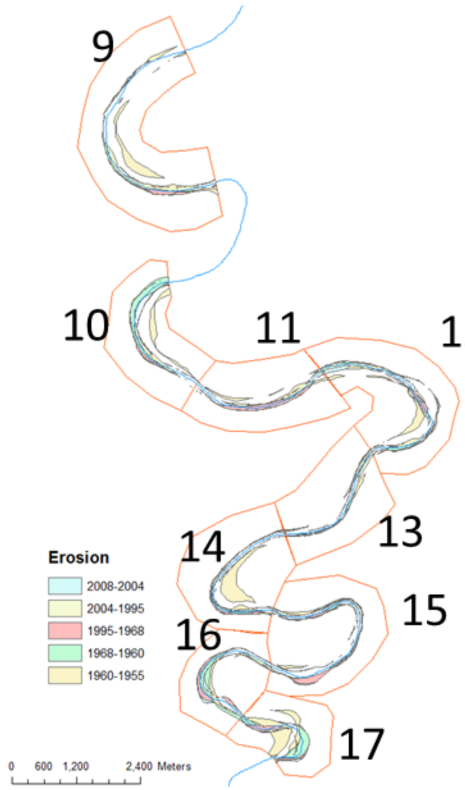

1
2
3
4
5
6
7
8
Deposition
2004-2008
1995-2004
1993-1995
1988-1993
1982-1988
1972-1982
1952-1972
0 450 900 1,800 Meters

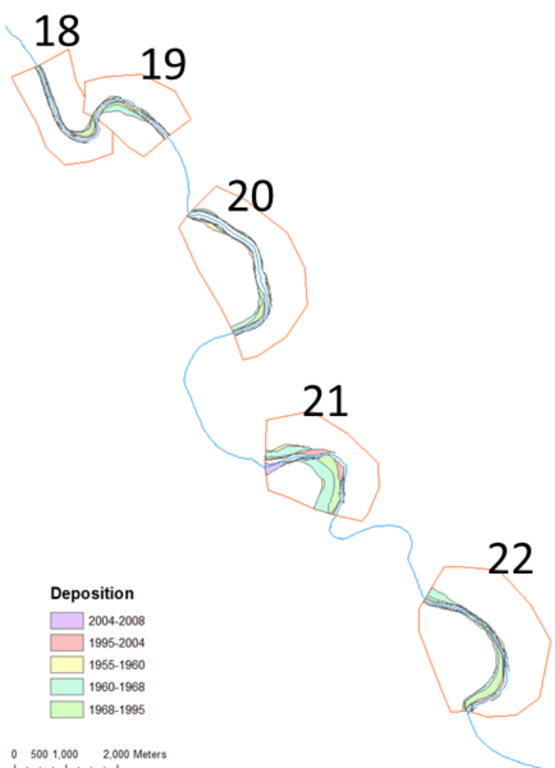

1
2
3
4
5
6
7
8
Erosion
2008-2004
2004-1995
1995-1993
1993-1988
1988-1982
1982-1972
1972-1952
0 500 1,000 2,000 Meters

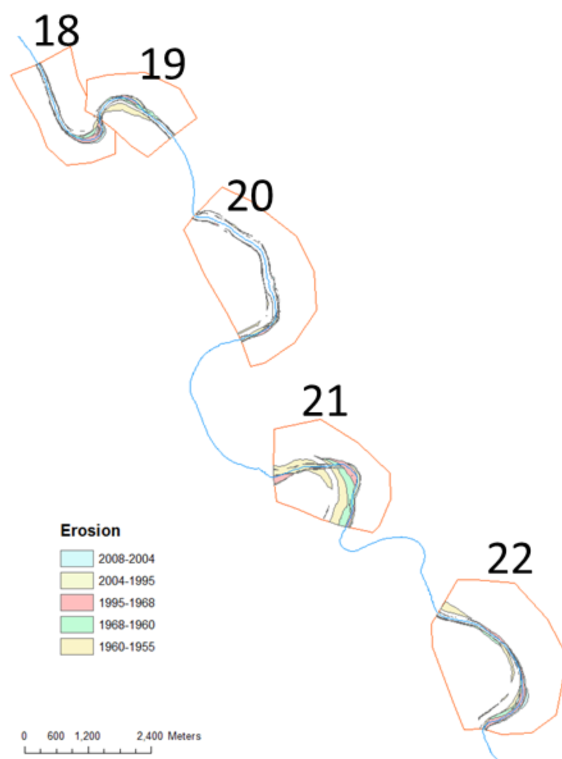

9
10
11
12
13
14
Deposition
2004-2008
1995-2004
1993-1995
1988-1993
1982-1988
1972-1982
1952-1972
0 400 800 1,600 Meters

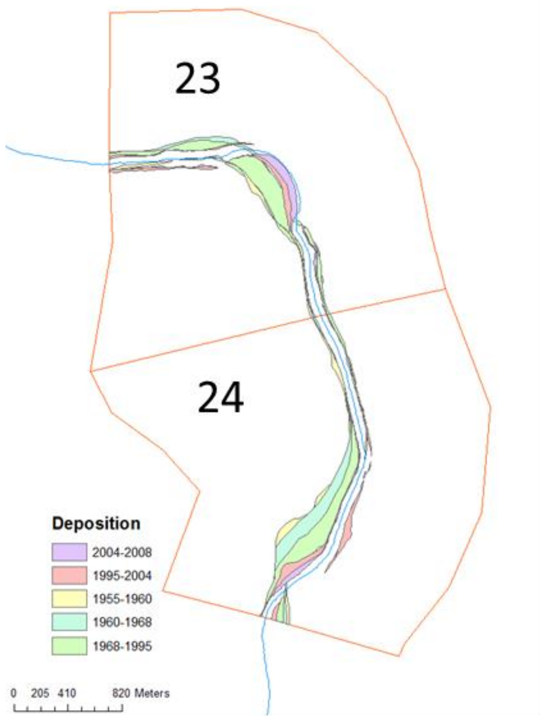

9
10
11
12
13
14
Erosion
2008-2004
2004-1995
1995-1993
1993-1988
1988-1982
1982-1972
1972-1952
0 500 1,000 2,000 Meters

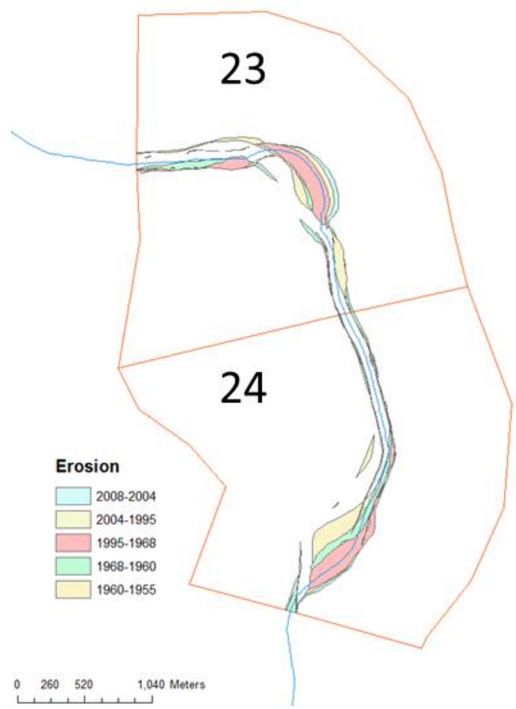

9
10
11
12
13
14
15
16
17
Deposition
2004-2008
1995-2004
1955-1960
1960-1968
1968-1995
0 500 1,000 2,000 Meters

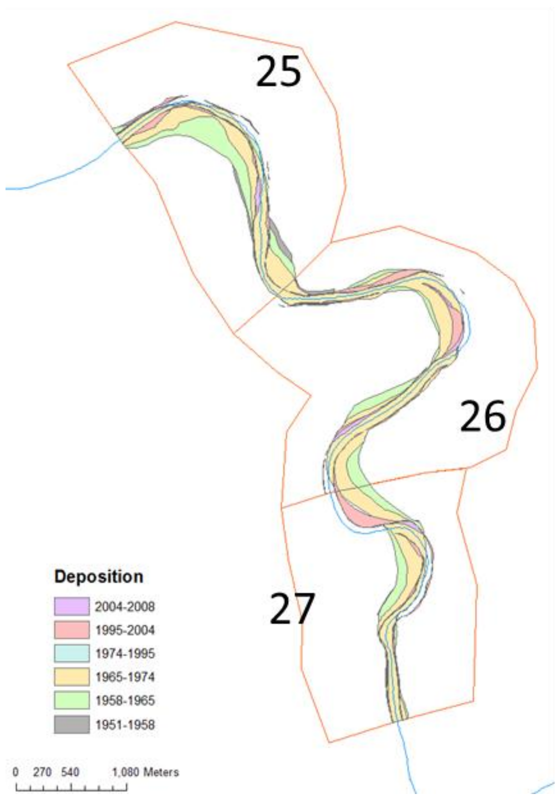

9
10
11
12
13
14
15
16
17
Erosion
2008-2004
2004-1995
1995-1968
1968-1960
1960-1955
0 600 1,200 2,400 Meters

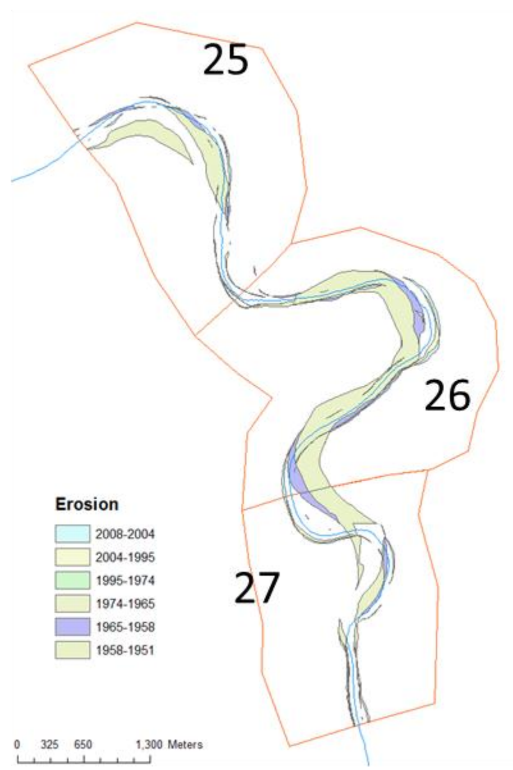

18
19
20
21
22
Deposition
2004-2008
1995-2004
1955-1960
1960-1968
1968-1995
0 500 1,000 2,000 Meters

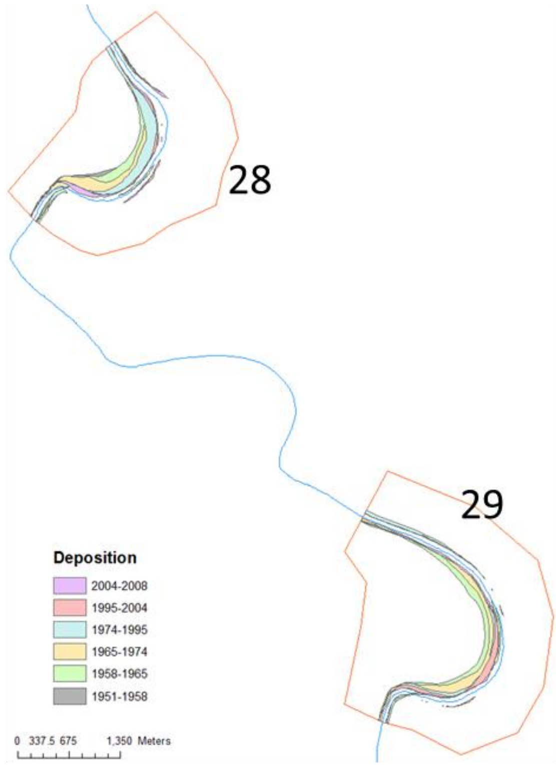

18
19
20
21
22
Erosion
2008-2004
2004-1995
1995-1968
1968-1960
1960-1955
0 600 1,200 2,400 Meters

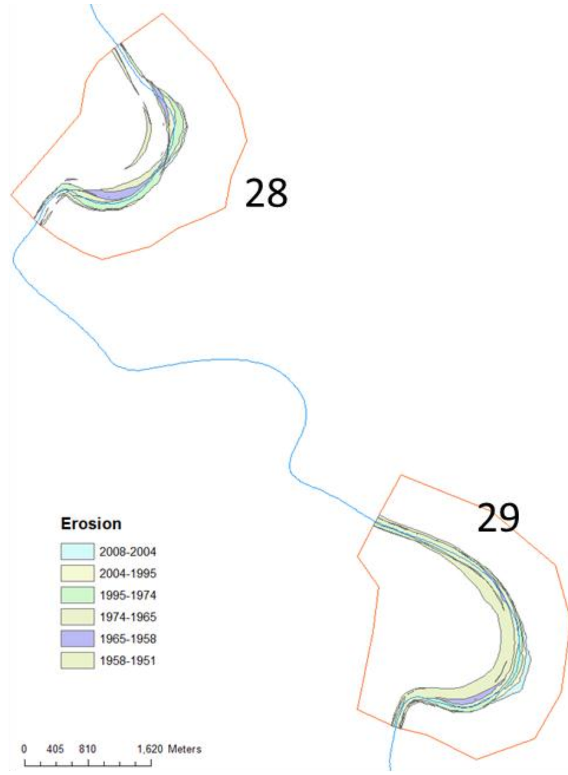

23
24
Deposition
2004-2008
1995-2004
1955-1960
1960-1968
1968-1995
0 205 410 820 Meters

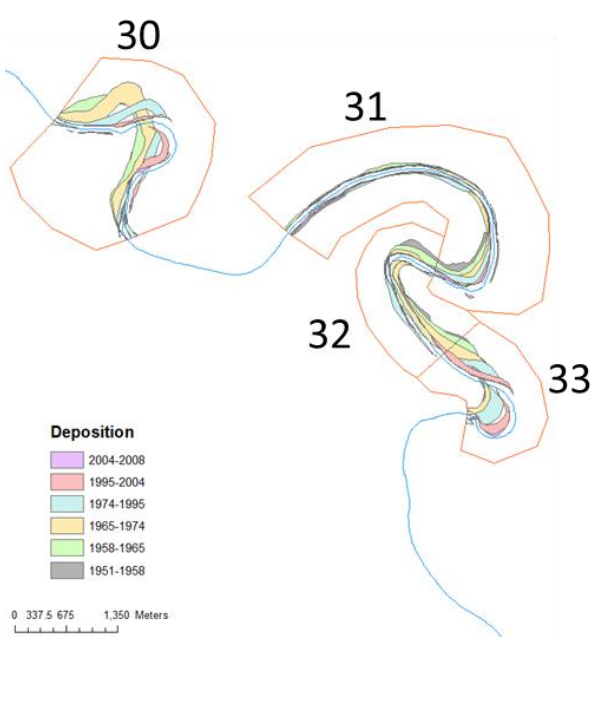

23
24
Erosion
2008-2004
2004-1995
1995-1968
1968-1960
1960-1955
0 260 520 1,040 Meters


25
26
27
Deposition
2004-2008
1995-2004
1974-1995
1965-1974
1958-1965
1951-1958
0 270 540 1,080 Meters


25
26
27
Erosion
2008-2004
2004-1995
1995-1974
1974-1965
1965-1958
1958-1951
0 325 650 1,300 Meters


28
29
Deposition
2004-2008
1995-2004
1974-1995
1965-1974
1958-1965
1951-1958
0 337.5 675 1,350 Meters


28
29
Erosion
2008-2004
2004-1995
1995-1974
1974-1965
1965-1958
1958-1951
0 405 810 1,620 Meters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Deposition
2004-2008
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1974-1995
1965-1974
1958-1965
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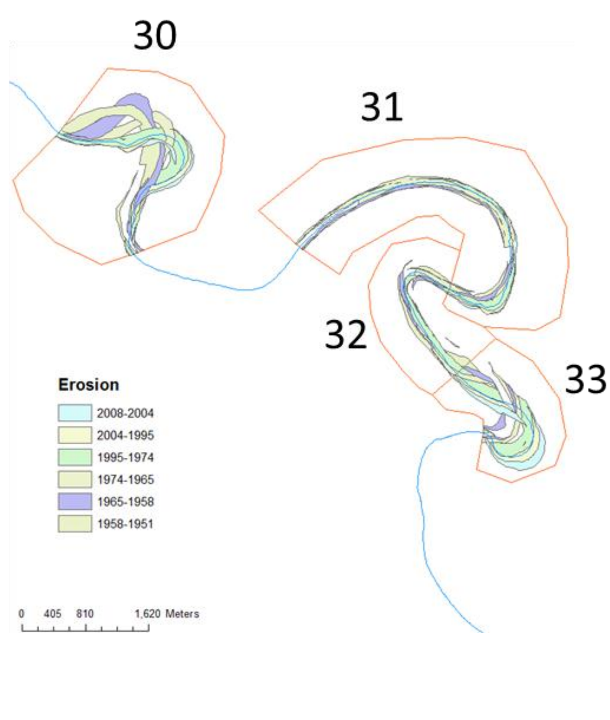
30
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32
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Erosion
2008-2004
2004-1995
1995-1974
1974-1965
1965-1958
1958-1951
0 405 810 1,620 Meters