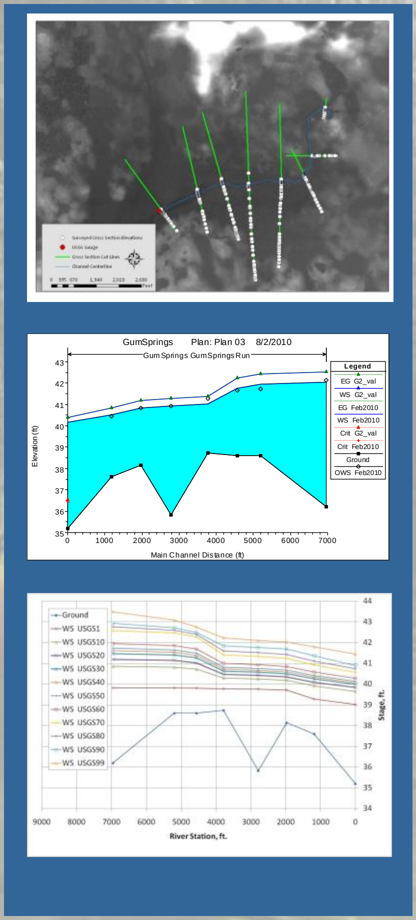
Gum Springs Run:

HEC-RAS Steady State Model Development



Prepared for:

The South Florida Water Management District

Prepared by:

INTERA

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Contents

List of Tables

List of Figures

Introduction

Gum Springs, the headwaters of Gum Slough, is located approximately six miles northeast of the Withlacoochee River in northwest Sumter County. A HEC-RAS model of the Gum Slough was constructed using the best available data provided by the District. Digital elevation model (DEM) data provided by the District was combined with surveyed vegetative cross section information in order to develop cross sections in HEC-RAS. Measured flow and stage data were utilized for model calibration. The model was calibrated well within the desired 6-inch tolerance desired by the District. All work was performed in NAVD88. The results of the predictive simulations will be utilized by the District for MFL analyses.

District Needs and Project Goals

In order to perform the required analysis of the MFLs, a calibrated steady state model of the spring run using HEC-RAS v4.0 was developed for the District. Discussion at the kickoff meeting included the District needs in the construction of the model, calibration methodology, and modeling results. It was also noted by the District that there is more concern with the performance of the calibration of low flows rather than high flows, due to the potential tailwater effects from the Withlacoochee River during high flows and stages. Additionally, the District desires calibration to be within less than six inches (0.5 feet) with regard to stage in order to increase the confidence in model results for MFL analysis.

Field Survey

A field survey of Gum Springs run was conducted on February 18, 2010. The GPS track from the field survey is shown in Figure 1. During the survey, the eight vegetative cross sections were examined. The field survey began upstream at the headwaters of Gum Springs and progressed downstream to the USGS gauge. During the field survey, thick vegetation was noted in the channel in the middle section of the run, and at several other locations within the channel.

Figure 1. Gum Springs Field Survey GPS Track

The site survey allowed further discussion of the District's data collection and findings to date and provided perspective and knowledge of the system including the lateral inflow points, cross section locations, and other hydraulic controls. During the site visit, photographs were taken as well as current position using a handheld GPS unit. Maps generated with the GPS tracks and several photographs from the field visit are shown in Figures 2 through 6.

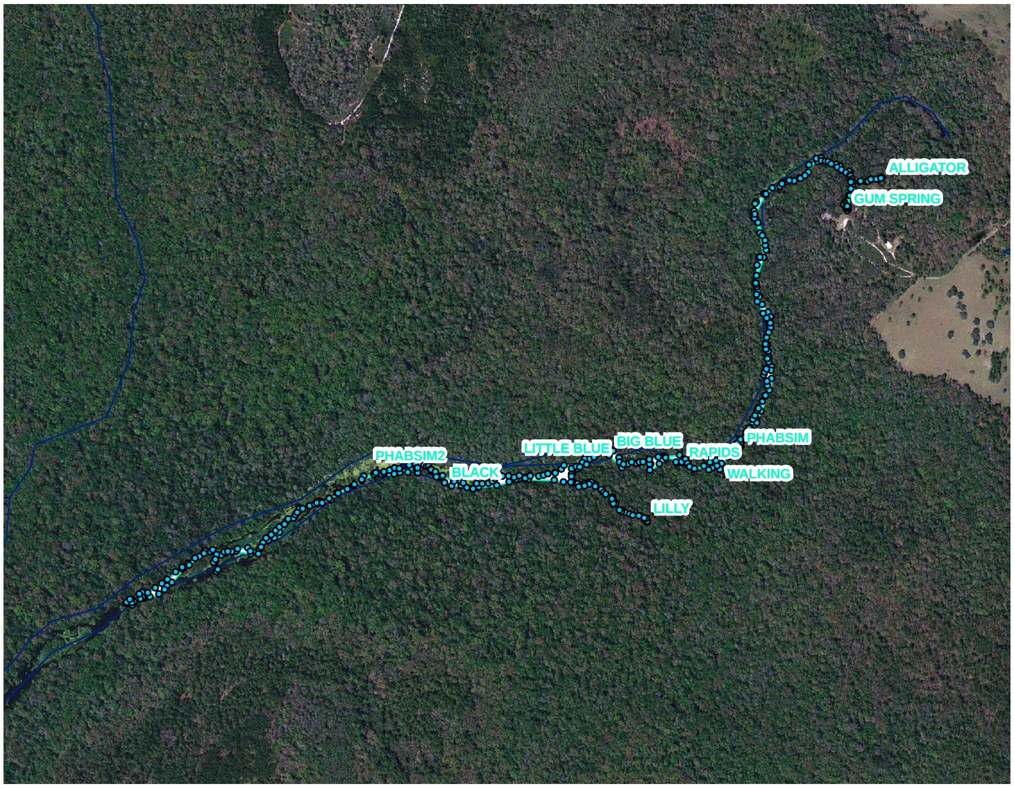

Figure 2. Handheld GPS tracks and marked waypoints

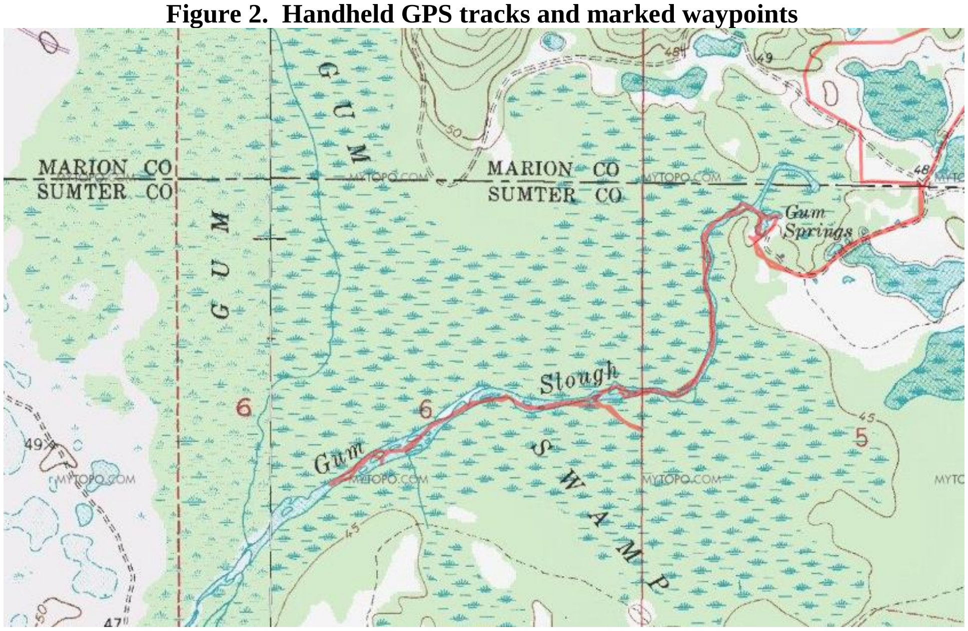

Figure 3. Handheld GPS track on the USGS quadrangle Denoting Gum Slough and Gum Springs

Figure 4. Gum Springs

Figure 5. USGS Gauge on Gum Slough

Figure 6. Gum Slough

Data Collection and Data Transfer

Data for model construction and calibration was provided by the District. This included DEM data, surveyed cross section data, and measured flows and stages. Additional flow data and stage data were obtained from the USGS for the Gum Springs at Holder gauge (USGS #02312764).

The data transferred from the District included the following:

- DEM for Sumter and Marion counties,
- Surveyed vegetative cross section data at eight cross sections,
- Flow measurements (high, medium and low flows) at 3 locations throughout Gum Slough, one of which corresponded to a vegetative cross section,
- One set of detailed flow measurements consisting of flow and stage at each of the vegetative cross sections (measured on February 26, 2010), and
- A statistical estimation of a long term record at the USGS Gum Springs at Holder gauge based on a regression of measured flow at Gum Springs and measured flow at nearby Rainbow Springs.

Cross Section Data and DEM

Relevant DEM tiles for Sumter and Marion counties were selected and merged into a single DEM for use in this project. In addition to the DEM data, eight surveyed cross section were provided by the District, as shown in Figure 7. Cross section data points were provided in a shapefile, and all surveyed elevations were provided in spreadsheet format.

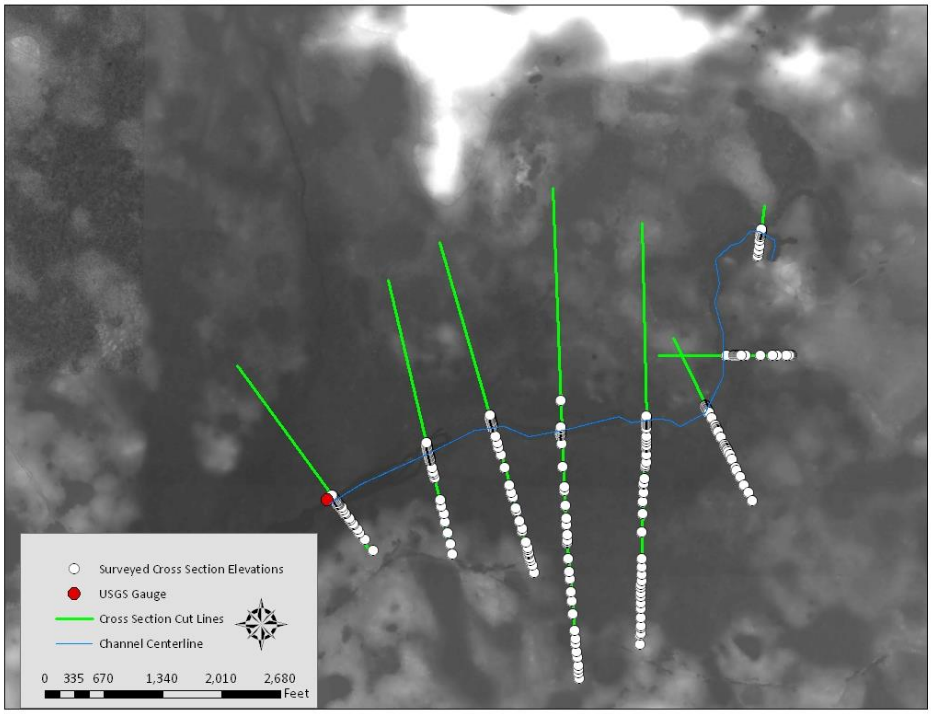

Figure 7. Gum Springs Vegetative Cross Sections

High, Medium, and Low Flow Measurements

Flow measurements were provided by the District for 3 flow regimes representing high, medium and low flows. A summary of the data provided by the District is shown in Table 1.

Table 1. High, Medium and Low Flow Measurements

Name of Data File	Date of Measurement	Measured Flow, cfs	Flow Regime
Gum Springs - Near Headspring	June 1, 2007	3.6	Low
	March 28, 2007	13.6	Medium
	November 7, 2007	27.0	High
Gum Springs - Pool at USGS Gauge	May 31, 2007	45.5	Low
	March 30, 2007	63.5	Medium
	November 7, 2007	91.2	High
Gum Springs - Run Below Springhole	May 31, 2007	35.8	Low
	March 30, 2007	50.4	Medium
	November 7, 2007	91.2	High
Gum Springs - Shoal Below Spring Channel	May 31, 2007	37.26	Low
	March 30, 2007	64.3	Medium
	November 7, 2007	81.0	High

Each of the data files shown above contained velocity and depth information across the cross section at 2-foot intervals. Based on the average depths at 2-foot intervals and the measured velocities, measurements were converted to discharge. This data is utilized in order to develop flow percentages for the predictive simulations.

Detailed Flow Measurements

Flow and stage at each cross section were measured by the District on February 26, 2010. The data is shown in Table 2. According to the USGS flow record, the total daily flow observed at the gauge was 103 cfs.

Table 2. Detailed Flow Measurement Data

Time	Site	Water Surface Elevation, ft.	Total Flow, cfs
	Veg #8	Not measured	
1200	Veg #7	40.44	87
1230	Veg #6	40.84	75
1310	Veg #5	40.94	69
1330	Veg #4	41.28	39
1345	Veg #3	41.67	35
1425	Veg #2	41.73	35
1445	Veg #1	42.15	27

USGS Gauge Data

The USGS Gum Springs at Holder gauge data was obtained from the USGS for use in model calibration, validation, and prediction. The gauge record begins on October 1, 2003. Data utilized for this analysis extends to July 25, 2010. The discharge record for the gauge is shown in Figure 8. The average discharge for the period of record is 98.5 cubic feet per second (cfs), with flow ranging from 25 cfs to 520 cfs for the period of record. Both discharge and stage were obtained from the USGS. Stage data was utilized as a boundary condition for calibration, verification, and predictive simulations, and is discussed at length in later sections. The USGS recorded gauge height, using a gauge with an undetermined datum. Based on information provided by the District, the gauge datum was estimated at 30.98 feet NAVD. There were a total of 2490 daily measurements available from this record.

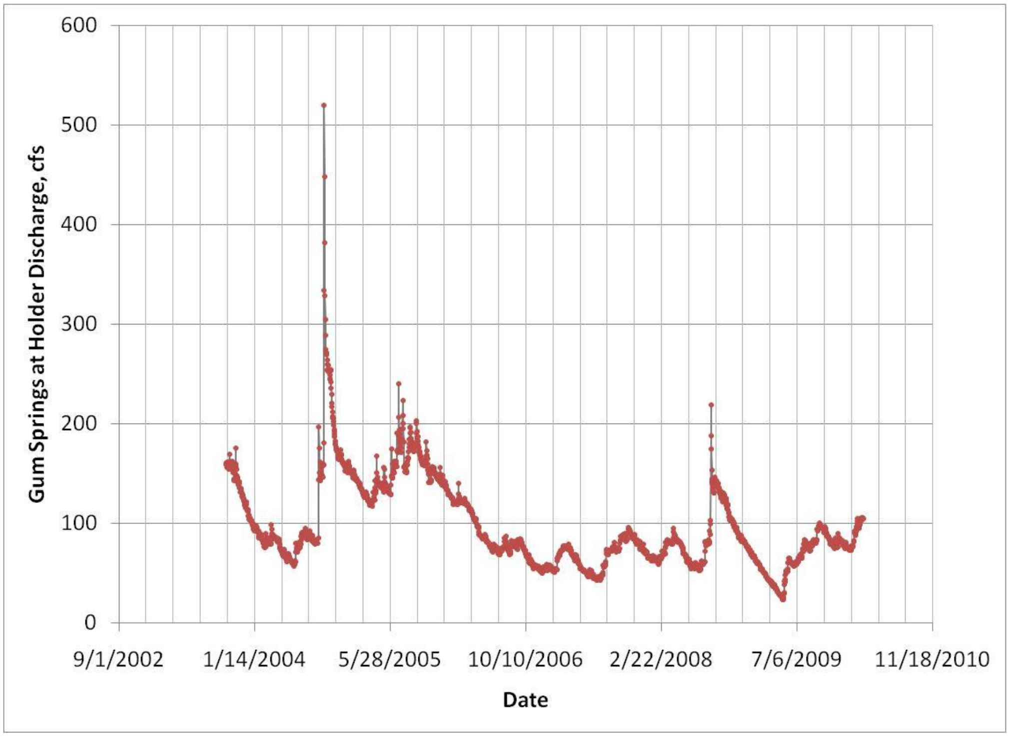

Figure 8. Gum Springs at Holder (USGS #02312764) Discharge Record

Flow Regression for Long Term Record

Since it was desired to have a long term record to utilize for developing flow percentiles for Gum Slough, the District developed a statistical model using linear regression of the USGS Gum Springs gauge data with Rainbow Springs data. The locations of the spring groups are shown in Figure 9. Rainbow Springs group has a much more extensive period of record, beginning on January 1, 1965. The data utilized for the regression development extended to August 6, 2009. A linear regression was developed for the period of overlap of the Rainbow Springs Group gauge with the Gum Springs group gauge, from October 1, 2003 to August 6, 2009 (Figure 10). The linear regression was compared to the observed flow at Gum Springs to determine the goodness of fit (Figure 11). As shown in the Figure, the linear regression estimates average and low flows (flows less than 200 cfs) well. In addition, the shape of the hydrograph is well represented. The linear regression does not estimate high flows well. High flows (flows greater than 200 cfs) represent a small portion of the record. Thus, the linear regression was utilized by the District to construct a long term record for Gum Springs group, shown in Figure 12. For the long term record, USGS observed flows were utilized when available (after October 1, 2003). Flows prior to October 1, 2003 were calculated using the regression between Gum Springs group and Rainbow Springs group.

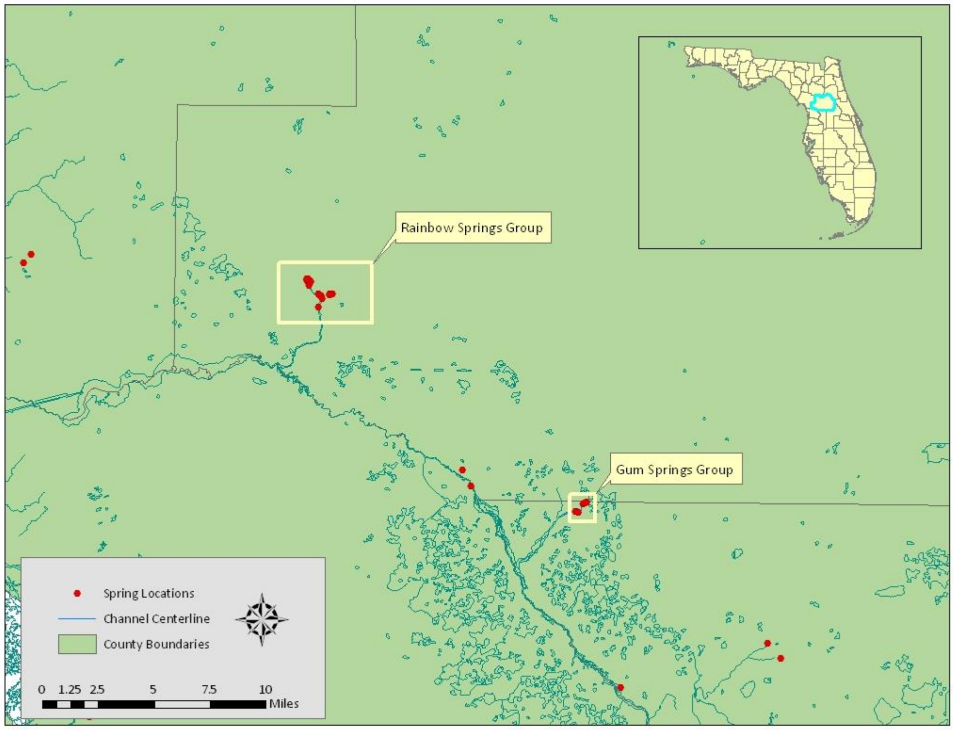

Figure 9. Gum Springs Group and Rainbow Springs Group

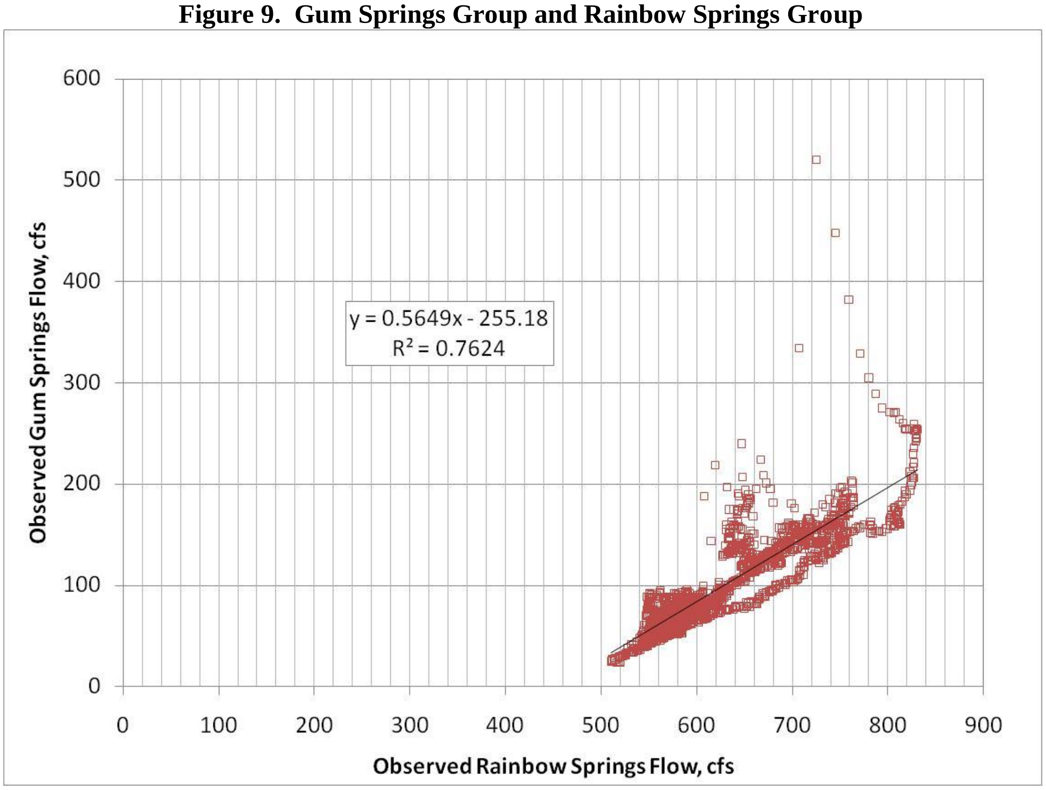

Figure 10. Gum Springs Statistical Model

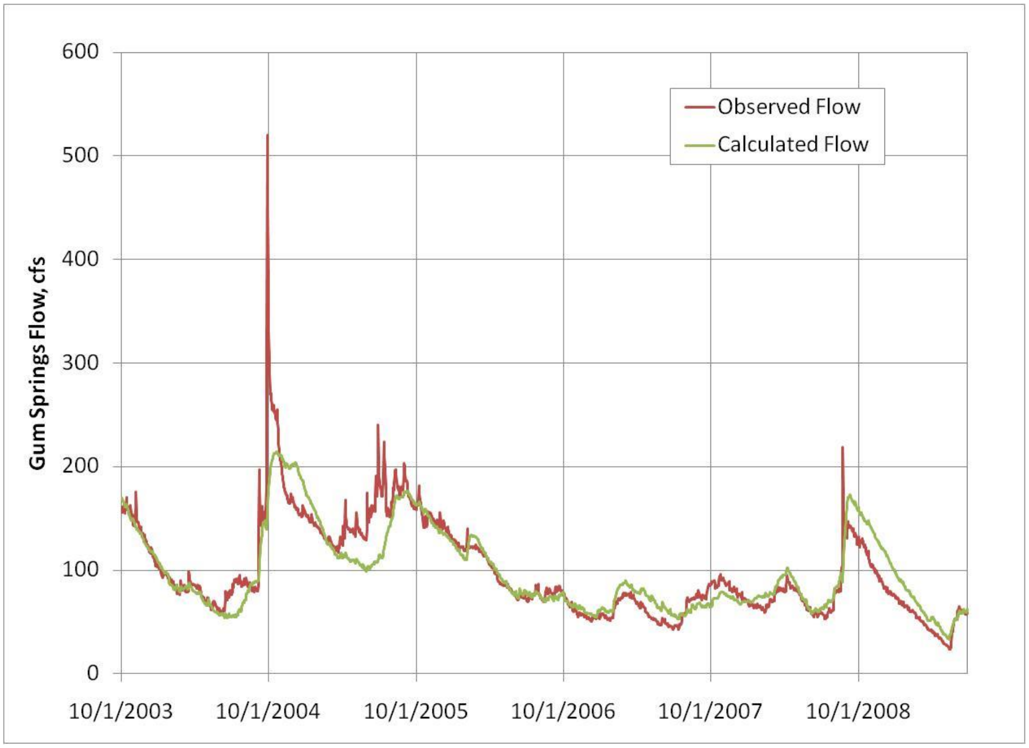

Figure 11. Gum Springs Observed and Calculated Flow

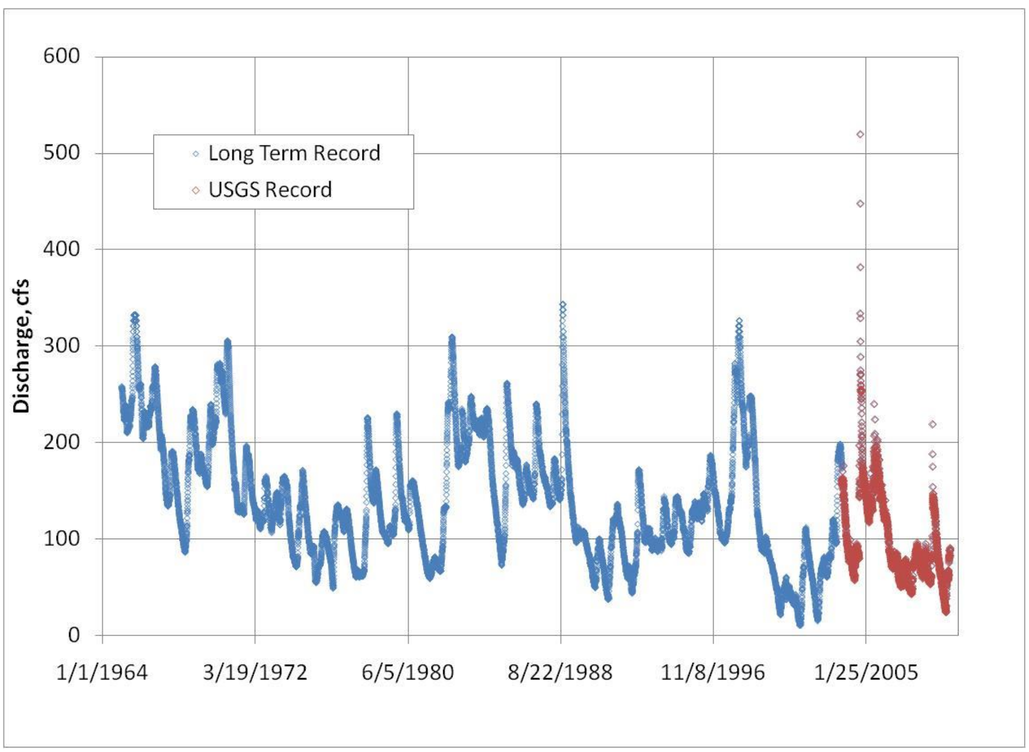

Figure 12. Gum Springs Long Term Record

Model Construction

The geometry of the model was constructed using GEO-RAS and HEC-RAS. Eight cross sections were placed in the model to correspond with the eight surveyed vegetative cross sections, as shown in Figure 13. The most downstream station of the model (Sta. 00+00) was assigned to the location corresponding to the USGS Gum Springs near Holder station (USGS #02312764). This station was used as the downstream boundary condition of the model.

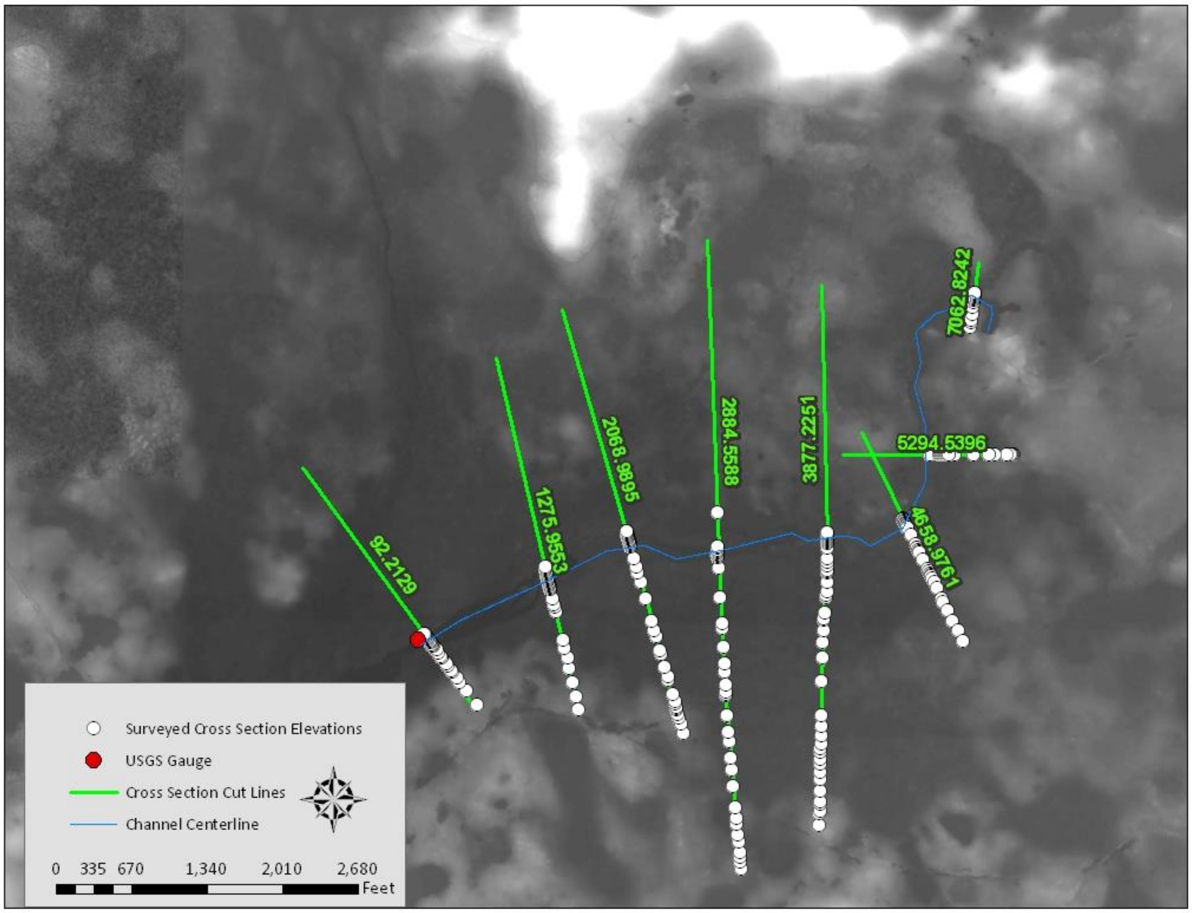

Figure 13. Cross Section Cut Lines and River Stations

Model Geometry

Model geometry was obtained by overlaying existing hydrography with the DEM and the surveyed cross sections. Cross sections were placed at each vegetative cross section location. Using GEO-RAS, the DEM was intersected with the cross sections to produce the cross section geometry. The cross sections were imported into HEC-RAS, and the DEM data was replaced in each cross section with all available survey data. Table 3 shows distances from left bank of the cross section where the survey data ends and the DEM data begins. Cross Sections for each river station are shown in Figures 14-21.

Table 3. Cross Section Information

Cross Section Name	River Station	Left Bank Station Point Name	Transition Station (from survey data to DEM)
G1	7062.824	G1-C010	308.61
G2	5294.539	G2-KH193	739.44
G3	4658.976	G3-KH32	1212.759
G4	3877.225	G4-KH3	2582.794
V5	2884.558	V5-KH2	3154.4
V6	2068.989	V6-C05	1853.259
V7	1275.955	V7-KH194	1295.97
V8	92.212911	V8-KH174	780.1

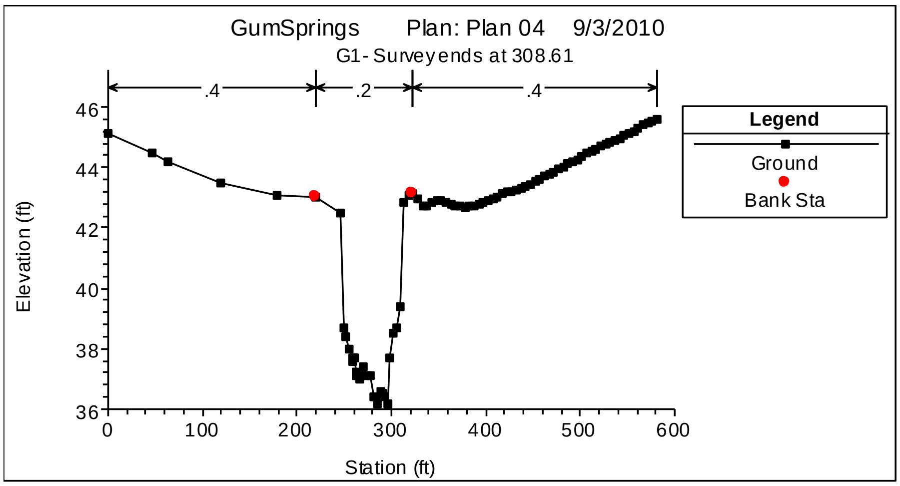

Figure 14. River Station 7062.824 Cross Section

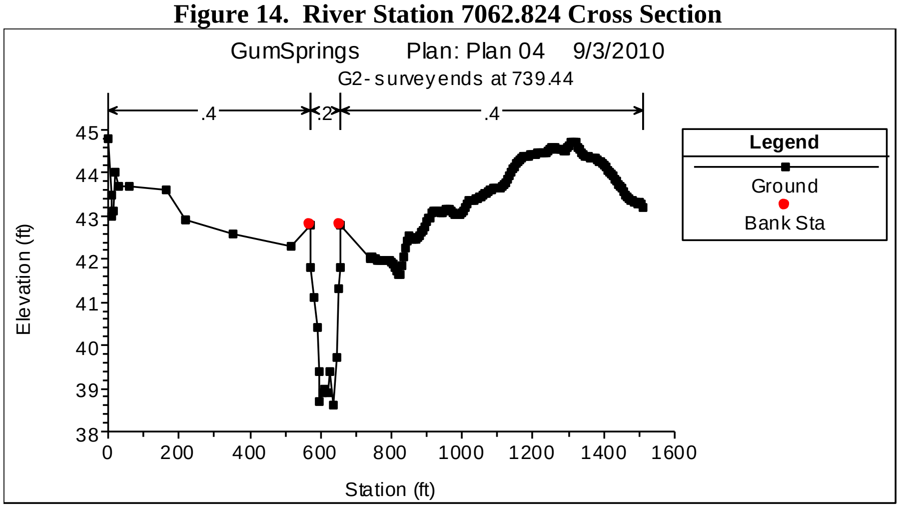

Figure 15. River Station 5294.539 Cross Section

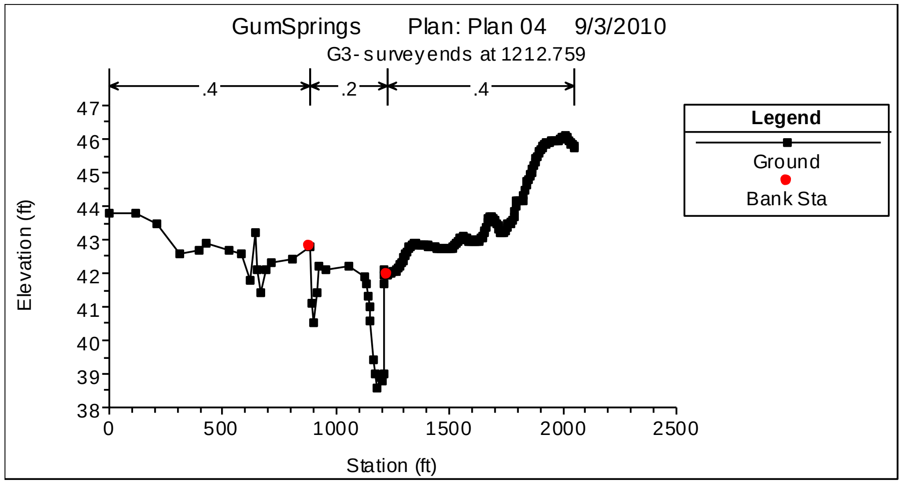

Figure 16. River Station 4658.976 Cross Section

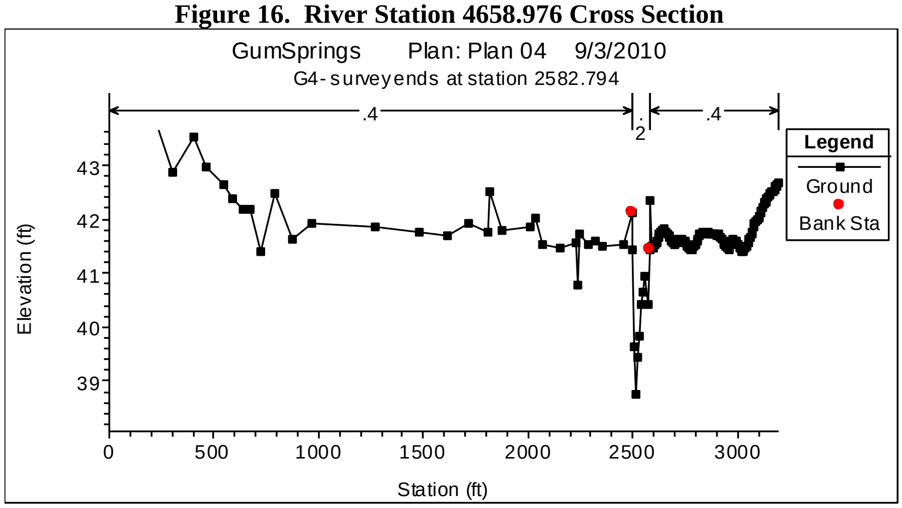

Figure 17. River Station 3877.225 Cross Section

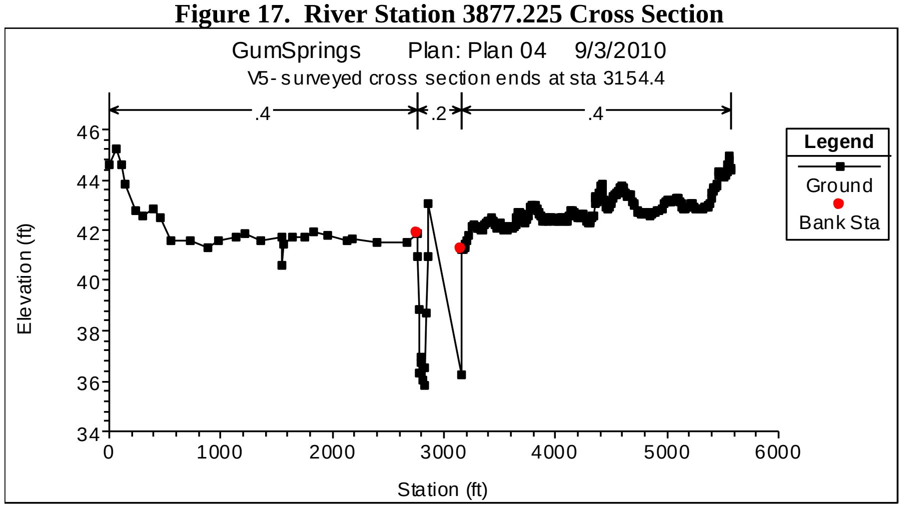

Figure 18. River Station 3877.225 Cross Section

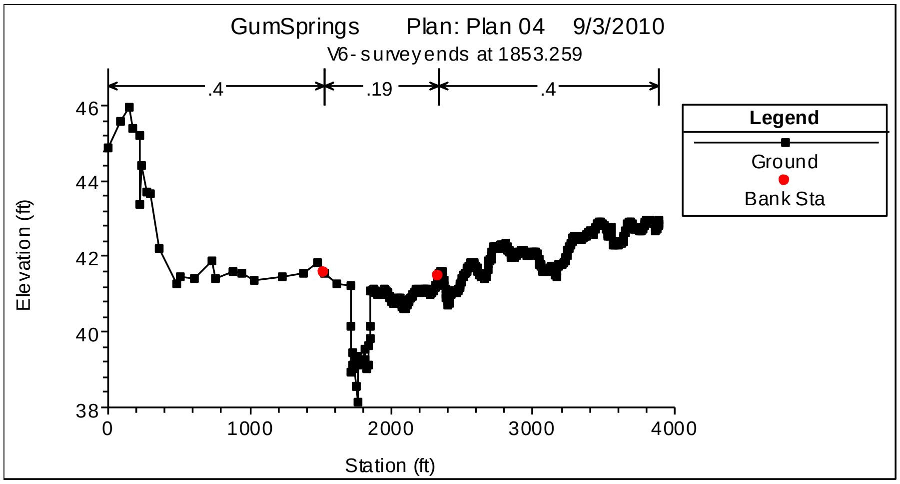

Figure 19. River Station 2068.989 Cross Section

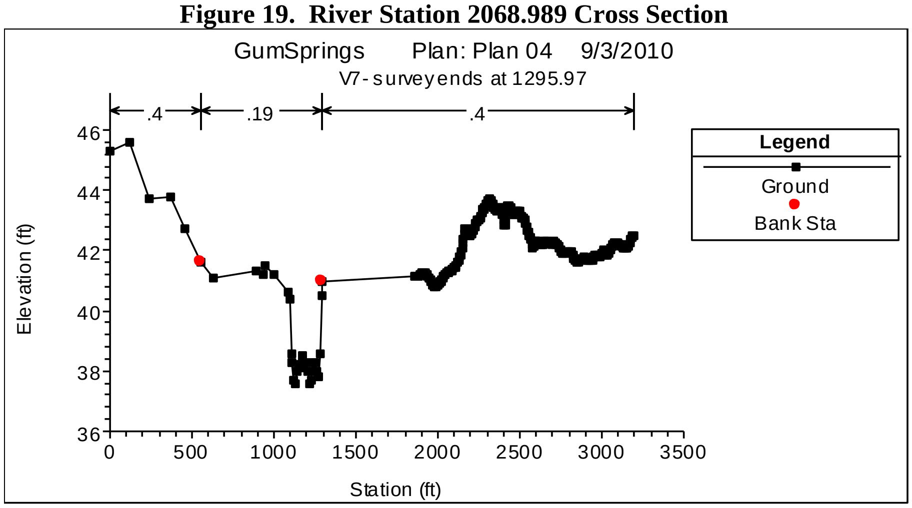

Figure 20. River Station 1275.955 Cross Section

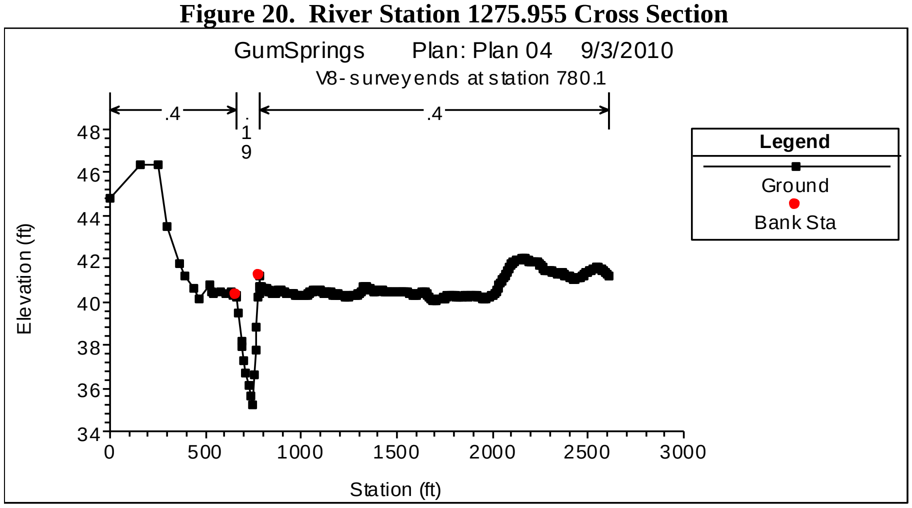

Figure 21. River Station 92.212911 Cross Section

Downstream Boundary Condition

The USGS gauge at Gum Springs at Holder (USGS 02312764) was used as the downstream boundary condition of the model. Both flow and gauge height were recorded at the gauge. The gauge record begins on October 1, 2003. Data utilized for this analysis extends to July 25, 2010. The discharge record for the gauge is shown in Figure 8. The average discharge for the period of record is 98.5 cubic feet per second (cfs), with flow ranging from 25 cfs to 520 cfs for the period of record. The flow record was used for calibration as well as verification and predictive simulations.

Model Calibration

The model was calibrated with the most complete stage-flow record available. In order to calibrate each cross section accurately, it is desirable to have stage and flow measurements at each cross section measured at the same time. While the high, medium, and low flow measurements recorded by the District provided good flow information, they lacked stage and flow measurements at each cross section. Additionally, for some flow regimes (such as the low flows) data was recorded on several days, which could necessitate the use of an average downstream boundary condition and increase model uncertainty. The best available calibration dataset was measured by the District on February 26, 2010, and was provided to INTERA in a spreadsheet (GSR Flow Measurements with Water Surface.xlsx). Since no measurements were taken at Vegetation cross section #8, the USGS gauge data was applied to this station. This is an appropriate estimation since this cross section is located approximately 92 feet upstream from the USGS gauge. Flow change locations were placed at each vegetative cross section based on the flow rates measured and shown in Table 4.

Table 4. Flow and Stage Calibration Data

Time	Site	Water Surface Elev.	Total Flow (cfs)	HEC-RAS River Station	Percent of USGS Flow
	USGS Holder (USGS Record)	40.16	103		100.00
	Veg #8	Not measured		92.21291	
1200	Veg #7	40.44	87	1275.955	84.47
1230	Veg #6	40.84	75	2068.989	72.82
1310	Veg #5	40.94	69	2884.558	66.99
1330	Veg #4	41.28	39	3877.225	37.86
1345	Veg #3	41.67	35	4658.976	33.98
1425	Veg #2	41.73	35	5294.539	33.98
1445	Veg #1	42.15	27	7062.824	26.21

The model was calibrated by modifying the Manning's n values in the main channel and the left and right banks. The resulting water surface profile is shown in Figure 22. The simulated and observed stages for each station are shown in Table 5. As shown in the table, the largest error was at River Station 3877.225, with an underestimation of stage of 0.27 feet (3.24 inches). This is well within the 0.5 foot tolerance desired by the District.

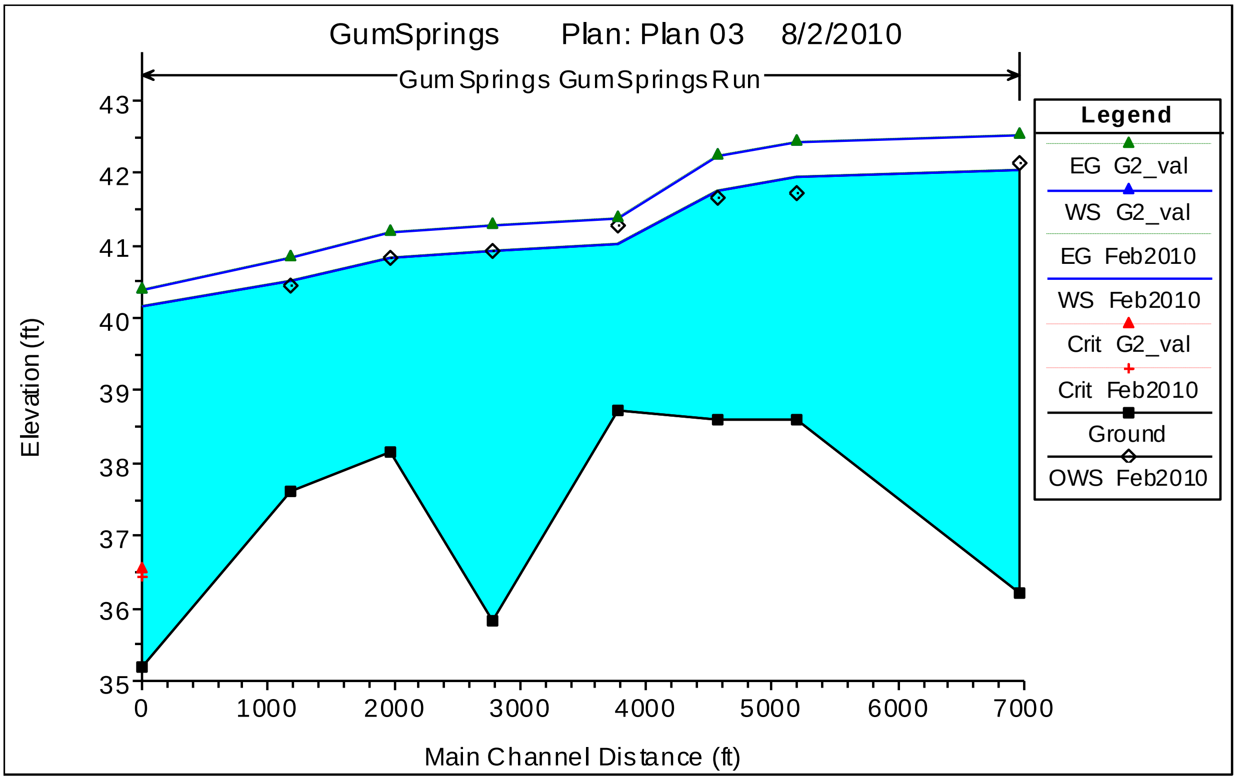

Figure 22. Calibration Water Surface Profile

The calibrated Manning's n values are shown for each station in Table 6. Compared to literature values, the calibrated values appear high. These values are reasonable, however, due to the reduced flow area present in a large portion of the slough due to moderately dense aquatic vegetation (shown in Figure 23). The surveyed cross sections (shown in Figures 14 through 21) are representative of the channel bottom. Gum Slough is, at times, characterized by dense vegetation filling the channel, which greatly reduces the effective flow area of the channel. Since Manning's n is a lumped parameter representing channel friction, the dense aquatic vegetation is lumped into this factor along with other head losses.

Table 5. Observed versus Predicted River Stage

HEC-RAS River Station	Measured Water Surface Elevation, ft.	Simulated Water Surface Elevation, ft.	Error (Simulated-Measured), ft.
92.21291	40.16	40.16	0
1275.955	40.44	40.52	0.08
2068.989	40.84	40.85	0.01
2884.558	40.94	40.94	0
3877.225	41.28	41.01	-0.27
4658.976	41.67	41.76	0.09
5294.539	41.73	41.94	0.21
7062.824	42.15	42.05	-0.1

Table 6. Calibrated Mannings n Values

HEC-RAS River Station	Left Over Bank Mannings n	Main Channel Mannings n	Right Over Bank Mannings n
92.21291	0.4	0.19	0.4
1275.955	0.4	0.19	0.4
2068.989	0.4	0.19	0.4
2884.558	0.4	0.2	0.4
3877.225	0.4	0.2	0.4
4658.976	0.4	0.2	0.4
5294.539	0.4	0.2	0.4
7062.824	0.4	0.2	0.4

Figure 23. Aquatic Vegetation on Gum Slough

Model Validation

In order to verify the performance of the model and gain confidence in its predictive capability, model validation was performed. The model was validated using stage data recorded during surveys of the vegetation cross sections. The surveyed edge of water elevation for each cross section is shown in Table 7. As shown in the table, vegetative survey occurred on eight separate days from March 24, 2010 through May 27, 2010. The corresponding stages and flows at the USGS gauge (the downstream boundary condition) are also shown in the table. The flow time series for the USGS gauge for this period is shown in Figure 24.

Table 7. Validation Data

Cross Section Name	Survey Date	Surveyed Edge of Water	USGS Flow, cfs	USGS Stage, ft.

		NAVD 88		
G1	5/27/2010	Not Recorded	118	40.33
G2	5/12/2010	42	124	40.39
G3	5/24/2010	41.9	119	40.33
G4	5/26/2010	41.5	121	40.36
V5	5/19/2010	41.9	121	40.36
V6	5/13/2010	41.2	123	40.38
V7	4/5/2010	40.6	142	40.58
V8	3/24/2010	40.5	134	40.5

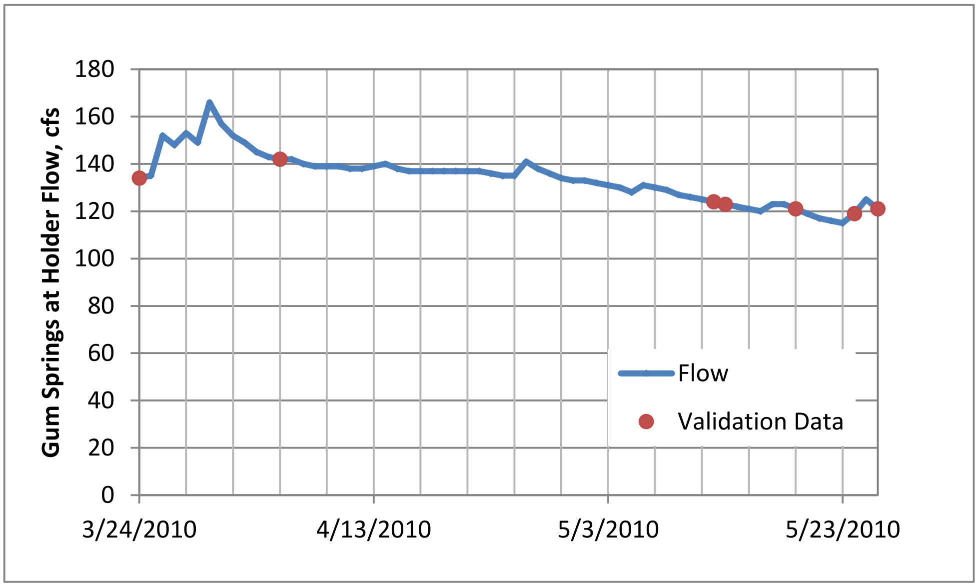

Figure 24. USGS Gum Springs Discharge: Validation Period

In order to develop flow profiles to be utilized for validation, the percent of the total flow observed at each station from the calibration data was applied to the validation data, as shown in Table 8. Flow dependent scale factors were not applied to develop the validation flows, as was done for the predictive flows discussed in the Predictive Simulation Section. The results of the validation simulations are shown in Table 9 and Figure 25. As shown, the model performs well during validation. The maximum absolute error of 0.65 feet occurred at cross section V5. The validation of V5 data was performed along with the validation at cross section G4. As shown in Figure 25, the measured stage at V5 was higher than the measured stage at cross section G4, making the data uncertain. Nevertheless, the model performed well during validation, which increases model confidence.

Table 8. Validation Data Input Flow Profiles

		Validation Flows

Cross Section Name	Flow Percentage	(Date of Observed Stage Data)					
		G2 (5/27/10)	G3 (5/24/2010)	G4 and V5 (5/26/2010 and 5/19/2010)	V6 (5/13/2010)	V7 (4/5/2010)	V8 (3/24/2010)
G1	0.262	32.50	31.19	31.72	32.24	37.22	35.13
G2	0.340	42.14	40.44	41.12	41.80	48.25	45.53
G3	0.340	42.14	40.44	41.12	41.80	48.25	45.53
G4	0.379	46.95	45.06	45.82	46.57	53.77	50.74
V5	0.670	83.07	79.72	81.06	82.40	95.13	89.77
V6	0.728	90.29	86.65	88.11	89.56	103.40	97.57
V7	0.845	104.74	100.51	102.20	103.89	119.94	113.18
V8	1.000	124.00	119.00	121.00	123.00	142.00	134.00

Table 9. Validation Results

Cross Section Name	Stage Date	Edge of Water (EOW)	Simulated EOW	Simulated-Observed EOW, ft
G2	5/12/2010	42	42.42	0.42
G3	5/24/2010	41.9	42.22	0.32
G4	5/26/2010	41.5	41.33	-0.17
V5	5/19/2010	41.9	41.25	-0.65
V6	5/13/2010	41.2	41.18	-0.02
V7	4/5/2010	40.6	41.03	0.43
V8	3/24/2010	40.5	40.5	0

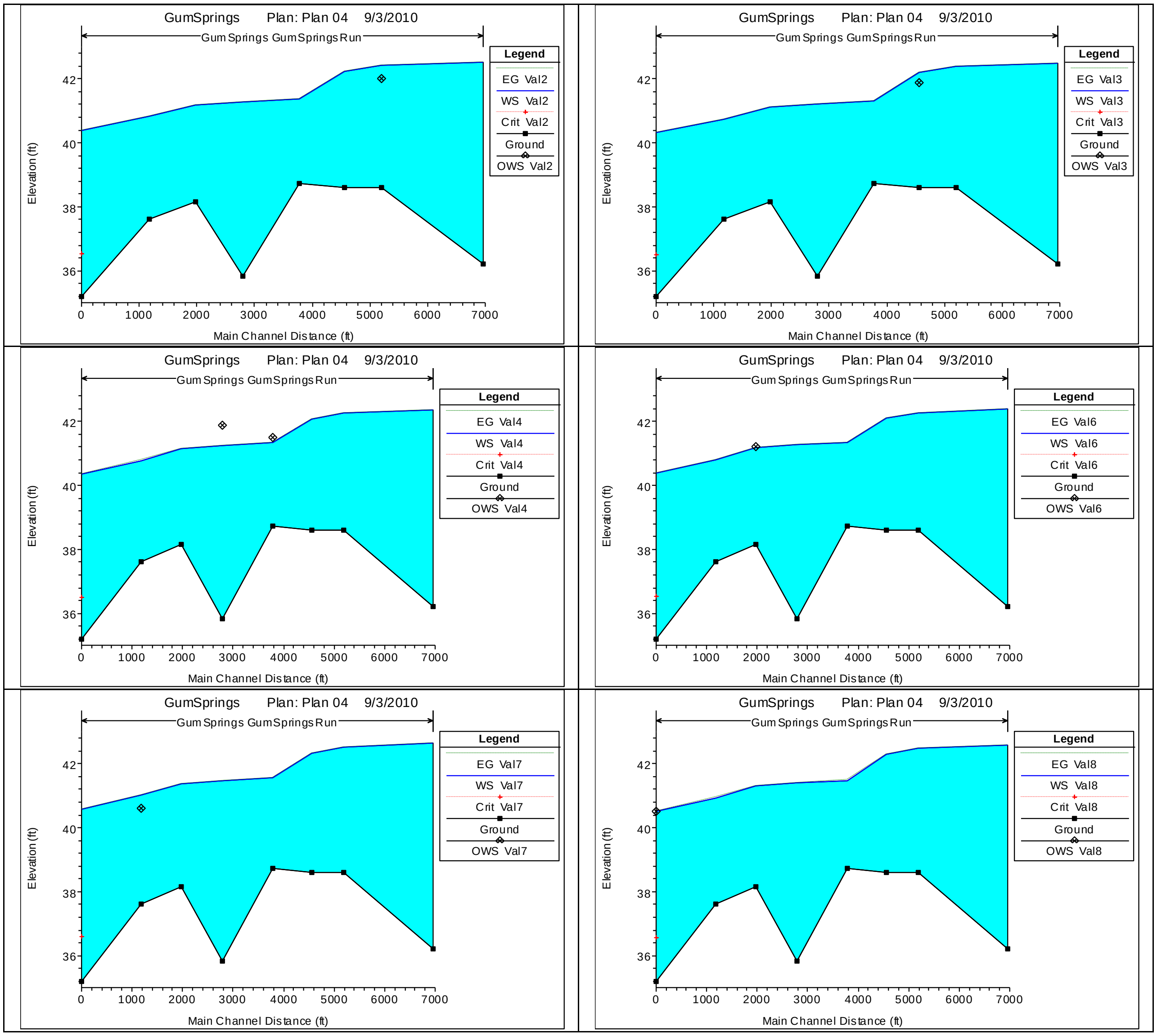

Figure 25. Validation Water Surface Profile

Predictive Simulations

After thorough model calibration and validation, the model was utilized for predictive simulations. It was desired by the District to run predictive simulations for incremental percentile flows. Percentile flows are based on the development of a probability of exceedance plot using the entire flow record. Using the flow record, flows are ranked in ascending order, and the corresponding probability of exceedance can be calculated. For a given flow with a rank of r, the probability of exceedance can be calculated as:

$$p = \left(1 - \frac{r}{n}\right) \qquad (1)$$

Where n = the total number of observations

Since the USGS Gum Springs record is fairly short, spanning approximately 6 years, the District also developed a regression between Gum Springs and Rainbow Springs (a nearby spring) to approximate a long term flow record for Gum Slough. It was decided to develop flow percentiles for both the USGS record and a record composed of the long term regression and the USGS flow record (when the USGS flow record was available). Both time series were augmented with 3 cfs of flow to account for the estimated impacts on Gum Slough due to groundwater withdrawals, as shown in Figure 26 (Basso, 2010).

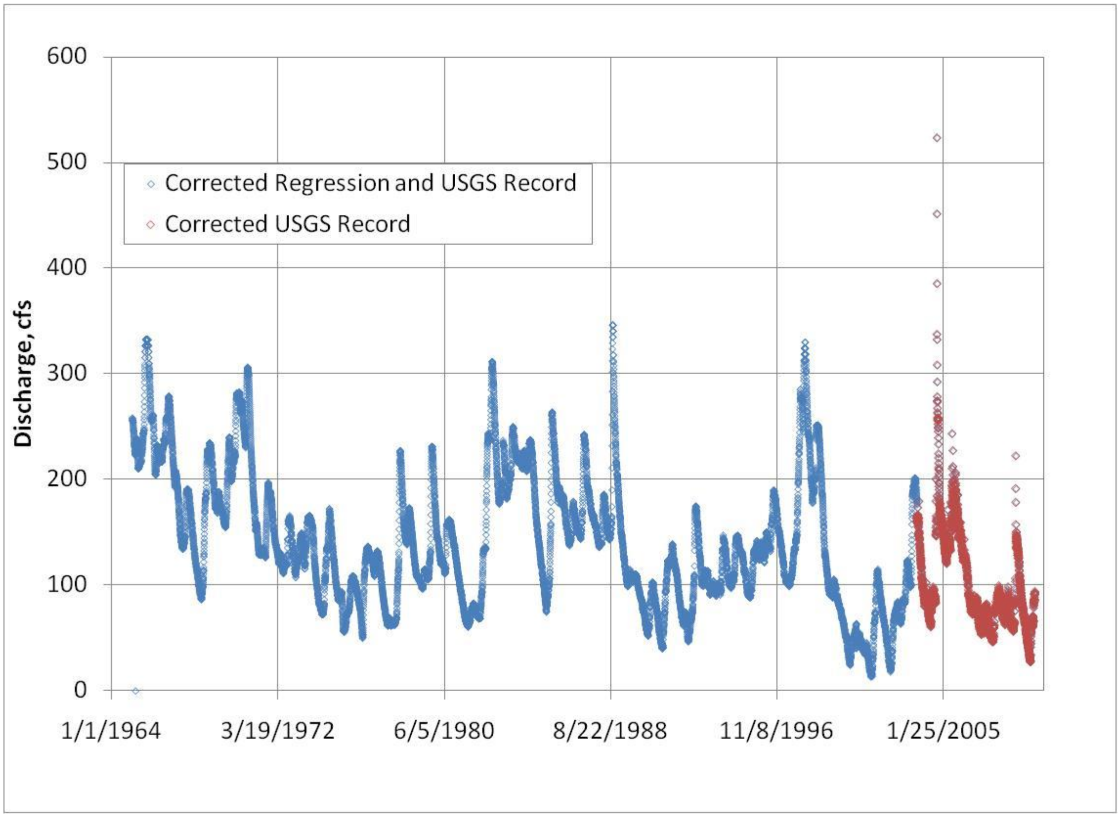

Figure 26. Gum Springs Adjusted Flow Records (Gum Spgs flow Record.xlsx)

Boundary Conditions: Percentile Flows

The adjusted flows shown in Figure 26 were utilized to develop probability distributions of flows at the downstream boundary condition (Figure 27 and Table 10). As shown in the figure and table, there are slight differences in the percentile flows between the two distributions. The distribution developed using the USGS record is, in essence, a sample of the long term record beginning in 2003. It was desired to simulate every 10th percentile of flow in the model. For the sake of completeness and for ease of use by the District, both sets of percentile flows were simulated in the model.

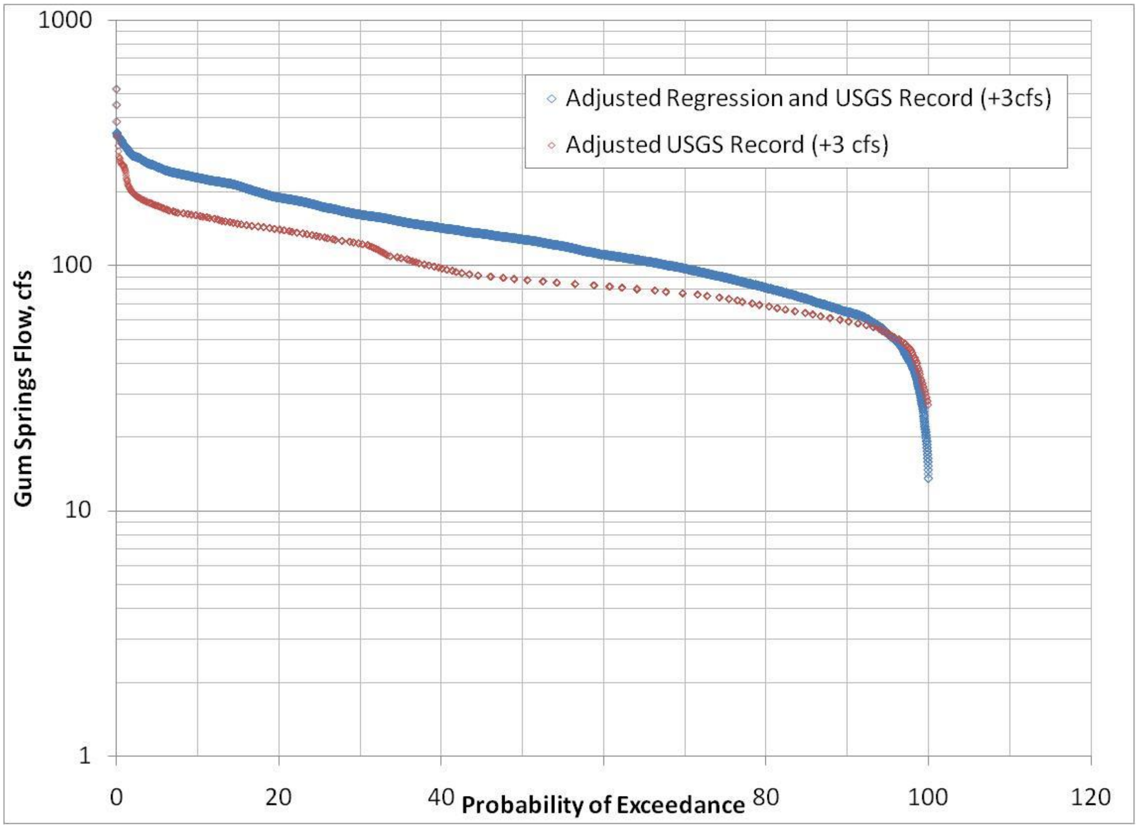

Figure 27. Probability of Exceedance (GumSpringsFlowRecordPercentiles.xlsx)

Table 10. Percentile Flows

Percentile	Adjusted Long Term Time Series Discharge, cfs	Adjusted USGS Gauge Discharge, cfs
99	29.3	35

90	64.4	59
80	80.9	68
70	97.1	77
60	110.6	82
50	127.5	87
40	142.2	97
30	161.1	122
20	189.0	140
10	227.6	159
1	305.7	248

In addition to a downstream boundary condition, it was necessary to develop flow profile for each percentile flow. The flow profile describes the increase in flow from upstream to downstream. One intensive set of flow measurements was made by the District on February 26, 2010, and was provided to INTERA in a spreadsheet (GSR Flow Measurements with Water Surface.xlsx, shown in Table 2). This dataset (which was also used for calibration) was utilized to determine the percent of downstream boundary flow observed at each of the eight cross sections. In addition to this intensive field survey, additional flow measurements were taken by the District during various flow regimes (high, medium and low flows) at two locations. This data was analyzed in order to determine how the percent of total flow at each station varies with the total flow volume.

Three flow measurements representing high, medium, and low flow taken near the headspring are shown in Figure 28. As shown in the figure, as the total flow in Gum Slough decreases, the flow at Gum Springs decreases. Using the regression equation shown in the figure, when there is no flow at Gum Springs (y=0), the flow at the downstream gauge is approximately 37.74 cubic feet per second (cfs). This agrees with anecdotal data from homeowners who live along the slough. A second set of flow measurements was taken near River Station 2884.6, as shown in Figure 29. Both of these flow dependent relationships were used to develop flow profiles along the channel.

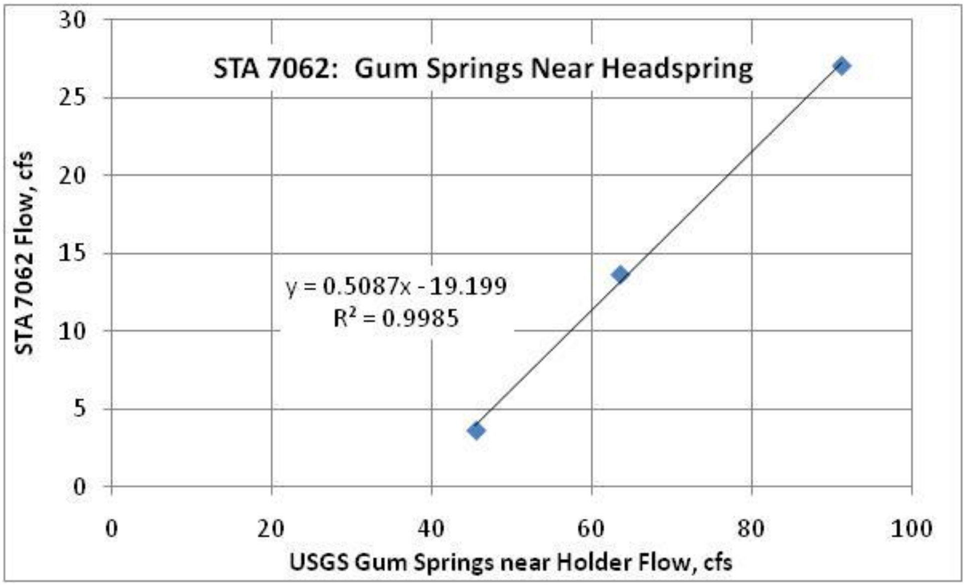

Figure 28. Gum Springs Near Headspring Flow Measurements

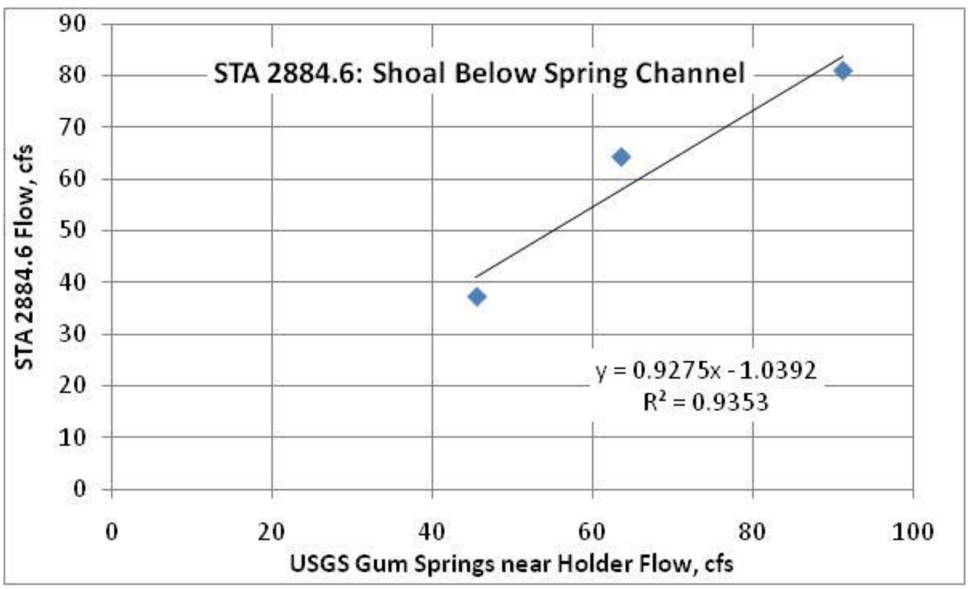

Figure 29. Shoal Below Spring Channel Flow Measurements

In order to use the above relationships for each station along Gum Slough, scale factors were developed for the six cross sections where flow measurements were not taken in order to apply observed flow relationships to the additional cross sections. Scale factors were determined using the observed flow regime shown in Table 2 and comparing the percent of the total flow at each station. The scale factor (shown in Table 11) was determined by dividing the flow at the station of interest by the nearest upstream station where the flow variability was measured (either Station 7062 or Station 2884.5).

Table 11. Cross Section Scale Factors

River Station	Percent flow	Scale Factor	Nearest Upstream Station
7062.824	26.21	1	7062.824
5294.539	33.98	1.296	7062.824
4658.976	33.98	1.296	7062.824
3877.225	37.86	1.444	7062.824
2884.558	66.99	1	2884.558
2068.989	72.82	1.087	2884.558
1275.955	84.47	1.260	2884.558
92.21291	100	1.493	2884.558

To determine the flow at each station, the regression equations shown in Figures 28 and 29 were applied to Stations 7062.824 and 2884.558. For the case of Station 7062.824, when the flow was less than 37.7 cfs, there was negligible flow at the station. After the flows at the two known locations were determined, the flows at the additional locations were calculated by multiplying the known flow by the scale factors shown in Table 11. After these flows were determined, a mass correction was applied at each station based on the difference between the flows calculated with the regressions and the flows recorded during the intensive survey. The application of this correction ensured that mass was conserved throughout the slough. The flow profiles for each data set (the USGS record and the combined USGS/regression record) are shown in Figures 31 and 32 and Tables 12 and 13. In each graph, the flow at 103 cfs (shown in yellow) represents the flow measurements taken during the intensive field survey by the District. As shown in the figures, all other flow profiles are essentially scaled representations of this flow profile, taking into account the spring flow inflow reductions with decreased total measured flow at the gauge.

Table 12. Corrected USGS Flow Record: Percentile Flows

Cross Section Name	River Station	1st	10th	20th	30th	40th	50th	60th	70th	80th	90th	99th
G1	7062.824	0.00	8.79	12.52	16.24	18.31	20.38	24.51	34.86	42.30	50.16	86.98
G2	5294.539	0.00	11.40	16.23	21.06	23.74	26.42	31.78	45.19	54.84	65.03	112.77
G3	4658.976	0.00	11.40	16.23	21.06	23.74	26.42	31.78	45.19	54.84	65.03	112.77
G4	3877.225	0.00	12.70	18.08	23.46	26.45	29.43	35.41	50.35	61.11	72.46	125.64
V5	2884.558	22.95	39.20	45.30	51.39	54.78	58.16	64.94	81.87	94.06	106.93	167.20
V6	2068.989	24.94	42.61	49.24	55.86	59.54	63.23	70.59	88.99	102.24	116.23	181.75
V7	1275.955	28.93	49.43	57.11	64.80	69.07	73.34	81.88	103.23	118.60	134.83	210.83
V8	92.21291	35.00	58.52	67.62	76.71	81.77	86.82	96.93	122.21	140.41	159.00	248.00

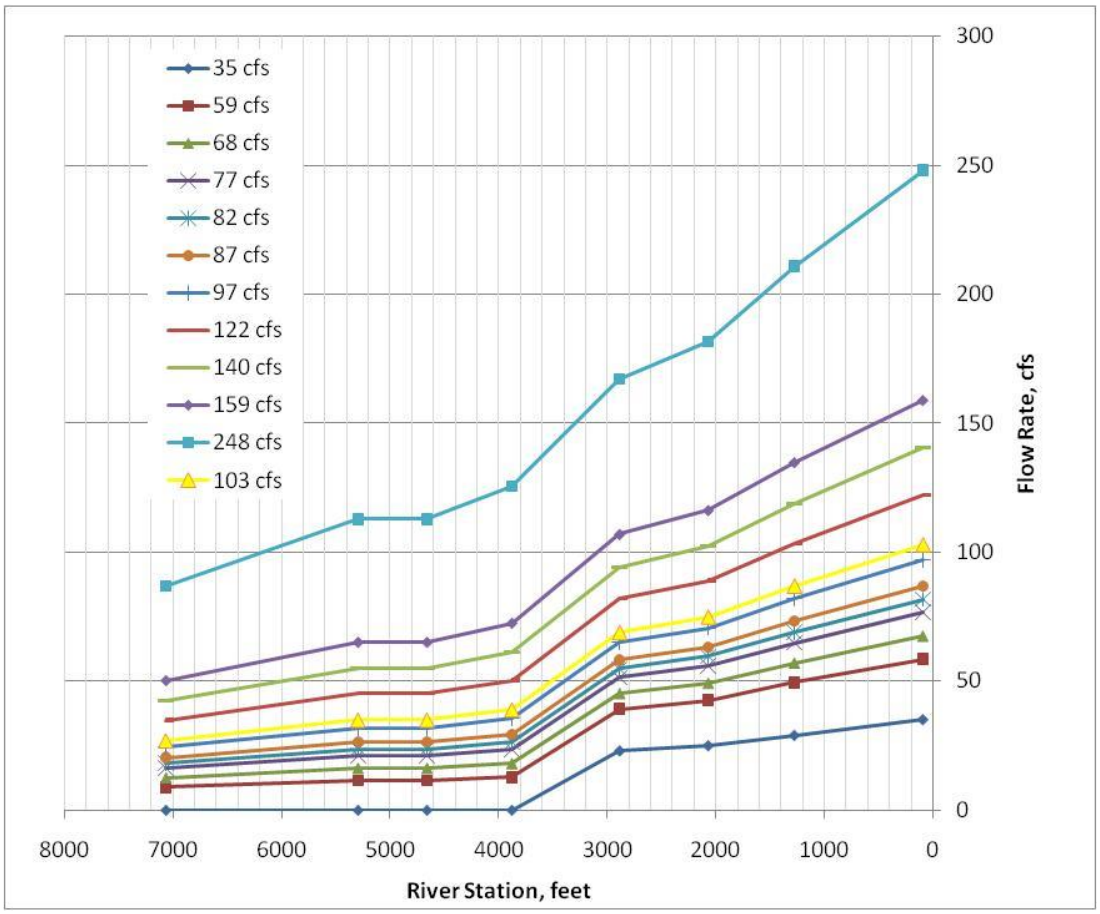

Figure 30. Corrected USGS Record: Flow Profiles

Table 13. Corrected Regression and USGS Flow Record: Percentile Flows

Cross Section Name	River Station	1st	10th	20th	30th	40th	50th	60th	70th	80th	90th	99th
G1	7062.824	0.00	11.01	17.87	24.54	30.14	37.14	43.21	51.04	62.59	78.53	110.86

G2	5294.539	0.00	14.28	23.17	31.81	39.08	48.15	56.02	66.18	81.15	101.81	143.73
G3	4658.976	0.00	14.28	23.17	31.81	39.08	48.15	56.02	66.18	81.15	101.81	143.73
G4	3877.225	0.00	15.91	25.82	35.44	43.54	53.64	62.42	73.73	90.41	113.44	160.14
V5	2884.558	19.11	42.83	54.06	64.97	74.15	85.60	95.55	108.37	127.27	153.37	206.30
V6	2068.989	20.78	46.56	58.77	70.63	80.61	93.05	103.86	117.80	138.35	166.72	224.26
V7	1275.955	24.10	54.01	68.17	81.93	93.50	107.94	120.48	136.65	160.49	193.39	260.14
V8	92.21291	29.34	64.36	80.95	97.05	110.61	127.51	142.20	161.13	189.04	227.58	305.73

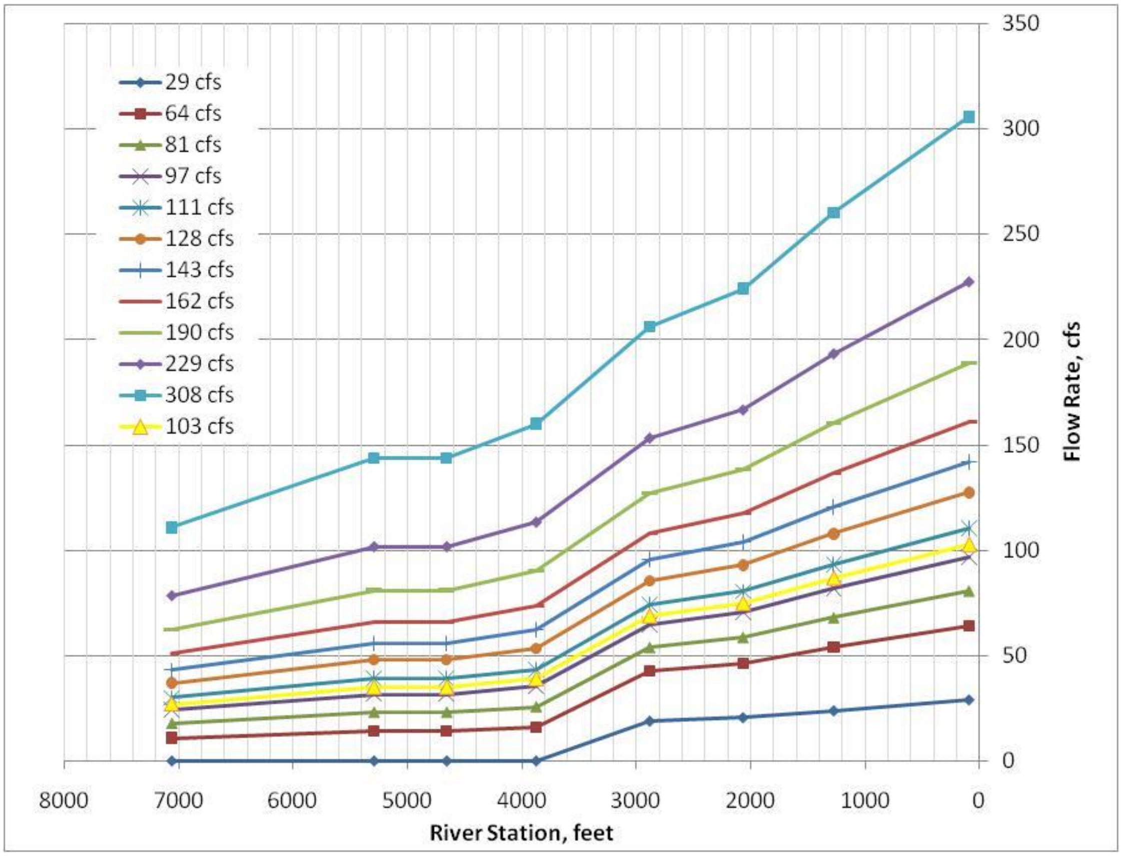

Figure 31. Corrected Regression and USGS Record: Flow Profiles

Boundary Conditions: Downstream Stage

In order to run predictive simulations, a downstream stage boundary condition is needed. A rating curve for the gauge was developed based on the USGS record (Figure 32). Based on the rating curve and the percentile flows shown in Tables 12 and 13, the stage boundary condition was calculated for each percentile flow based on the regression equation shown in the Figure. The resulting boundary conditions for each percentile flow are shown in Table 14.

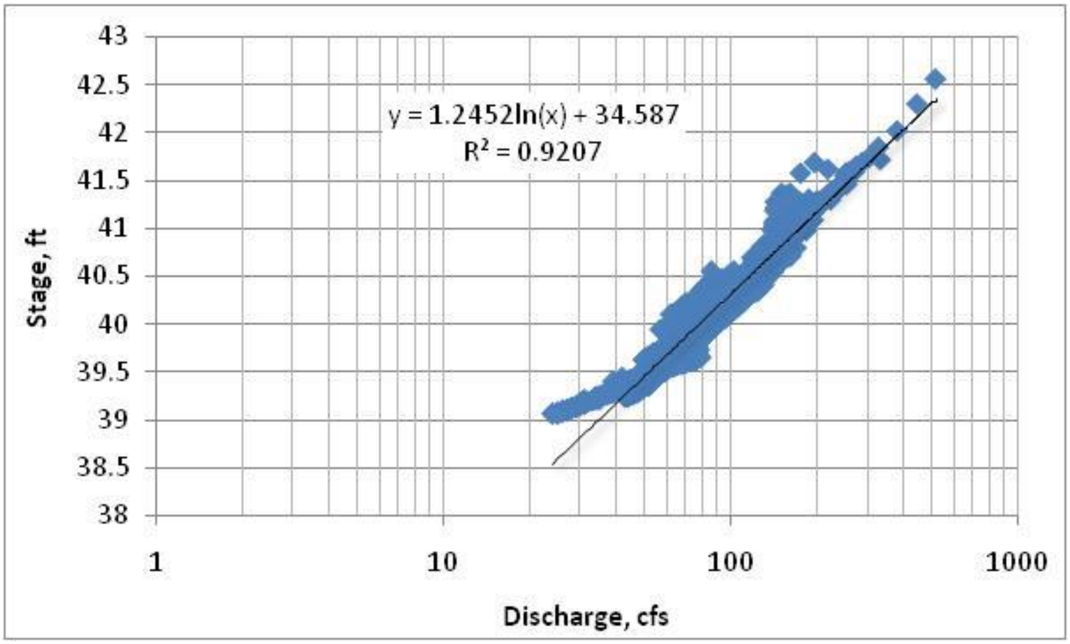

Figure 32. Gum Springs at Holder Rating Curve

Table 14. Predictive Simulation: Downstream Stage Boundary

Percentile Flow	Adjusted Long Term Time Series: Stage, ft.	Adjusted USGS Gauge: Stage, ft.
1st	38.8	39.0
10th	39.8	39.7
20th	40.1	39.8
30th	40.3	40.0
40th	40.4	40.1
50th	40.6	40.1
60th	40.8	40.3
70th	40.9	40.6
80th	41.1	40.7
90th	41.3	40.9
99th	41.7	41.5

Predictive Simulation Data Set 1: USGS Flow Record

Predictive simulations were run using the flows derived from the adjusted USGS flow record (shown in Figure 30) and the calculated stage boundary conditions. The resulting water surface profiles are shown in Figure 33. Simulated stages at each of the River Stations are shown in Table 15.

Table 15. Adjusted USGS Record: Simulated Stages (ft.)

River Station	WS USGS1	WS USGS10	WS USGS20	WS USGS30	WS USGS40	WS USGS50	WS USGS60	WS USGS70	WS USGS80	WS USGS90	WS USGS99

0	39.01	39.65	39.83	39.99	40.07	40.15	40.28	40.57	40.74	40.90	41.45
1182.139	39.28	39.91	40.09	40.26	40.34	40.42	40.58	40.92	41.11	41.37	41.80
1975.382	39.72	40.19	40.35	40.51	40.59	40.68	40.85	41.25	41.43	41.69	42.03
2790.345	39.76	40.25	40.42	40.58	40.66	40.75	40.94	41.34	41.52	41.76	42.11
3784.859	39.78	40.29	40.47	40.63	40.72	40.81	41.00	41.41	41.60	41.85	42.23
4563.704	39.81	40.72	41.02	41.27	41.38	41.50	41.69	42.28	42.40	42.49	42.75
5198.78	39.81	40.82	41.14	41.41	41.53	41.65	41.85	42.47	42.60	42.72	43.08
6963.033	39.82	40.86	41.20	41.48	41.61	41.74	41.95	42.59	42.77	42.94	43.49

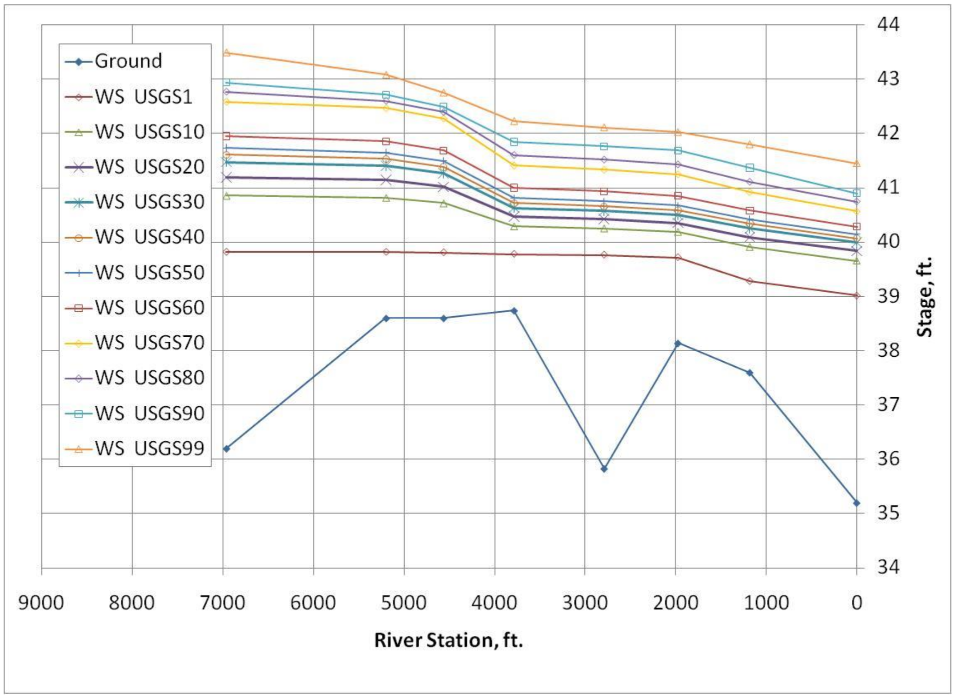

Figure 33. Adjusted USGS Record: Water Surface Profiles

Predictive Simulation Data Set 2: Regression Record

Predictive simulations were run using the flows derived from the adjusted long term flow record (shown in Figure 31) and the calculated stage boundary conditions. The resulting water surface profiles are shown in Figure 34. Simulated stages at each of the River Stations are shown in Table 16.

Table 16. Adjusted Regression Record: Simulated Stages (ft.)

River Station	WS REG1	WS REG10	WS REG20	WS REG30	WS REG40	WS REG50	WS REG60	WS REG70	WS REG80	WS REG90	WS REG99
0	38.79	39.77	40.06	40.28	40.45	40.62	40.76	40.92	41.11	41.35	41.71
1182.139	39.08	40.03	40.33	40.58	40.78	40.98	41.19	41.38	41.53	41.72	42.03

1975.382	39.63	40.29	40.57	40.85	41.10	41.30	41.54	41.70	41.81	41.96	42.22
2790.345	39.67	40.36	40.65	40.93	41.19	41.39	41.61	41.77	41.89	42.04	42.31
3784.859	39.68	40.40	40.70	41.00	41.26	41.47	41.69	41.86	41.99	42.15	42.43
4563.704	39.72	40.90	41.36	41.69	41.93	42.32	42.41	42.50	42.59	42.70	42.89
5198.78	39.73	41.02	41.51	41.85	42.11	42.51	42.62	42.73	42.86	43.01	43.27
6963.033	39.73	41.07	41.59	41.95	42.23	42.65	42.79	42.96	43.16	43.39	43.77

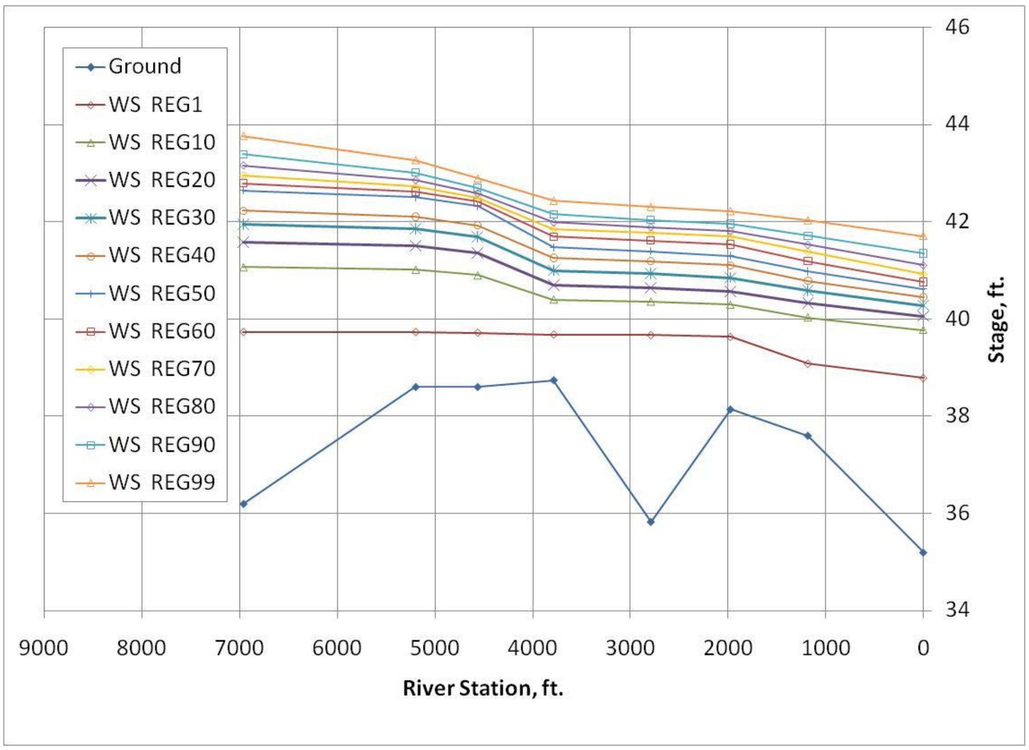

Figure 34. Adjusted Regression Record: Water Surface Profiles

Conclusions and Recommendations

A steady state HEC-RAS model was developed for Gum Slough extending from its headwaters at Gum Springs to the USGS gauge at Holder. Data collected by the District was utilized for model constriction, calibration, and verification. This included surveyed cross section information at eight cross sections in the model domain, DEM data, and flow and stage data collected by the District. In addition to the District data, data from the UGSG gauge was utilized as the downstream boundary condition of the model.

The calibrated model has an absolute maximum error of 0.27 feet, which is well within the 0.5 feet desired by the District. The average error for the calibrated model was 0.0025 feet, indicating very little bias in the model. The model also performed well during the validation phase, with an average error of 0.055 feet.

Percentile flows were developed based on the available USGS record at Gum Springs, and a long term composite record based on the USGS record at Gum Springs and a regression between Gum Spring group and Rainbow Springs group. Both sets of percentile flows were adjusted in order to account for impacts due to groundwater withdrawals. Predictive simulations were run on both sets of percentile flows. Through the use of regression analyses of high, medium and low flow data, care was taken to ensure that the pickup along the channel agreed with anecdotal information regarding the no flow conditions at Gum Springs, thus increasing confidence in the low flow simulations. The stages at each of the eight cross sections can be utilized by the District for MFL analyses.

The linear regression developed by the District to estimate the long term record at Gum Springs compared favorably to the USGS record when predicting low and average flows. If it is desired by the District to improve the statistical model relating Rainbow Springs flow to Gum Springs flow, it is highly recommended that another type of statistical model be investigated, such as a multiple linear regression or an artificial neural network (ANN). ANNs have been shown to outperform linear regression techniques for the prediction of spring flow (INTERA 2010) since multiple input variables (such as rainfall, ground water level, and flow at a nearby spring) can be utilized to estimate spring flow.

Since the model was calibrated and validated to average conditions, confidence in the model's predictive capability in this flow regime is high. In order to increase model confidence in other flow regimes, it would be useful to collect additional data during high and low flows. The collection of stage and flow data at each of the eight cross sections during low and high flows would yield highly useful validation data for the model. If desired by the District in the future, the current model can be extended downstream to include the experimental portion of the slough. The District is installing weirs to control the flow in one of the braids of the slough. A HEC-RAS model of that portion will enable prediction of hydraulic responses and may be useful in the design of the weirs. Cross sections downstream from the current downstream boundary condition can be added, and the model can be re-calibrated to include this portion of the channel. Developing a hydrodynamic model may also prove useful. Dynamic models allow the calibration of a suite of flows and stages. The additional calibration of various flow events increases the confidence over the wider range of flows.

References

Basso, Ron. (2010). *Hydrologic Conditions near Gum Springs and Predicted Groundwater Withdrawal Impacts based on Numerical Model Results.* Technical Memorandum, Southwest Florida Water Management District.

INTERA (2010). *Estimation of White Springs Discharge Using Artificial Neural Networks.* Draft Technical Memorandum for the St. Johns River Water Management District.

Appendix 1: Review Comments and Responses

Comments by Ahmed Said from ECT and the INTERA responses to comments are shown below.

I reviewed the Gum Springs model set up, parameters, coefficients, model results and the draft report. Overall, model was addressed in fairly good details. I only have few points that I tried to apply but haven't changed the results or the calibration of the model much:

1. Some bank stations can be adjusted to match the flow area (it makes very little changes such as you can use Manning's as 0.2 for all the cross sections with very little reductions in the errors)

   Response: Using 0.2 for the entire cross section is not recommended. The channel Manning's n values of 0.2 and 0.19 have been calibrated and perform well within the calibrated flow regime. Changing the left bank and right bank Manning's n values from 0.4 to 0.2 is not recommended since this would represent the bank areas with an identical friction factor as the main channel. The bank areas contain vegetation that is much more dense than the main channel. In addition, the presence of trees in the left and right banks further decreases the effective flow area in the bank. Although there is some uncertainty in using 0.4, the Manning's n should be higher than the channel. If desired by the District, additional calibration data should be collected at high flows to verify and/or re-calibrate the model.

2. The contraction and expansion coefficients can be adjusted to 0.3 & 0.5, respectively, for the typical bridge cross-sections, per the HEC-RAS Reference Manual (I don't think it has been used in the model and didn't make change).

   Response: Contraction and expansion coefficients are utilized by HEC-RAS to calculate the losses associated with the changes in a channel cross section. Energy losses are common at locations where the cross section changes suddenly, particularly when there is a major change of a cross section, such as one associated with a bridge. Gum Slough has no bridges, abutments, or other man-made structures along the modeled section. There are changes in the channel cross section, but the transitions between the cross section are relatively smooth and gradual. For this reason, the use of the current contraction and expansion coefficients (0.1 and 0.3, respectively) is recommended. If anything, the coefficients could be lowered to account for the mild transitions between cross sections, but increasing the contraction and expansion coefficients from the current values is not recommended. Under most conditions, the majority of Florida rivers flow in a subcritical flow regime. The contraction and expansion coefficients should not be increased to 0.3 and 0.5.

3. Few editing/missing notations (e.g., EOW in Table 9 needs to be clarified, Figure # needs to be added in the last line in page 22)

   Response: Appropriate edits were made.

4. In the seventh line from the bottom in page 11: estimates average and low flows (flows less than 100 cfs): may need to change to: estimates average and low flows (flows less than 200 cfs)? I think that low flow is less than 100 cfs, medium flow is between 100 and 200 cfs so average and low flow together are less than 200 cfs.

   Response: Appropriate edit was made.