# F-1

# DAVINROY

## DOGTOOTH BEND (REWRITE BY GAINES)

AG, rewrite 9/11/02

# Dogtooth Bend Case Study: A Typical Process of Modeling, Design, & Construction

The following describes the Dogtooth Bend model study and how the recommended conceptual design from this model was transferred to a final design, was constructed in the river and how the resultant bed configuration compared to the bed forms predicted by the model study.

During the early 1980's numerous collisions and groundings involving tows were occurring in bends on the Mississippi River within the St. Louis District. Two of these accidents resulted in major oil spills into the river. Due to point bar formation, repetitive maintenance dredging was required to artificially maintain adequate widths in these bends during low water conditions. Therefore, between 1984 and 1992, a movable bed model at WES was used by the St. Louis District to address these problems. Figure 1 shows the 1983 prototype bathymetry of the reach that was used for model verification. Figure 2 shows the model Base Test bathymetry used for making relative comparisons between alternative plans. In Figures 1 and 2, elevations above -10 LWRP are not color coded and appear shaded, light-blue represents elevations between -10 and -20 LWRP, dark blue represents elevations between -20 and -30 LWRP, and white represents elevations below -30 LWRP.

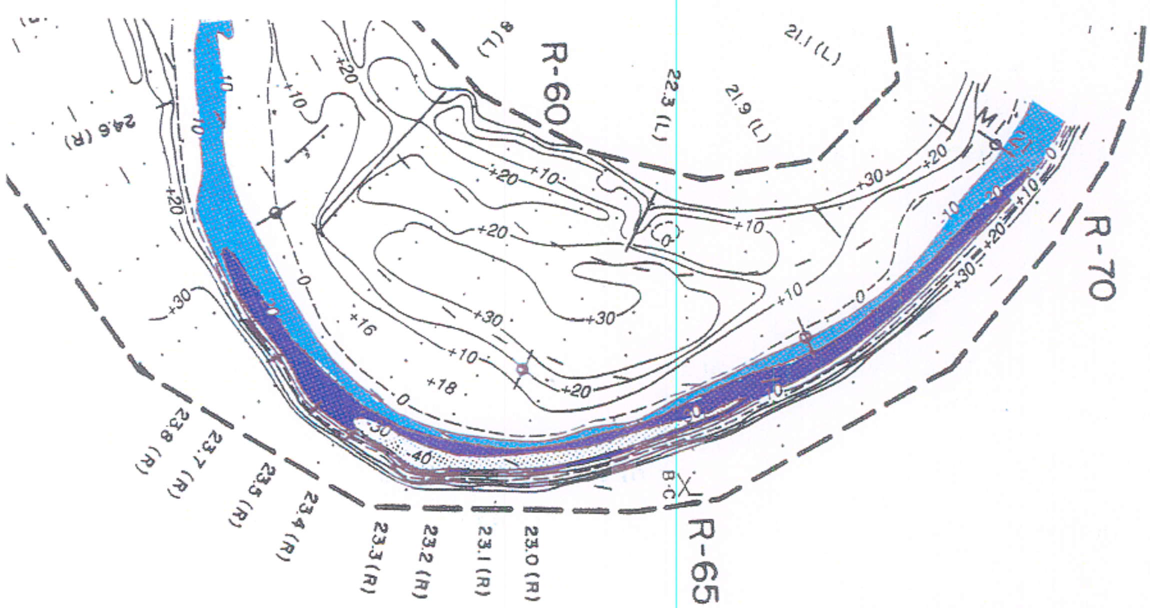


Figure 1 Prototype Bathymetry from 1983 Survey, Dogtooth Bend WES Model

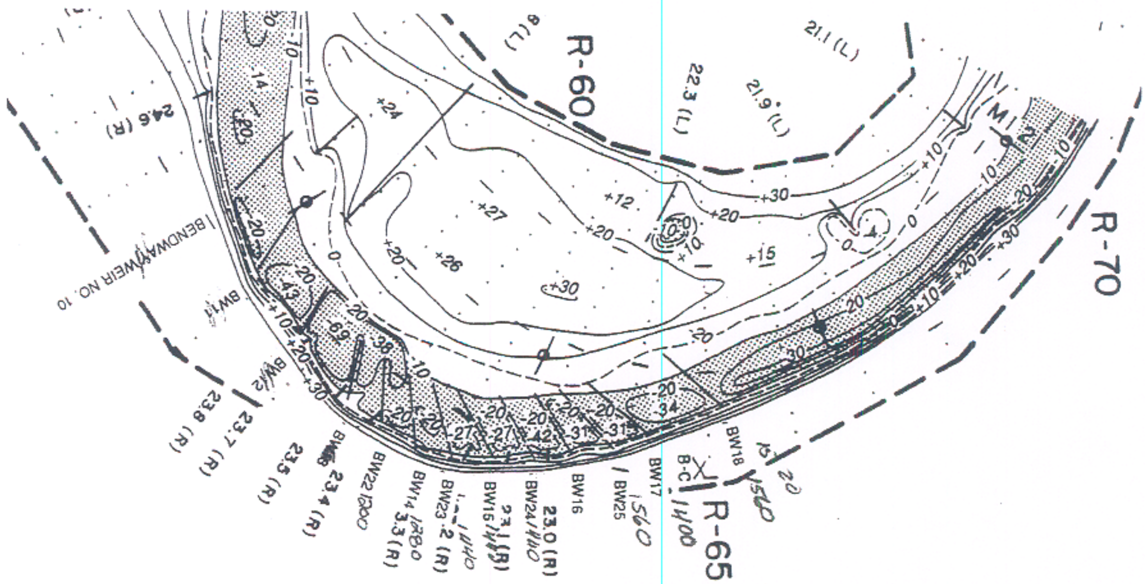


Figure 3 Recommended Bendway Weir Design Configuration and the Resultant Bed Configuration of the Dogtooth Bend WES Model.

Therefore, the lengths of the weirs had to be constructed considerably shorter than those tested in the model.

Table 1 shows weir lengths from the recommended design plan of the model study as compared to the actual constructed design. All weirs were model tested and constructed at –15 feet LWRP.

Table 1 Model Designed and Actual Constructed Bendway Weir Lengths.

| Weir Number | Model Length (ft) | Actual Construction Length (ft) | Difference Model to Prototype (ft) |
|---|---|---|---|
| Weir 24.2 | 1520 | 650 | 870 |
| Weir 23.8 | 1440 | 617 | 823 |
| Weir 23.7 | 1060 | 525 | 535 |
| Weir 23.5 | 1160 | 935 | 225 |
| Weir 23.4 | 1200 | 880 | 320 |
| Weir 23.3 | 1280 | 894 | 386 |
| Weir 23.2 | 1440 | 962 | 478 |
| Weir 23.1 | 1440 | 780 | 660 |
| Weir 23.0 | 1440 | 735 | 705 |
| Weir 22.9 | 1560 | 700 | 860 |
| Weir 22.8 | 1400 | 700 | 700 |
| Weir 22.7 | 1560 | 610 | 950 |
| Weir 22.45 | 1520 | 610 | 910 |

Figure 5 shows the location of cross-sectional ranges used for the comparison of differences in the bed configuration ~~produced by~~ observed in the prototype and predicted by the model. The ranges were slightly skewed in order to align the sections between weirs and to ensure that the structure profiles were not incorporated in the analysis. Cross-sectional plots of the model bed (blue) versus the 2000 sweep survey (red) are shown in Figures 6 through 14.

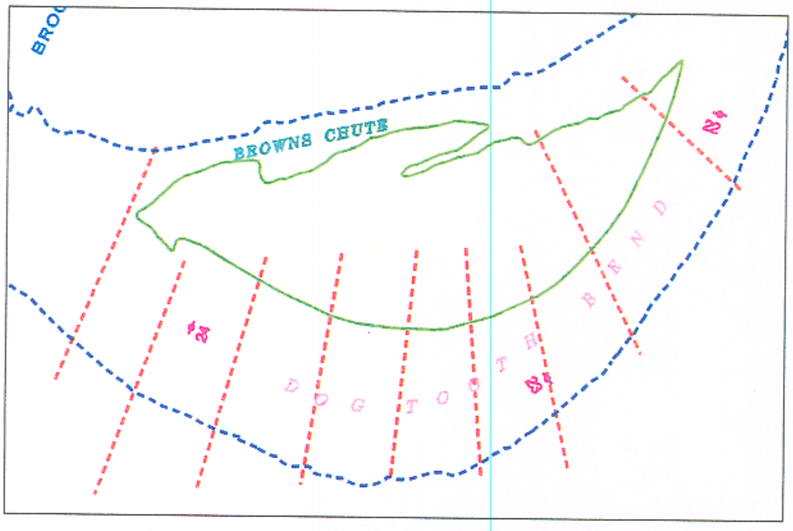


Figure 5 Cross-Sectional Ranges Established for Model to Prototype Comparison

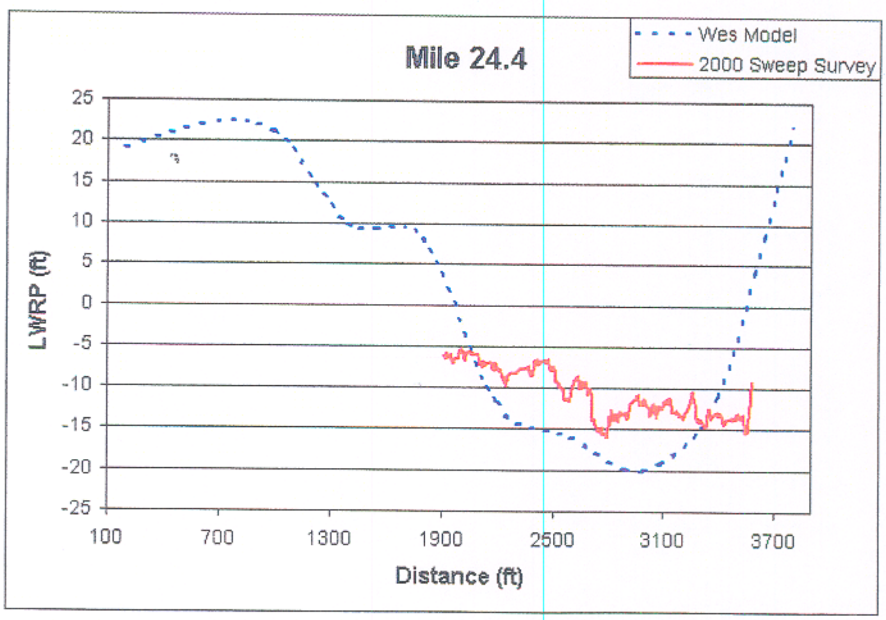


Figure 6 Cross Section at Mile 24.4

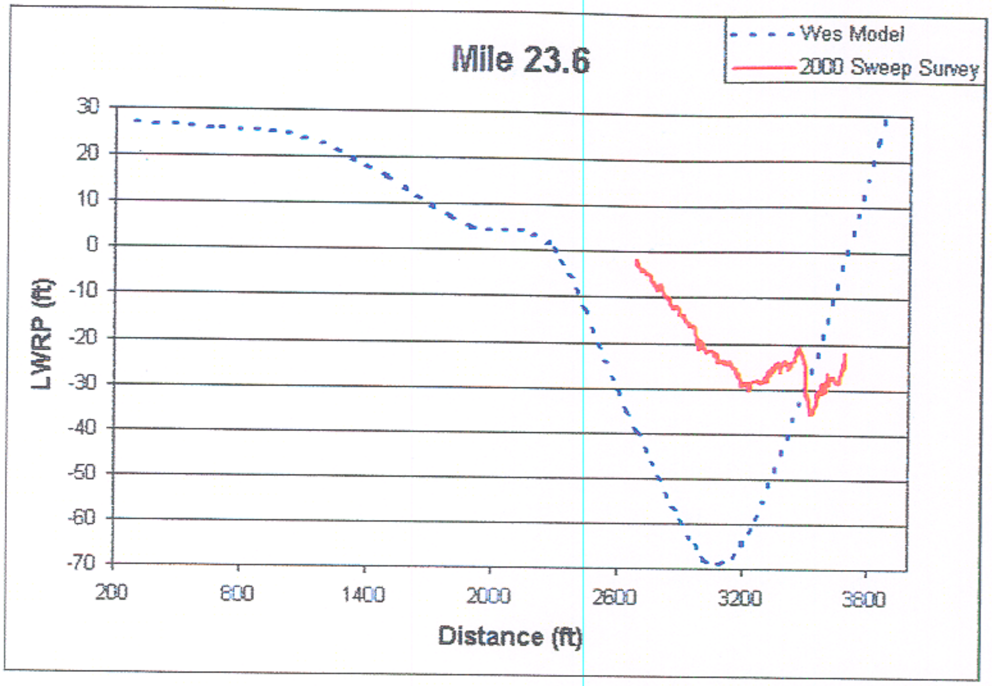


Figure 9  Cross Section at Mile 23.6

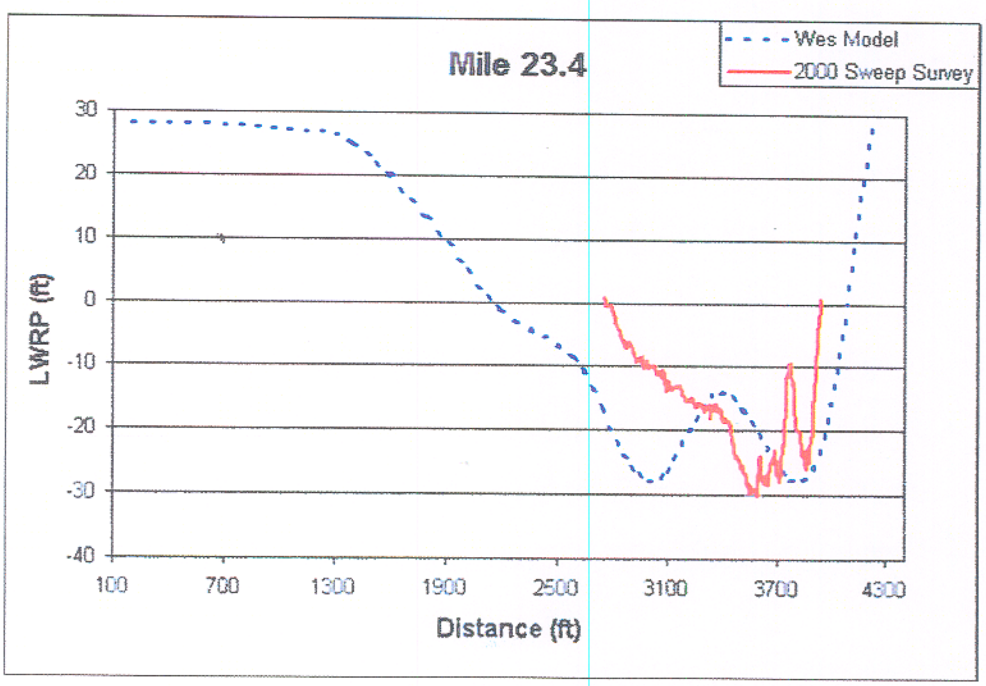


Figure 10  Cross Section at Mile 23.4

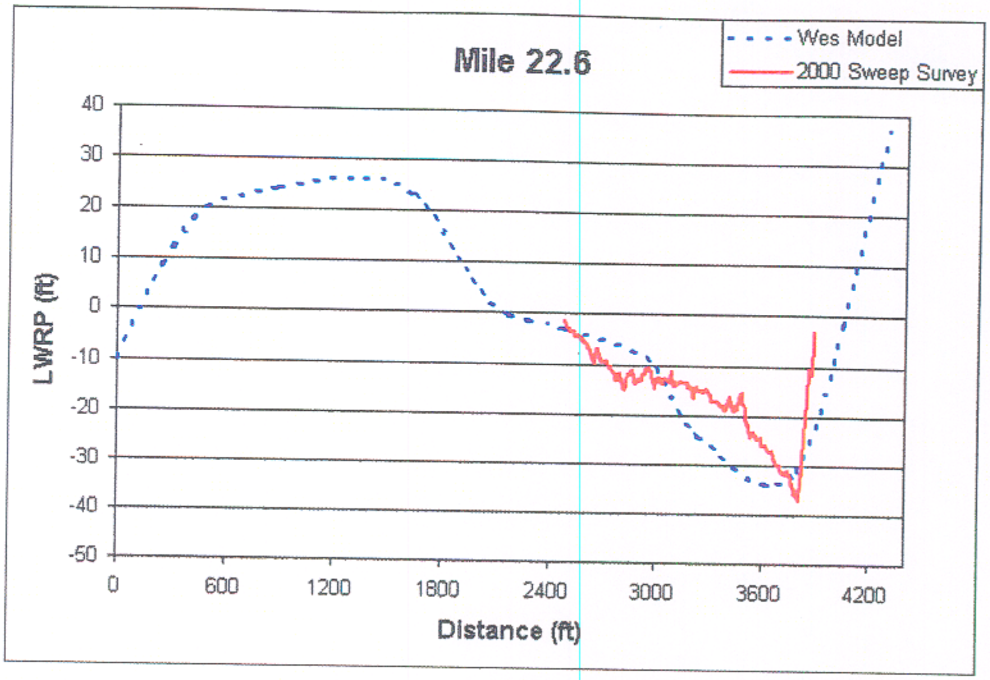


Figure 13 Cross Section at Mile 22.6

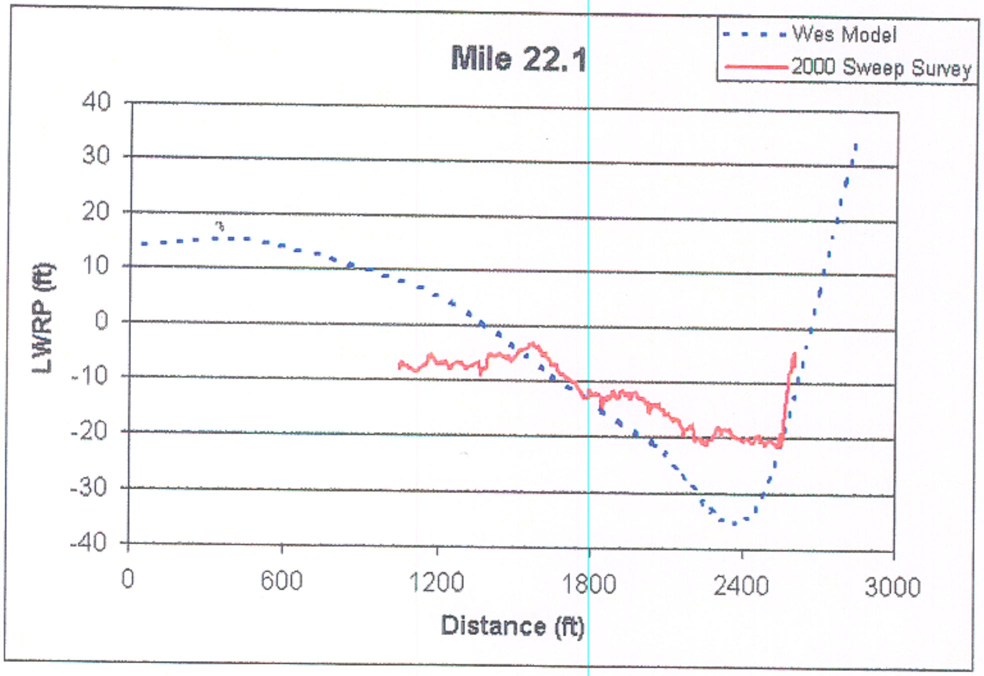


Figure 14 Cross Section at Mile 22.1

A key factor for the success of this design was the use of a phased construction approach, with intense prototype monitoring conducted before, during, and after construction. Today, 185 of these structures have been constructed in phases at various bends in the river. Both accidents and dredging have been greatly reduced in these bends. As part of this phased approach, towboat pilots were interviewed as engineers rode through the bend to receive feedback on the navigation effects of the weirs. Adjustments were then made where appropriate.

The end result has been the successful implementation of a newly developed river training structure using a model that did not perform exactly like the prototype. However, were the engineers fooling themselves by using the results of this model? As with all other movable bed models of the past, the answer was no, because the engineers used the model as a general indicator of what could be expected to occur in the prototype and not the absolute indicator. The river engineers knew the limitations that existed in the model and still proceeded with design and construction. Then what were the consequences of the model being wrong? The better question is, what would be the consequences of ignoring the results of the model and not building any structures? The answer to this last question would be millions of dollars worth of additional dredging, more collisions and groundings, and more oil spills resulting in substantial environmental damage, and finally, the possibly of the loss of human life.

Davinroy

**Dogtooth Bend Case Study: A Typical Process of Modeling, Design, & Construction**

The following describes the Dogtooth Bend model study and how the recommended conceptual design from this model was transferred to a final design, was constructed in the river and how the resultant bed configuration compared to the bed forms predicted by the model study.

During the early 1980's numerous collisions and groundings involving tows were occurring in bends on the Mississippi River within the St. Louis District. Two of these accidents resulted in major oil spills into the river. Due to point bar formation, repetitive maintenance dredging was required to artificially maintain adequate widths in these bends during low water conditions. Therefore, between 1984 and 1992, a movable bed model at WES was used by the St. Louis District to address these problems.

Two particular bends (Prices Bend at Mile 30 and Dogtooth Bend at Mile 22) that contained the highest rates of incidences were modeled as part of the Dogtooth Bend Movable Bed Model Study, Miles 40 to 20 (Technical Report HL-94-10). The scale of the model was 1:400 horizontal, 1:100 vertical, with a distortion of 4. The model was used to study a variety of design alternatives to address the bend problems, including channel realignment, dikes, spurs, hard points, and other type of structures. The Bendway Weir was eventually developed using this model. ~~Design~~ details such as structure spacing, height, length, and angle were recommended ~~in~~ the model study ~~from~~ a result of numerous alternative tests.

The recommended plan (Figure 1) called for the installation of 13 Bendway Weirs in Dogtooth Bend. The results of flow visualization using surface floaters were also called out in the recommended plan as compared to the base test. However, prototype velocity data was not collected for the calibration of surface flow patterns.

Figure 1 shows the 1983 Prototype bathymetry of the reach described herein. Figure 2 shows the model Base Test bathymetry used for making relative comparisons between alternative plans.

Fig 1 1983 Prototype

Fig 2 Base Test.

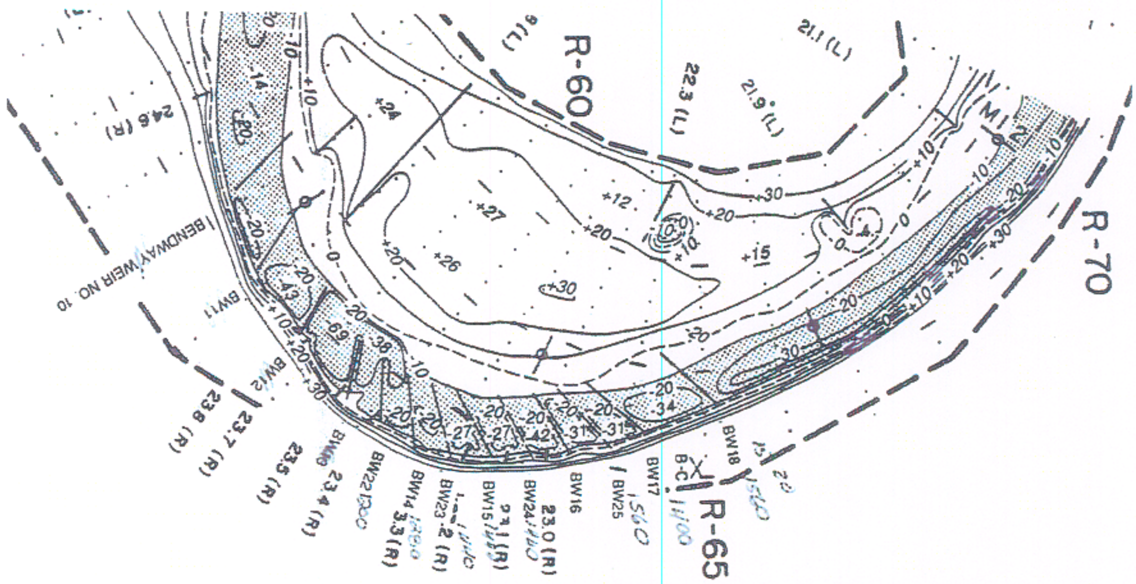


**Figure 1: Recommended Bendway Weir Design Configuration and the Resultant Bed Configuration of the Dogtooth Bend WES Model.**

During the preparation of plans and specs of the recommended plan, hydrographic surveys of the river showed that the bed configuration of the prototype had narrower widths and less depth than was shown in the model. The scour depth and width estimate for the model base test and the recommended plan was far greater than was actually present in the prototype. Therefore, the lengths of the weirs had to be constructed considerably shorter then those recommended by the model.

| Weir Number | Model Length (ft) | Actual Construction Length (ft) | Difference Model to Prototype (ft) |
|---|---|---|---|
| Weir 24.2 | 1520 | 650 | 870 |
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**Table 1: Model Designed and Actual Constructed Bendway Weir Lengths.**

Table 1 shows weir lengths from the recommended design plan of the model study as compared to the actual constructed design. All weirs were model tested and constructed at –15 feet LWRP.

Figure 2 is a plan view map depicting a year 2000 channel sweep survey of the Mississippi River at Dogtooth Bend. The channel sweep is an extremely high-resolution survey representing hundreds of thousands of points. In Figure 2, the weir lengths developed in the model study plan (blue) are superimposed over the actual weir lengths constructed in the prototype (red). The angle or orientation of the weirs in the prototype was constructed as close as possible to the recommended model plan. Some slight angle deviations existed due to unforeseen problems during construction. Generally, most weirs were either built at the exact same angle as called out in the model plan or were built at a slightly different angle of just a few degrees. The bankline alignments have remained the same as they were at the time of the model study and no other construction activity has occurred in the reach.

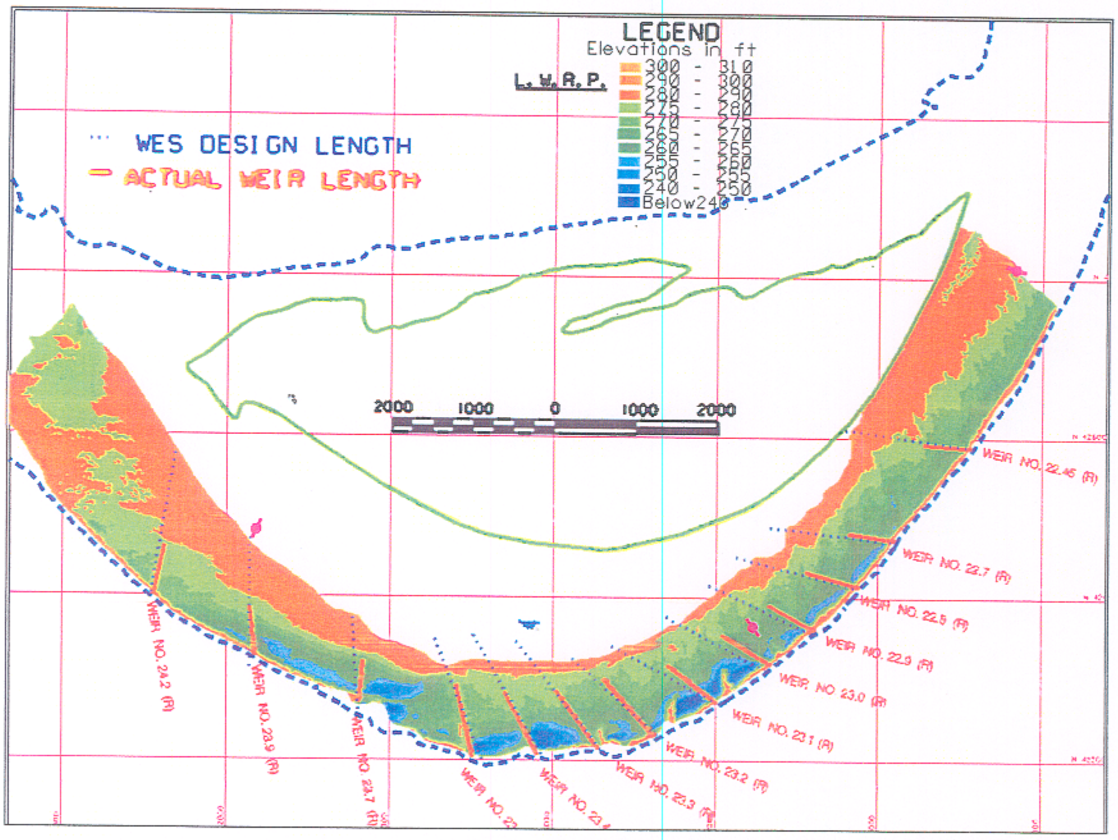


**Figure 2: Year 2000 Hydrographic Channel Sweep Survey with the WES Model Recommended Design (Blue) Shown with the Constructed Structures (Red).**

Figure 3 shows the location of cross-sectional ranges used for the comparison of differences in the bed configuration produced by the prototype and predicted by the model. The ranges were slightly skewed in order to align the sections between weirs and to ensure that the structure profiles were not incorporated in the analysis. Cross-sectional plots of the model bed (blue) versus the 2000 sweep survey (red) are shown in Figures 4 through 12.

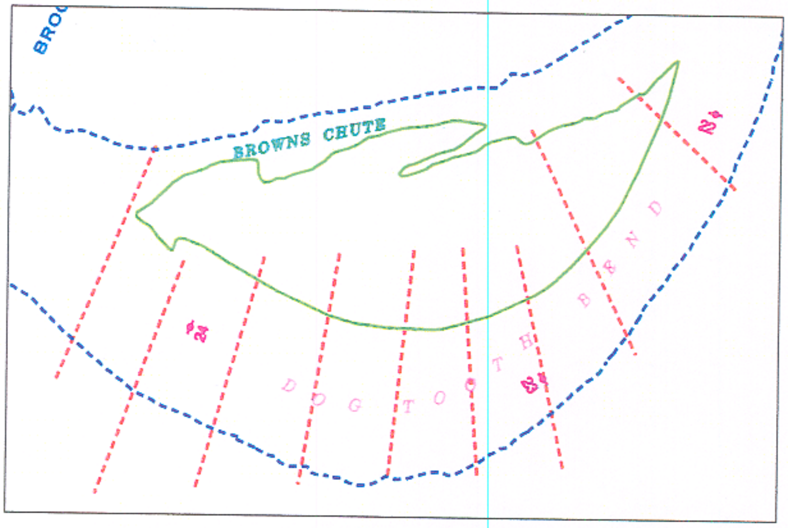


**Figure 3: Cross-Sectional Ranges Established for Model to Prototype Comparison.**

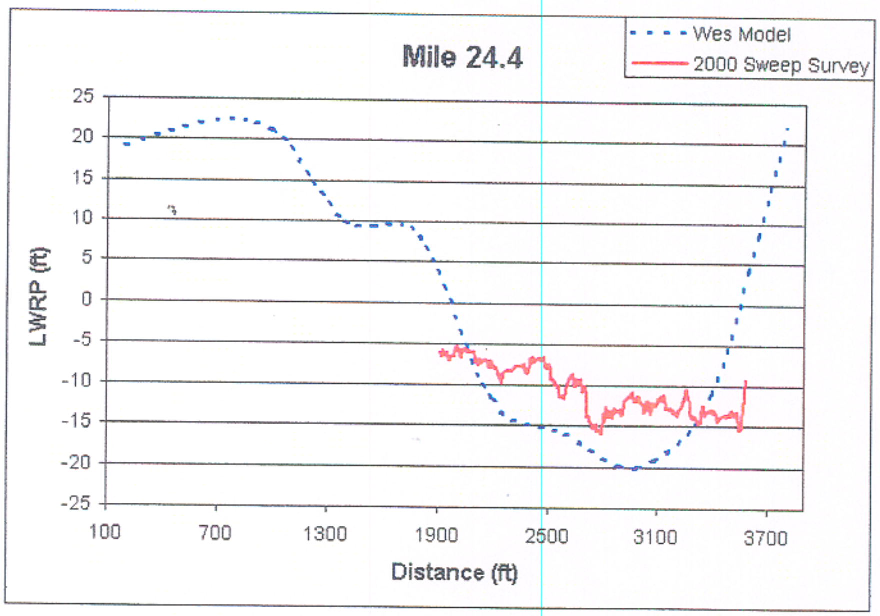


**Figure 4: Cross Section at Mile 24.4.**

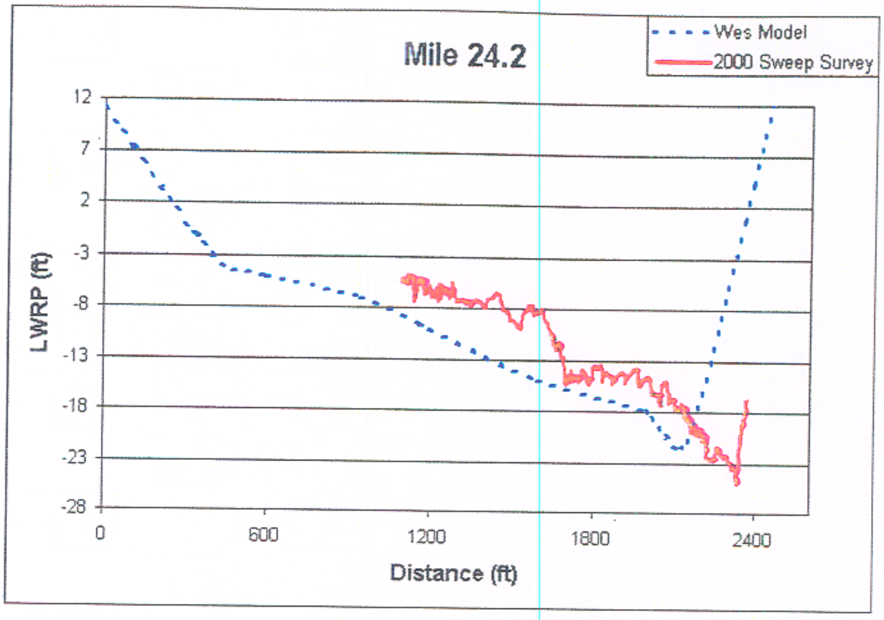


Figure 5: Cross Section at Mile 24.2.

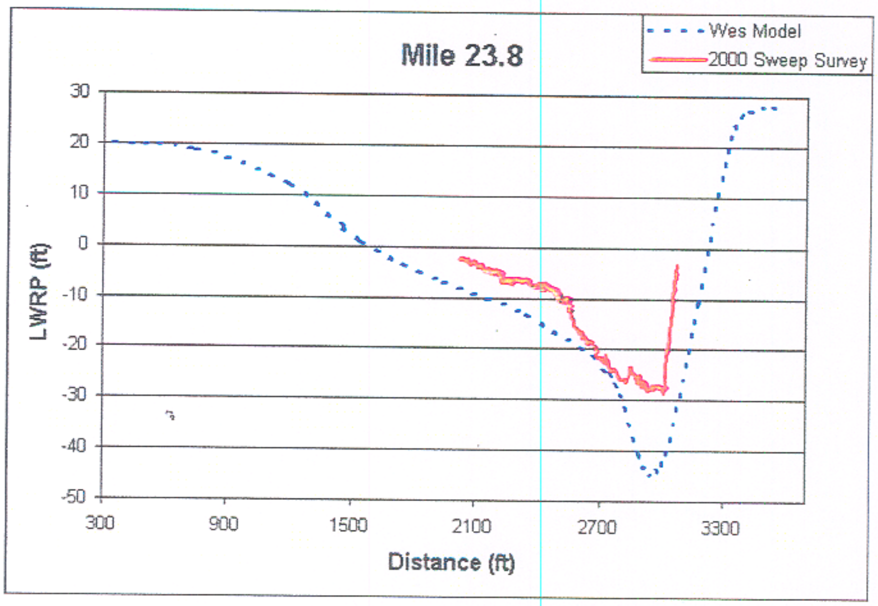


Figure 6: Cross Section at Mile 23.8.

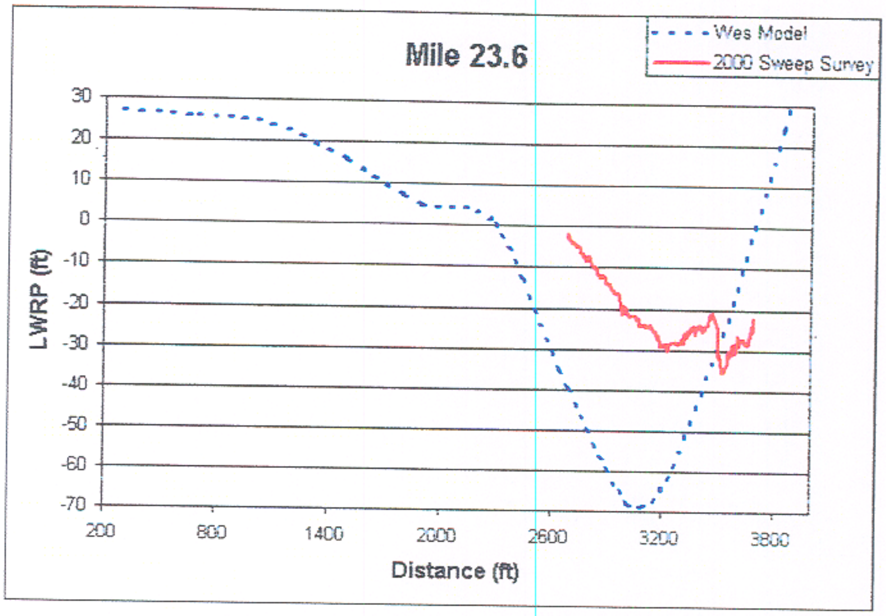


Figure 7: Cross Section at Mile 23.6.

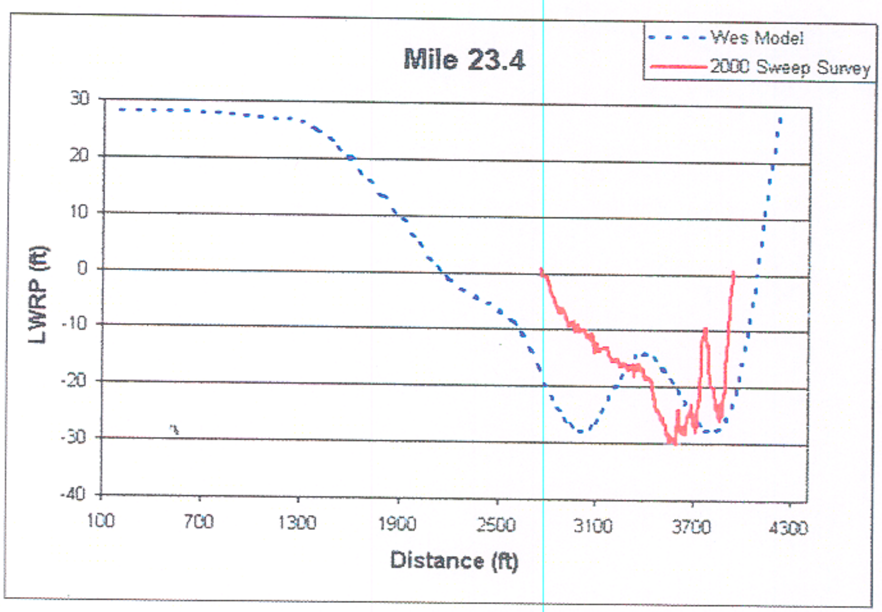


Figure 8: Cross Section at Mile 23.4.

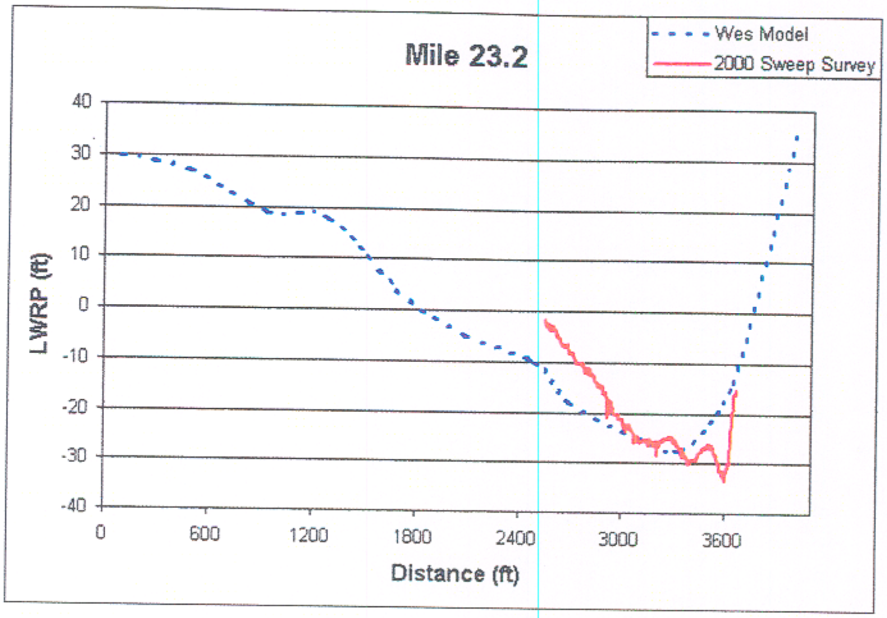


Figure 9: Cross Section at Mile 23.2.

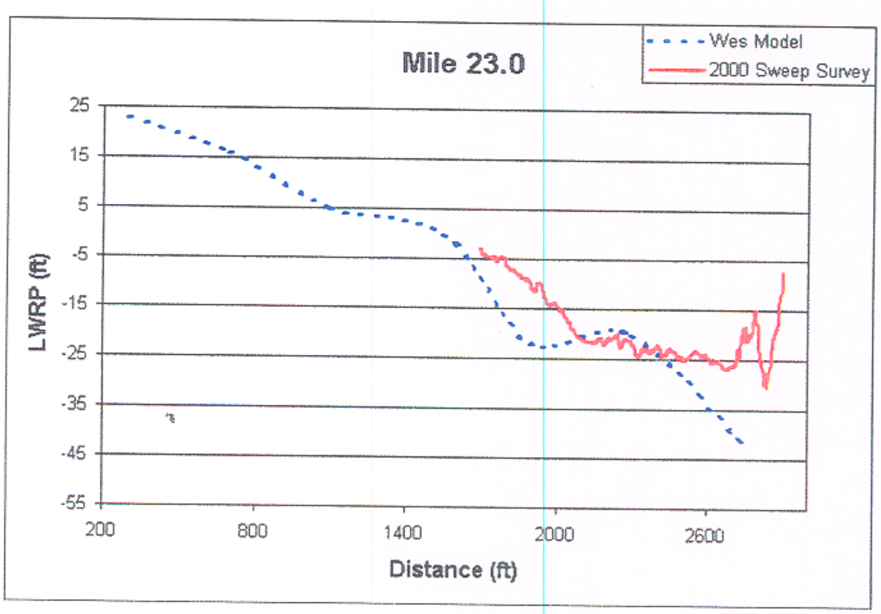


Figure 10: Cross Section at Mile 23.0.

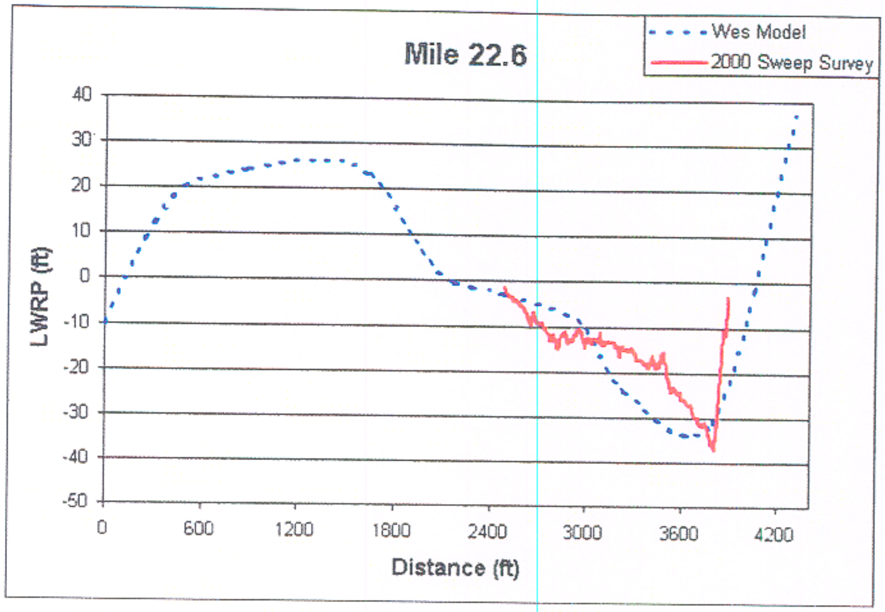


Figure 11: Cross Section at Mile 22.6.

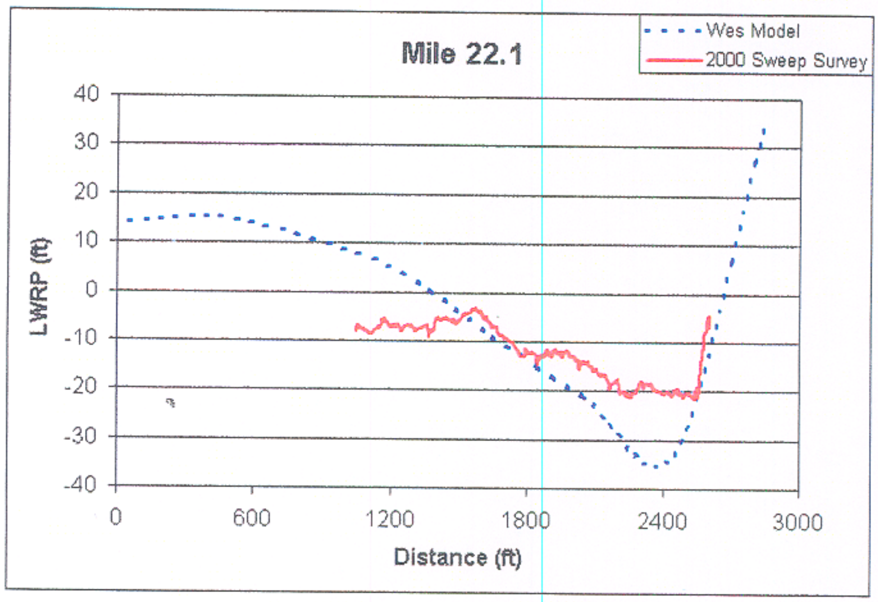


Figure 12: Cross Section at Mile 22.1.

Figures 6 through 14 clearly show that the resultant bed configuration formed by the recommended plan in the model varied considerably from what actually formed in the prototype. This was because the differences in the model base test allowed for much greater length of weirs than could be physically built in the prototype. This resulted in a generally wider and deeper channel being developed in the model as compared to the prototype.

The consequences of this model being wrong were enormous. In this particular study, a considerable risk was imposed on the St. Louis District for implementing the model design into the actual river, not only from an economic perspective, but from a safety concern as well. Volatile commodities were being transported through this extremely treacherous reach of river on a regular basis. Furthermore, these types of underwater structures had never before been implemented on any navigable waterway. The structures were designed to have tows pass directly over top of the weirs but their effects on current patterns had not been completely established. Although flow visualization of surface floaters was used in the model, no prototype velocity data was collected to calibrate the model to.

In addition, there were other factors associated with the model itself that increased the risk. The base test bed configuration did not accurately match the prototype, which led to a design that could not be fully implemented in the river. Furthermore, several sections of the concrete flume floor in the model along the outside of the bend were exposed from exaggerated bed scour. This inconsistency created an armoring affect that laterally widened the bed scour along the inside of the bend.

Ultimately, the Bendway Weirs implemented in the Mississippi River at Dogtooth Bend have been a success, as in other bends on the river. Even though the final design and the ultimate bed response was far different than what occurred in the model, the general trends in the prototype after construction have been positive. The extent of the point bar has been reduced and the bend has widened such that maintenance dredging has been eliminated. The flow patterns have been very favorable through the bend after construction and mimics the general flow trends observed with the model flow visualization.

A key factor for the success of this design was the use of a phased-construction approach, with intense prototype monitoring conducted before, during, and after construction. Today, 185 of these structures have been phase-constructed in the river. Both accidents and dredging have been greatly reduced in these bends. As part of this phased approach, towboat pilots were interviewed as engineers rode through the bend to receive feedback on the navigation effects of the weirs. Adjustments were then made where appropriate.

The end result has been the successful implementation of a newly developed river training structure using a model that did not perform exactly like the prototype. However, were the engineers fooling themselves by using the results of this model? As with all other movable bed models of the past, the answer was no, because the engineers used the model as a general indicator of what could be expected to occur in the prototype and not the absolute indicator. The river engineers knew the limitations that existed in the model and still proceeded with design and construction. Then what were the consequences of the model being wrong? The better question is, what would be the consequences of ignoring the results of the model and not building any structures? The answer to this last question would be millions of dollars worth of additional dredging, more collisions and groundings, and more oil spills resulting in substantial environmental damage, and finally, the possibly of the loss of human life.