Chapter

Reduction of the Diffusion Hydrodynamic Model to Kinematic Routing

Theodore V. Hromadka II and Chung-Cheng Yen

Abstract

In this chapter, the kinematic routing option of the diffusion hydrodynamic model for one-dimensional flows is presented along with the underlying pinning of kinematic flow. The kinematic model results are compared with the full model and K-634 model output data for the mild and steep channel.

Keywords: one-dimensional flow, kinematic routing, channel slope, flow discharge, routing

1. Introduction

The two-dimensional DHM formulation as given by Eq. (32) in Chapter 1 can be simplified into a kinematic wave approximation of the two-dimensional equations of motion by using the slope of the topographic surface rather than the slope of the water surface is the friction slope in Chapter 1, Eq. (28). That is, flow rates are driven by Manning's equation, while backwater effects, reverse flows, and ponding effects are entirely ignored. As a result, the kinematic wave routing approach cannot be used for flooding situations such as considered in the previous chapter. Flows which escape from the channels cannot be modeled to pond over the surrounding land surface nor move over adverse slopes nor are backwater effects being modeled in the open channels due to constrictions which, typically, are the source of flood system deficiencies.

In a report by Doyle et al. [1], an examination of approximations of the one-dimensional flow equation was presented. The authors write: "It has been shown repeatedly in flow-routing applications that the kinematic wave approximation always predicts a steeper wave with less dispersion and attenuation than may actually occur. This can be traced to the approximations made in the development of the kinematic wave equations wherein the momentum equation is reduced to a uniform flow equation of motion that simply states the friction slope is equal to the bed slope. If the pressure term is retained in the momentum equation (diffusion wave method), then this will help to stop the accumulation of error that occurs when the kinematic wave approximation procedure is applied." More background information relating to relating to kinematic and diffusion wave equations can be found in the works of Ponce and others [2–5].

2. Application 8: kinematic routing (one-dimensional)

To demonstrate the kinematic routing feature of the DHM, the one-dimensional channel problem used for the verification of the DHM is now used to compare results between the DHM and the kinematic routing.

For the steep channel, both techniques show similar results up to 10 miles for the maximum water depth (**Figure 1**) and discharge rates at 5 and 10 miles (**Figures 2–5**). For the mild channel, the maximum water surface and discharge rates deviate increasingly as the distance increases downstream from the point of channel inflow.

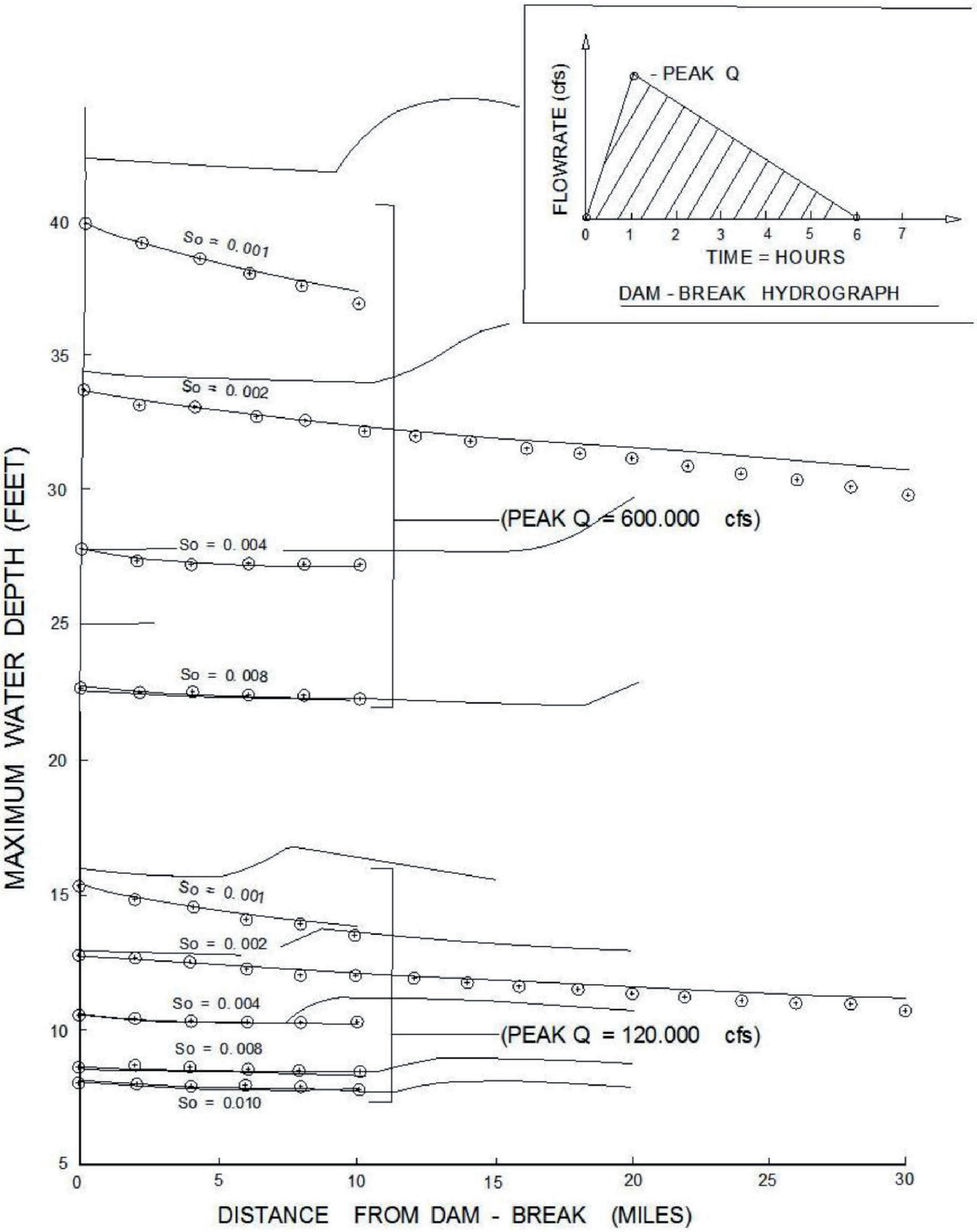

Figure 1.
Diffusion model (⊙), kinematic routing (dashed line), and K-634 model results (solid line) for 1000 feet width channel, Manning's n = 0.040, and various channel slopes, S_o.

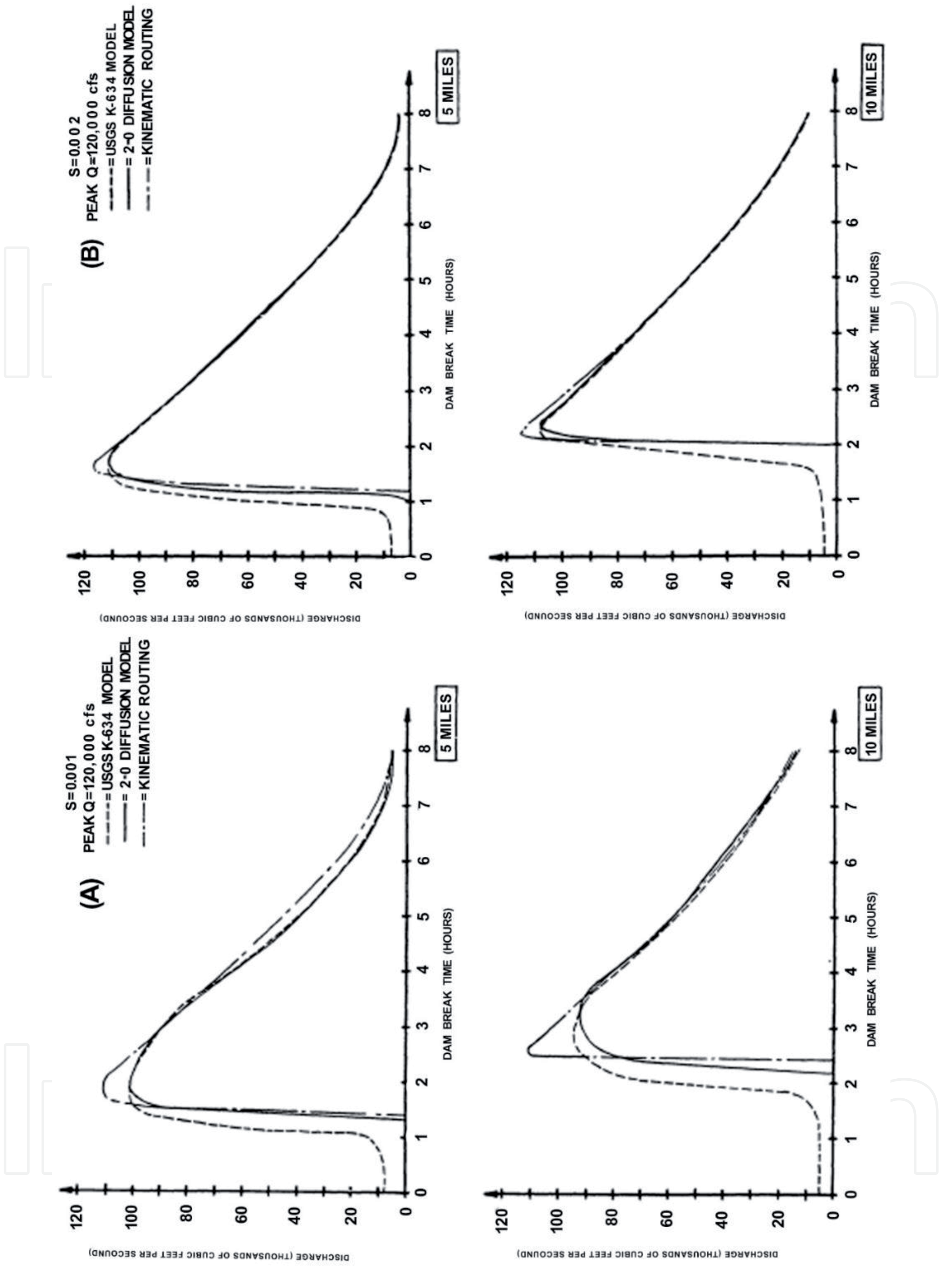

Figure 2.
Comparisons of outflow hydrographs at 5 and 10 miles downstream from the dam-break site (peak Q = 120,000 cfs).

3. Conclusions

The reliability of the kinematic routing option in DHM was tested by applying it over mild and steep channels. The DHM results were compared with the diffusion model and K-634 model results. The close agreement of the results for the steep channel between the models across the length of flow underscores the reliability of this option in DHM.

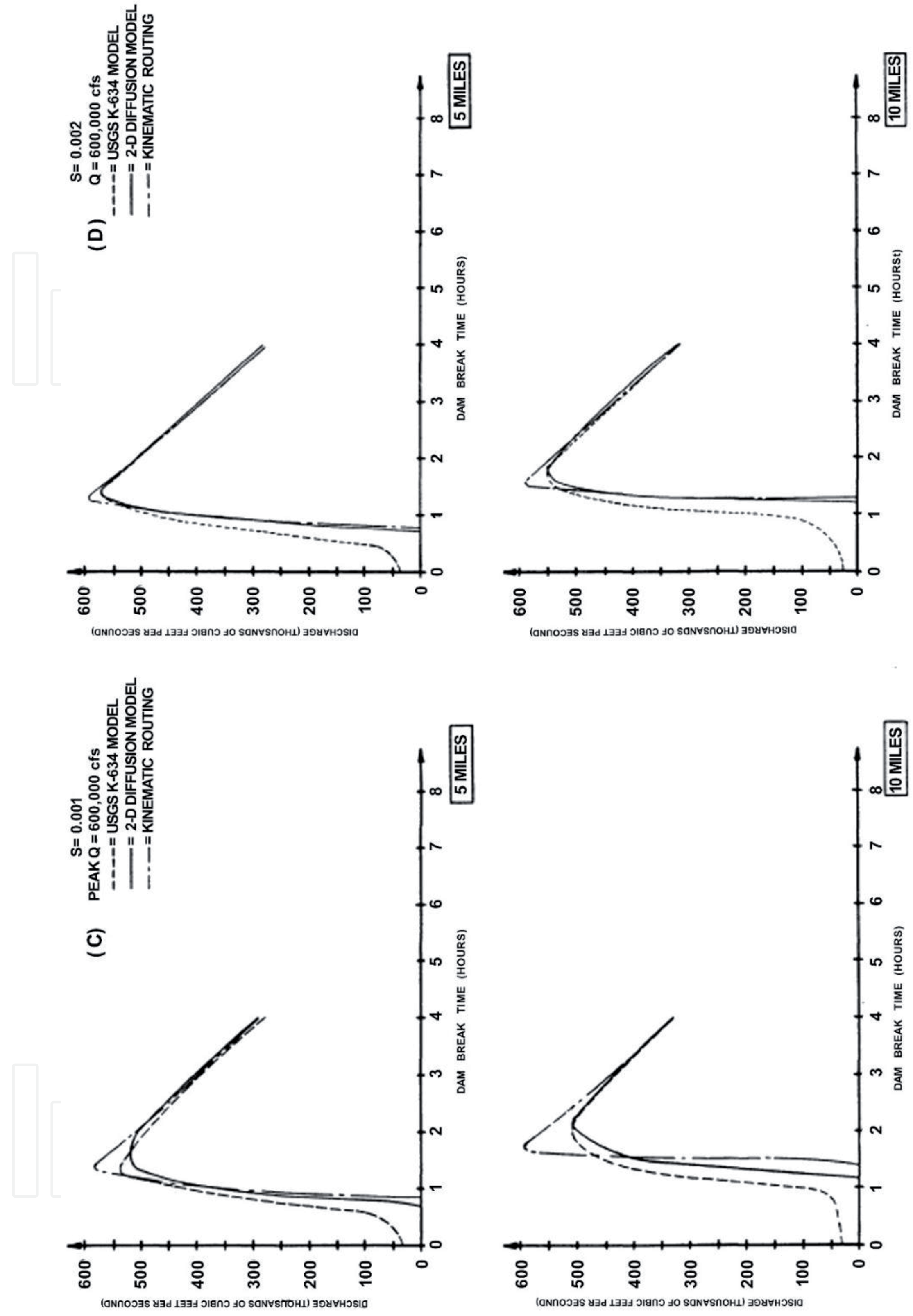

Figure 3.
Comparisons of outflow hydrographs at 5 and 10 miles downstream from the dam-break site (peak Q = 600,000 cfs).

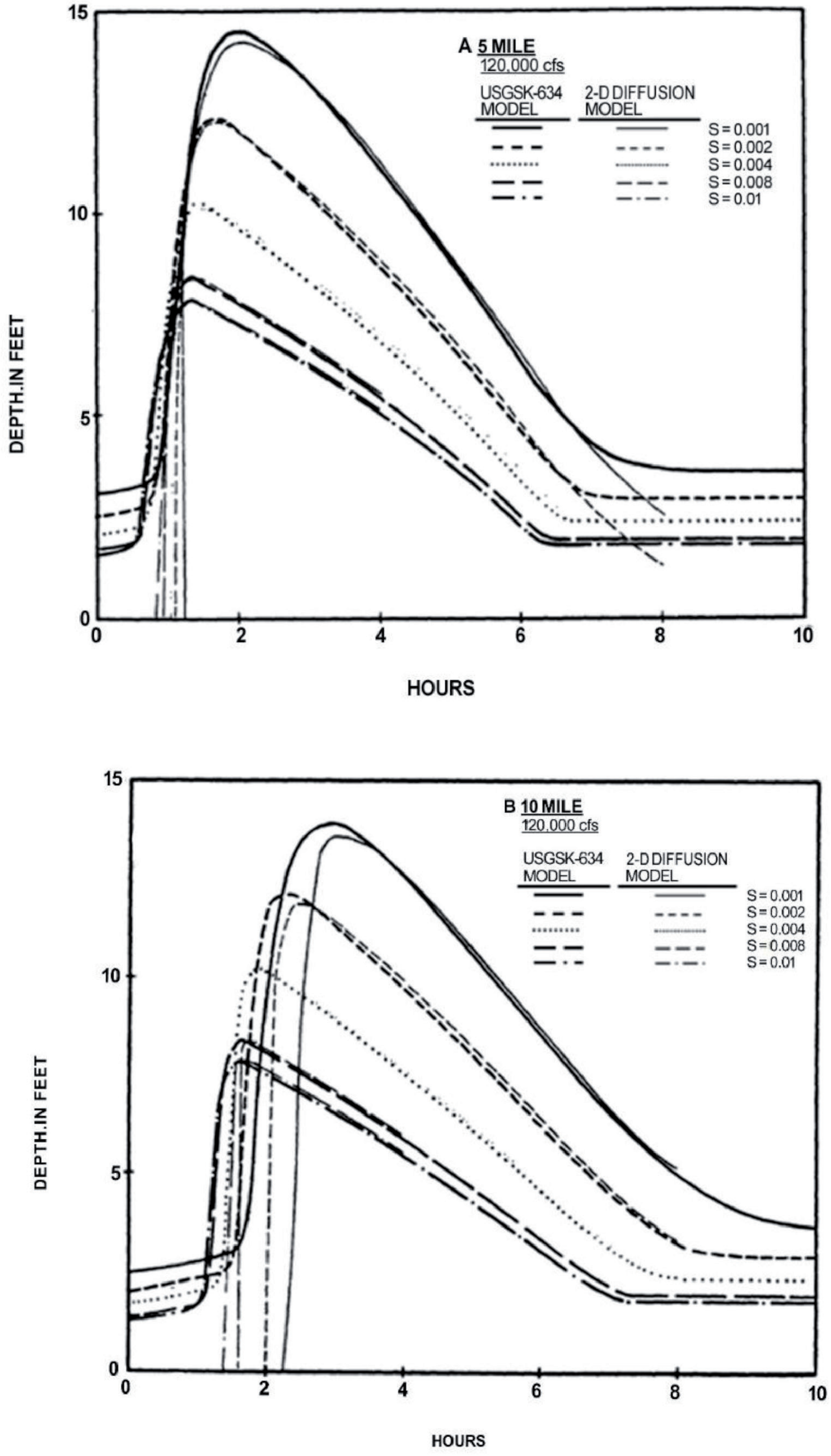

Figure 4.
Comparisons of depths of water at 5 and 10 miles downstream from the dam-break site (peak Q = 120,000 cfs).

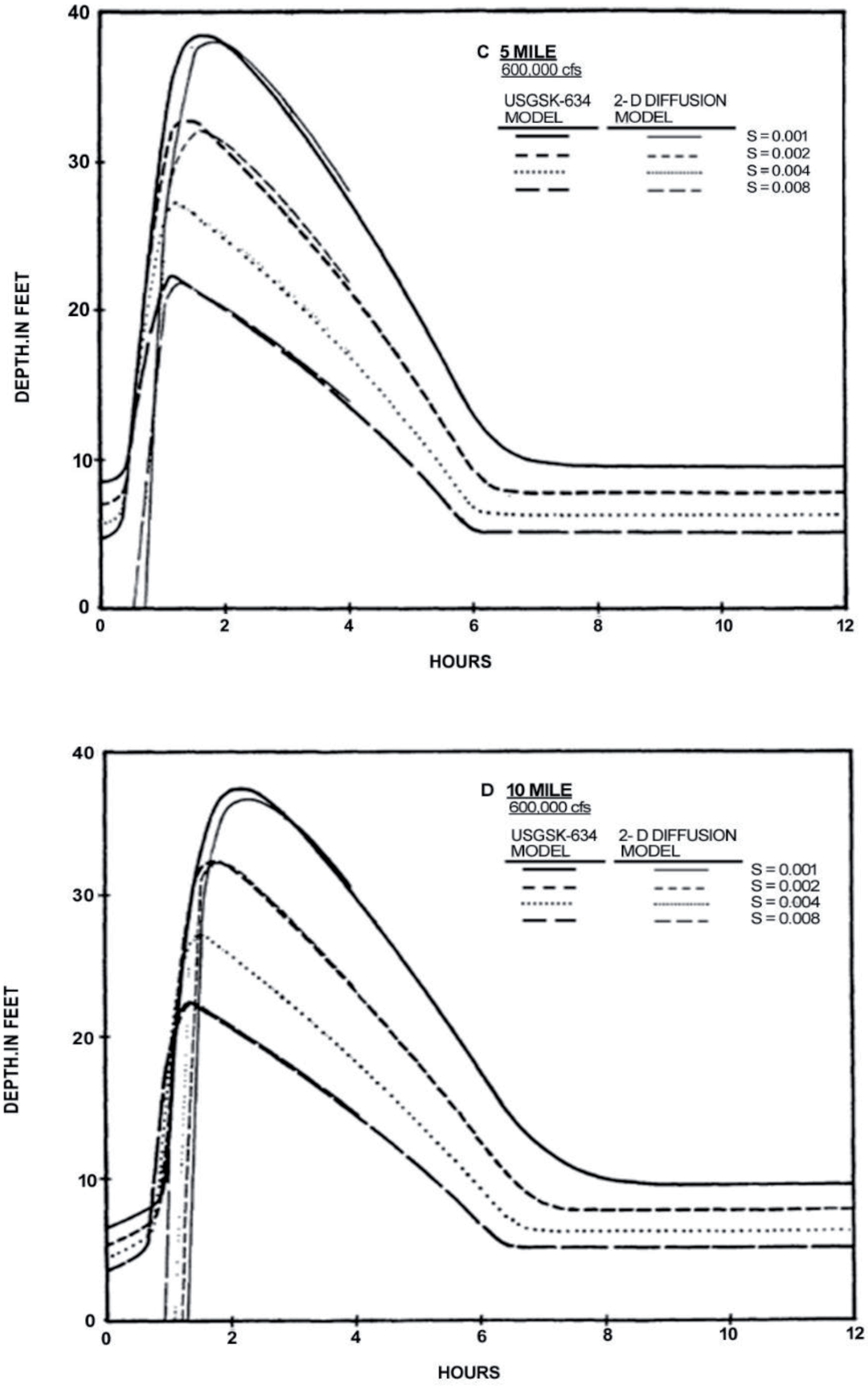

Figure 5.
Comparisons of depths of water at 5 and 10 miles downstream from the dam-break site (peak Q = 600,000 cfs).

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References

[1] Doyle WH, Shearman JO, Stiltner GJ, Krug WR. A digital model for Streamflow routing by convolution method. Water-Resources Investigations Report. 1983:83-4160. DOI: 10.3133/wri834160

[2] Ponce VM. Modeling surface runoff with kinematic, diffusion, and dynamic waves. In: Singh VP, Kumar B, editors. Proceedings of the International Conference on Hydrology and Water Resources, New Delhi, India, December 1993. Dordrecht: Water Science and Technology Library, Springer; 1996. p. 16

[3] Moramarco T, Pandolfo C, Singh VP. Accuracy of kinematic wave approximation for flood routing, II: Unsteady analysis. Journal of Hydrologic Engineering. 2008;**13**(11):1089-1096

[4] Moramarco T, Pandolfo C, Singh VP. Accuracy of kinematic wave approximation for flood routing, II: Unsteady analysis. Journal of Hydrologic Engineering. 2008;**13**(11):1089-1096

[5] Xiong Y, Melching CS. Comparison of kinematic wave and nonlinear reservoir routing of urban watershed runoff. Journal of Hydrologic Engineering. 2005;**10**(1):39-49