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Brigham Young University and Universidad Autonoma de Zacatecas

Runoff Analysis and Culvert Design for “La Presa Bernardez”

Guadalupe, Zacatecas, Mexico



Problem: Development and paving in the Bernardez Basin are leading to increased frequency and severity of flash floods. As development continues this problem will continue to get worse.

Location: The sub-basin Bernardez is located in the developing area between the suburb of Guadalupe and the city of Zacatecas. These cities have populations of 140,000 and 100,000 respectively, are located at an elevation of 7,700 ft, and are located in a high desert climate. The soil is characterized best as desert hardpan and there is little natural ground cover other than coarse grasses, shrubs, and cactus. The basin area is about 500 acres. The three photos below are of the undeveloped ground cover (Figure 1), the developing area (Figure 2), and a developed area (Figure 3) in the basin.



Figure 1. Area of the basin that is undeveloped.



Figure 2. Area of the basin that is being developed.



Figure 3. Area of the basin that is already developed.

Objective: Calculate the current and future runoff for the basin and determine potential methods for mitigation.

Methods: Watershed Modeling System (WMS) was used to create a digital model of the watershed, combining topographic, precipitation, soil type, natural ground cover, and land use data to perform hydrologic analyses. Figure 4 (to the right) depicts the model as a Google Earth image. The theoretical precipitation used for this analysis was according to the five-year, two- and twenty-four hour historical design storm data, per Zacatecas standards, with an SCS Type-II 24-hour temporal distribution.

Results: Figure 5 (far right) shows one of the runoff hydrographs produced from the analysis. The maximum flows for both design storms are shown in Table 1 below.

	Maximum Flow (cfs)	
	2 hour	24 hour
Current	70	550
Projected	270	1020

Table 1. Maximum flows for the basin.

Currently, a total volume of 73 acre-feet of runoff is produced from the 5-year, 2-hour storm.

Design : One of the areas that needs special attention in this basin is a section of road directly upstream of an existing detention basin, as shown in the foreground of Figure 6 (to the right). This road serves as an on-ramp from local streets to the major highway seen in the background. The box culvert beneath the highway is obviously sufficient, but due to the limited size of the double-barrel culvert below, storm runoff consistently overtops the on-ramp, causing hazardous conditions for vehicles as well as potential wash-outs.

A new box culvert, shown in Figure 9, was designed to replace the existing double-barrel culvert. Figure 7 shows the results of an HY-8 analysis, indicating that the water level for the 5-year, 24-hour design storm will not overtop the road if this culvert is installed. Figure 8 below shows a cost estimate for the culvert replacement, including materials, labor, engineering, permits, and legal fees.

Design Specifications:

- Pre-cast reinforced concrete box culvert
- Span: 2.5 meters
- Rise: 1.5 meters
- Length: 10 meters
- Cover: 0.5 meters
- 45°-Wingwalls at inlet and outlet

Engineer's Estimate for Box Culvert in the Bernardez Watershed in Zacatecas, Zacatecas, Mexico				
Zacatecas Proyecto 2, Las Cuenas de Bernardez y El Chulito				
Estimate includes Materials and Labor				
Item	Qty	Unit	Unit Cost (US\$)	Total Cost (US\$)
Mobilization	1	LS	\$ 1,500.00	\$ 1,500.00
Site Preparation	1	LS	\$ 500.00	\$ 500.00
Removal and disposal of culvert and road covering	1	LS	\$ 1,000.00	\$ 1,000.00
Excavation	1	LS	\$ 1,000.00	\$ 1,000.00
2.5 meter x 1.5 meter Precast Concrete Box Culvert	10	LM	\$ 1,500.00	\$ 15,000.00
Wing walls	2	EA	\$ 750.00	\$ 1,500.00
Replacing Roadway, including pavement and striping	100	SM	\$ 50.00	\$ 5,000.00
Traffic Diversion	1	LS	\$ 1,000.00	\$ 1,000.00
Subtotal				\$ 26,500.00
Engineering Fees (15%)				\$ 3,975.00
Permits and Legal Fees (10%)				\$ 2,650.00
Total Engineer's Estimate (US\$)				\$ 33,125.00

Figure 8. Cost estimate for culvert replacement.



Figure 4. Screenshot of basin.

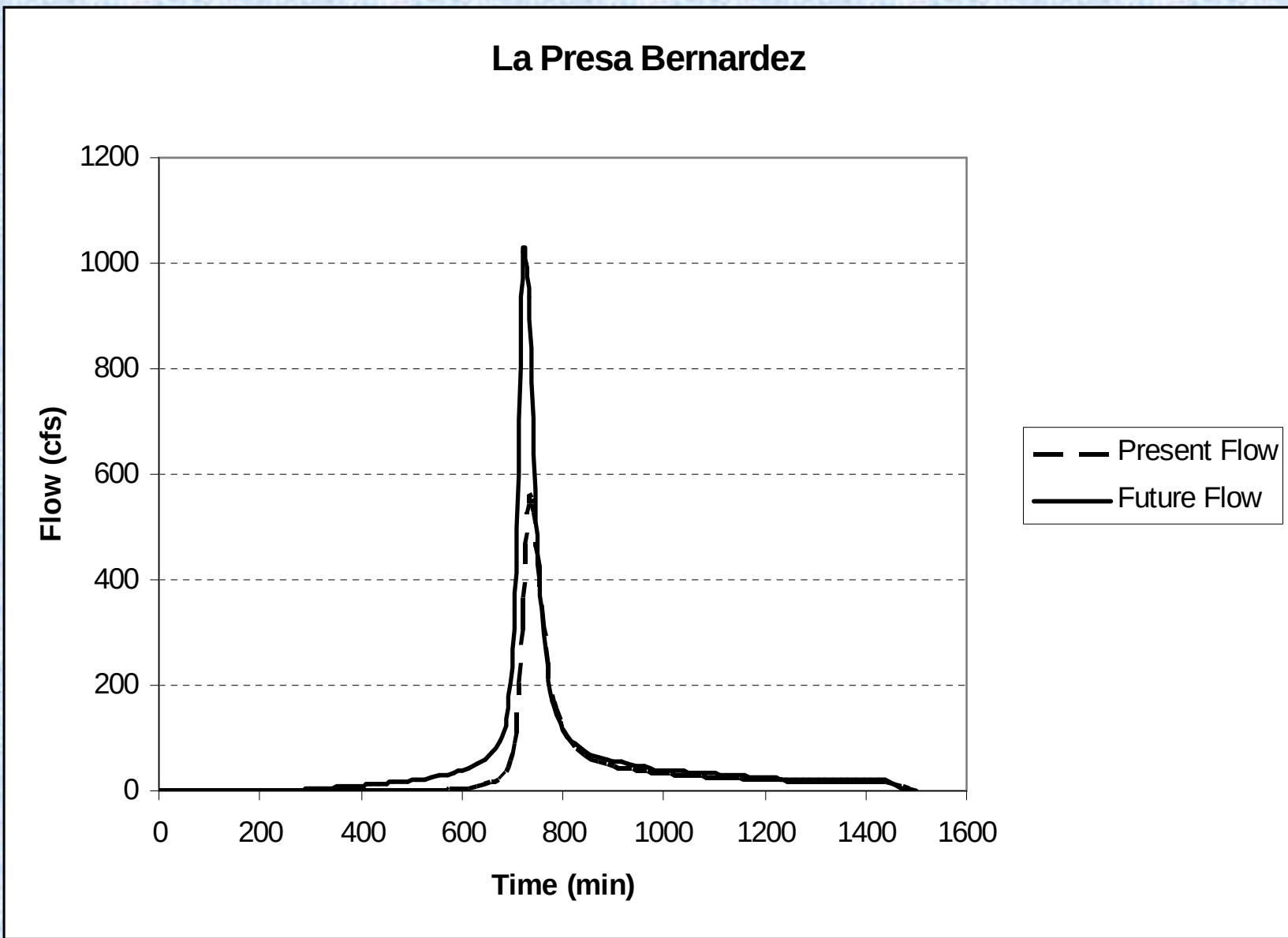


Figure 5. Runoff hydrograph for 5-year, 24-hour storm.



Figure 6. Photo of existing culverts.

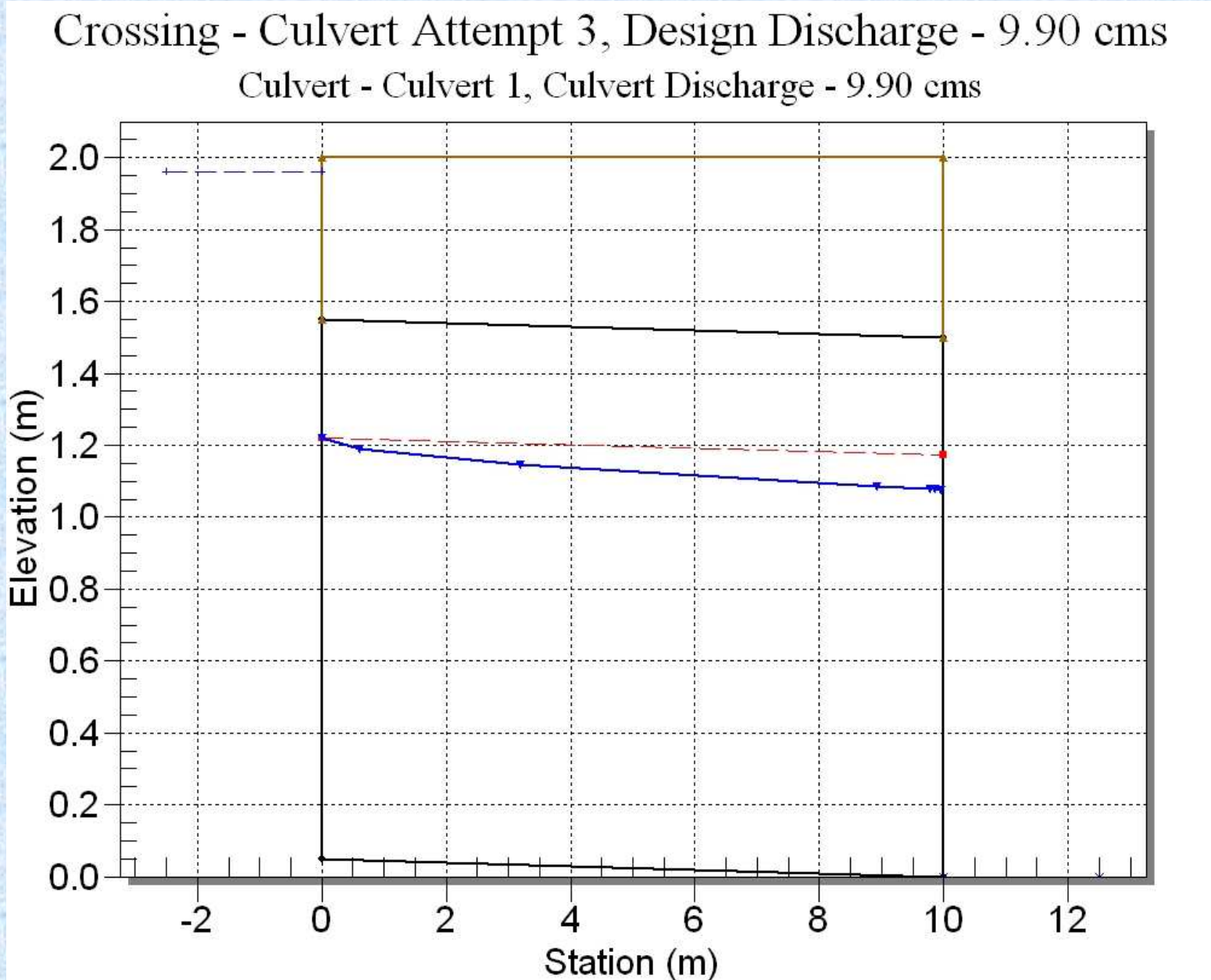


Figure 7. HY-8 culvert analysis.

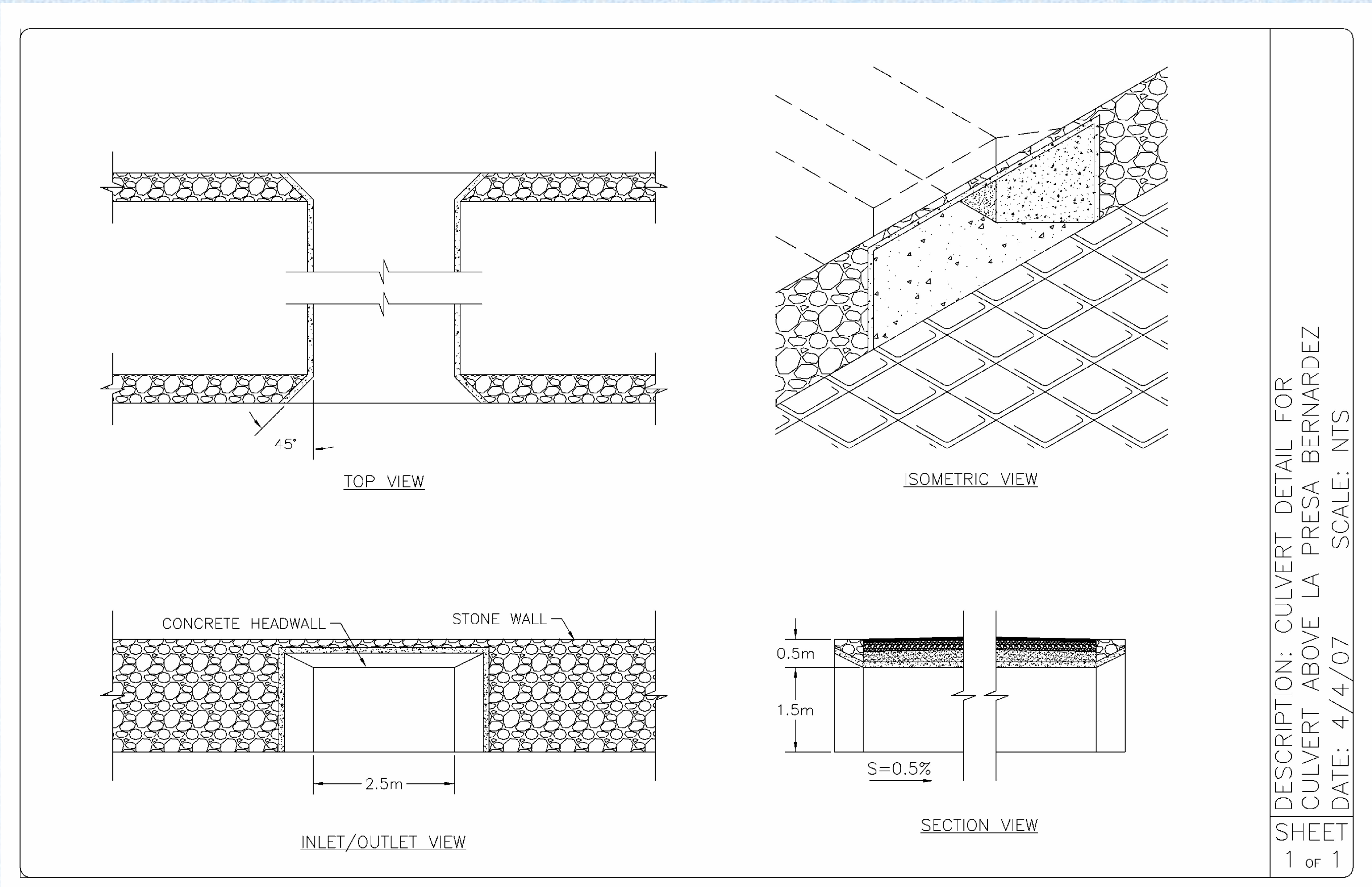


Figure 9. Replacement box culvert design.

Additional Recommendations:

1. Restore the abandoned detention basin and control the outflow with an adjustable gate retrofitted to the existing basin outlet.
2. Determine the basin volume necessary to sufficiently delay and attenuate the peak flow through the outlet, and size the detention basin accordingly.
3. Grade the basin side slopes 3:1 or less to reduce the risk of having children get stuck and drown.

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