CLARK CREEK WATERSHED STUDY

TECHNICAL MEMORANDUM

JANUARY 2012

PREPARED FOR

SAUK COUNTY, WISCONSIN
CONSERVATION, PLANNING AND ZONING DEPARTMENT

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1 INTRODUCTION

1.1 BACKGROUND

The Clark Creek watershed experienced extreme flooding in June of 2008, causing extensive damage to private and public property on State Highway (STH) 113 south of Baraboo, Wisconsin. The Clark Creek watershed has experienced repeated damaging and hazardous flooding such as the 2008 event over the last 20 years. An initial evaluation of the flooding issues on Clark Creek and potential mitigation actions was completed by the Federal Emergency Management Agency (FEMA) in September 2008. In March 2011, a follow-up study was conducted by Montgomery Associates: Resource Solutions, LLC (MARS) to evaluate potential measures to mitigate damages due to future floods similar to the June 2008 event and to recommend which options are likely to be feasible and cost effective.

Based on the results of the MARS study, Sauk County chose to pursue multiple flood mitigation options, including construction of upland storage areas for flood peak flow reduction (**Figure 1**). The Wisconsin Department of Natural Resources (DNR) owns the land where flood storage areas are being considered and currently leases it to farmers. The leases will expire at the end of this year for two areas: north of Tower Road near Neuman Road (area 7 on **Figure 1**), and south of Tower Road just west of the quarry (areas 5, 6 and 12 on **Figure 1**). The County hired MARS to provide a more detailed analysis of these two upland flood storage areas for flood mitigation.

For this analysis, the two upland flood storage areas were evaluated for flood mitigation effectiveness and habitat considerations. Specifically, MARS evaluated the effectiveness to reduce peak flood discharge for an event similar to the June 2008 event. The habitat implications were evaluated by modeling hydrologic conditions in the storage areas during frequent (1- to 2-year) rain events.

Based on the results of this analysis, the County may continue with implementation of one or both of the options evaluated in this memo, pursue other alternatives, or a combination of these. The models used for this analysis are intended for use as planning tools only, and additional technical analysis will be required for the final design of alternatives.

2 DATA SOURCES

In addition to data collected for the MARS 2011 Watershed Study, this analysis made use of several data sources as described below.

2.1 SURVEY

To aid in preparing a more detailed technical analysis, John Vosberg of the Natural Resources Conservation Service (NRCS) provided survey data of channel transects, extents of a high-quality sedge meadow near the US Fish and Wildlife Service (USFWS) wetland, and select ground shots (**Figure 2**). The survey included data from the locations in this report, as well as other areas that the County may wish to review at a later date.

2.2 FLOOD INSURANCE STUDY DATA

Hydrologic and hydraulic analyses conducted for the December 2009 Flood Insurance Study revision for Sauk County provided valuable tools for this analysis. Wisconsin DNR conducted a hydrologic analysis of the Clark Creek watershed, which is described in an internal report dated November 2, 2007. This study tabulated rainfall and watershed data, and it developed a rainfall-runoff model for the watershed using the U.S. Army Corps of Engineers program HEC-HMS. This model subdivided the Clark Creek watershed into nine subwatersheds and utilized descriptions of the subwatershed land-use, channel characteristics, and the storage routing provided by two wetland areas north of Tower Road to predict peak discharge rates at several points in the watershed. Model layout is shown on **Figure 3**. DNR modeled the storage for the wetland areas using storage-discharge curves developed by running various discharges through a HEC-RAS model of the storage areas and determining the storage volume associated with each discharge. This wetland storage HEC-RAS model was also utilized for this analysis.

2.3 RAINFALL

Based on the analysis in the MARS 2011 Watershed Study, the June 2008 flood (Design Flood) on Clark Creek was simulated using the FEMA FIS 100-year rainfall of 5.92 inches under extremely wet soil conditions. The DNR hydrologic model was modified to reflect this wet condition by adjusting runoff curve numbers from the typical Antecedent Moisture Condition 2 (used in the FEMA study) to Antecedent Moisture Condition 3 (representing very wet soil).

The Wisconsin DNR hydrologic analysis for the FEMA FIS describes 24-hour rainfall depths in the Clark Creek watershed as shown in **Table 1**. The FEMA study does not include values for the 1- and 2-year events. For this analysis, the 1- and 2-year events are represented by the Sauk County rainfall depth. Both the Sauk County and FEMA study rainfall depths are based upon the US Weather Bureau 1961 publication Technical Paper No. 40, Rainfall Frequency Atlas of the United States.

Table 1. 24-hour rainfall depths

Storm Event	FEMA Study rainfall depth (in)	Sauk County rainfall depth (in)
1-year storm:	--	2.5
2-year storm:	--	2.9
10-year storm:	3.98	4.2
50-year storm:	5.14	5.3
100-year storm:	5.92	6.1
500-year storm:	7.01	--

3 ANALYSIS

3.1 ANALYSIS APPROACH SUMMARY

The Wisconsin DNR owns the land where flood storage areas are being considered and currently leases it to farmers. The leases will expire at the end of this year for two areas with storage potential. One storage option, the quarry tributary, consists of three basins created by berms along the drainage located south of Tower Road just west of the quarry (areas 5, 6 and 12 on **Figure 1**). The second storage option, storage area 7, consists of one basin and is located north of Tower Road near Neuman Road, just west (downstream) of the US Fish and Wildlife (USFWS) wetland restoration (area 7 on **Figure 1**). Each area was evaluated for reduction in peak flood discharge and the depth and duration of flooding in the storage area.

The analysis was completed by modifying the DNR HEC-HMS and HEC-RAS models to include storage at proposed locations. Storage areas were modeled as basins formed by low berms. The low flow outlets were modeled as culverts for simplicity, however other types of outlet structures could be considered for final design. A 50-foot long weir at an elevation 0.5 feet lower than the crest of the berm was included to pass high flows. The peak attenuation was analyzed using the design flood conditions (see **Section 2.3**). Peak flow was evaluated at the HEC-HMS component located 1000 feet upstream of STH 113, representing the reach of Clark Creek that experienced the most substantial damages in the June 2008 flood. The depth and duration were determined using the design flood, the 1-year and 2-year events (see **Section 2.3**).

The analysis specifics for the two proposed storage areas differed slightly. The analysis for the quarry tributary was completed by modifying the DNR HEC-HMS model to include new storage areas at proposed locations with stage-area relationships based on topographic data and outflow culvert and weir structures. Storage area 7, however, was complicated by the fact that the HEC-HMS model already includes natural storage in this area. The DNR modeled this natural storage using storage-discharge curves extracted from their HEC-RAS model. MARS modified this HEC-RAS model to include a berm and culvert at the proposed storage location. The updated storage-discharge curves were then applied to HEC-HMS to evaluate proposed conditions.

3.2 QUARRY TRIBUTARY

This alternative includes three storage areas as shown on **Figure 1**. The original HEC-HMS model was modified to include these storage areas. Additionally, to more accurately reflect how much water enters the storage areas, the watershed draining to the storage areas (R100W70) was conservatively divided into 2 identical subwatersheds so 50% of flow enters the three storage areas and 50% bypasses them. Three configurations of the storage areas were analyzed to document the benefit of higher berms and smaller culverts. Note that all berm heights are measured from the culvert invert to the top of berm, so a majority of the berm may be shorter than the indicated height, because the ends of the berms tie into existing grades. These storage areas would not be classified as large dams subject to NR 333 based on either height or storage capacity. The configurations are:

- 4-foot berms with 4-foot diameter culverts
- 6-foot berms with 4-foot diameter culverts
- 6-foot berms with 2-foot diameter culverts

Results indicate that peak discharge from the design storm could be reduced by up to 15%, as shown in **Table 2**. In some simulations of the June 2008 flood, some of the berms were overtopped slightly. Final design of berms and outlets should be adjusted to prevent berm overtopping during this design event.

Table 2. Peak Discharge Reduction for Quarry Tributary

Configuration	Peak Discharge Reduction*
4' berms	11%
6' berms	14%
6' berms with 2' culverts	15%

*Peak flow was evaluated at the HEC-HMS component located 1000 feet upstream of STH 113.

Ponding depth and duration in the storage areas is shown on **Figure 4**. Generally, the ponding depth increases with higher berms and smaller culverts, and the duration increases with decreasing culvert size. The water level for the 6-foot berm configuration is 0.5′ or more above the culvert invert for about 20-25 hours for the 100-year (design) storm.

Planning-level cost estimates are summarized in **Table 3**. These estimates do not include long-term maintenance costs. Cost estimates may change based on the layout and construction details of the storage areas. The cost of storage area 7 is smaller because there is only one basin, and the land narrows at the outlet to allow for a smaller berm.

Table 3. Planning Level Cost Estimates

Location	Cost
Quarry Tributary	$260,000
Storage Area 7	$90,000

*Cost estimate for Quarry Tributary assumes 4-foot berm configuration

3.3 STORAGE AREA 7

Storage area 7 is located northwest of the intersection of Tower Road and Neuman Road (**Figure 2)**. This alternative would entail a single basin downstream of the existing sedge meadow and restored wetland. Potential impacts to this sedge meadow have been identified as a concern to be evaluated.

MARS examined storage options that would minimize impacts to the sedge meadow. The extent of the sedge meadow was surveyed by John Vosberg of NRCS as part of this study. The sedge meadow extends further west than anticipated, about halfway into proposed storage area 7 **(Figure 2)**. The elevation of the sedge meadow is approximately equal to the existing land surface at the

downstream end of the proposed storage area. Even a small berm would have the potential to change the inundation frequency, depth and duration of the sedge meadow. Therefore, options for storage at this location that avoid impacts to the sedge meadow may be limited.

Off-Line Storage

Off-line basins are one option for storage that was considered for this study. Off-line storage is created by diverting water from the main channel into a basin, or basins, in an overbank area. This is typically less effective for flood control, but it may be easier to permit as it requires no structure in the main channel. Unfortunately, off-line basins would have minimal benefit for proposed storage area 7 due to the flat land surface and shallow groundwater conditions. Effective off-line storage requires an elevation drop from the main channel to the storage area to create an efficient diversion from the main channel. Given the flat grades, this would require excavation of basins. However, surveyed water levels were within approximately 0.5′ of the existing ground surface leaving little potential for such excavation. No additional analysis of off-line basins was completed due to the lack of storage potential in this location.

In-Line Storage

Existing Conditions

The potential for in-line storage, which would be constructed with a berm and a culvert in the channel, was evaluated using the DNR HEC-HMS model. As part of this evaluation, MARS reviewed the DNR's modeling of storage provided by the existing wetland in this area. The locations and geometry of the cross sections in the HEC-RAS model used to develop the storage-discharge relationship for the wetland appear reasonable, compared with the 2-ft elevation contours and survey data collected for this study.

The storage in this area is complicated by a farm driveway and culvert approximately 800 feet downstream of storage area 7. Erosion on the downstream side of the driveway embankment indicates that the road has been overtopped in the past (**Figure 5**), and this is consistent with predicted upstream flood discharge and the typical capacity of a culvert of this diameter. Although the DNR model does not include this culvert, the DNR's stage-discharge relationship for the upstream wetland is generally consistent with the presence of this driveway. Thus, DNR's model appears to be a reasonable existing conditions model for comparison with flood mitigation alternatives.

The DNR model indicates that the natural storage provided by this wetland greatly reduces the impact of this tributary on peak flood discharge in the lower reach of Clark Creek along STH 113. The flow from these subwatersheds is not insignificant; the peak outflow from the wetland is about 20% of the peak flow downstream near STH 113. However, the model shows that the peak outflow from the wetland occurs *after* the peak near STH 113. If the two watersheds upstream of the wetland are eliminated from the model entirely, the predicted peak discharge near STH 113 is only reduced by 3%. This suggests that there is very little potential for additional peak flow reduction at STH 113.

Proposed Conditions

Proposed storage area 7 was simulated, as described above, by modifying the HEC-RAS model to include a 4-ft-high berm and 4-ft-diameter culvert at the downstream end of the wetland to develop

a new discharge-stage-storage relationship. The storage-discharge relationship was added to the HEC-HMS model to evaluate the benefit of enhanced storage for flood peak attenuation.

The proposed berm and culvert reduced the peak discharge in the reach immediately downstream of the wetland by 35%. As expected, the peak discharge reduction in the lower reach of Clark Creek along STH 113 was minimal – only 1%. This storage area would not be classified as a large dam subject to NR 333 based on height.

Depth-duration curves for storage area 7 are shown in **Figure 4**. The change is minimal for the 1-year and 2-year events. For the design flood, the stage is increased by approximately 0.5 ft for a given duration, and the duration of inundation at any particular stage is increased by a few hours.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

- Three storage basins constructed on the quarry tributary could reduce the peak discharge of a flood similar to the June 2008 event by 11 – 15% in the lower reach of Clark Creek along Highway 113.
- Construction of additional flood storage in the wetland north of Tower Road would only reduce the peak discharge of this design event by a few percent in the lower reach of Clark Creek along Highway 113. Storage provided by the existing wetland already delays the peak runoff from this tributary, so that it is not a major contributor to peak discharge in lower Clark Creek.
- However, additional flood storage in this wetland could reduce peak flood discharge by approximately 35% in the reach immediately downstream, where this tributary flows from the wetland, along the north side of Tower Road, to the confluence with other branches of Clark Creek.

4.2 RECOMMENDED ACTION PLAN

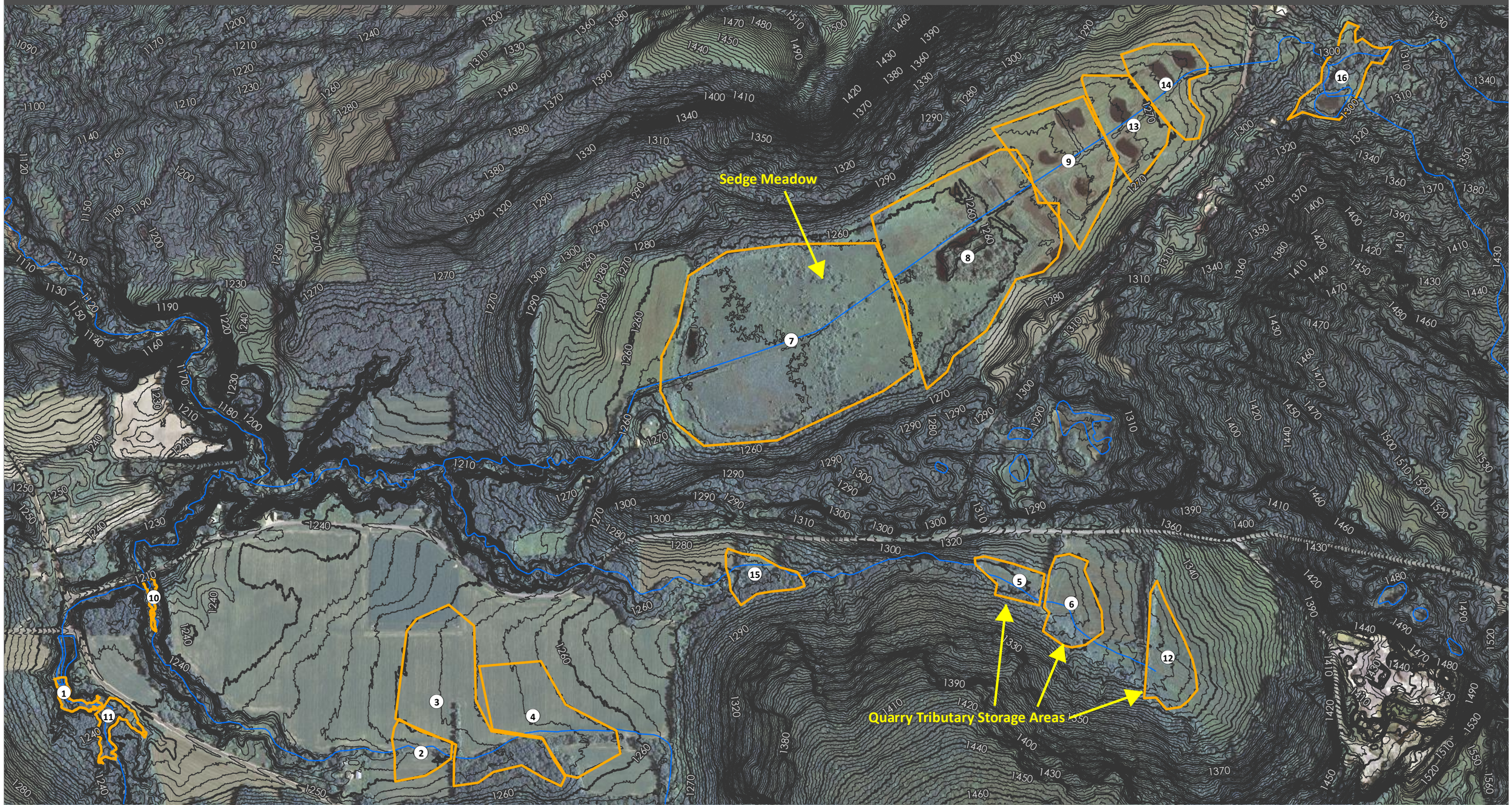
1. We recommend detailed consideration of the quarry tributary area for implementation of flood storage areas 5, 6 and 12. This includes continuing discussions with DNR regarding permit requirements, preparing preliminary designs and an opinion of probable cost, obtaining permits, and preparing final design and construction documents. Final design of berms and outlets should accommodate the design flows without berm overtopping.
2. We recommend additional consideration of flood storage area 7 in the wetland north of Tower Road only as a measure to reduce flood flows in the reach immediately downstream of the wetland, because this alternative would have minimal peak reduction benefit in the lower reach of Clark Creek along Highway 113.
3. We recommend evaluating the flood storage potential of other upland locations, including for the southern tributary where it crosses the large agricultural field south of Tower Road.

FIGURES

Clark Creek Watershed Study
Sauk County, WI

Figure 1
Wetland Storage Areas

Montgomery Associates: Resource Solutions, LLC
119 South Main Street, Cottage Grove, WI 53527
(608) 839-4422 | www.ma-rs.org | 01/20/2012



Clark Creek Watershed Study
Sauk County, WI

FIGURE 2

Survey Data
December 2011

Montgomery Associates: Resource Solutions, LLC
119 South Main Street, Cottage Grove, WI 53527
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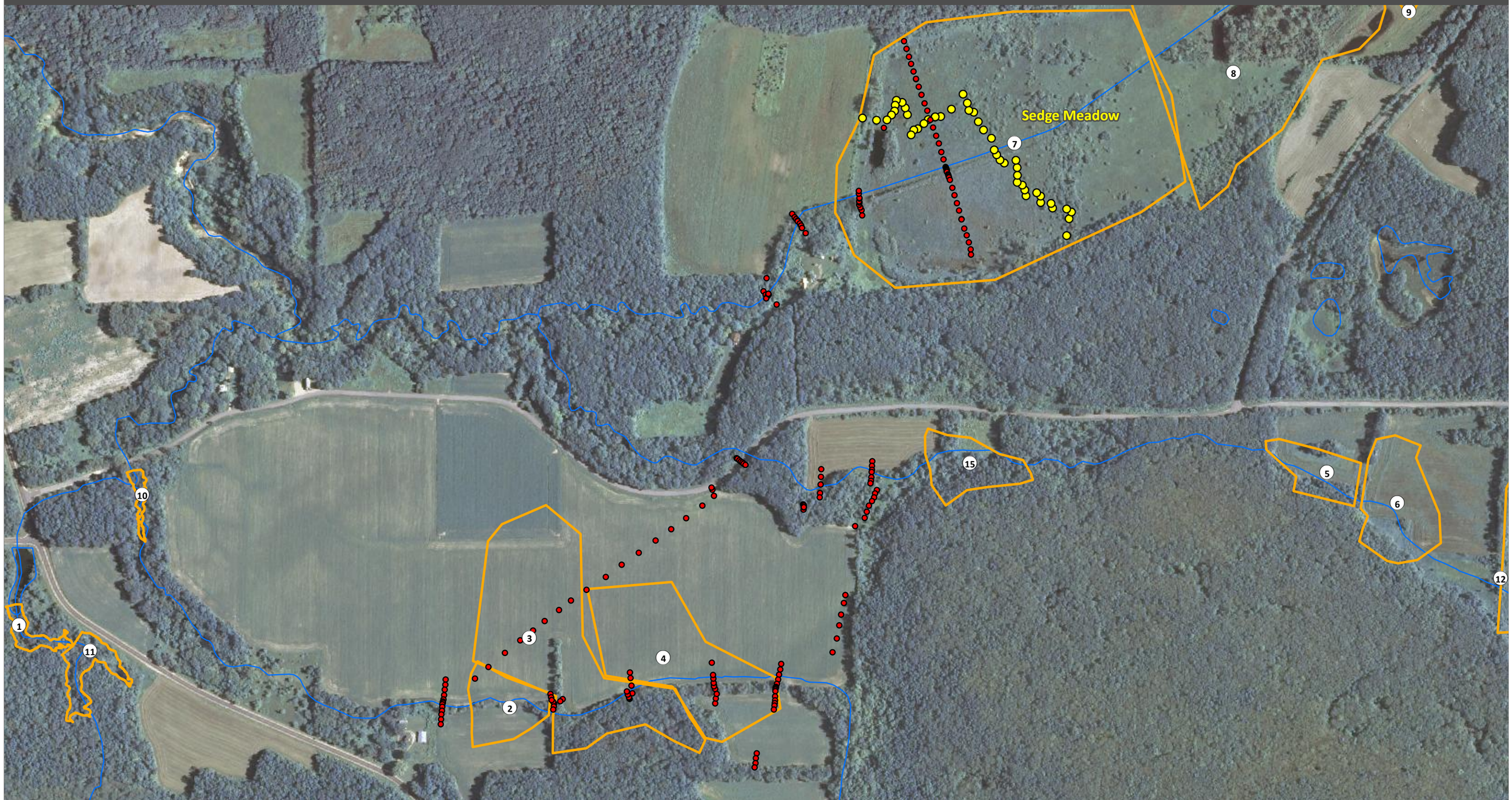
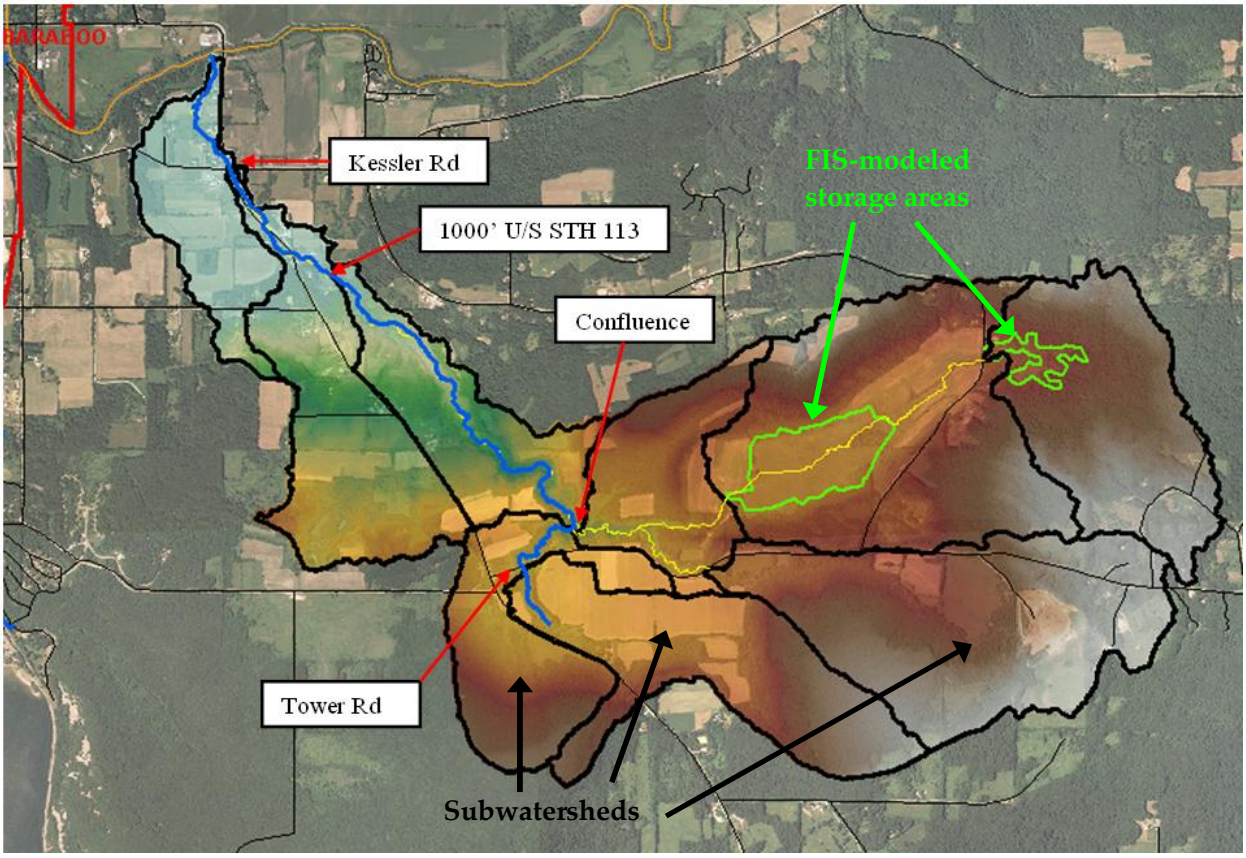
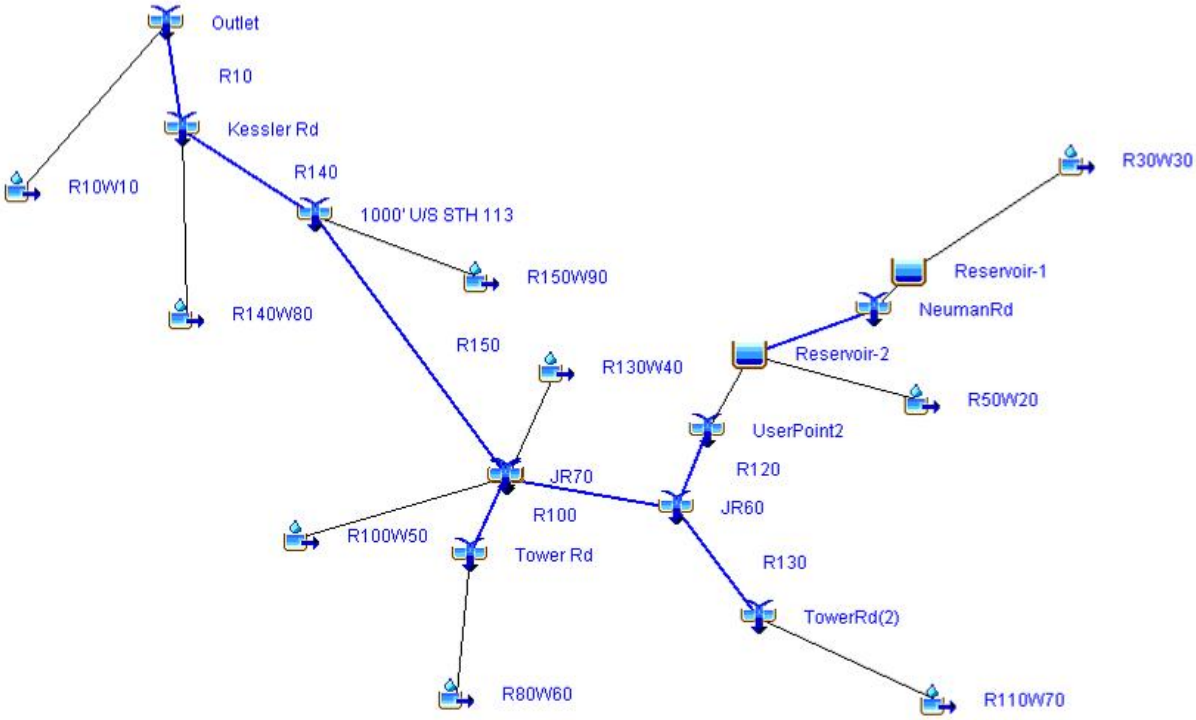


Figure 3: Watershed Hydrologic Model Layout



Above: Layout of watersheds in model. Below: HEC-HMS components.



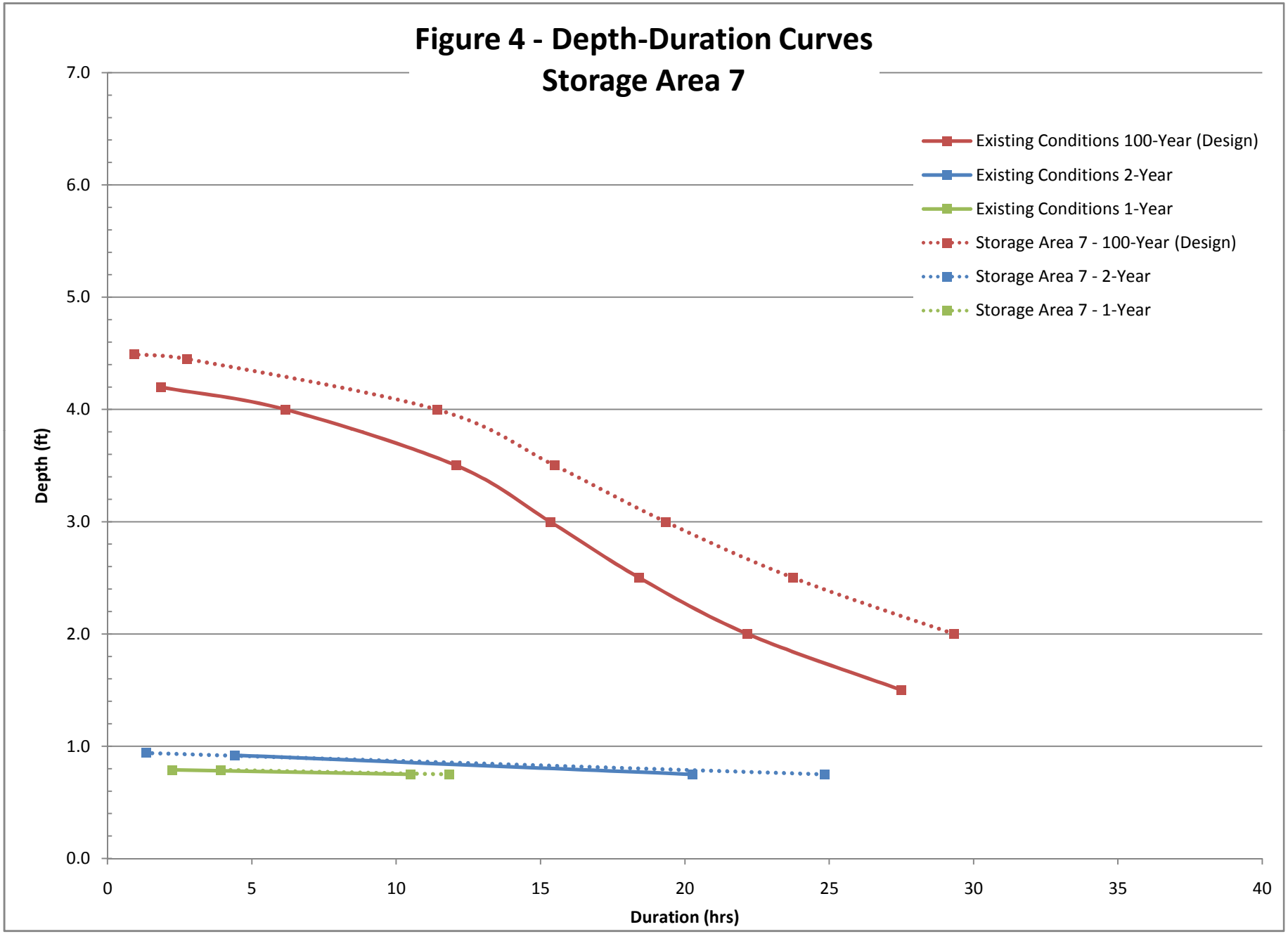
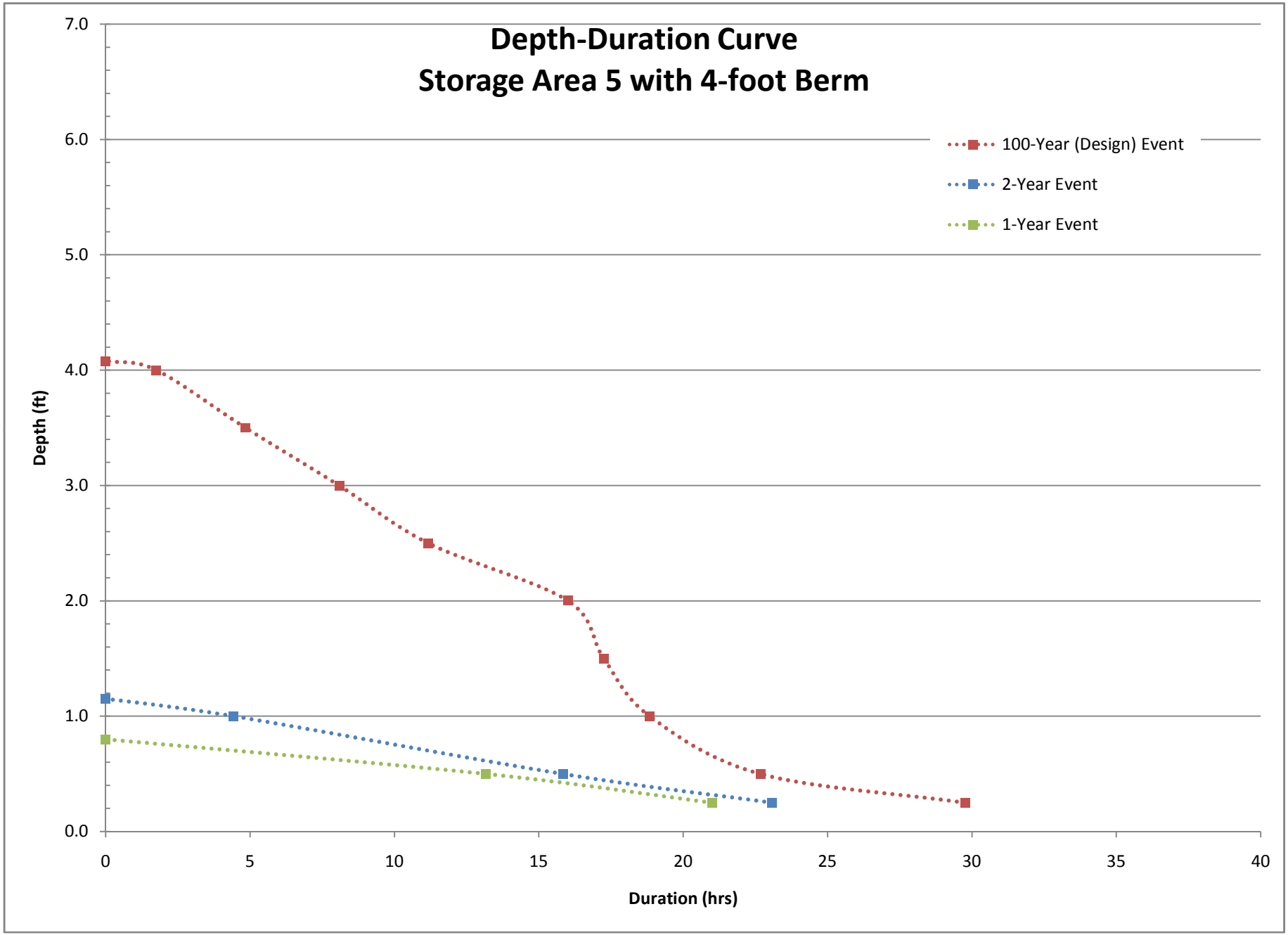
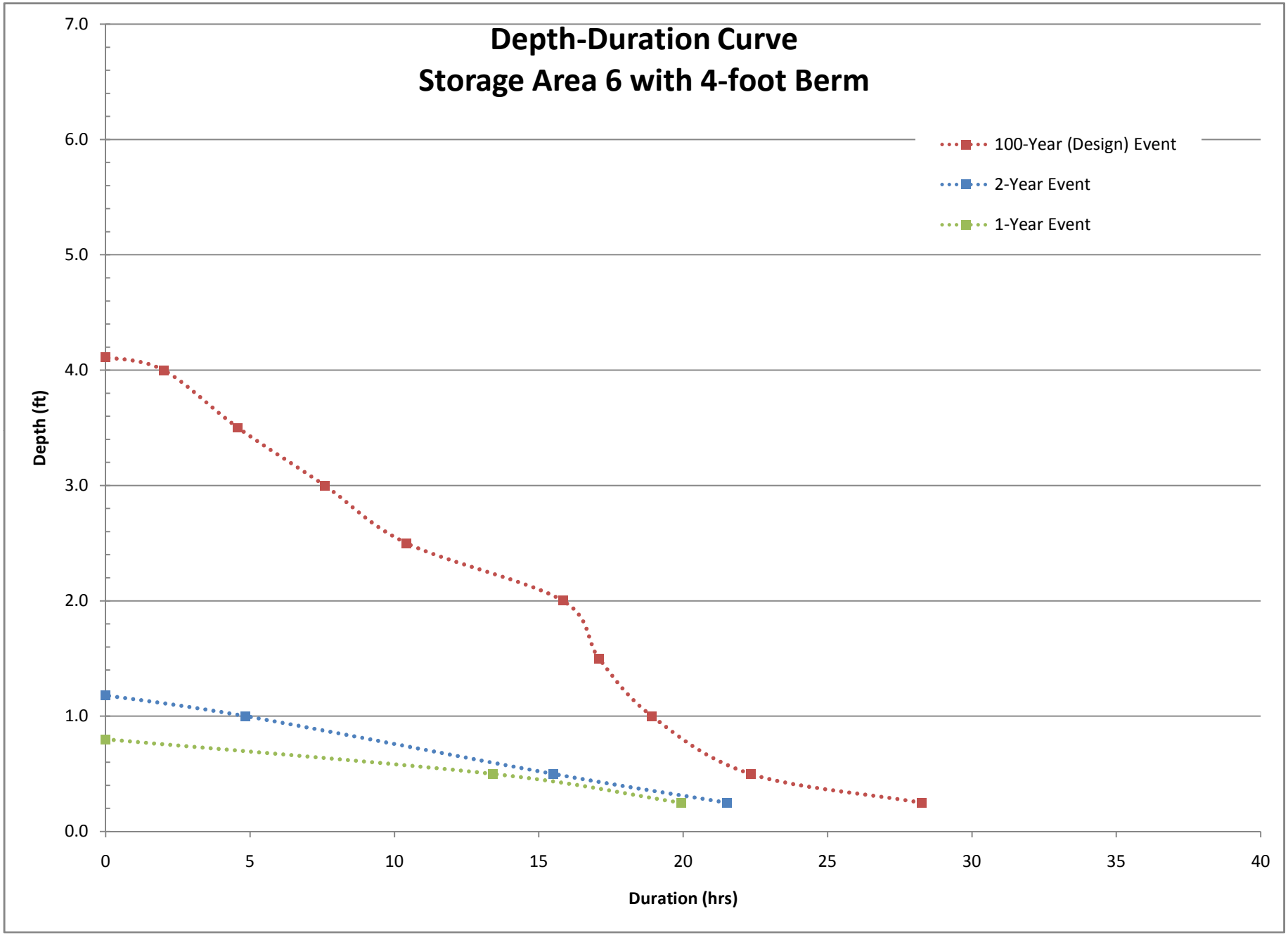
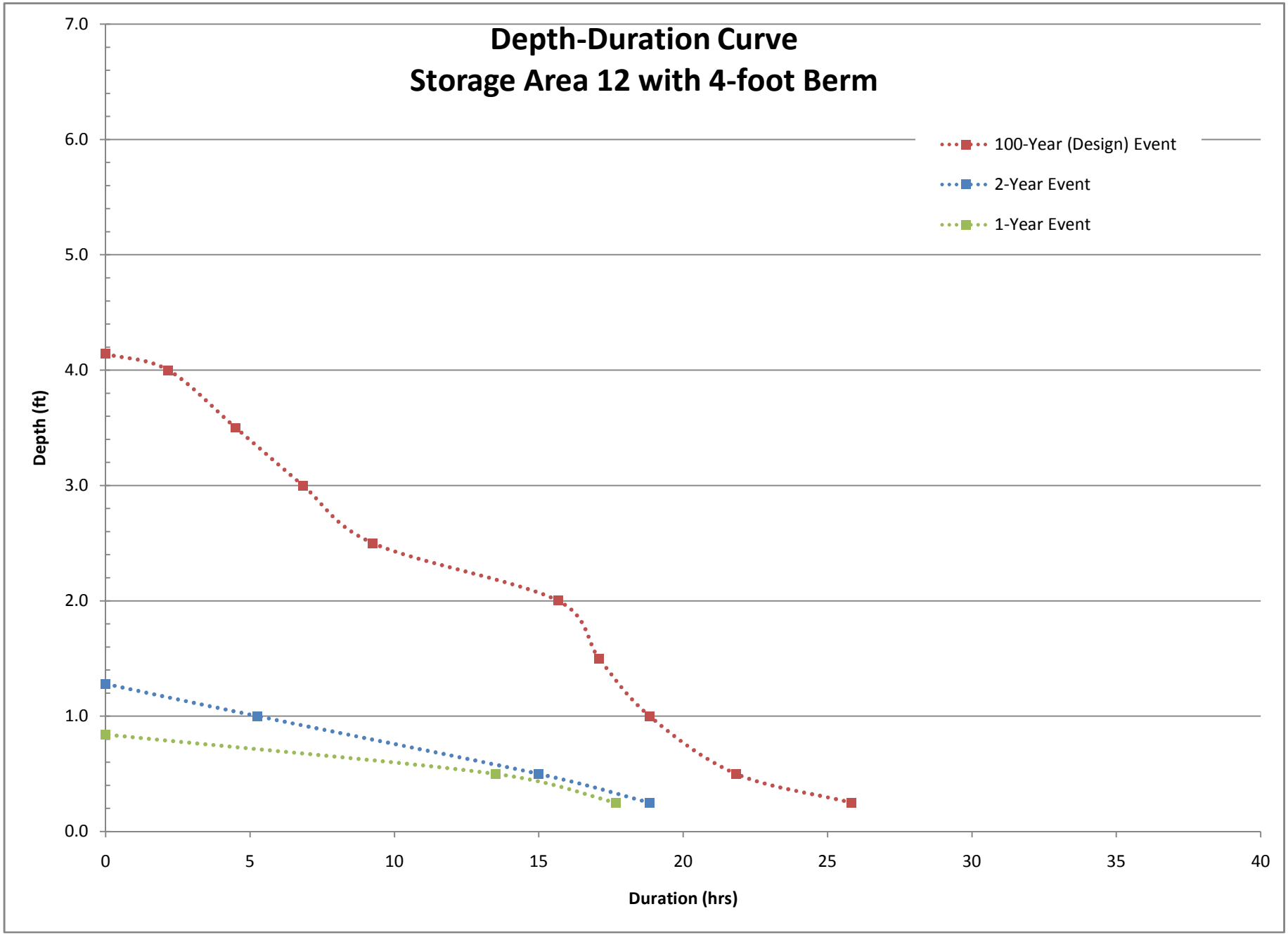
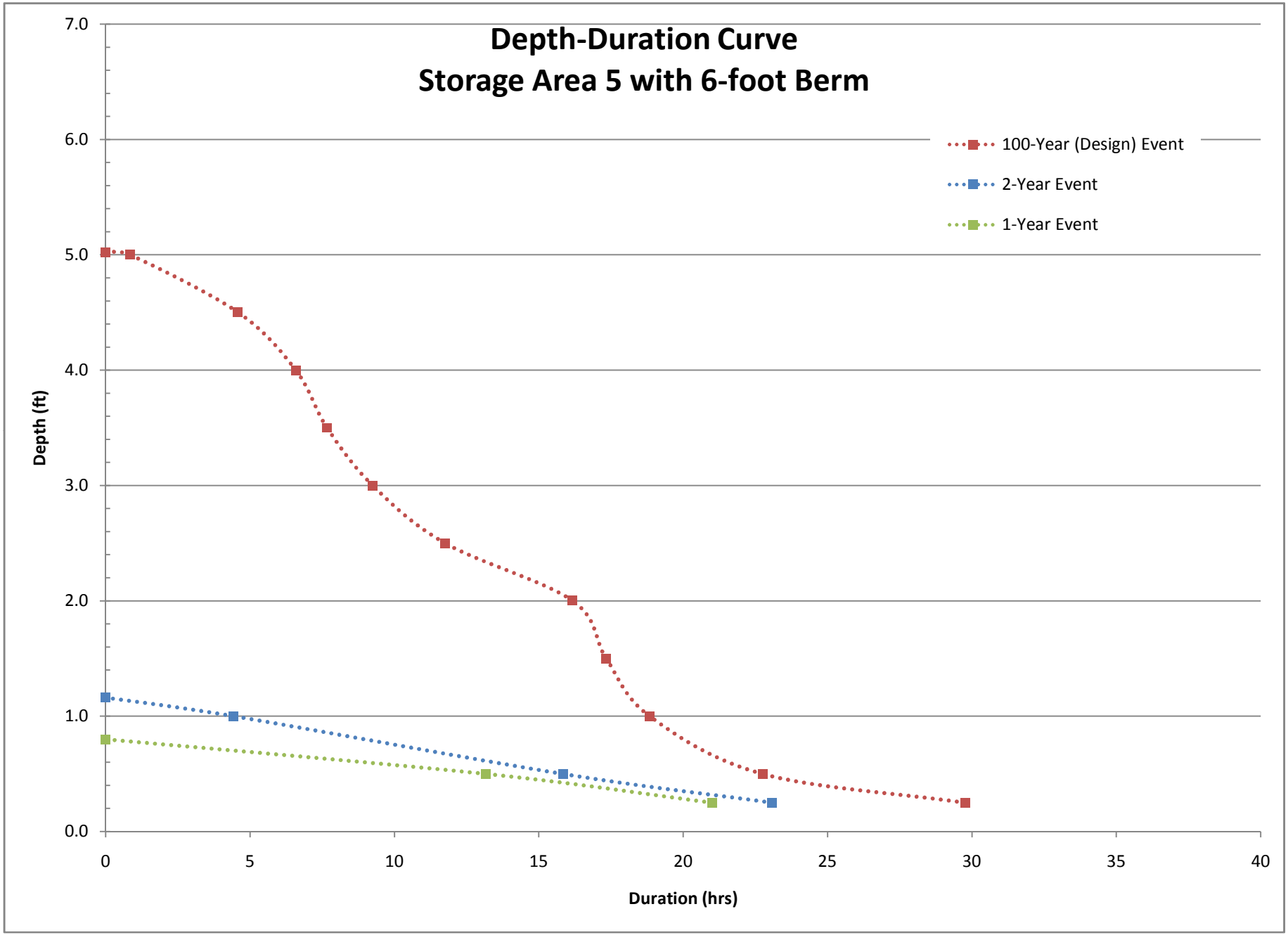


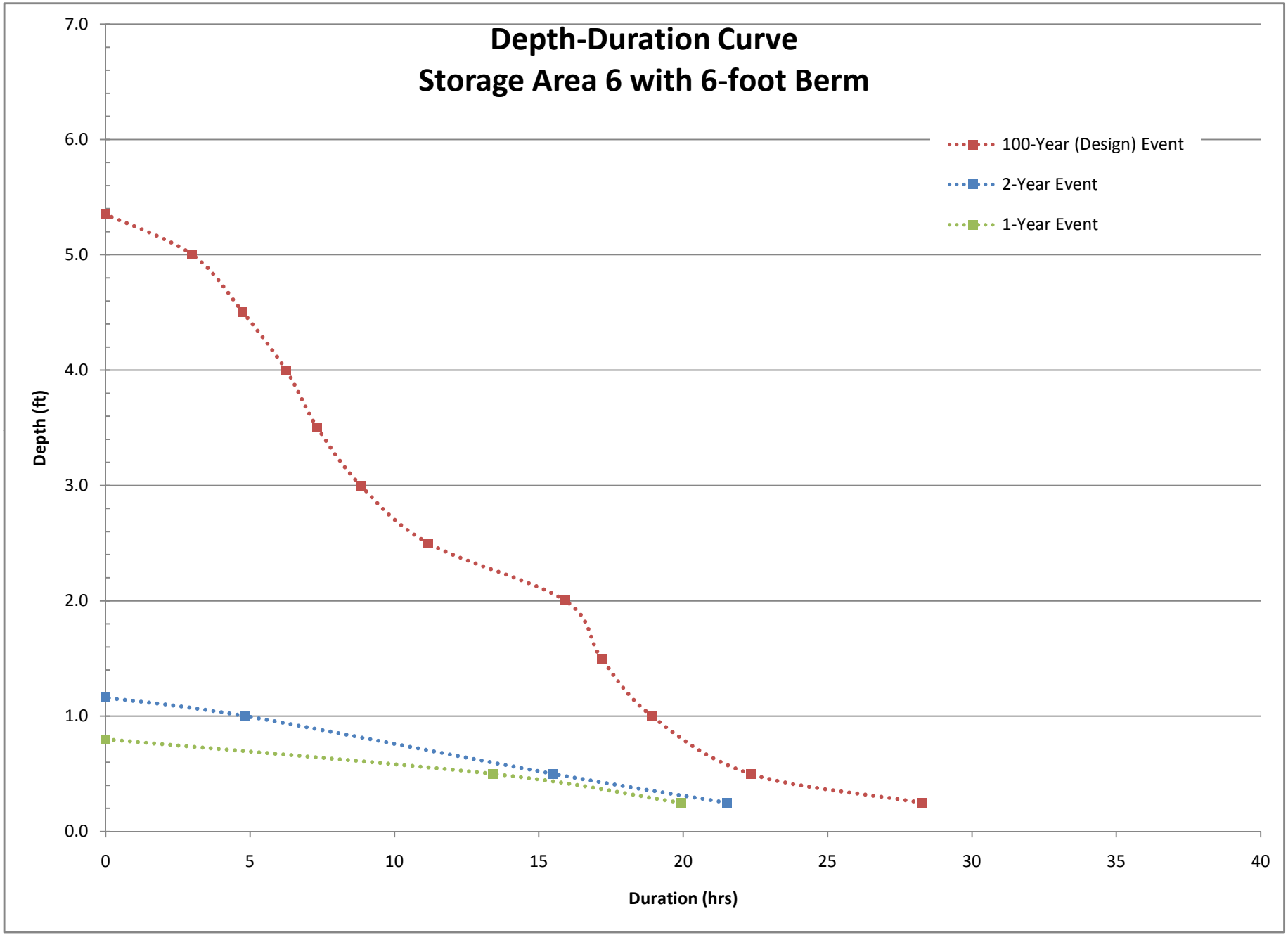
Figure 4 - Depth-Duration Curves
Storage Area 7
Existing Conditions 100-Year (Design)
Existing Conditions 2-Year
Existing Conditions 1-Year
Storage Area 7 - 100-Year (Design)
Storage Area 7 - 2-Year
Storage Area 7 - 1-Year
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)

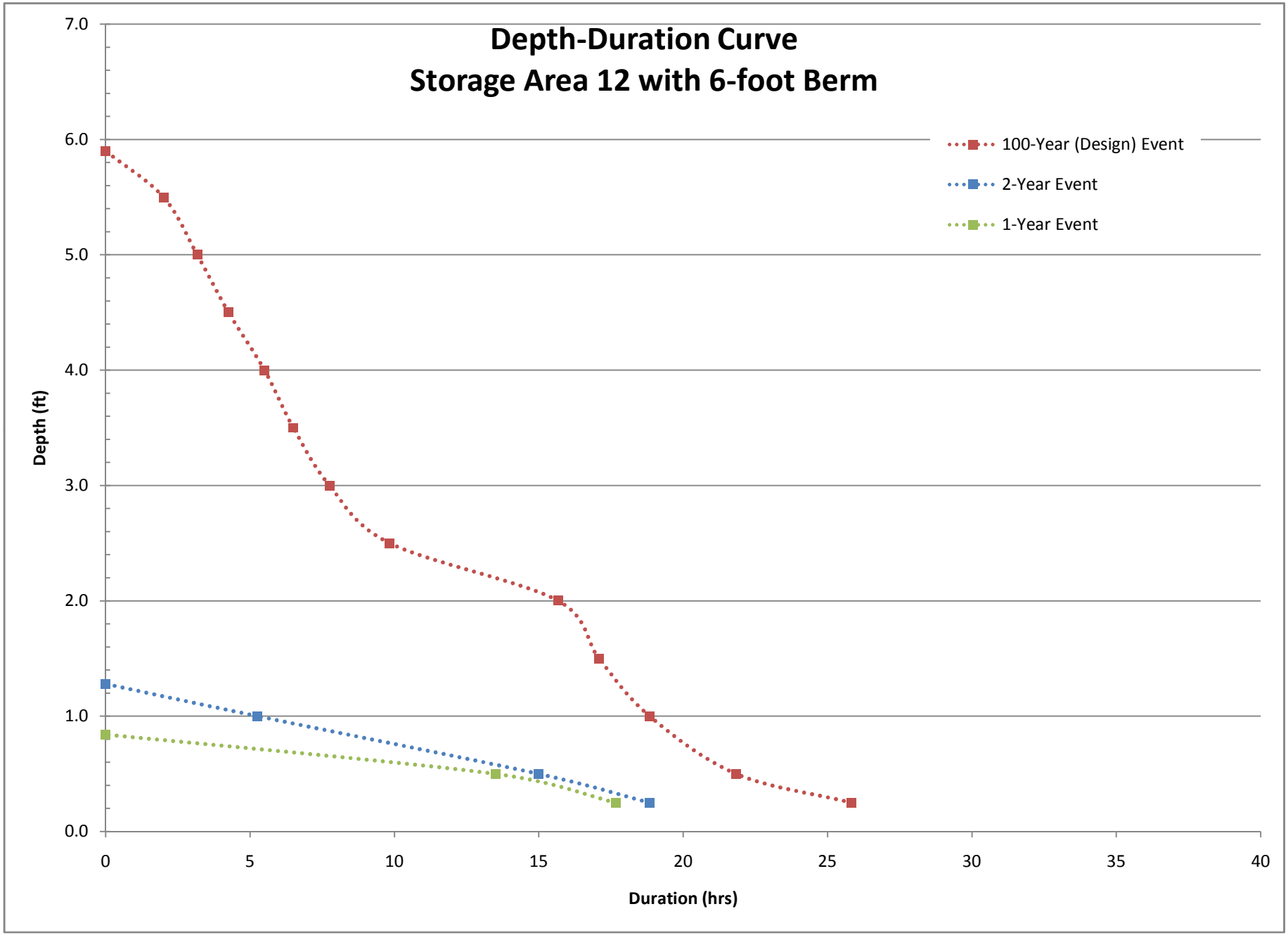

Depth-Duration Curve
Storage Area 5 with 4-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)

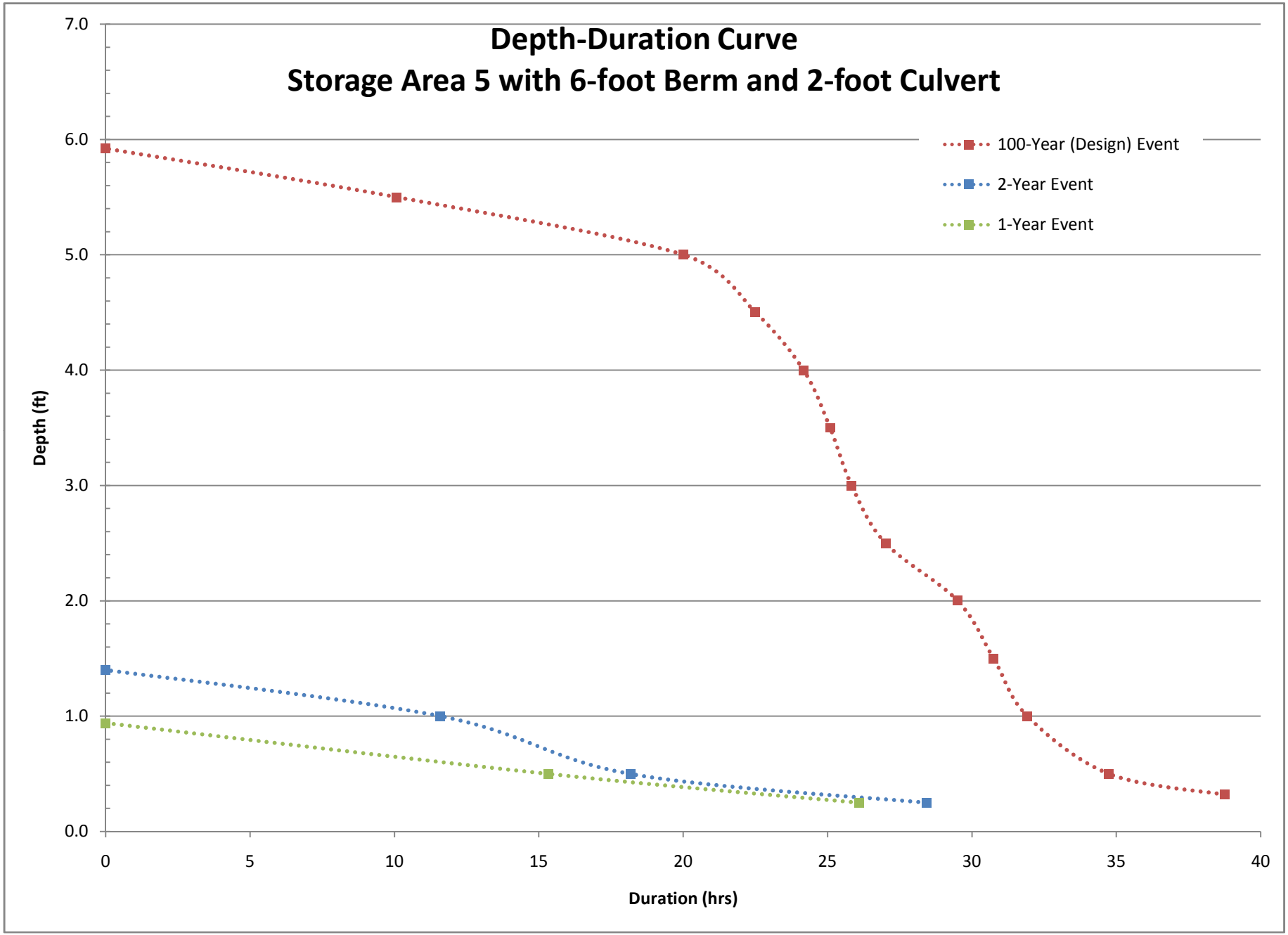

Depth-Duration Curve
Storage Area 6 with 4-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)

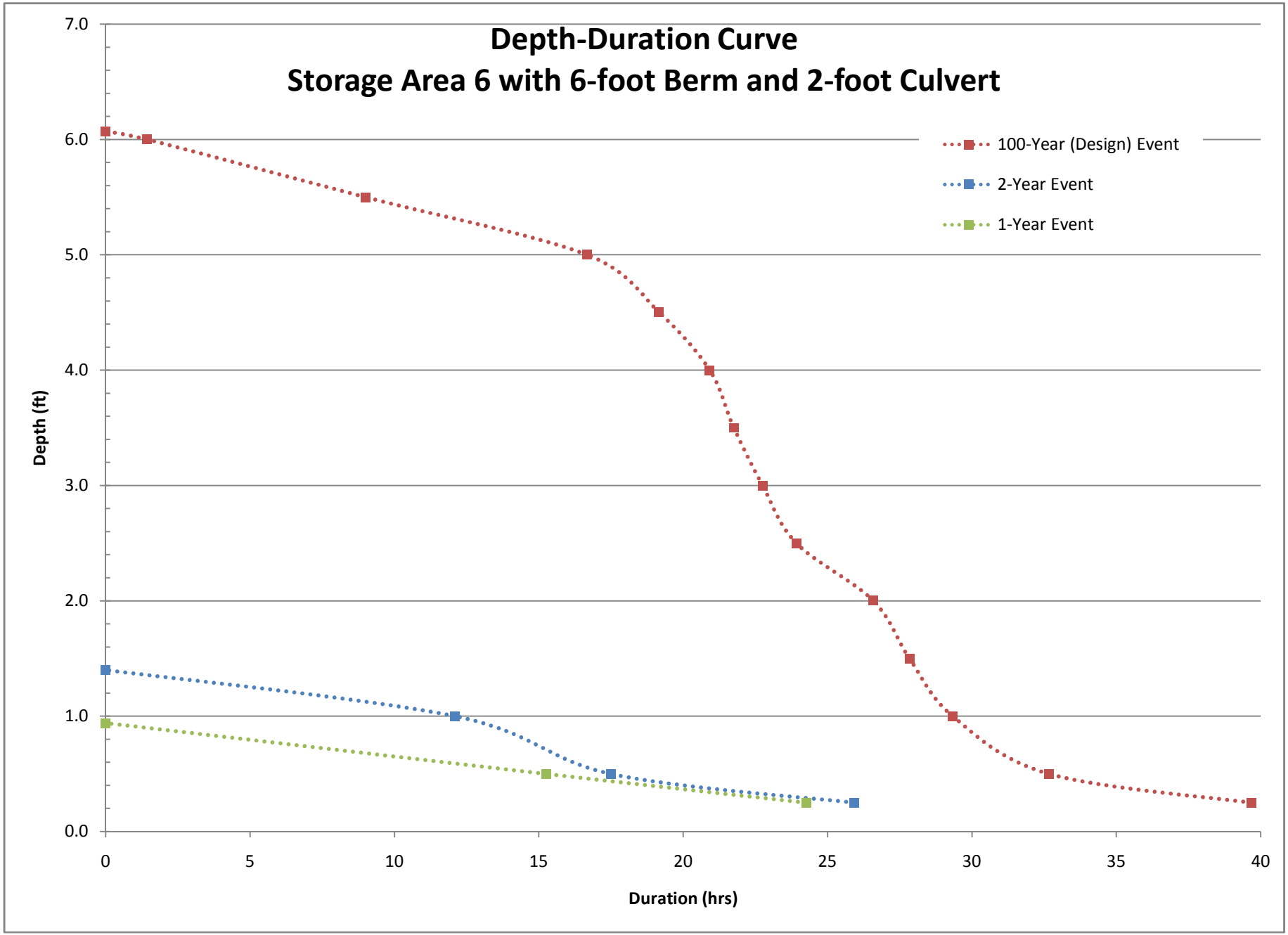

Depth-Duration Curve
Storage Area 12 with 4-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)


Depth-Duration Curve
Storage Area 5 with 6-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)


Depth-Duration Curve
Storage Area 6 with 6-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)


Depth-Duration Curve
Storage Area 12 with 6-foot Berm
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)


Depth-Duration Curve
Storage Area 5 with 6-foot Berm and 2-foot Culvert
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)


Depth-Duration Curve
Storage Area 6 with 6-foot Berm and 2-foot Culvert
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)

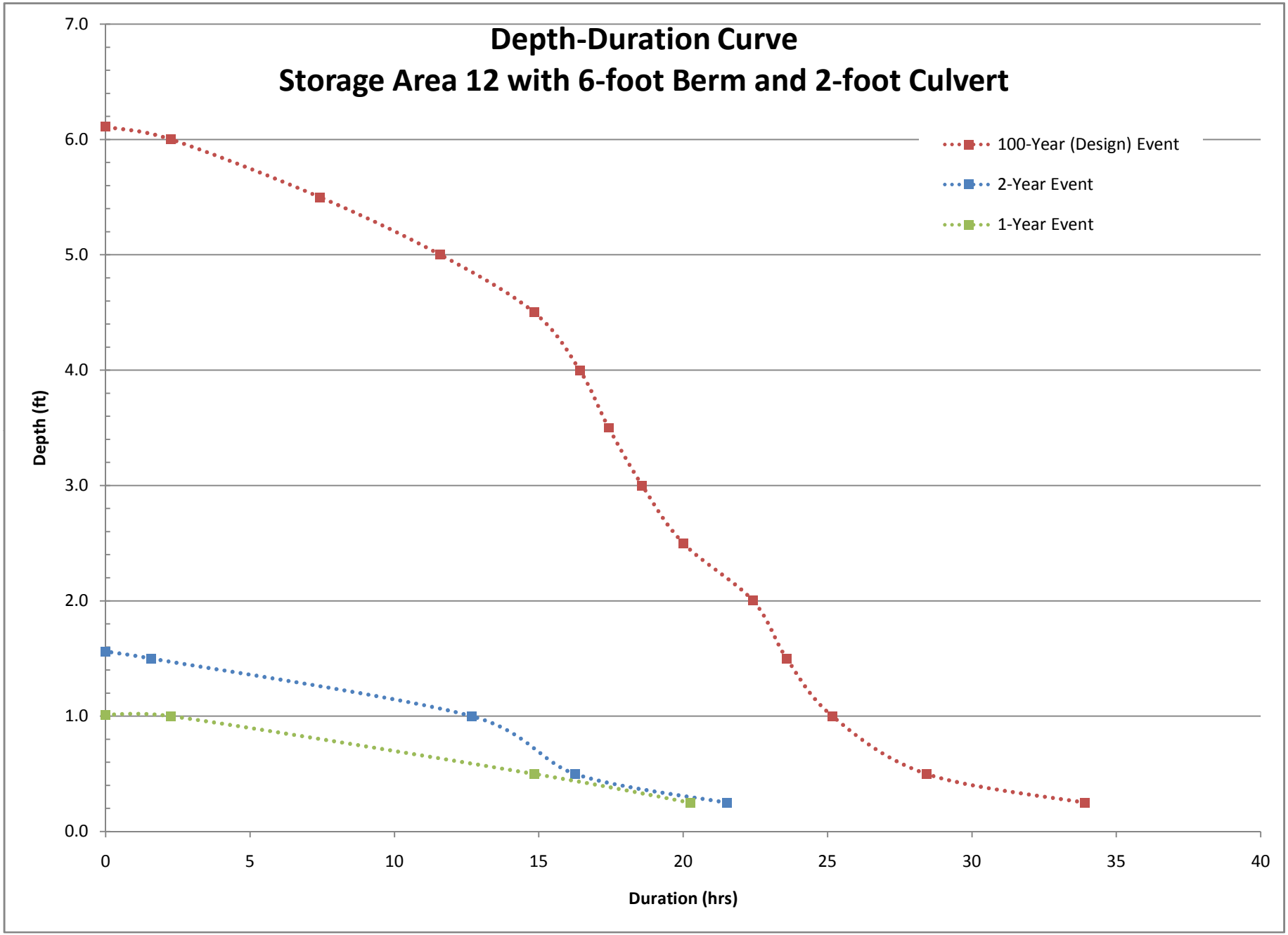
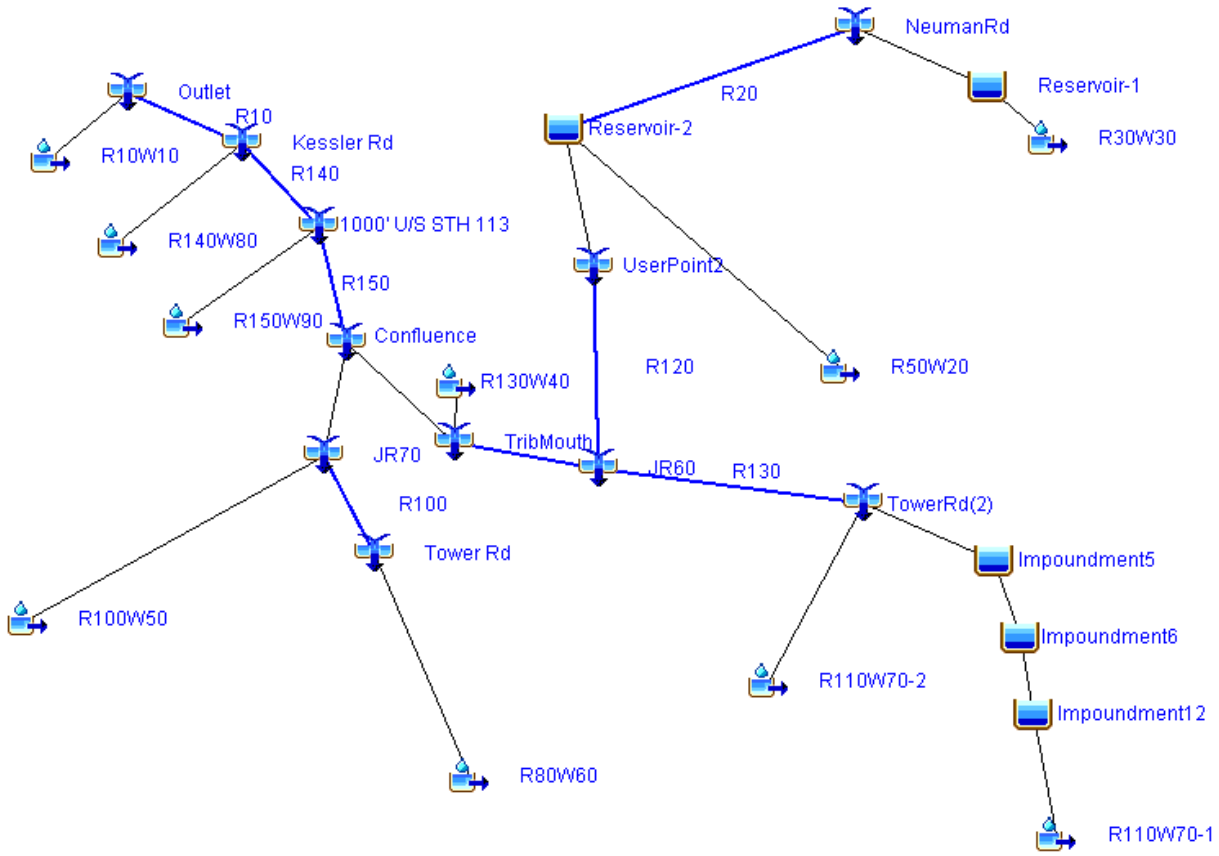
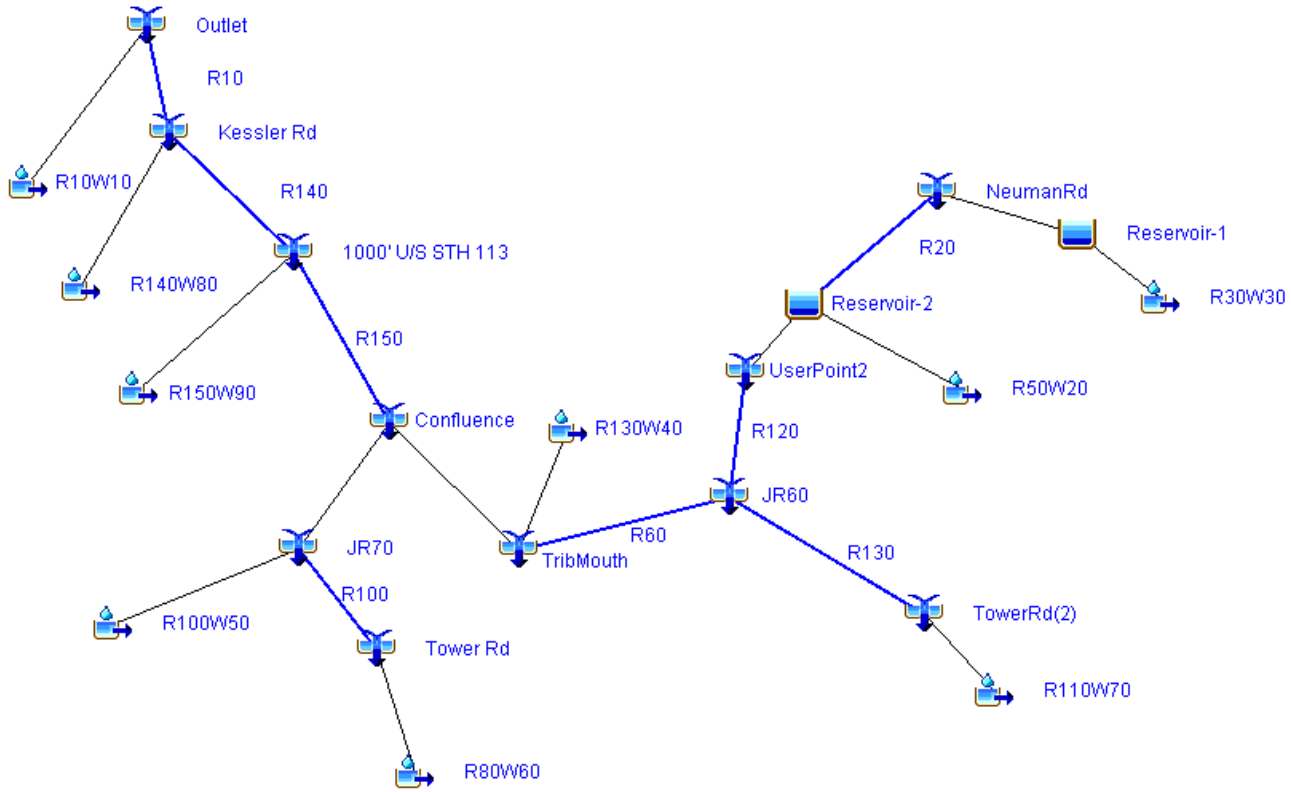

Depth-Duration Curve
Storage Area 12 with 6-foot Berm and 2-foot Culvert
100-Year (Design) Event
2-Year Event
1-Year Event
Depth (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
35
40
Duration (hrs)

Figure 5: Farm Culvert Downstream of Storage Area 7

APPENDIX A - HEC-HMS MODEL DETAILS

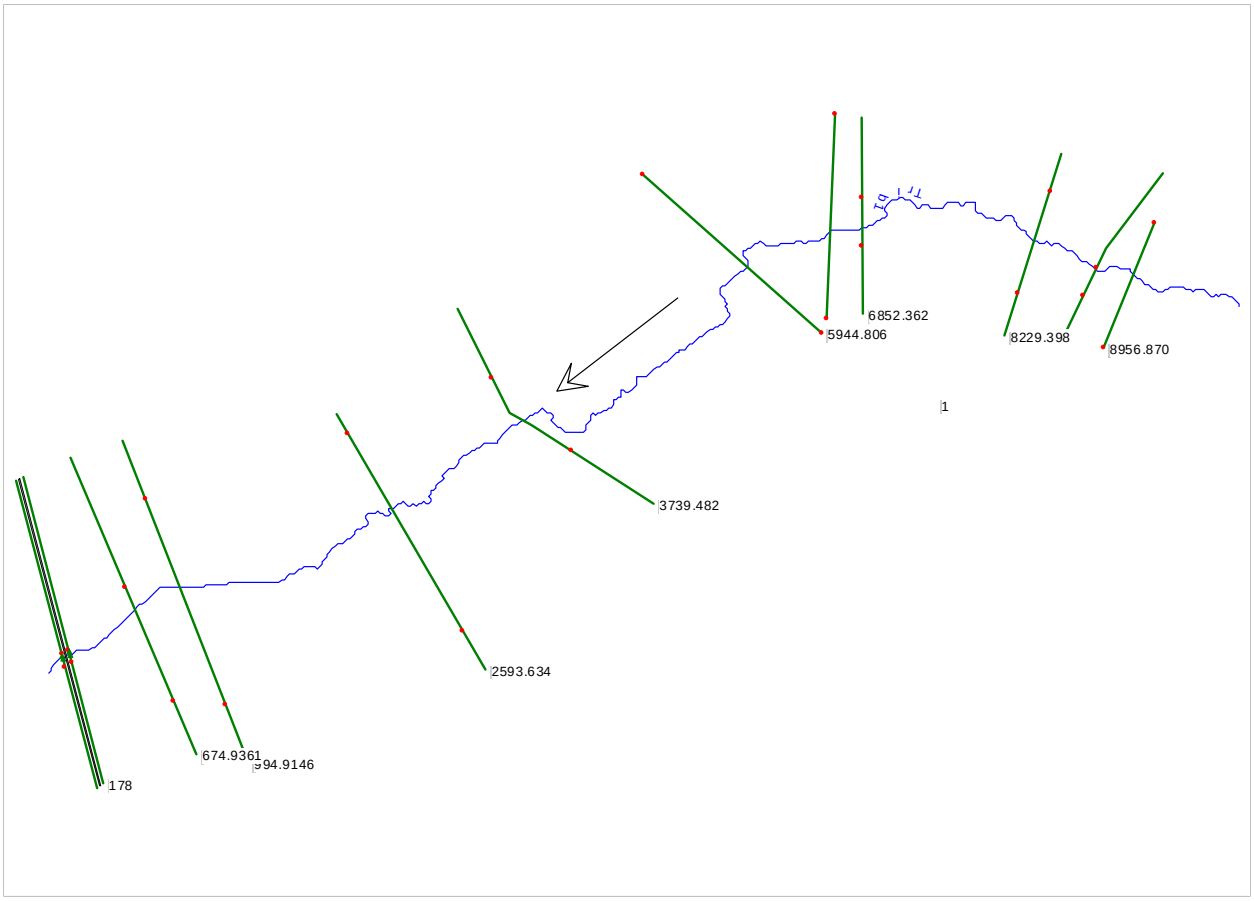


Layout of HEC-HMS model of quarry tributary storage area (proposed conditions).

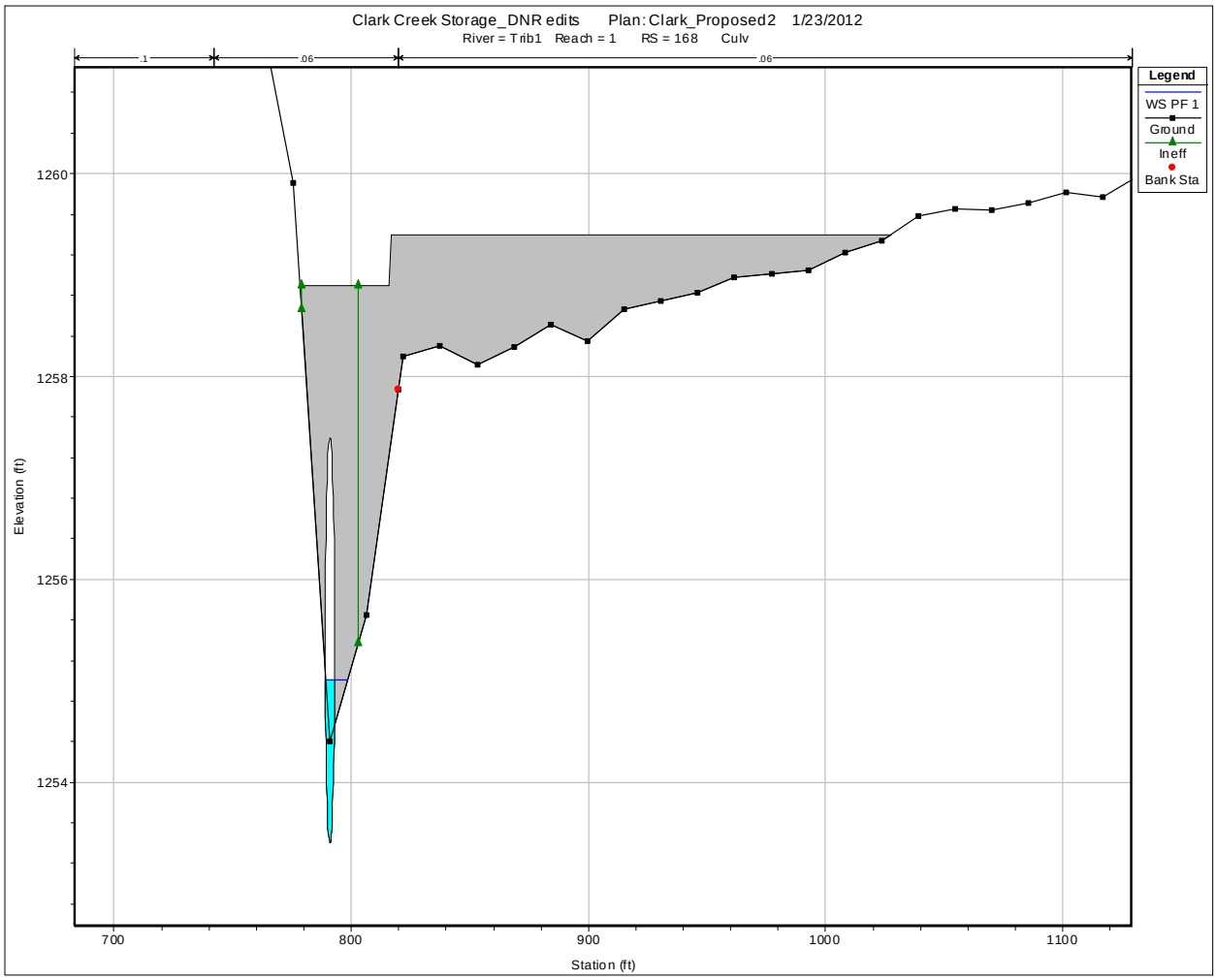


Layout of HEC-HMS model of storage area 7 (proposed conditions). Reservoir-2 was used to model storage area 7.

APPENDIX B - HEC-RAS MODEL DETAILS



Layout of HEC-RAS model of wetland storage area 7 (proposed conditions).



HEC-RAS cross section for proposed berm, weir section and culvert for wetland storage area 7