SAND CANYON OUTLET STRUCTURE ALTERNATIVES ANALYSIS

PREPARED FOR:

SAN LUIS OBISPO COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

BY:

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Executive Summary

Oceano is subject to periodic flooding near the intersection of Meadow Creek and Arroyo Grande Creek. Meadow Creek is a complex system that functions both as a conveyance channel and a storage basin. It is also influenced by tides and flows in Arroyo Grande Creek. The lack of storage capacity in the Meadow Creek watershed and the Meadow Creek Lagoon combined with the current outlet capacity at the Sand Canyon Flap Gate structure results in a level of flood protection that is less than the 100-year event for some Oceano residents.

This report was prepared at the requests of the San Luis Obispo County Flood Control and Water Conservation District (SLOFCWCD) and represents the opinion of the Coastal San Luis Resource Conservation District. It attempts to address questions about feasibility, impact and potential effectiveness of modifying the Sand Canyon outlet structure to reduce upstream flooding based on the limited information available at the time. However, a detailed hydrologic analysis is beyond the scope of this report. The hydraulic and hydrologic modeling provided is only intended to provide a reasonable framework to discuss and evaluate options. The models are not detailed and not intended to accurately reflect conditions in the watershed. Many potential factors that impact flooding, such as tidal surges, wave run-up, water surface elevations in Arroyo Grande Creek were not accounted for in the models due to a lack of data. It should also be noted that this report is a small piece of a multi-step effort by the SLOFCWCD to address flooding in Oceano. Additional studies are recommended.

Various options for improving the functionality of the Sand Canyon outlet were considered and evaluated using limited hydrologic and hydraulic models intended to provide a reasonable framework to asses relative benefits for potential options to improve the functionality of the Sand Canyon Outlet Structure. This report shows that modifications to the outlet may provide benefits during smaller storm events-. However, such improvements will likely not reduce flooding in the 100-year event. The results of the modeling and analysis indicate the following:

1. The size of the existing culverts is appropriate based on the elevations of the flow line of the creek and the head limitations imposed by low finished floor elevations in nearby homes. Increasing the size and/or lowering the elevation of the culverts would have minimal effect on flood elevations.

2. The existing heavy, top-hinged flap gates currently in operation are an appropriate choice for this application. Other types could be as effective with additional environmental benefit.

3. Increasing the number of culverts is the most efficient way to reduce flood elevations in smaller events.

4. Increasing outlet capacity alone is likely inadequate for reducing flood elevations in the larger storm events. Upstream solutions may be required to provide a higher level of protection.

5. Potential solutions such as weirs, pre-storm pumping, siphons and tailwater elevation reduction yield questionable benefit.

Increasing the capacity will be helpful in reducing flood frequency, but will not eliminate flood risk due to the significant inflow to the lagoon. Adding two culverts similar in size to the existing outlet structure may be sufficient to reduce flooding from events similar to the storm experienced in

December of 2010. Outlet improvements are unlikely to provide increased flood protection in the 100-year storm event because the entire area is located within the FEMA 100-year flood plain. Future efforts should include studies on a watershed level to provide alternatives to reduce inflows to the lagoon further enhancing the ability of the lagoon system to provide necessary flood protection to the surrounding residents.

Introduction

The County of San Luis Obispo Flood Control and Water Conservation District (District), in an effort to reduce the extent and frequency of flooding in the area surrounding the Meadow Creek Lagoon, commissioned the Coastal San Luis Resource Conservation District (RCD) to prepare this alternatives study to evaluate options for improving the functionality of the Sand Canyon Outlet Structure. The RCD has conducted the following engineering analysis to compare available equipment and technology, explore alternatives, and identify areas where additional study is warranted. This analysis includes an evaluation of the pros and cons for several back flow prevention type gates, as well as a benefit analysis associated with various options for improving the flow conveyance of the Sand Canyon outlet structures in order to reduce area flooding.

Setting

The Meadow Creek watershed encompasses approximately ten square miles, including portions of Arroyo Grande, Grover Beach, Pismo Beach and unincorporated Oceano. Land uses include urban, rural residential, rangeland, and wildlife habitat/open space. Meadow Creek flows to the ocean at two locations: at Carpenter Creek and through the outlet culverts at Meadow Creek Lagoon (known as Sand Canyon Outlet Structure) in the community of Oceano.

Meadow Creek Lagoon (also called Oceano Lagoon) is located in the community of Oceano, where the downstream end of Meadow Creek meets Arroyo Grande Creek at its outlet to the Pacific Ocean. The lagoon is located on property owned by the California Department of Parks and Recreation. Surrounding properties include private residences, parcels owned by the County of San Luis Obispo, the South County Sanitation District and the Oceano Airport (See Appendix IV for a detailed ownership map). Originally a dune lake, the lagoon has evolved into its current state in part due to the installation of the flood control infrastructure at the confluence of Meadow Creek and Arroyo Grande Creek in 1958 when the Arroyo Grande Creek Levee System was constructed. This facility is known as the Sand Canyon Outlet Structure is the focus of this report.

The Sand Canyon Outlet Structure consists of two arch pipe culverts, approximately 48 inch by 71 inch in cross section and 65 feet long (Note: culvert size measurements vary due to potential settling and / or sediment accumulation). The culverts convey storm flows from the Oceano Lagoon, to the mouth of the Arroyo Grande Creek where storm flows are discharged to the Pacific Ocean. At the inlet of the culverts is a trash rack, or debris screen. At the outlet of each culvert are iron flap gates (Hydrogate model 50C or similar) that prevent high flows from Arroyo Grande Creek, as well as high tides from the Pacific Ocean, from flowing into Oceano Lagoon. A manually operated winch system has been installed / connected to the flap gates which allows for the manual opening of the flap gates. Flap gates are not operated manually during storms, but are operated (opened and closed) monthly during facility inspections to verify function and check for debris.

The Sand Canyon Outlet Structure and surrounding area is located within the FEMA 100-year flood plain (See Appendix IV). The invert elevation is approximately 6.4. The lowest finished floor elevation of homes in the surrounding area is approximately 10.4.

Problem

Oceano is impacted by frequent flooding in the neighborhoods surrounding the Meadow Creek Lagoon. Meadow Creek Lagoon is a complex system that functions both as a conveyance channel and a storage basin. Flooding occurs when the inflow volume and/or flow rate exceed the combined storage and outlet capacity of the lagoon. Due to the size of the watershed inflow rates frequently exceed the outflow capacity at the Sand Canyon Outlet Structure. As a result runoff is stored in the lagoon. Flooding results when the storage capacity of the lagoon is exceeded.

Increasing outlet capacity is one of several viable watershed solutions that would typically be evaluated. Other solutions aimed at the reduction of inflow, vegetation and sediment removal are outside the scope of this report as they are outside the District's immediate control and are areas where further study will be necessary. Therefore, the focus of this report is to identify feasible modifications to the Sand Canyon Outlet Structure, as well as any other solutions, that can be implemented by the District to provide immediate, near term flood protection benefits to the areas surrounding the Meadow Creek Lagoon.

Modifications to be identified will involve changes in physical features, such as size, number, and elevation of existing structure, as well as improvements relating to new technologies in back flow prevention type gates. Other solutions that may improve the flooding situation in and around the Meadow Creek Lagoon will also be identified and evaluated.

The analysis addresses the following questions / objectives:

1. Will increasing the size of the culverts improve the flooding situation in Meadow Creek Lagoon?

2. Will increasing the number of culverts improve the flooding situation in the Meadow Creek Lagoon?

3. Will changing the invert elevation of the culverts improve the flooding situation in the Meadow Creek Lagoon?

4. Will changing the type of back-flow prevention gates improve the flooding situation in the Meadow Creek Lagoon?

5. Are any solutions capable of improving the flooding situation in the Meadow Creek Lagoon?

6. What additional studies are recommended / needed in the future to fully address the Meadow Creek Lagoon flooding problem?

This report presents a limited hydrologic and hydraulic analysis intended to provide a reasonable framework to evaluate potential options for improvement and to better understand the constraints of the system. A limited hydraulic and hydrologic model was developed to simulate a 72 hour storm event similar to the December 2010 storm.

Preliminary Alternatives Assessment

The following preliminary alternatives assessment was prepared to evaluate options for increasing outflow from the Meadow Creek Lagoon. Consideration was given to modifying the existing Sand Canyon Structure (as described in the previous section). This section will review other potential options for increasing flood storage and outlet capacity. The CSLRCD evaluated several options including; pre-storm pumping, downstream water level reduction, inverted siphons, and roller gates, along with the traditional option of adding culverts.

The alternatives evaluated below were identified as options since they are in the immediate vicinity of the existing structure. Options for increasing upstream storage or improving outlet capacity at Carpenter Creek are outside the scope of this study (as they are outside the immediate operation and maintenance control of the District). Further study of these solutions is recommended.

A detailed discussion of alternatives is provided. Table 1 below summarizes the results of this assessment.

Table 1. Alternative solutions

OPTION	IMPACT	COMMENTS
Pre-Storm Pumping	Minimal	The amount of storage gained is negligible when compared to the amount of runoff generated in storm events. This storage would be unavailable by the time peak flows occur.
Tailwater Reduction	Undetermined	Modeling results indicate that reducing the tailwater elevation, through sandbar management or other alterations to Arroyo Grande Creek, may increase culvert capacity by changing the flow characteristics from outlet control to inlet control. However, the data available to fully analyze this option was not available at the time this report was written.
Siphon	Similar to adding more culverts	Impact could potentially be similar to adding culverts. However, the size required would be as large as or larger than culverts alone, the downstream end would likely be influenced by tidal shifts, the length pipe required would require significant maintenance making it unreliable, and likely cost more.
Weir Structures	Similar to adding more culverts	Wier structures like roller gates could potentially reduce flood elevations in smaller storms. However, they appear to be no more effective than adding culverts. Physical constraints such as the height of the levee could drive cost up.

Pre-Storm Pumping

Pre-storm pumping was identified as a potential option for increasing the available storage in the lagoon in advance of a storm event. The hydraulic and hydrologic models (previously discussed) were used to evaluate the feasibility and effectiveness of this solution. These models indicate that pre-storm pumping could provide as much as 14 AF of additional storage in the lagoon by pumping the majority of the water out prior to the storm event. This would require pumping approximately 450 GPM for seven days prior to the storm. However, the basin model indicates that this additional storage would have no appreciable impact for the custom design storm simulation. The peak flood elevation changed by less than 0.1 feet because the additional 14 AF of storage gained by pre-storm pumping would be filled with runoff before the peak of the hydrograph. The additional 14 AF of storage generated by pre-storm pumping Is inadequate to provide meaningful flood reduction due to the large volume of runoff generated from the watershed.

Tailwater Reduction

The outlet capacity of the existing Sand Canyon Flap Gates is clearly limited by downstream water surface elevations. Water surface elevations on the downstream side of the gate are dictated by flow in Arroyo Grande Creek and sea level elevations downstream. During storm events the Sand Canyon Gates can be forced closed because the water surface elevation on the downstream side of the gates is higher than the water surface elevation in the lagoon. This is necessary to prevent water in Arroyo Grande Creek from entering the lagoon. However, during the period when the Sand Canyon Gates are closed, water can continue to collect in the lagoon.

Water surface elevations downstream of gates are not available for the December 2010 event. However, water surface data collected by the county since early 2011 indicates a strong likelihood that water surface elevation in Arroyo Grande Creek impact outflows from the lagoon.

Increasing the width of Arroyo Grande Creek in the vicinity of the Sand Canyon Gates, or cutting an outlet straight through the dunes to the ocean (sandbar management), could feasibly reduce the water surface level downstream of the gates and thus increase the outflow from the lagoon. The hydraulic and hydrologic models (previously discussed) were used to evaluate the impact of tailwater reduction on peak flow. The models indicate that reducing the tailwater elevation could increase the capacity of the culverts by changing the culvert flow condition from outlet control to inlet control. However, the impact of this potential capacity increase on flood elevations could not be calculated because data on the water surface elevations in Arroyo Grande Creek was not available at the time this report was written. Reducing the water level in Arroyo Grande Creek may reduce the time period when the Sand Canyon Flap Gates are completely closed, and therefore reduce peak flood elevations in the lagoon. Detailed analysis of tailwater fluctuations is beyond the scope of this report, but additional study is underway.

Siphon

An inverted siphon, often referred to as a siphon, is a conduit for conveying water under obstructions. It is distinct from a culvert because the outlet is higher than the pipe conveying the flowing water. The capacity of a siphon is determined by the length and size of pipe as well as the head difference between the inlet and the outlet. Since flow at the Sand Canyon Flap Gates is often restricted because the water surface elevation in Arroyo Grande Creek is higher than the water surface elevation in the lagoon, a siphon could provide additional outlet capacity capable of conveying runoff when tailwater at the Sand Canyon structure precludes flow.

A siphon could be used to convey water from the lagoon to an outlet point where the water surface is lower than the water surface immediately downstream of the existing outlet structure. This would allow water to flow out of the lagoon during times when the flap gates are forced closed by water in Arroyo Grande Creek.

A detailed analysis of this option is not possible because topographic information provided from this report does not include areas outside of the vicinity of the Meadow Creek lagoon. However, it is likely that a siphon could convey water from the lagoon to an outlet point on the beach or near the Arroyo Grande Creek outfall. However, inverted siphons are susceptible to plugging from debris and sediment build-up. Additional maintenance may be required. Similar protection could be obtained by adding new culverts at the Sand Canyon outlet.

Roller gates

Roller gates are designed to control flow through larger waterway openings. They consist of a fabricated steel slide with cast iron rollers and rubber seals and function like a weir with controlled release. Roller gates can open upwards or downwards depending on the application. A roller gate could be configured to release large amounts of water quickly whenever the water level in Arroyo Grande Creek is lower than the water level in the Meadow Creek lagoon. These gates are controlled manually or by sophisticated programming. Depending on the size of the gate, they could be operated manually or by an electric motor. Gates that rely on man-power and/or electric power are not preferred options since there is room for error when operation is not automatic. Passive devices are the most preferred eliminating risks of human error or power failure.

Figure 1. Roller Gate

Roller gates would require significant modification to the levy. Due to the height of the levy roller gates would likely be more expensive than adding culverts. Additional cost benefit analysis is warranted. Based on the physical constraints at the Sand Canyon Outlet, roller gates or weirs are unlikely to provide flood protection superior to traditional culverts with flap gates.

Conclusions

The hydraulic and hydrologic analysis indicates that adding culverts to the existing outlet structure is the most efficient way to reduce flood elevations. Analysis of the above solutions indicates that pre-storm pumping is likely to have minimal impact on flood elevations.

Reducing water surface elevations in Arroyo Grande Creek via sandbar management or other methods will likely reduce the amount of time that the Sand Canyon flap gates are closed. However, the data available at the time of this report was insufficient to quantify these results.

Analysis of the siphon option indicates that it could possibly be as effective as adding culverts, although it is unlikely to provide a significant advantage over traditional culverts with flap gates. It is likely that this option will result in higher implementation costs and increased maintenance costs with minimal increased benefit. A preliminary cost comparison between a siphon option and a traditional culvert option may be warranted to confirm this assumption.

Analysis of weir type structures like roller gates indicates that they could be as effective as adding culverts, since their installation would similarly result in increasing the outlet capacity, thereby reducing flood elevations in smaller storms. However, physical constraints may cause the costs to be non-competitive with culverts. Additional cost benefit analysis is warranted.

Gate Selection

The existing iron flap gates on the Sand Canyon Outlet structure were installed in 1958. The following analysis is intended to evaluate other potential flap gate devices in order to determine if the existing gates are appropriate, and if superior options are available. There are many types of flap gates to be considered. This section provides a brief analysis of several different types of flap gates and recommendations for selection. The list of potential gates below, while not exhaustive, represents the majority of flap gate options available for consideration.

Considerations

The primary considerations for selecting gates for the Sand Canyon / Meadow Creek Lagoon are ability to improve flood conveyance, long-term operation and maintenance needs, reliability and cost. Secondary considerations for selection should include water quality impacts, habitat impacts, fish passage and permit requirements. Several types of gates were evaluated to determine applicability for this location.

Evaluation

Several potential types of flap gate types were evaluated as possible alternatives to the existing gates. Table 2 below summarizes the results of flap gate comparison.

<u>Table 2. Flap Gate Types</u>

TYPE OF GATE	APPLICABILITY	COMMENT
Heavy top-hinged	Applicable	Existing gates are effective and reliable.
Rubber Top-hinged	Not recommended	Less durable than heavy metal gates
Self Regulating Tide Gate	Not recommended	Reliability concerns
Pet Door Gate	Not applicable	Can result in upstream flooding
Side Hinged	Applicable	Less reliable than top-hinged.
Muted Tide Regulator	Applicable	Potential environmental benefit
Side-Hinged Variable Backflow	Applicable	Potential environmental benefit
Duckbill Check Valves	Not recommended	Plugging and headloss concerns. Susceptible to damage from wildlife.
Sluice Gate	Not recommended	Requires power and/or manual operation. Additional cost for minimal additional benefit.

The following is a list of potential types of flap gate types and an analysis of the applicability of each type for installation in the Meadow Creek Lagoon. Pros and cons are provided with respect to the selection considerations shown above.

Heavy Top Hinged Flap Gates: The existing Sand Canyon Flap Gates are Iron (cast or ductile) Top Hinged Flap Gates.

Pros: Simple, durable, reliable and proven to be effective for this location. No electric power required. Automatic, passive operation.

Cons: Subject to clogging from debris, does not allow for fish passage, does not allow for tidal or freshwater exchange, and may degrade water quality upstream. Heavy gates may result in excessive head loss during low flows.

Applicability: Clearly applicable based on the operation of the existing gates. Research and field evaluation indicate that head loss is minor during high flows. (Burrows, 1988)

Rubber Flap Gates: Top Hinged Gates with a rubber flap rather than an iron flap.

Pros: Simple, reliable and less expensive than Iron. No electric power required.

Cons: Subject to clogging from debris, does not allow for fish passage, does not allow for tidal or freshwater exchange, and may degrade water quality upstream. Less durable than iron.

Applicability: Not Applicable due to rubber material and the existence of rubber eating rodents in the project vicinity. Less reliable than a Heavy Top Hinged Gate.

Self Regulating Tide Gates: Top Hinged Gates operated with a buoyant flap controlled by floats.

Pros: Simple. Allows for significant exchange of water. Passive operation; No electric power required.

Cons: Subject to clogging from debris.

Applicability: Not applicable due to reliability concerns.

Pet Door Gates: Top Hinged Gates with an opening for fish passage.

Pros: Simple. Allows for fish passage and some water exchange.

Cons: Subject to clogging from debris. Allows backflow that may increase the upstream water level.

Applicability: Not applicable for this project due to potential impact to upstream water levels.

Side Hinged Flap Gates: Similar in operation to Top Hinged Flap Gates.

Pros: Simple, reliable and less impacted by debris. Allows for some fish passage.

Cons: Does not allow for tidal or freshwater exchange, and may degrade water quality upstream unless kept open. Requires significant structural bracing to prevent gate sagging and misalignment.

Applicability: Applicable but less reliable than a Heavy Top Hinged Gate.

Muted Tide Regulator: Specific type of Side Hinged Flap Gate. Mechanically operated and controlled by a float on the upstream side. Can be left open to allow for water exchange and fish passage.

Pros: Simple, reliable and less impacted by debris. Allows for fish passage and water exchange. Requires no electric power. Automatic, passive operation.

Cons: More expensive and complex than standard gates. Complexity may impact reliability and maintenance cost.

Applicability: Applicable. The gate can be left open by default providing some environmental benefit. Can be controlled by upstream water level to allow for tidal flushing while still providing defense against higher flood flows from downstream.

Side-Hinged Variable Backflow Flap Gate: Specific type of Side Hinged Flap Gate. Mechanically operated and controlled by a float on the upstream side. Can be left open to allow for water exchange and fish passage.

Pros: Simple, reliable and less impacted by debris. Allows for fish passage and water exchange. Requires no electric power

Cons: More expensive and complex than standard gates.

Applicability: Applicable. The gate can be left open by default providing some environmental benefit. Can be controlled by upstream water level to allow tidal flushing while still providing defense against higher flood flows from downstream.

Duckbill Check Valves: Flexible synthetic sleeve that “deforms” or ‘unrolls” when upstream water exerts pressure.

Pros: Simple, reliable, durable and inexpensive. Sleeve will even seal up to the downstream water elevation, and if the upstream water elevation is higher – the top of the sleeve will open to allow continued outflows (but will not allow back flows).

Cons: High head loss, subject to clogging from debris, does not allow for fish passage, does not allow for tidal or freshwater exchange, and may degrade water quality upstream.

Applicability: Not applicable due to potential debris at the project location and rubber eating varmints at the project site. High head loss will result in higher upstream water levels than other types of gates.

Sluice Gate: Ridged gate that slides upward rather than opening on a hinge.

Pros: Allows for direct control of operation. Can be programmed or operated manually.

Cons: Must be operated manually or with an electric motor.

Applicability: Not applicable due to lack of power source. Benefits do not justify the cost or lack of reliability.

Gate Recommendations

Based on this analysis the existing heavy top-hinged flap gates currently in place at the Sand Canyon outlet structure are an appropriate choice. Although the heavy gates may lead to excessive head loss during very low flow, research and field observations indicate that the head loss is minimal. Changing the type of gate in operation will not have an appreciable effect on upstream flooding. With proper monitoring, maintenance and debris removal, replacement of these gates for the purpose of improving capacity is not warranted. However, alternative gate types should be considered if secondary considerations such as fresh water exchange and fish passage are desirable.

If additional culverts are added to increase outlet capacity, further analysis of the Muted Tide Regulator and the Side-Hinged Variable Backflow Flap Gate should be considered. The reliability and durability of these gates are similar to the existing heavy top-hinged gates. However these particular types of side-hinged gates offer some exchange of water and fish passage that could be beneficial to the lagoon environment. Additional analysis is warranted.

Hydraulic and Hydrologic Analysis Methodology

Various hydraulic and hydrologic models were developed to aid in this analysis. The hydraulic model was constructed to assess the impact of changing the size, elevation, or number of culverts at the Sand Canyon structure. This model was also used to assess the impact of potential flood improvement solutions such as pre-storm pumping, tail water elevation reduction and weir type structures. The hydrologic model was developed to provide a storm frequency context for this analysis.

Disclaimer: Additional study and design will be required to implement any options discussed below. A detailed hydrologic study is beyond the scope of this report. As such, the accuracy of any flow rates and hydraulic calculations are limited by the assumptions of the hydrologic model. Calculations contained in this report should not be used for engineering design.

In addition to the modeling described above, research was conducted to address the adequacy of the existing flap gates and suggest possible alternatives. This research, while non-quantitative, is summarized in pro vs. con fashion and can be used to rank available options.

Basin Model

A basin model was developed to compare the impact of various improvements to the outlet structure. Bathymetric and topographic data prepared by Cannon, Inc (2005) was provided by the District for use in constructing this model. Hydraflow Hydrographs software was used to model storage in the Meadow Creek Lagoon. Storage for the lagoon is provided in Table 3 below.

Table 3. Lagoon Storage

Contour Elevation	Incremental Storage	Total Storage	Total Storage	Notes
(Ft)	(Cubic Feet)	(Cubic Feet)	(Acre Feet)	
4	65016	65016	1.5	
5	162756	227772	5.2	
6	317655	480411	11.0	
6.44	301860	619515	14.2	Culvert Invert Elevation
7	502470	820125	18.8	Effective Stage Between Culvert invert and Lowest FFE = 57.2 AF
8	775656	1278126	29.3	
9	1106082	1881738	43.2	
10	1580067	2686149	61.7	
10.37	1531251	3111318	71.4	Lowest Finished Floor Elevation
11	2360367	3940434	90.5	
12	3255876	5616243	128.9	

Lagoon storage is based on the available bathymetric and topographic information and does not take into account any storage loss due to vegetation. Additional sediment may have accumulated in the lagoon since the completion of the bathymetric study.

Hydrologic Modeling

A limited hydrologic model was prepared using Hydraflow Hydrographs software. Detailed hydrologic modeling intended to accurately predict the watershed response to precipitation events is beyond the scope of this assessment. The hydrologic modeling provided by the RCD is not detailed and is not intended to provide accurate estimates of flow rates or volumes. The limited hydrologic analysis prepared by the RCD is only intended to provide a reasonable framework to evaluate potential options for improvement and to better understand the constraints of the system. Flow rates and flow volumes developed using this model should not be used for anything other than comparing the effects of different improvement options.

A custom design storm distribution was developed in an attempt to replicate the 2010 storm event of December 18-20. The model storm event is a 72 hour rainfall event totaling 5.47 inches which corresponds to between a 10-year and 25-year storm event per NOAA Point Precipitation Frequency Estimates (See Appendix II). The rainfall distribution was estimated based on rainfall data collected at the Halcyon rain gauge (see appendix II). Table 4 below presents the rainfall distribution used in the model storm event.

In addition to the custom rainfall distribution, hydrographs were developed to simulate 100-year storm events. Hydrographs were developed for a 6-hour, 100-year event of 3.00 inches as well as a 24-hour, 100-year event of 4.75 inches using the SCS type I rainfall distribution. However, after initial evaluation it was determined that the topographic information required to analyze the flood levels for these storm events was insufficient. Furthermore, the Sand Canyon Outlet is completely submerged during these events indicating that increased capacity at the culverts is unlikely to reduce flood elevations. Further study on is recommended.

Table 4. Custom Rainfall Distribution

Time Increment (Hour)	**Incremental Rainfall** (Inches)	**Cumulative Rainfall** (Inches)	**Percent of total** (%)
6	0.10	0.10	2%
12	0.10	0.21	4%
18	1.24	1.45	26%
24	1.24	2.68	49%
30	0.75	3.43	63%
36	0.75	4.18	76%
42	0.38	4.55	83%
48	0.38	4.93	90%
54	0.07	5.00	91%
60	0.07	5.06	93%
66	0.20	5.27	96%
72	0.20	5.47	100%
	5.47		

Table 5 summarizes the results of the hydrologic model for the custom design storm.

Table 5. Hydrologic Model

Storm Duration (Hours)	**Storm Frequency** (Years)	**Rainfall distribution**	**Tailwater Elevation** (Ft)	**Curve Number** (Cubic Feet)	**Area**** (Acres)	**Peak In-Flow** (CFS)	**Peak Out-Flow** (CFS)	**Peak Flood Elevation** (Feet)
72	10-25	Custom	8.6***	53*	6423	243	196	11.2

* Assumed for calibration only. *** Assumed for comparison. Data unavailable
** From Chipping report

Calibration

A theoretical inflow hydrograph was developed for the custom design storm based on the information in Table 3 (above). The watershed area was assumed to be 6,423 Acres (Chipping, 1989). No attempt was made to model upstream storage or impervious areas within the watershed.

Custom Design Storm

The custom design storm was calibrated by routing the custom design storm inflow hydrograph through the basin storage model to produce a peak flood elevation approximately equal to that experienced during the December 2010 flood. The flood elevation reached during the December 2010 flood event was estimated to be 11.2 feet (NAVD88). This estimate is based on information provided by the County and topographic information prepared by Cannon, Inc. The inflow hydrograph was calibrated by adjusting the curve number until the flood elevation of the model storm reached 11.2 feet corresponding to the flood elevation observed during the December 2010 storm. Since this storm is theoretical and a detailed hydrologic study was beyond the scope of this report, no attempt was made to quantify storage or impervious area within the watershed. Instead a curve number was selected to calibrate the flood elevations from the model storm to flood elevations documented by the County during the 2010 flood. The SCS curve number used (53) is used only for calibration and does not represent the actual curve number associated with the Meadow Creek Watershed (see Appendix I for more information). This calibration was not intended to estimate actual flows and should not be used to do so. It is predicated on the assumption that all flow from Arroyo Grande Creek is successfully excluded from the Meadow Creek Lagoon by functioning flap gates. The calibration is only intended to provide a reference for comparing outlet options.

Hydraulic Modeling

Hydraflow software was used to model the function of the existing culverts as well as the effect of various improvements to the outlet structure. The calibrated model allowed for changing the outlet culverts size, elevation, and number of culverts. The flood elevation and peak outflow was then re-calculated with the new outlet conditions enabling a comparison to the existing conditions. This analysis was conducted to reveal the potential impact of various improvements for each of the model storm event described above.

The Arch culverts were modeled using two 60 inch circular culverts for ease of calculation. According to the National Corrugated Steel Pipe Association (NCSPA), two 60 inch diameter circular pipes are considered equivalent to the existing 71 inch x 48 inch arch pipes. This is an acceptable substitute for modeling the existing culverts. See Appendix IV for more information.

The tailwater condition at the Sand Canyon Flap Gates is dictated by the water level in Arroyo Grande Creek and the tidal elevation at the beach outlet. As such, the tailwater elevation varies during a storm event. A detailed analysis of the tailwater level is beyond the scope of this report. The initial tailwater elevation used for this model was 8.6 feet (NAVD88) was assumed based on the starting water surface in the lagoon on December 18, 2010. The starting water surface elevation downstream of the culverts is unavailable for the December 2010 storm, but it is assumed to be similar to the elevation measured in the lagoon.

The hydraulic model enabled analysis of different improvements to the Sand Canyon outlet structure such as:

1. Adding culverts,
2. Increasing the size of culverts,
3. Lowering the elevation of Culverts, and
4. Using roller gates or other weir type structures.

The results of this analysis are included above in previous sections of the report.

Results

The hydraulic model previously described was used to assess and compare the potential impact of modifying or expanding the Sand Canyon structure. A model of the existing conditions was constructed to serve as the baseline for comparison. Various combinations of outlet improvements were analyzed and compared to the model of the existing (baseline) condition to evaluate the effectiveness. The goal of this analysis was to identify the options with the highest likelihood of reducing upstream flooding for a given model storm event. This also allows for the identification of options with a low likelihood of reducing flooding.

Existing Condition

The custom design storm was calibrated to produce flood elevations similar to those experienced during the December 2010 flood. The peak flood elevation of 11.2 feet corresponds to a peak outflow of approximately 196 CFS. The peak inflow in this event was estimated to be approximately 243 CFS resulting in runoff being stored in the lagoon.

The 100-year storm events produce flooding that exceeds the limits of the topographic and bathymetric data provided. The storage available in the model is inadequate to contain the 100-year flows resulting in an overflow condition and therefore the model cannot be calibrated. This is to be expected due to the fact that the entire area is within the FEMA 100-year flood plain (see Appendix III).

Effect of Increasing the Number of Culverts

Adding a single 71 inch x 48 inch arch culvert and flap gate to the Sand Canyon outlet could reduce the peak flood elevation in the custom design storm from 11.2 feet to 9.9 feet, which is below the finished floor elevation of the homes that were flooded in the December 2010 storm (See Appendix III). Adding two new 71 inch x 48 inch arch culverts could reduce the peak flood elevation in the custom design storm from 11.2 feet to 9.4 feet. However, this option would likely not result in significant flood reduction during the 100-year events because the entire area is located within the FEMA 100-year flood plain.

During the 24-hour, 100-year storm the tailwater elevation at the flap gates is approximately 11 feet (see FIRM map in Appendix IV). This may indicate that relieving capacity constraints at the meadow creek outlet will not relieve flooding in the 100-year event. The flap gates on the downstream end of the Sand Canyon structure prevent flow from Arroyo Grande Creek from entering the Meadow Creek lagoon. While it may be feasible to modify the outlet structure to accommodate peak flows from a 24-hour, 100-year storm event, the impact of such modifications is not likely to result in flood reduction due to tailwater constraints in Arroyo Grande Creek and flow capacity constraints within Meadow Creek.

Effect of Increasing the Size of the Culverts

Analysis using the above referenced models was also performed to assess the impact of increasing the size of the culverts at the Sand Canyon outlet. As previously discussed, improvements to the outlet capacity are not anticipated to be effective during the 100-year event. Therefore increasing the culvert size was only evaluated for the custom storm event to simulate the impact of such an improvement during an event similar to that experienced in December of 2010. While it is feasible to increase the size of these culverts, the modeling analysis indicates that doing so will have limited impact on the upstream flood elevations. Increasing the size of the culverts would increase the open area available for water to flow through. However, this increased flow area would be above the finished floor of some of the flood prone the buildings in the surrounding area. Therefore most of the increased capacity would not be utilized until after flood levels impact existing structures.

Effect of Lowering the Elevation of the Culverts

Lowering the elevation of the culverts to the elevation of the Thalweg in Arroyo Grande Creek has limited benefit. This solution does not provide meaningful capacity increase because the capacity of the culverts is dictated, in part, by the downstream tailwater elevation. Lowering the culverts has no effect on the downstream tailwater elevation. Furthermore, lowering the culverts could have an adverse environmental impact by permanently lowering the permanent water surface elevation of the Meadow Creek Lagoon.

Effect of Alternative Structures (Weirs or Roller Gates)

The model was also configured to evaluate the affects of alternative structures (see Alternatives Assessment below for more information). Weirs are flow control structures with no top constraint. Roller gates are weir-like structures with adjustable top constraints. The model indicates that using weirs or roller gates would not have a significant impact on flood reduction for the same reasons that increasing the size of the existing culverts is ineffective. The potential increased capacity would occur only when the upstream water surface elevation exceeds the finished floor of some surrounding structures.

Results Summary

These results are limited by the lack of a detailed hydrologic model. However, they indicate that it could be feasible to reduce flood elevations in smaller storm events by increasing outlet capacity by installing additional culverts. Doubling the outlet capacity, by adding two (2) new 71 inch by 48 inch culverts, could result in a meaningful reduction in the peak flood elevation during similar low-peak, long-duration storms.

71 inch x 48 inch arch culverts appear to be the appropriate size for these culverts. Increasing the size of the culverts is only minimally effective in reducing flood elevation due to upstream head constraints. Adding roller gates or weir structures also has limited benefit for similar reasons.

Lowering the elevation of the culverts has minimal impact on flood elevations in any of the model storm events. Lowering the elevation of the culverts could also lower the water surface elevation in the lagoon during low flow periods. This may result in negative environmental impacts associated with shallow ponds.

These results also indicate that increasing outlet capacity will not appreciably reduce flood elevations in the 100-year storm events. During these high-peak events, upstream capacity constraints and downstream tailwater constraints will likely limit the effectiveness of additional culverts. Additional methods for reducing flow into the lagoon should be considered. Adding two (2) 71 inch x 48 inch arch culverts in combination with efforts to reduce storm inflow will likely yield the greatest flood reduction benefit.

Recommendations

The hydraulic and hydrologic analysis indicates that adding culverts to the existing outlet structure is the most efficient way to reduce flood elevations. 71 inch x 48 inch arch culverts appear to be the appropriate size for these culverts. If additional culverts are added, Muted Tide Regulator and Side-Hinged Variable Backflow Flap Gates should be considered for added environmental benefit.

The CSLRCD offers the following recommendations:

1. Increase outlet capacity in the Sand Canyon Flap Gate area by adding additional gated culverts. Adding two (2) new 71 inch x 48 inch arch culverts at the Sand Canyon location may reduce the likelihood of upstream flooding from a storm similar to that which occurred in December of 2010.

2. Heavy, top-hinged flap gates like those currently in operation are adequate for flood protection. Consider using Muted Tide Regulator or the Side-Hinged Variable Backflow Flap Gates for added environmental benefit.

3. Modification of the Sand Canyon Structure for 100-year flood protection is infeasible. Investigate options for preventing stormwater from entering the lagoon. These options could include increasing outlet capacity at Carpenter Creek and increasing storage capacity throughout the watershed.

4. Detailed hydrologic study is recommended for detailed design.

5. Detailed hydraulic analysis of points of constriction within the lagoon is recommended to determine if the conveyance capacity of the lagoon is adequate for larger storm events.

Summary and Conclusions

Based on the results of this study it is feasible to reduce flood risk in the Meadow Creek lagoon during smaller storm events by increasing capacity at the Sand Canyon Outlet Structure. The existing Sand Canyon culverts and flap gates appear appropriate in size and location. The addition of identical culverts at this location may reduce upstream flooding in smaller storm events. Increasing the size of the culverts has minimal affect on flood reduction due to the limited head available. Lowering the culverts also has minimal effect and could potentially result in negative environmental impacts in the Meadow Creek Lagoon.

While it may be feasible to increase the capacity of the outlet structure to convey the peak flow from larger storm events such as the 100-year events, this may not result in adequate flood protection due to upstream conveyance capacity constraints and downstream tailwater constraints. A detailed hydrologic analysis and study of the tailwater elevations is recommended to determine the point where adding capacity at the outlet is no longer justified by flood elevation reduction.

The existing heavy, top-hinged flap gates are an appropriate choice for the conditions. Consideration should be given to Muted Tide Regulator or the Side-Hinged Variable Backflow Flap Gates if new culverts are added. These gates may provide additional environmental benefit to the meadow creek lagoon.

The potential for alternative solutions to reduce flood frequency is limited at this location. However, additional upstream measures to reduce inflow should be considered to further reduce flood risk. Options such as enhancing watershed storage and increasing capacity at Carpenter Creek are outside of the County's control and thus beyond the scope of this report. However, additional study is warranted because the potential for reducing flood levels by increasing outlet capacity appears limited.

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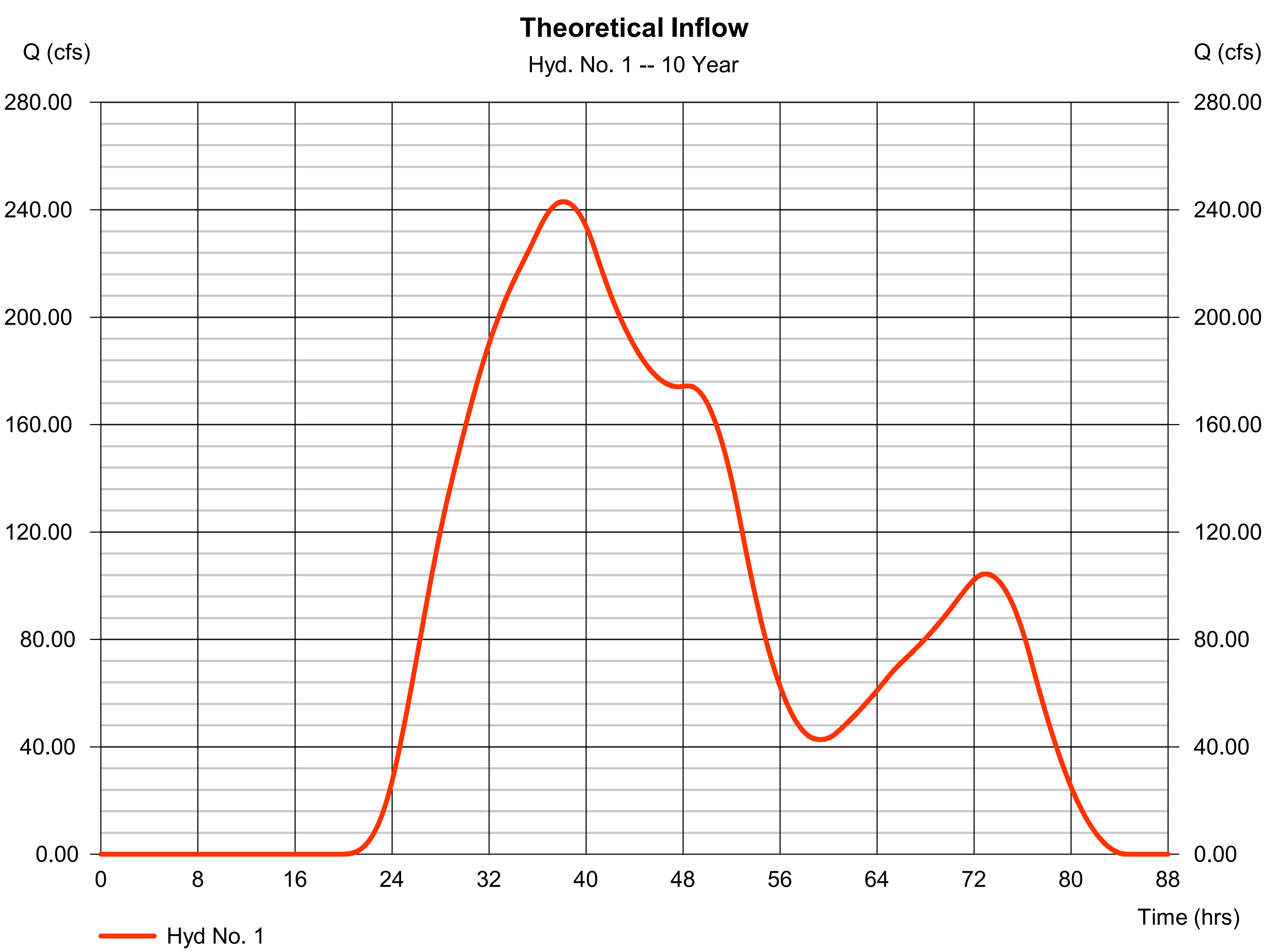
Appendix I - Existing Conditions Model

Hydrograph Report

Hyd. No. 1

Theoretical Inflow

Hydrograph type	= SCS Runoff	Peak discharge	= 243.03 cfs
Storm frequency	= 10 yrs	Time to peak	= 38.13 hrs
Time interval	= 2 min	Hyd. volume	= 25,377,430 cuft
Drainage area	= 6423.000 ac	Curve number	= 53
Basin Slope	= 2.0 %	Hydraulic length	= 5000 ft
Tc method	= User	Time of conc. (Tc)	= 480.00 min
Total precip.	= 5.47 in	Distribution	= Custom
Storm duration	= Sample.cds	Shape factor	= 484



Hydrograph Report

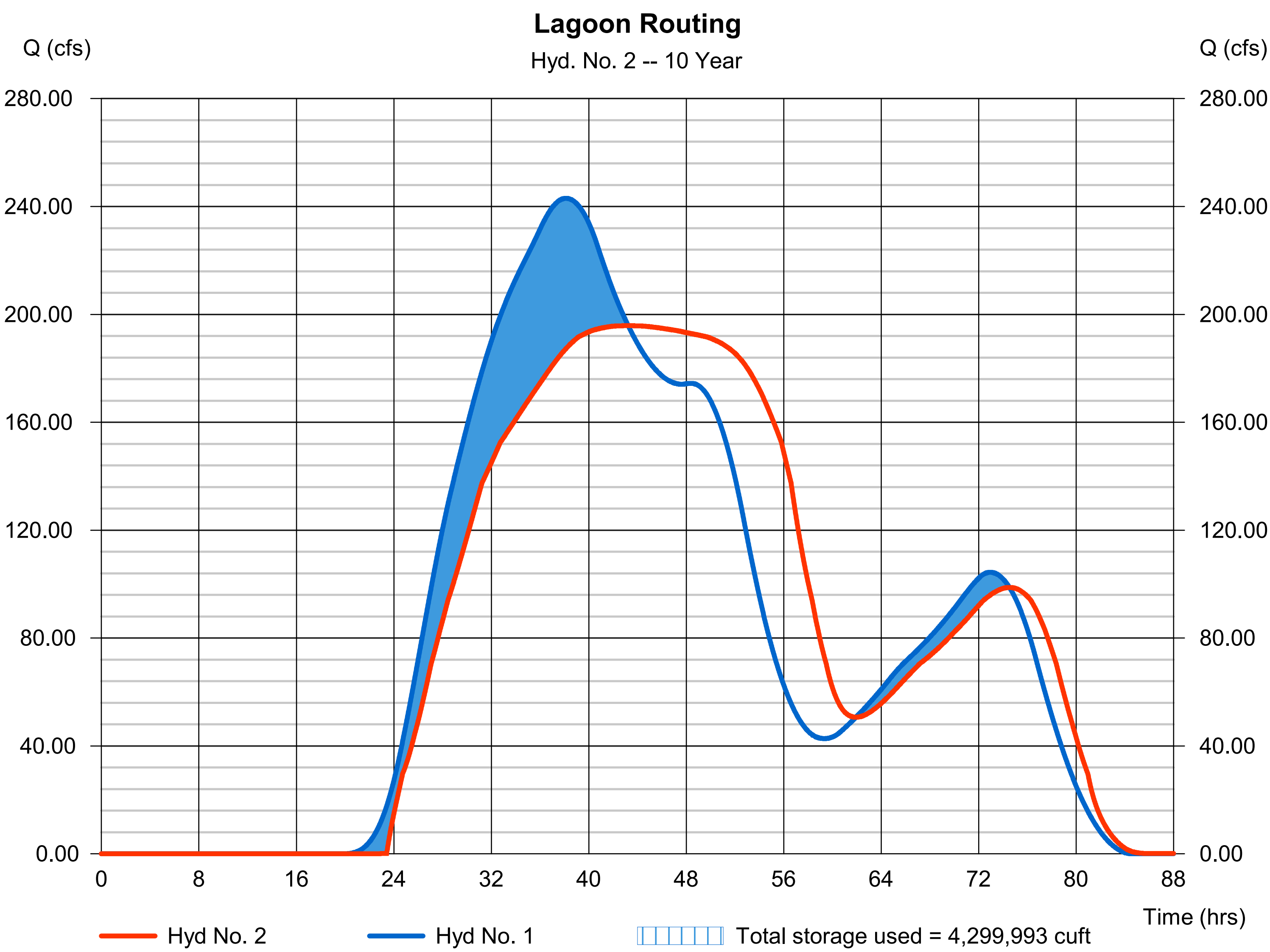
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2010 by Autodesk, Inc. v9.24 | Sunday, Mar 10, 2013

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 195.80 cfs
Storm frequency	= 10 yrs	Time to peak	= 43.23 hrs
Time interval	= 2 min	Hyd. volume	= 25,321,390 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 11.21 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 4,299,993 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Pond Report

Pond No. 1 - Meadow Creek Lagoon

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	3.00	n/a	0	0
1.00	4.00	n/a	65,016	65,016
2.00	5.00	n/a	162,756	227,772
3.00	6.00	n/a	252,639	480,411
4.00	7.00	n/a	339,714	820,125
5.00	8.00	n/a	458,001	1,278,126
6.00	9.00	n/a	603,612	1,881,738
7.00	10.00	n/a	804,411	2,686,149
8.00	11.00	n/a	1,254,285	3,940,434
9.00	12.00	n/a	1,675,809	5,616,243

Culvert / Orifice Structures

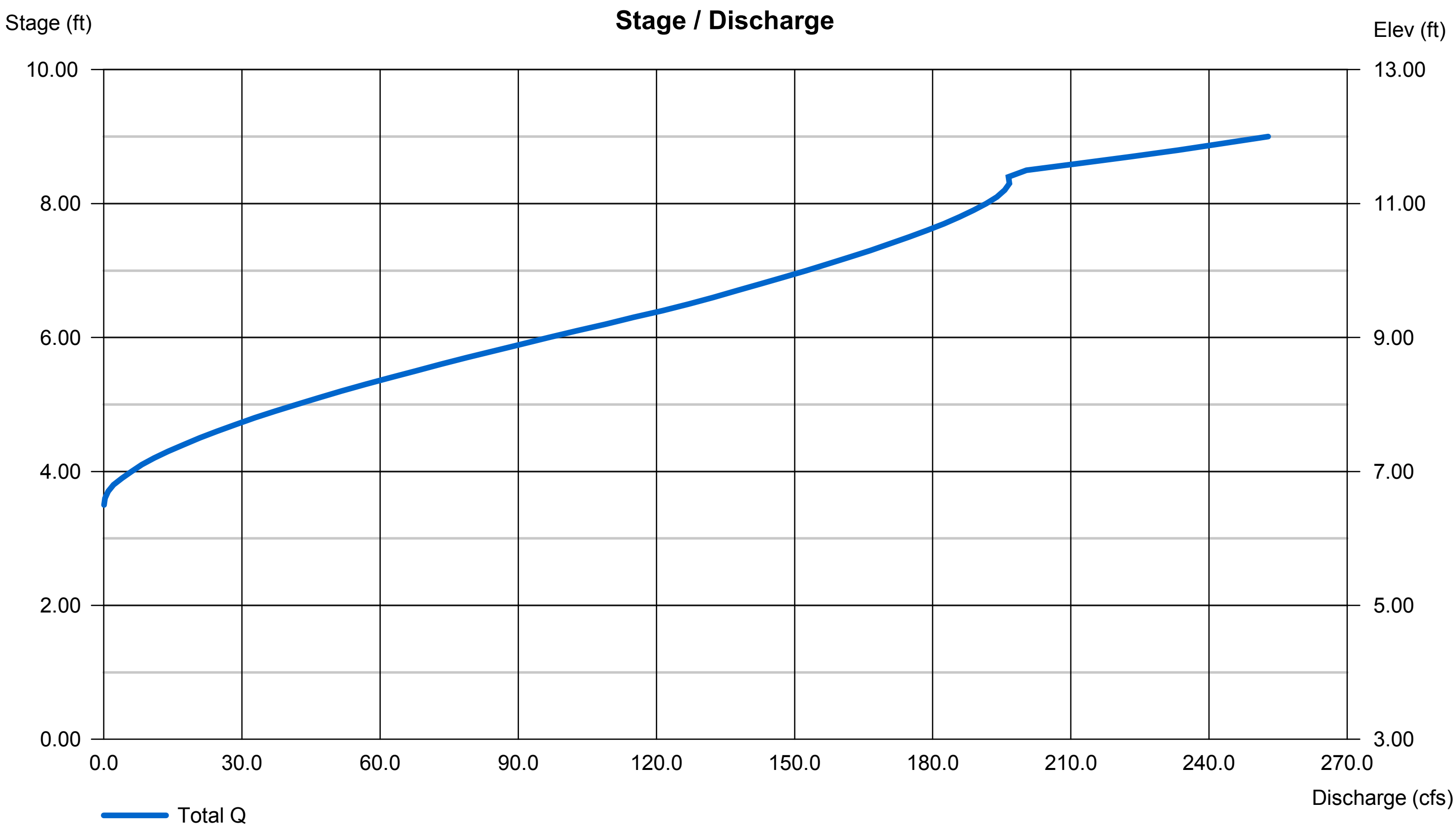
	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 60.00	60.00	Inactive	0.00
Span (in)	= 60.00	60.00	60.00	0.00
No. Barrels	= 10	10	20	0
Invert El. (ft)	= 6.44	6.46	6.44	0.00
Length (ft)	= 50.00	50.00	50.00	0.00
Slope (%)	= 2.20	1.12	2.20	n/a
N-Value	= .024	.024	.024	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.330.00	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0 (by Wet area)
TW Elev. (ft) = 6.44

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydrograph Report

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 195.80 cfs
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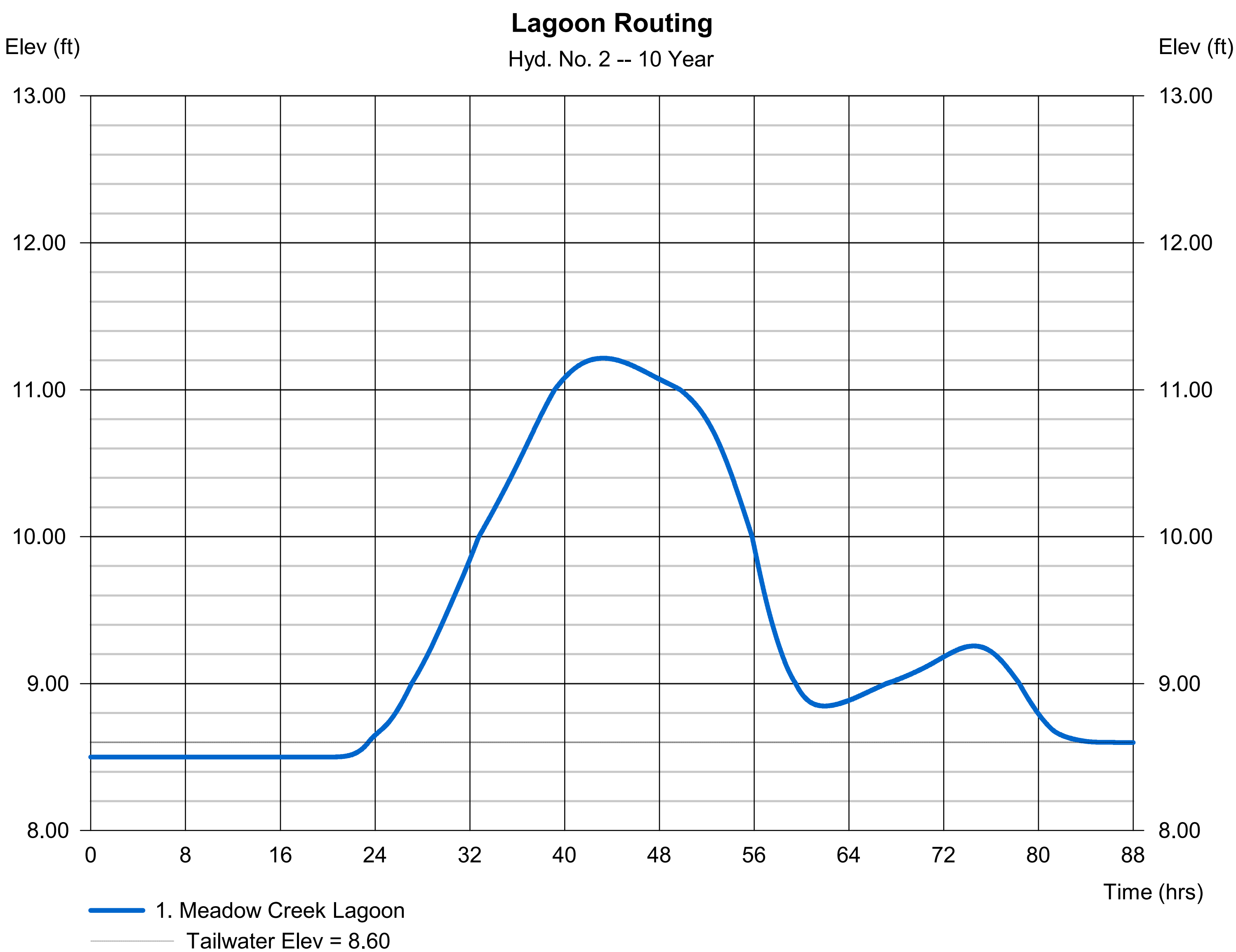
Time interval	= 2 min	Hyd. volume	= 25,321,390 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 11.21 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 4,299,993 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Appendix II - Precipitation Data

NOAA Atlas 14, Volume 6, Version 2
Location name: Grover Beach, California, US*
Coordinates: 35.1237, -120.6241
Elevation: 70ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**0.116** (0.104-0.131)	**0.147** (0.132-0.166)	**0.187** (0.167-0.212)	**0.218** (0.193-0.250)	**0.260** (0.221-0.309)	**0.291** (0.241-0.355)	**0.323** (0.260-0.405)	**0.354** (0.276-0.459)	**0.395** (0.293-0.538)	**0.426** (0.304-0.604)
10-min	**0.166** (0.149-0.188)	**0.211** (0.189-0.238)	**0.268** (0.239-0.303)	**0.313** (0.276-0.358)	**0.373** (0.317-0.444)	**0.418** (0.346-0.509)	**0.462** (0.372-0.580)	**0.507** (0.395-0.658)	**0.567** (0.421-0.771)	**0.611** (0.436-0.865)
15-min	**0.201** (0.180-0.227)	**0.255** (0.228-0.288)	**0.324** (0.289-0.367)	**0.378** (0.334-0.433)	**0.451** (0.383-0.536)	**0.505** (0.419-0.616)	**0.559** (0.450-0.702)	**0.614** (0.478-0.796)	**0.685** (0.509-0.932)	**0.739** (0.527-1.05)
30-min	**0.284** (0.254-0.320)	**0.359** (0.322-0.406)	**0.456** (0.407-0.517)	**0.533** (0.471-0.610)	**0.635** (0.539-0.756)	**0.712** (0.590-0.868)	**0.788** (0.634-0.989)	**0.865** (0.674-1.12)	**0.965** (0.717-1.31)	**1.04** (0.743-1.47)
60-min	**0.403** (0.361-0.455)	**0.511** (0.457-0.577)	**0.649** (0.578-0.734)	**0.758** (0.670-0.867)	**0.903** (0.767-1.08)	**1.01** (0.838-1.23)	**1.12** (0.902-1.41)	**1.23** (0.958-1.59)	**1.37** (1.02-1.87)	**1.48** (1.06-2.10)
2-hr	**0.615** (0.551-0.694)	**0.766** (0.685-0.865)	**0.953** (0.850-1.08)	**1.10** (0.970-1.26)	**1.28** (1.09-1.53)	**1.42** (1.18-1.73)	**1.55** (1.25-1.95)	**1.68** (1.31-2.18)	**1.85** (1.37-2.51)	**1.97** (1.40-2.78)
3-hr	**0.781** (0.700-0.881)	**0.968** (0.866-1.09)	**1.20** (1.07-1.36)	**1.37** (1.21-1.57)	**1.60** (1.36-1.90)	**1.76** (1.46-2.14)	**1.91** (1.54-2.40)	**2.06** (1.61-2.67)	**2.25** (1.67-3.06)	**2.39** (1.70-3.38)
6-hr	**1.09** (0.978-1.23)	**1.35** (1.21-1.53)	**1.67** (1.49-1.89)	**1.90** (1.68-2.18)	**2.20** (1.87-2.62)	**2.41** (2.00-2.94)	**2.61** (2.10-3.28)	**2.80** (2.18-3.64)	**3.04** (2.26-4.14)	**3.22** (2.29-4.55)
12-hr	**1.38** (1.24-1.56)	**1.73** (1.54-1.95)	**2.15** (1.92-2.43)	**2.47** (2.18-2.83)	**2.88** (2.45-3.43)	**3.18** (2.63-3.88)	**3.47** (2.79-4.35)	**3.74** (2.92-4.85)	**4.10** (3.04-5.57)	**4.35** (3.10-6.16)
24-hr	**1.73** (1.57-1.95)	**2.18** (1.97-2.46)	**2.76** (2.49-3.13)	**3.22** (2.88-3.68)	**3.83** (3.30-4.54)	**4.29** (3.61-5.21)	**4.75** (3.89-5.92)	**5.20** (4.13-6.69)	**5.81** (4.40-7.82)	**6.27** (4.57-8.76)
2-day	**2.10** (1.90-2.37)	**2.69** (2.43-3.03)	**3.45** (3.11-3.90)	**4.07** (3.64-4.65)	**4.91** (4.22-5.81)	**5.54** (4.66-6.73)	**6.19** (5.07-7.72)	**6.85** (5.44-8.81)	**7.75** (5.87-10.4)	**8.44** (6.16-11.8)
3-day	**2.38** (2.16-2.68)	**3.07** (2.78-3.46)	**3.98** (3.59-4.50)	**4.73** (4.22-5.40)	**5.75** (4.95-6.82)	**6.54** (5.50-7.94)	**7.36** (6.02-9.17)	**8.20** (6.50-10.5)	**9.35** (7.08-12.6)	**10.2** (7.48-14.3)
4-day	**2.59** (2.35-2.92)	**3.35** (3.03-3.78)	**4.38** (3.95-4.95)	**5.22** (4.67-5.96)	**6.39** (5.50-7.57)	**7.30** (6.14-8.86)	**8.25** (6.75-10.3)	**9.23** (7.33-11.9)	**10.6** (8.03-14.3)	**11.7** (8.51-16.3)
7-day	**3.04** (2.75-3.42)	**3.95** (3.58-4.46)	**5.20** (4.69-5.88)	**6.24** (5.57-7.12)	**7.69** (6.62-9.12)	**8.84** (7.44-10.7)	**10.0** (8.21-12.5)	**11.3** (8.96-14.5)	**13.0** (9.89-17.6)	**14.4** (10.5-20.2)
10-day	**3.40** (3.08-3.83)	**4.45** (4.02-5.02)	**5.87** (5.29-6.64)	**7.06** (6.31-8.07)	**8.75** (7.53-10.4)	**10.1** (8.48-12.2)	**11.5** (9.40-14.3)	**13.0** (10.3-16.7)	**15.0** (11.4-20.2)	**16.7** (12.2-23.3)
20-day	**4.30** (3.89-4.84)	**5.67** (5.13-6.40)	**7.55** (6.81-8.54)	**9.14** (8.16-10.4)	**11.4** (9.80-13.5)	**13.2** (11.1-16.0)	**15.1** (12.3-18.8)	**17.1** (13.6-22.0)	**19.9** (15.1-26.8)	**22.2** (16.2-31.0)
30-day	**5.22** (4.73-5.88)	**6.91** (6.25-7.79)	**9.21** (8.31-10.4)	**11.2** (9.98-12.8)	**13.9** (12.0-16.5)	**16.2** (13.6-19.6)	**18.5** (15.1-23.0)	**21.0** (16.6-26.9)	**24.4** (18.5-32.9)	**27.2** (19.9-38.1)
45-day	**6.30** (5.70-7.09)	**8.32** (7.52-9.38)	**11.1** (10.0-12.5)	**13.4** (12.0-15.3)	**16.7** (14.4-19.8)	**19.4** (16.3-23.5)	**22.2** (18.2-27.6)	**25.1** (19.9-32.3)	**29.3** (22.2-39.4)	**32.6** (23.8-45.6)
60-day	**7.38** (6.68-8.31)	**9.70** (8.78-10.9)	**12.9** (11.6-14.6)	**15.6** (13.9-17.8)	**19.3** (16.6-22.9)	**22.4** (18.8-27.1)	**25.5** (20.9-31.8)	**28.9** (22.9-37.1)	**33.6** (25.5-45.2)	**37.3** (27.3-52.2)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

History for KDYCAOCE2

Halcyon and Hwy 1, Oceano, CA — Current Conditions

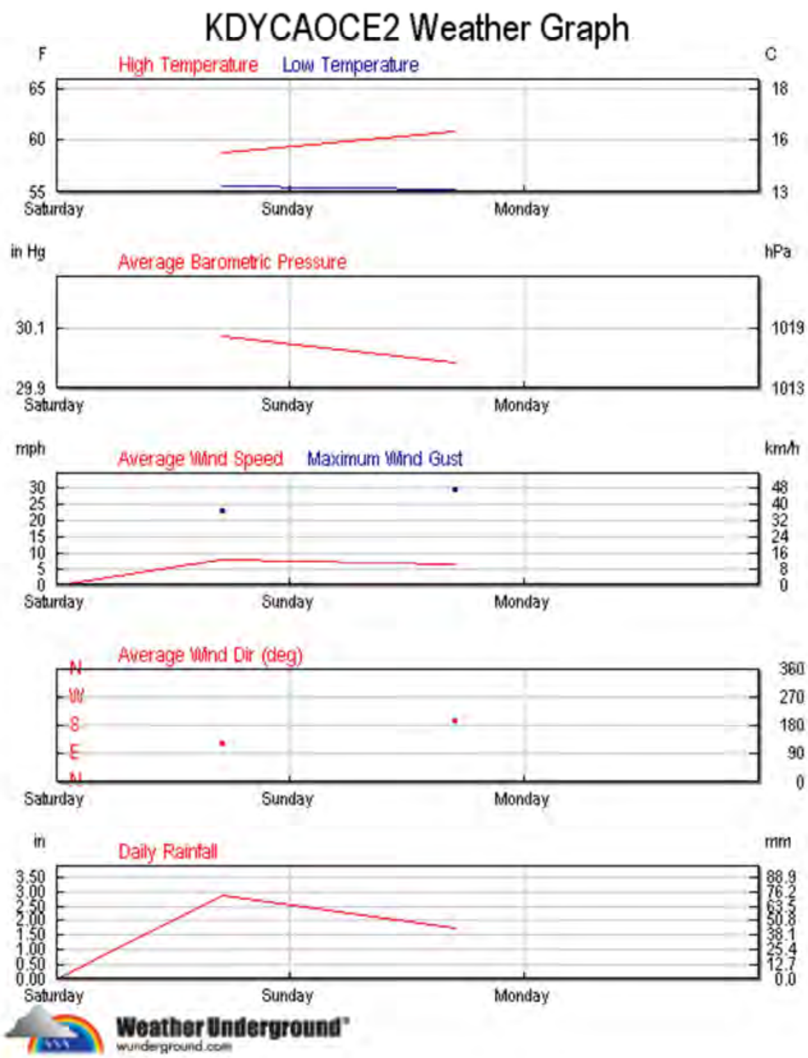
Station Status:12/31/12 I have upgraded to a Davis Vantage Pro2 my rainfall and Baro will now work again. Amos

Daily Summary for December 18, 2010 - December 20, 2010

December 18 2010 - TO - December 20 2010 Go

Daily | Weekly | Monthly | Yearly | **Custom**

	High:	Low:	Average:
Temperature:	**60.8** °F	**50.2** °F	**55.8** °F
Dew Point:	**58.2** °F	**35.6** °F	**51.5** °F
Humidity:	92.0%	45.0%	86.0%
Wind Speed:	**25.7**mph from the SW	-	**4.7**mph
Wind Gust:	**29.3**mph from the SSW	-	-
Wind:	-	-	South
Pressure:	**30.12**in	**29.91**in	-
Precipitation:	**5.47**in		



Certify This Report

Custom Date Range's Tabular Data

2010	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Pressure (in)			Visibility (mi)			Wind (mph)			Precip (in)
Dec	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	gust	sum
18	59	57	56	54	50	36	85	76	45	30.12	-	30.03	-	-	-	23	8	23	2.87
19	61	58	55	58	55	53	91	90	85	30.06	-	29.91	-	-	-	26	6	29	1.73
20	55	52	50	53	50	48	92	92	91	30.03	-	29.91	-	-	-	8	0	8	0.87

Comma Delimited File

Appendix III - Modeling Results

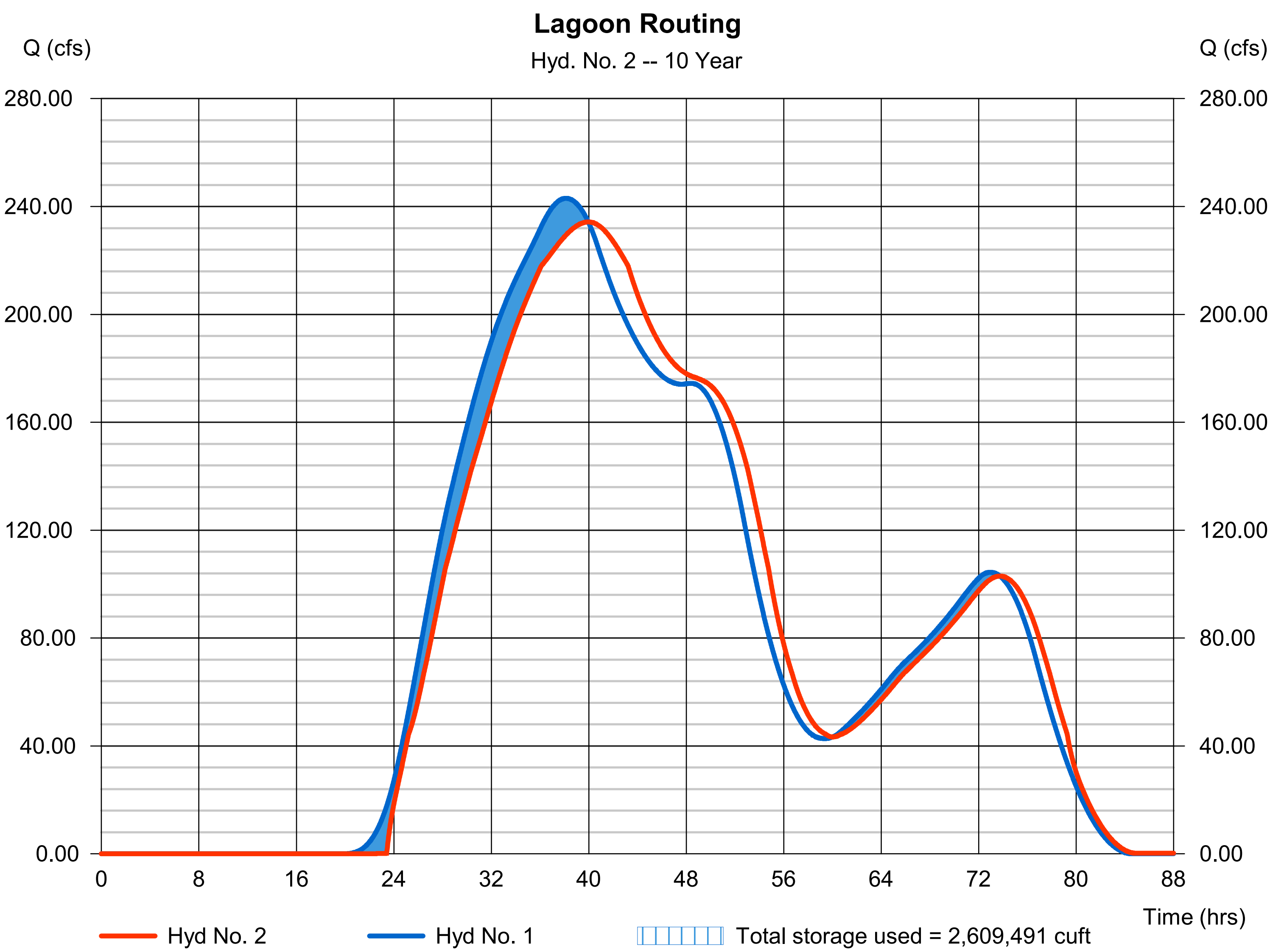
Hydrograph Report `Single Additional Culvert`

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 234.26 cfs
Storm frequency	= 10 yrs	Time to peak	= 39.97 hrs
Time interval	= 2 min	Hyd. volume	= 25,323,970 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 9.90 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 2,609,491 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Hydrograph Report `Single Additional Culvert`

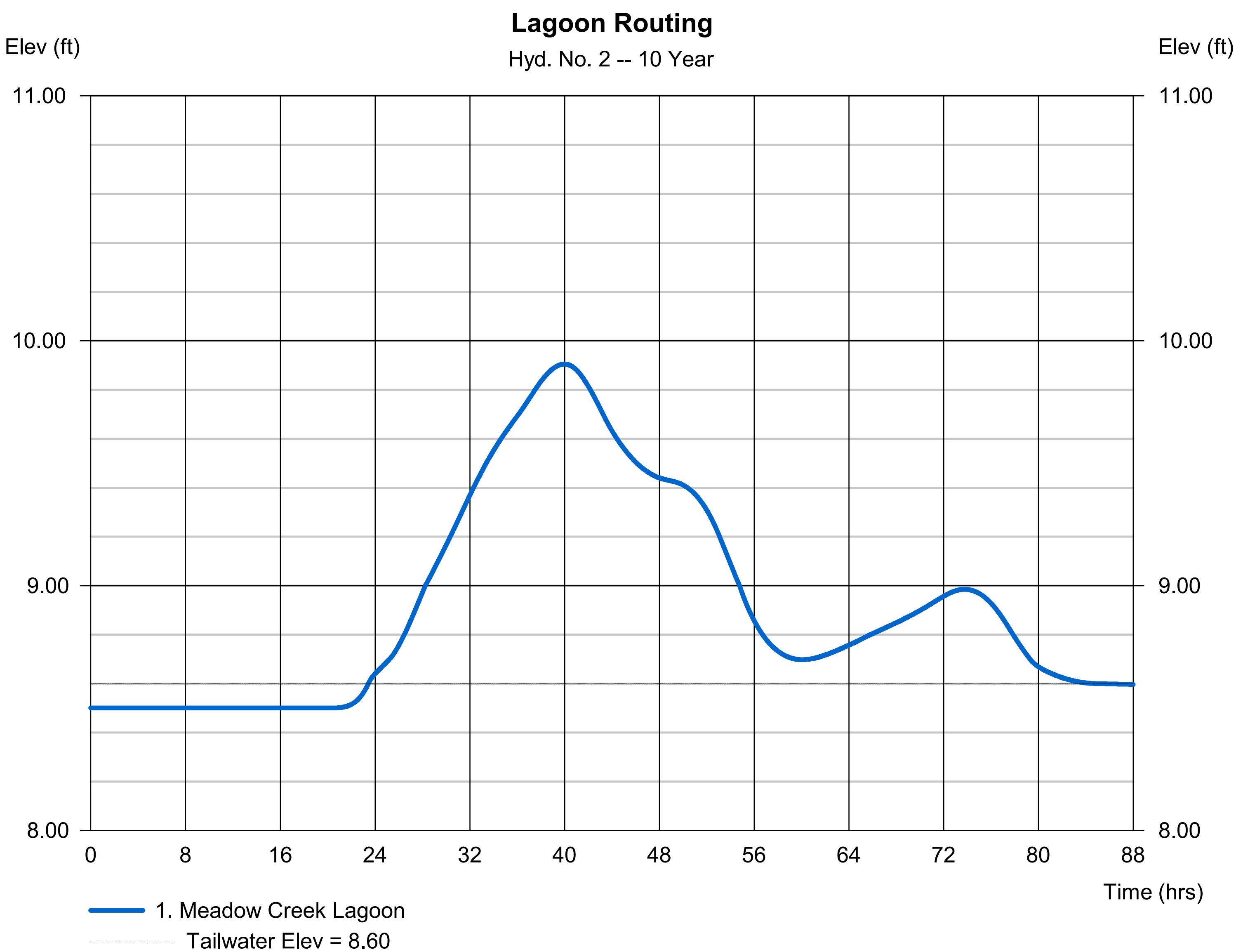
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2010 by Autodesk, Inc. v9.24 Sunday, Mar 10, 2013

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 234.26 cfs
Storm frequency	= 10 yrs	Time to peak	= 39.97 hrs
Time interval	= 2 min	Hyd. volume	= 25,323,970 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 9.90 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 2,609,491 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Hydrograph Report `Two Additional Culverts`

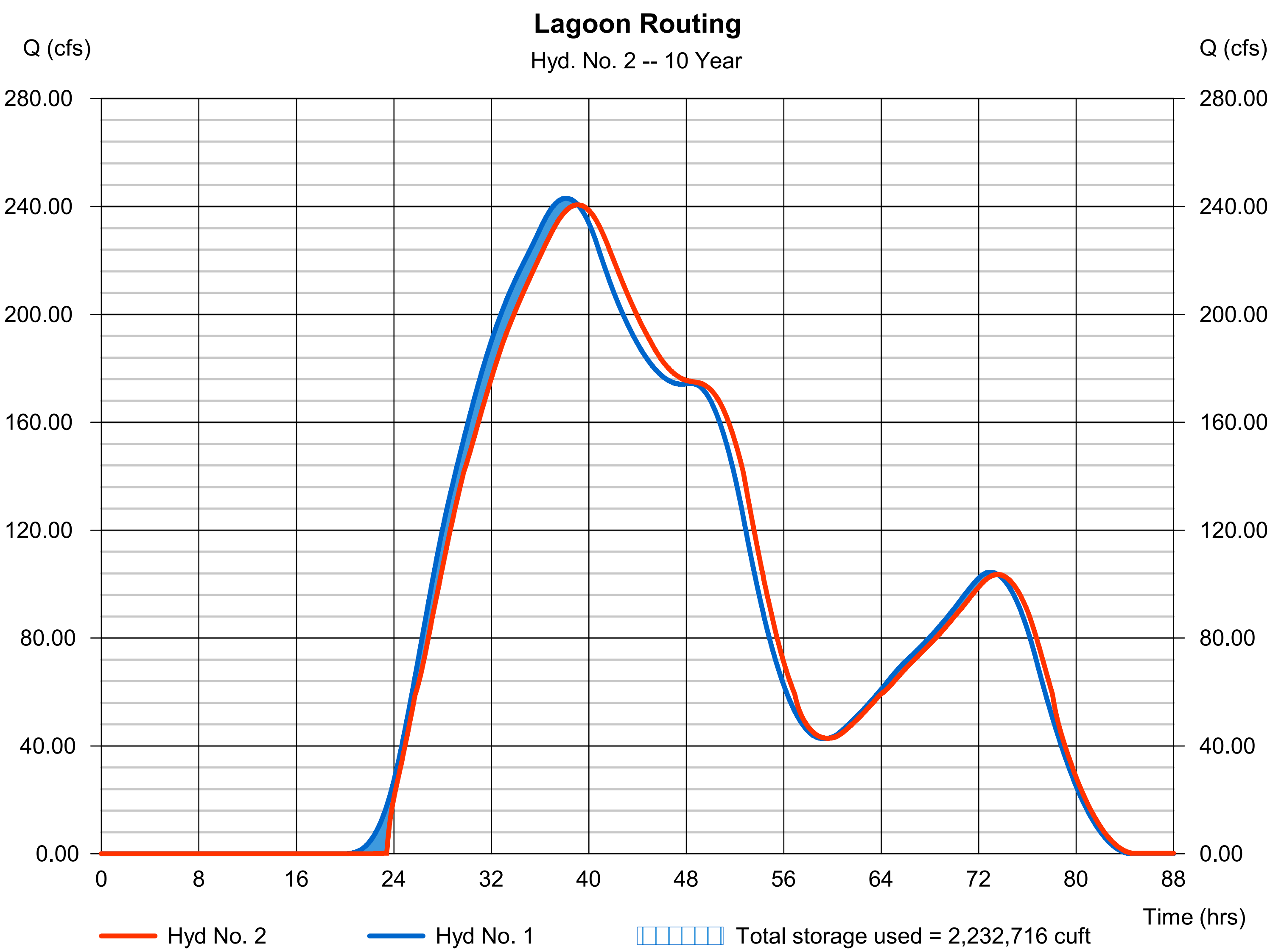
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2010 by Autodesk, Inc. v9.24 Sunday, Mar 10, 2013

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 240.63 cfs
Storm frequency	= 10 yrs	Time to peak	= 39.10 hrs
Time interval	= 2 min	Hyd. volume	= 25,326,250 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 9.44 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 2,232,716 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Hydrograph Report   Two Additional Culverts

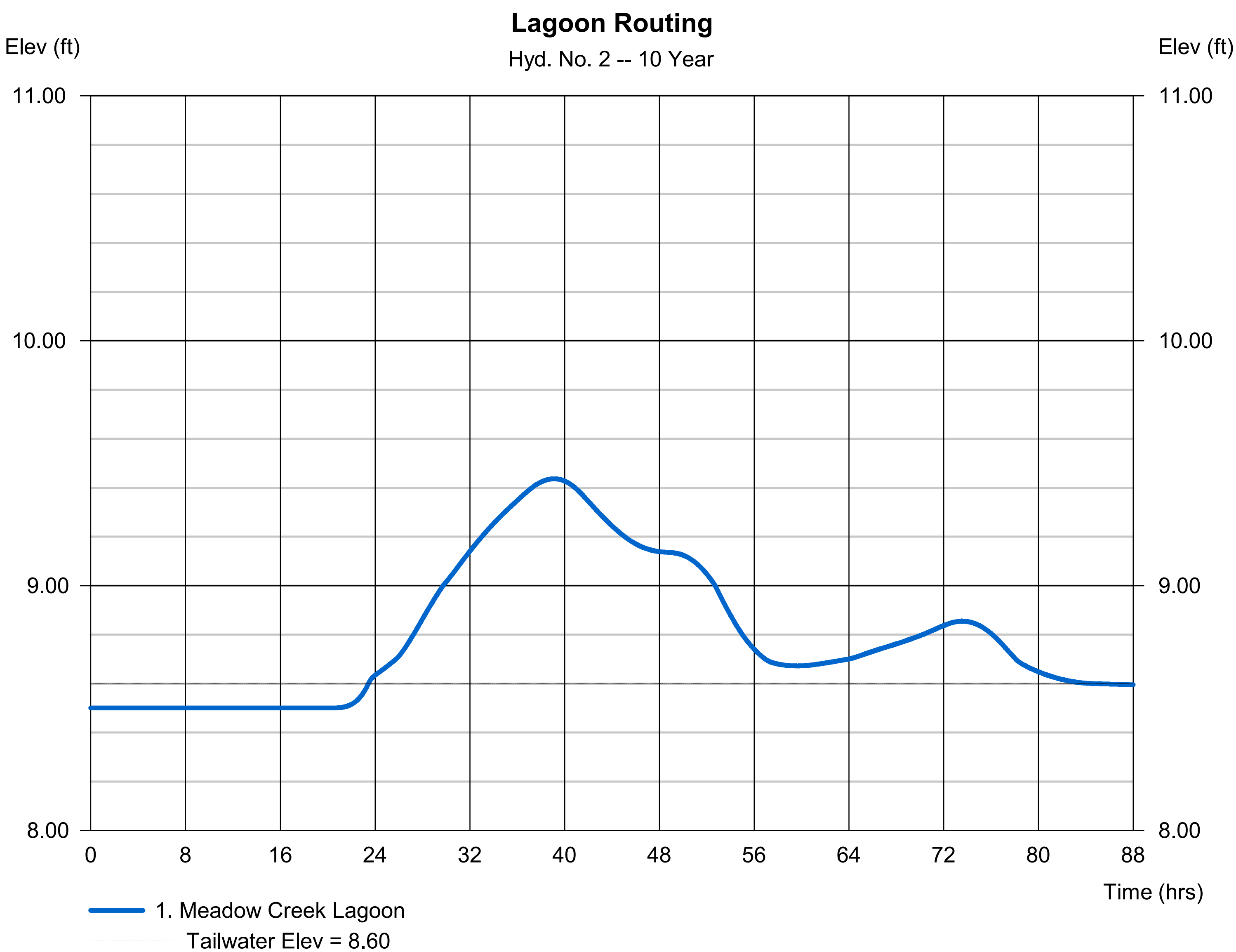
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2010 by Autodesk, Inc. v9.24   Sunday, Mar 10, 2013

Hyd. No. 2

Lagoon Routing

Hydrograph type	= Reservoir	Peak discharge	= 240.63 cfs
Storm frequency	= 10 yrs	Time to peak	= 39.10 hrs
Time interval	= 2 min	Hyd. volume	= 25,326,250 cuft
Inflow hyd. No.	= 1 - Theoretical Inflow	Max. Elevation	= 9.44 ft
Reservoir name	= Meadow Creek Lagoon	Max. Storage	= 2,232,716 cuft

Storage Indication method used. Wet pond routing start elevation = 8.50 ft.



Culvert Report

Outlet Control (high tailwater condition)

Invert Elev Dn (ft)	= 6.40
Pipe Length (ft)	= 65.00
Slope (%)	= 0.06
Invert Elev Up (ft)	= 6.44
Rise (in)	= 60.0
Shape	= Cir
Span (in)	= 60.0
No. Barrels	= 2
n-Value	= 0.020
Inlet Edge	= 0
Coeff. K,M,c,Y,k	= 0.0045, 2, 0.0317, 0.69, 0.5

Embankment

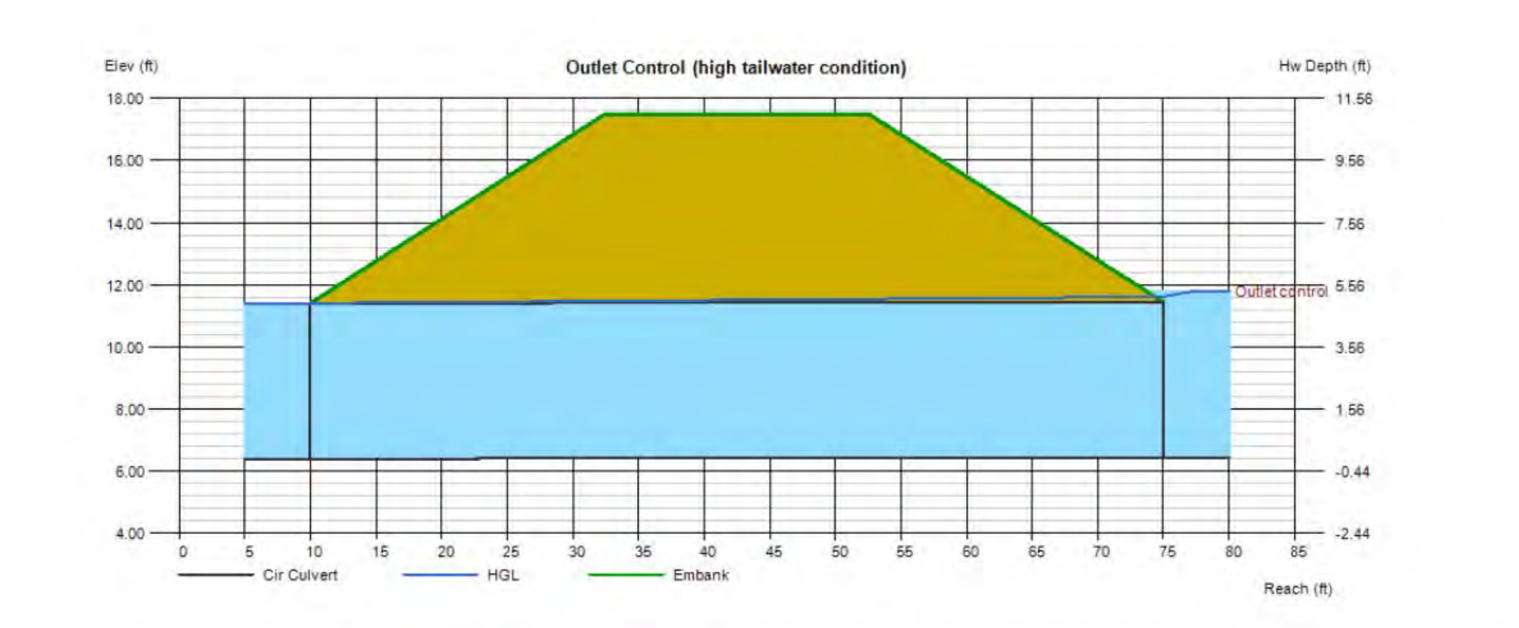
Top Elevation (ft)	= 17.50
Top Width (ft)	= 20.00
Crest Width (ft)	= 100.00

Calculations

Qmin (cfs)	= 195.00
Qmax (cfs)	= 195.00
Tailwater Elev (ft)	= 0

Highlighted

Qtotal (cfs)	= 195.00
Qpipe (cfs)	= 195.00
Qovertop (cfs)	= 0.00
Veloc Dn (ft/s)	= 4.97
Veloc Up (ft/s)	= 4.97
HGL Dn (ft)	= 11.40
HGL Up (ft)	= 11.62
Hw Elev (ft)	= 11.81
Hw/D (ft)	= 1.07
Flow Regime	= Outlet Control



Culvert Report

Inlet Control (low tailwater condition)

Invert Elev Dn (ft)	= 6.40
Pipe Length (ft)	= 65.00
Slope (%)	= 0.06
Invert Elev Up (ft)	= 6.44
Rise (in)	= 60.0
Shape	= Cir
Span (in)	= 60.0
No. Barrels	= 2
n-Value	= 0.020
Inlet Edge	= 0
Coeff. K,M,c,Y,k	= 0.0045, 2, 0.0317, 0.69, 0.5

Embankment

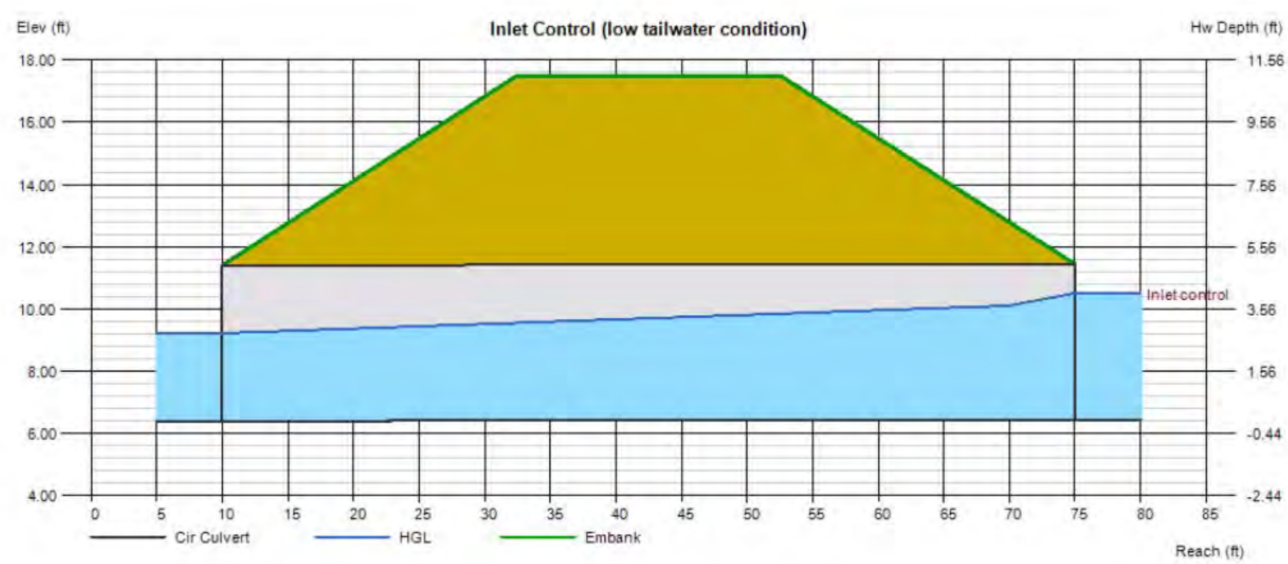
Top Elevation (ft)	= 17.50
Top Width (ft)	= 20.00
Crest Width (ft)	= 100.00

Calculations

Qmin (cfs)	= 195.00
Qmax (cfs)	= 195.00
Tailwater Elev (ft)	= 0

Highlighted

Qtotal (cfs)	= 195.00
Qpipe (cfs)	= 195.00
Qovertop (cfs)	= 0.00
Veloc Dn (ft/s)	= 8.54
Veloc Up (ft/s)	= 6.19
HGL Dn (ft)	= 9.22
HGL Up (ft)	= 10.18
Hw Elev (ft)	= 10.51
Hw/D (ft)	= 0.81
Flow Regime	= Inlet Control



Appendix IV - Exhibits

N
W
E
S
Pier Ave
Truman Dr
Norswing Dr
Pershing Dr
STATE PARK
CO PARK
Lakeside Ave
Air Park Dr
McCarthy Ave
STATE PARK
CO PARK
Mendel Dr
Juanita Ave
(COUNTY)
South Fourth St
Pike Ln
Crest St
Island Ct
Sixteenth St
Wilmar Ave
PALACE AVE ASSOC.
Belridge St
Strand Way
Thirteenth St
Fourteenth St
Rice St
Honolulu St
Laguna Dr
York St
Warner St
Fifteenth St
Aloha Pl
Utah Av
Maui Cir
Fountain Ave
PISMO COAST VILLAGE
Railroad St
AIRPORT
Paso Robles St
(COUNTY)
STATE PARK
SO CO SANITATION DIST
Flap Gate
Ocean St
Ocean St
Arroyo
Grande
Creek
PISMO COAST VILLAGE
PALACE AVE ASSOC
PISMO COAST VILLAGE
SO CO SANITATION DIST
USE
AIRPORT
STATE PARK
COUNTY PARK
COUNTY - OTHER
OCEANO LAGOON
and
ARROYO GRANDE
CREEK CHANNEL
PUBLIC WORKS
GIS SERVICES
SAN LUIS OBISPO COUNTY

C:\Users\CharlieG\AppData\Local\Temp\AcPublish_3756\CE100405EX0006-80sc.dwg 2-29-12 07:58:34 AM charlieg

0 80 160
1 INCH = 80 FEET

DATUM:

HORIZONTAL CONTROL IS BASED ON THE CALIFORNIA STATE COORDINATE SYSTEM, ZONE 5, EPOCH DATE 1991.35, AT NGS MONUMENT "HPGN CA 05 05", PID# FV2048, SAN LUIS OBISPO COUNTY, CALIFORNIA.

VERTICAL CONTROL IS BASED NGS MONUMENT X 532 SAN LUIS OBISPO COUNTY, CALIFORNIA, HAVING A NAVD88 PUBLISHED VALUE OF 13.5 FEET.

THE BENCHMARK FOR THIS SURVEY LOCATED AT:
NORTH: 2234405.96
EAST: 5776596.56

GENERAL NOTES:

1. THE AVERAGE WATER SURFACE ELEVATION WAS SURVEYED TO BE 8.3-FT ON SURVEY DATES: 10/06/2011, 10/24/2011, 11/09/2011.
2. THE AVERAGE WATER SURFACE ELEVATION WAS SURVEYED TO BE 8.5-FT ON SURVEY DATE: 10/31/2011.
3. WATER CAPACITY OF MEADOW CREEK LAGOON TO THE 12-FT CONTOUR IS 47,171,200 GALLONS.
4. IN-ACCESSIBLE DENSE REED AND OTHER GROWTH CONTOURS DEVELOPED FROM 2005 AERIAL SURVEY PREPARED BY CENTRAL COAST AERIAL MAPPING, INC.

LEGEND

EXISTING CONTOURS
EXISTING TREE
EXISTING PARCEL
DENSE REED AND OTHER GROWTH
IN-ACCESSIBLE DENSE REED AND OTHER GROWTH. SEE NOTE 4.
BENCHMARK

REV. NO	DATE	REVISED	DESTROY ALL PRINTS BEARING EARLIER DATE	REV. BY	CKD. BY	APRD BY

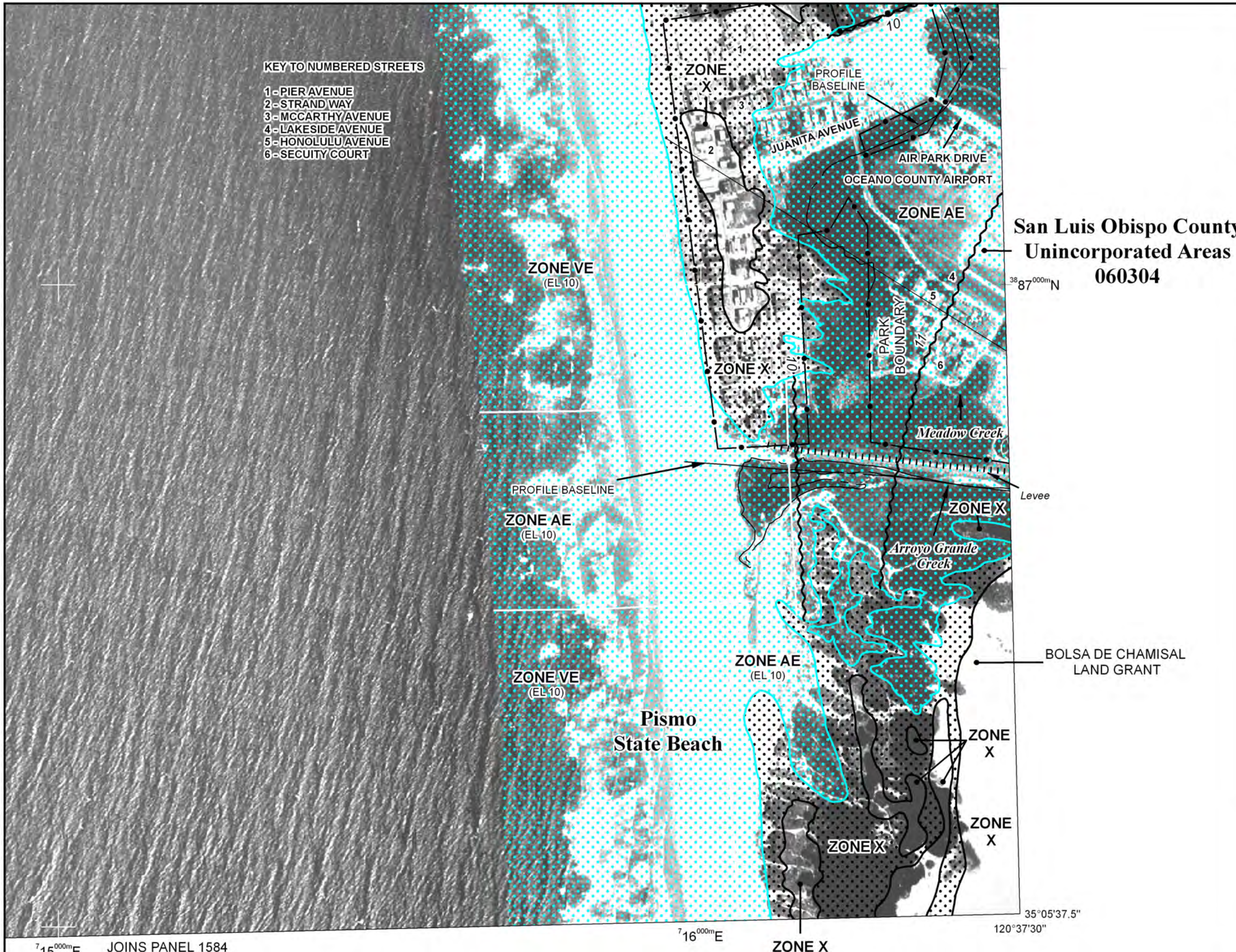
Cannon
1050 Southwood Drive
San Luis Obispo, CA 93401
P 805.544.7407 F 805.544.3863

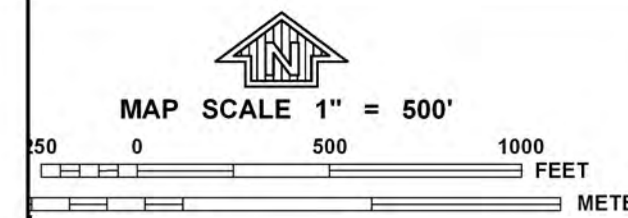
MEADOW CREEK LAGOON

BATHYMETRIC SURVEY MAP (2012) EXHIBIT

COUNTY OF SAN LUIS OBIPSO

DRAWN BY	DATE	CA JOB NO.
KK	02/27/2012	100405
CHECKED BY	SCALE	SHEET
	1" = 80'	1 OF 1





NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1582F

FIRM

FLOOD INSURANCE RATE MAP

SAN LUIS OBISPO COUNTY, CALIFORNIA
AND INCORPORATED AREAS

PANEL 1582 OF 2050

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
GROVER BEACH, CITY OF	060306	1582	F
SAN LUIS OBISPO COUNTY	060304	1582	F

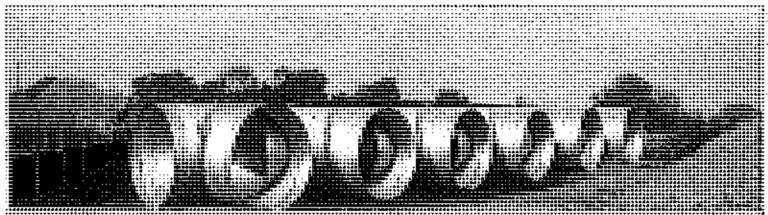
Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
06079C1582F

EFFECTIVE DATE
AUGUST 28, 2008

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



Pipe Arches

Corrugated steel pipe and structural plate pipe offer designers a wide choice of standard cross-sectional arch shapes. Planned size and site conditions often impact the shape selected, with strength and economy as additional factors. See the tables below for sizes and layout details.

Sizes and layout details – CSP Pipe Arches (2 2/3 x 1/2 in. corrugation)

Equiv. Diameter	Design		Waterway Area	Layout Dimensions			
	Span	Rise		B	Rc	Rt	Rb
(in.)	(in.)	(in.)	(ft2)	(in.)	(in.)	(in.)	(in.)
15	17	13	1.1	4 1/8	3 1/2	8 5/8	25 5/8
18	21	15	1.6	4 7/8	4 1/8	10 3/4	33 3\1/8
21	24	18	2.2	5 5/8	4 7/8	11 7/8	34 5/8
24	28	20	2.9	6 1/2	5 1/2	14	42 1/4
30	35	24	4.5	8 1/8	6 7/8	17 7/8	55 1/8
36	42	29	6.5	9 3/4	8 1/4	21 1/2	66 1/8
42	49	33	8.9	11 3/8	9 5/8	25 1/8	77 1/4
48	57	38	11.6	13	11	28 5/8	88 1/4
54	64	43	14.7	14 5/8	12 3/8	32 1/4	99 1/4
60	71	47	18.1	16 1/4	13 3/4	35 3/4	110 1/4
66	77	52	21.9	17 7/8	15 1/8	39 3/8	121 1/4
72	83	57	26.0	19 1/2	16 1/2	43	132 1/4

Notes: Layout dimensions are typical manufactured dimensions. Specified dimensions are found in ASTM A760.

Sizes and layout details – CSP Pipe Arches (3 x 1 or 5 x 1 in. corrugation)

Equiv. Diameter	Nominal Size	Design		Waterway Area	Layout Dimensions			
		Span	Rise		B	Rc	Rt	Rb
(in.)	(in.)	(in.)	(in.)	(ft2)	(in.)	(in.)	(in.)	(in.)
48	53 x 41	53	41	11.7	15 1/4	10 3/18	28 1/16	73 7/16
54	60 x 46	58 1/2	48 1/2	15.6	20 1/2	18 3/4	29 3/8	51 1/8
60	66 x 51	65	54	19.3	22 3/4	20 3/4	32 5/8	56 1/4
66	73 x 55	72 1/2	58 1/4	23.2	25 1/8	22 7/8	36 3/4	63 3/4
72	81 x 59	79	62 1/2	27.4	23 3/4	20 7/8	39 1/2	82 5/8
78	87 x 63	86 1/2	67 1/4	32.1	25 3/4	22 5/8	43 3/8	92 1/4
84	95 x 67	93 1/2	71 3/4	37.0	27 3/4	24 3/8	47	100 1/4
90	103 x 71	101 1/2	76	42.4	29 3/4	26 1/8	51 1/4	111 5/6
96	112 x 75	108 1/2	80 1/2	48.0	31 5/6	27 3/4	54 7/8	120 1/4
102	117 x 79	116 1/2	84 3/4	54.2	33 5/8	29 1/2	59 3/8	131 3/4
108	128 x 83	123 1/2	89 1/4	60.5	35 5/6	31 1/4	63 1/4	139 3/4
114	137 x 87	131	93 3/4	67.4	37 5/8	33	67 3/8	149 1/2
120	142 x 91	138 1/2	98	74.5	39 1/2	34 3/4	71 5/8	162 3/8
126	150 x 96	146	102	81	41	36	76	172
132	157 x 101	153	107	89	43	38	80	180
138	164 x 105	159	113	98	45	40	82	184
144	171 x 110	165	118 1/2	107	47	41	85	190

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