University of California, Berkeley

Flow Analysis of the Mad River between Forest Glen and Arcata, CA

CE101: Fluid Mechanics of Rivers, Streams, and Wetlands Final Project

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CE101, Fall 204, Prof. Stacey
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For our river analysis, we selected the Mad River in Northern California. We selected an 84.2 mile stretch of the Mad River beginning upstream of Ruth Reservoir in Trinity County and ending at the mouth of the river as it enters into the ocean in Arcata County. To find our river, we used the National Inventory of Dams and looked at maps, searching for a river that had both a dam, flow gauges, and relatively few tributary streams feeding into it. While the last criteria was difficult to fulfill, our stretch of river has four streamflow gauges, so were able to interpolate what the flow would be at various transition locations.

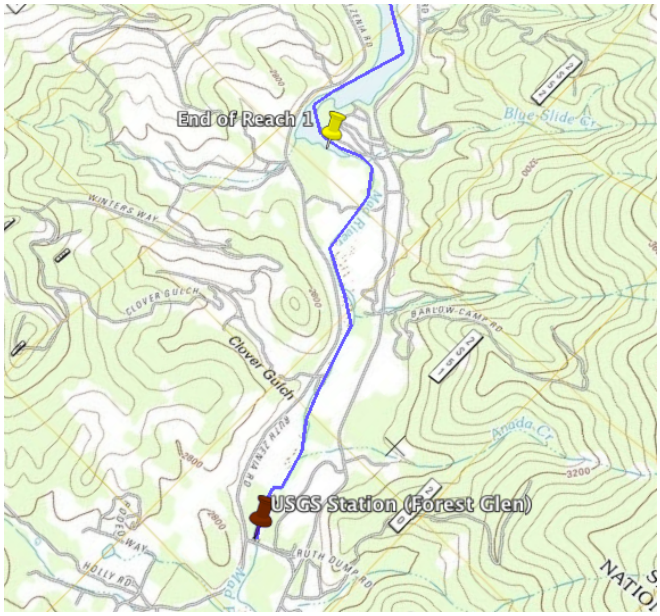
We divided the river stretch into five reaches of various lengths. To do this we first charted the path of the river on Google Earth, which enabled us to see the changes in elevation along our chosen stretch of the river. We chose our divisions based on transitions that occur in the river including slope changes, flow into a reservoir, and flow out of a reservoir. To estimate the reach and transition lengths, the river widths, and elevations we used Google Earth. We estimated three widths for each river stretch to determine an average width. Using elevation and length estimates, we determined the slopes of the five reaches. The reach characteristics are summarized in Table 1 at the end of the report.

For flow data, we used USGS streamflow data. Our river stretch has four USGS flow gauges, one just upstream of the dam, one at the outflow of the dam, one 8.3 miles downstream of the dam, and the fourth located in Arcata before the river enters the ocean. The USGS site numbers for the four gauges are 11480390, 11480410, 11408500, and 11481000 respectively. For each location there was over thirty years of daily streamflow data available. Over the available time spans for each gauge, we took the monthly averages. We selected the highest flow month to be January and the lowest flow month to be July. For our in between flows, we selected April and November flow data.

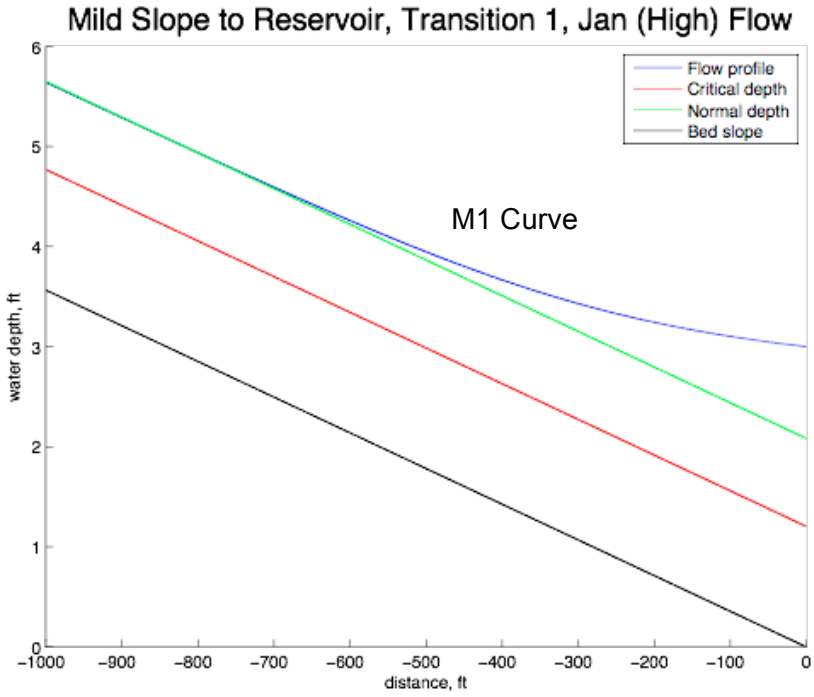
To estimate the flow of the Mad River without a dam, we determined how much flow is currently being restricted by the dam. Based off the USGS data, the flow into Ruth Reservoir is actually smaller than the flow that exits the dam at the bottom of the reservoir. By more closely examining Ruth Reservoir and its watershed, we determined that more flow from Mad River exits the reservoir then enters because there are multiple tributaries that conclude at the reservoir. There are 26 tributaries and creeks that enter Ruth Reservoir after the USGS gage just upstream the reservoir. To account for the extra inflow into the reservoir, we estimated the percent of the watershed that enters Ruth Reservoir through the Mad River and then we calculated the total flow into Ruth Reservoir. We estimate that each of the tributaries has about 5% of the flow of the Mad River. Therefore the actual flow into the Ruth Reservoir is 230% (100% +5%*26) of the flow from the Mad River. We then calculated the amount of flow that is being restricted by the dam and then added this amount to the flow to analyze the hydraulics of Mad River if there were no dam.

To determine the roughness of the Mad River bed, we found Manning's n for each reach by again using Google Earth as wells as Ven Te Chow's 1959 Table of Manning's n coefficients. We used Google Earth to characterize the amount of vegetation and rock in the channel and then used Chow's table to determine a value of Manning's n. For reaches one through four, we characterized them as mountain streams that are winding with some pools, weeds, stones, and boulders and estimated the Manning's n to be 0.05. For the fifth reach in Arcata, we characterized the river bed as winding, clean and having some pools and estimated the Manning's n to be 0.04.

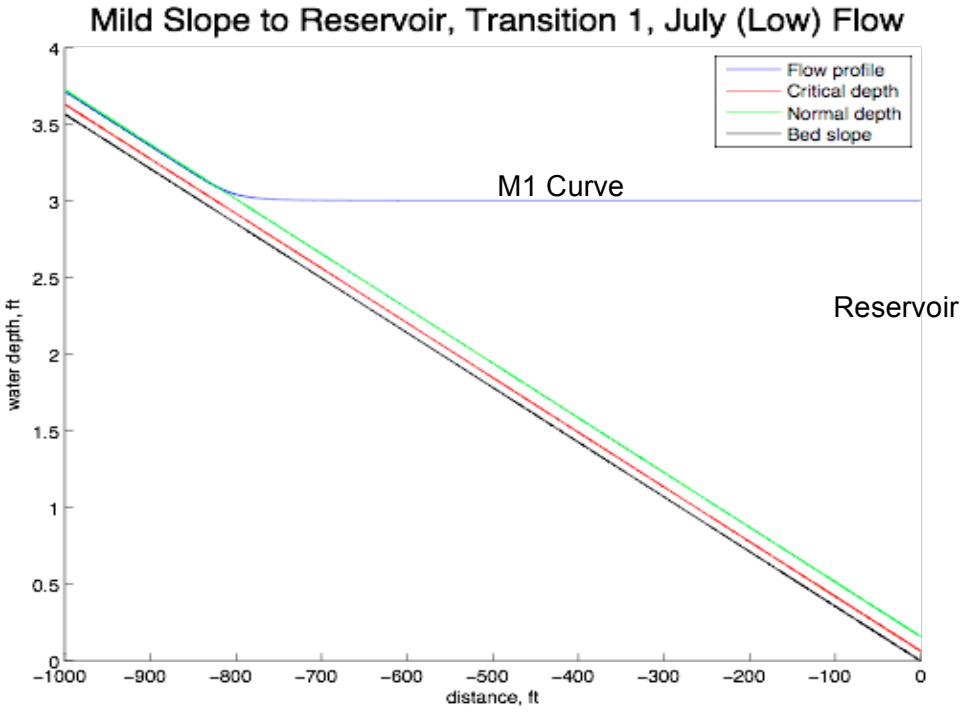
Transition 1: Flow into Ruth Reservoir



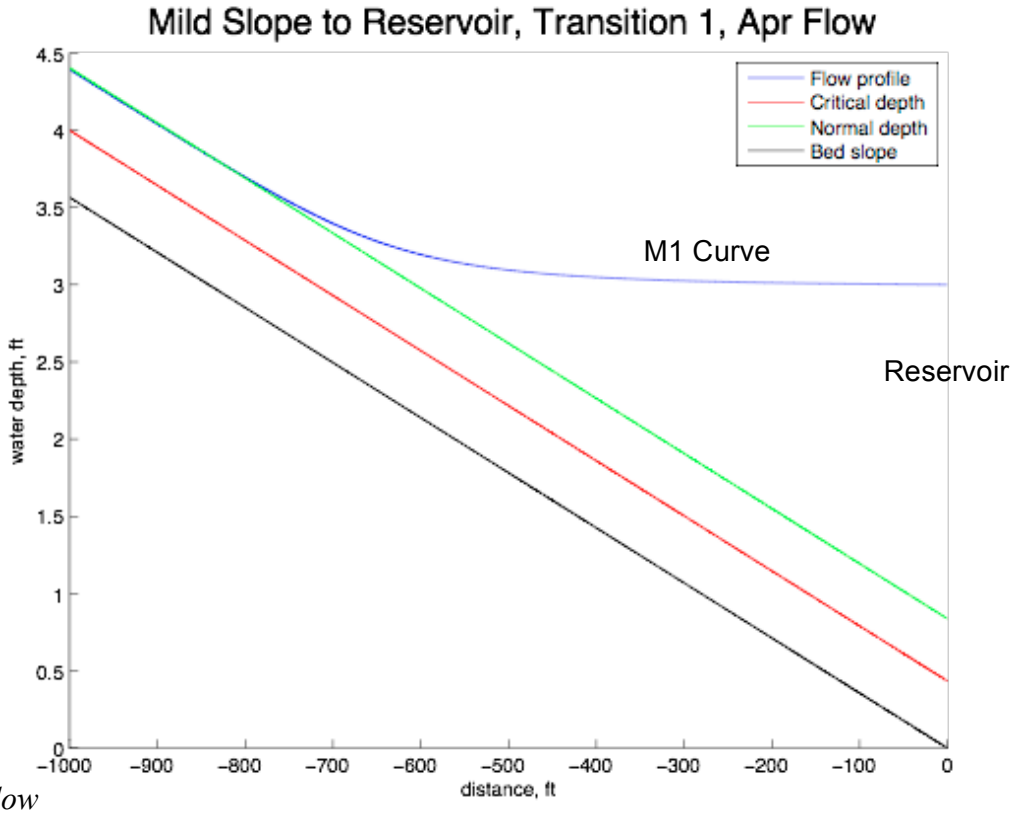
January (High) Flow



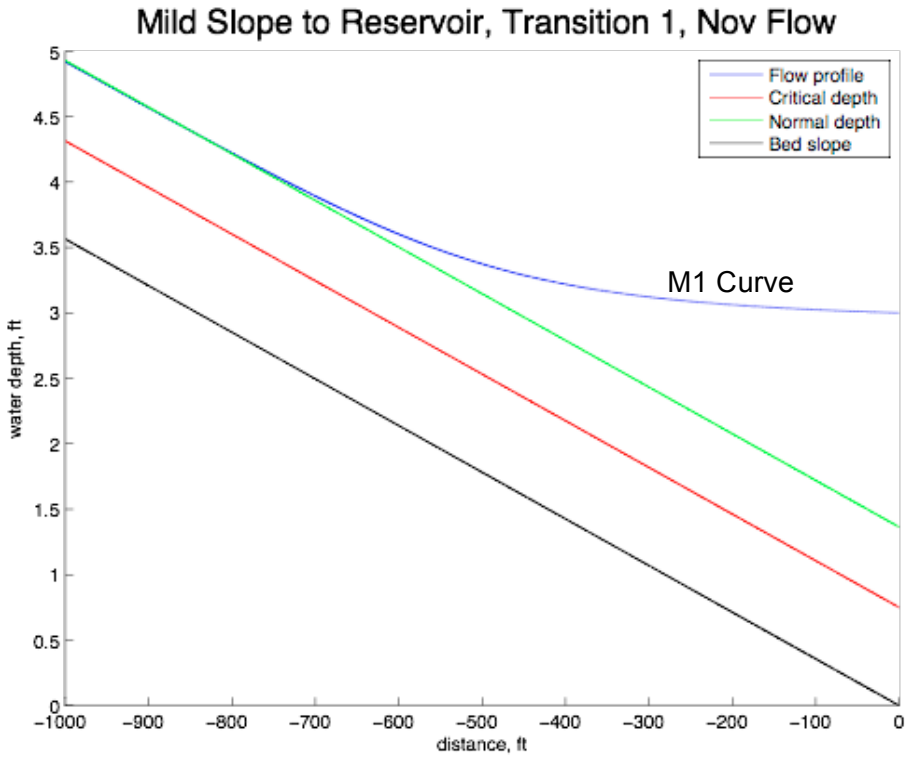
July (Low) Flow



April Flow

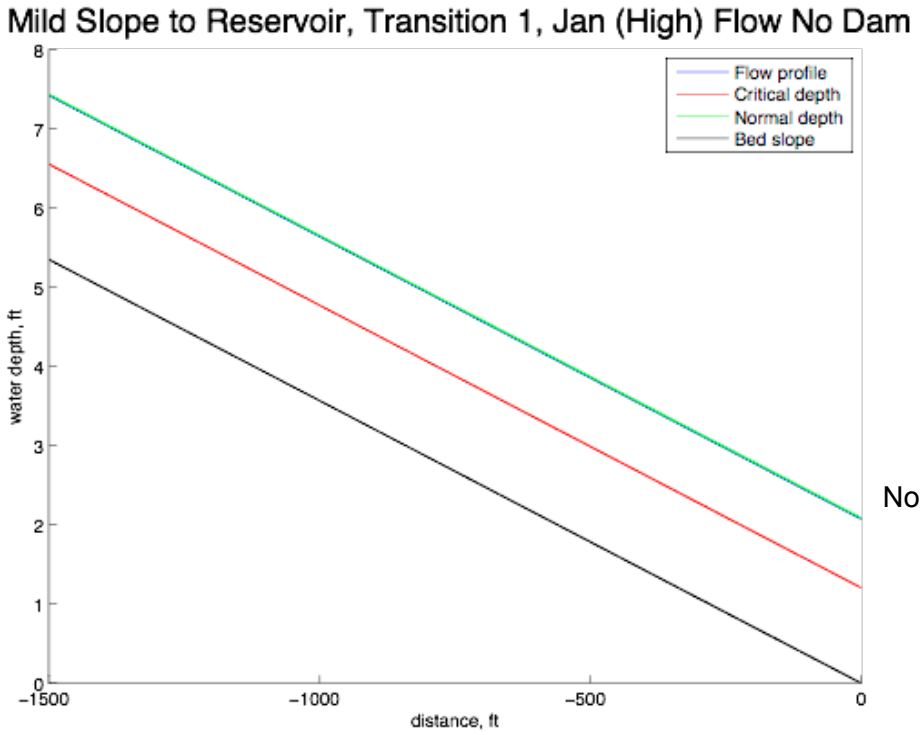


November Flow



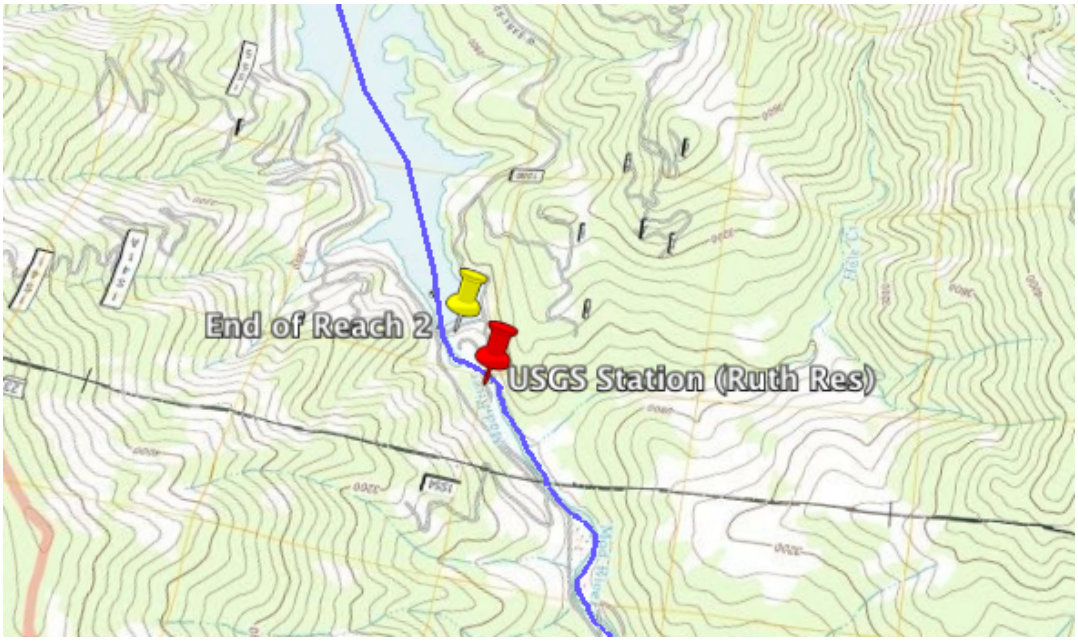
Reservoir

No Dam High Flow

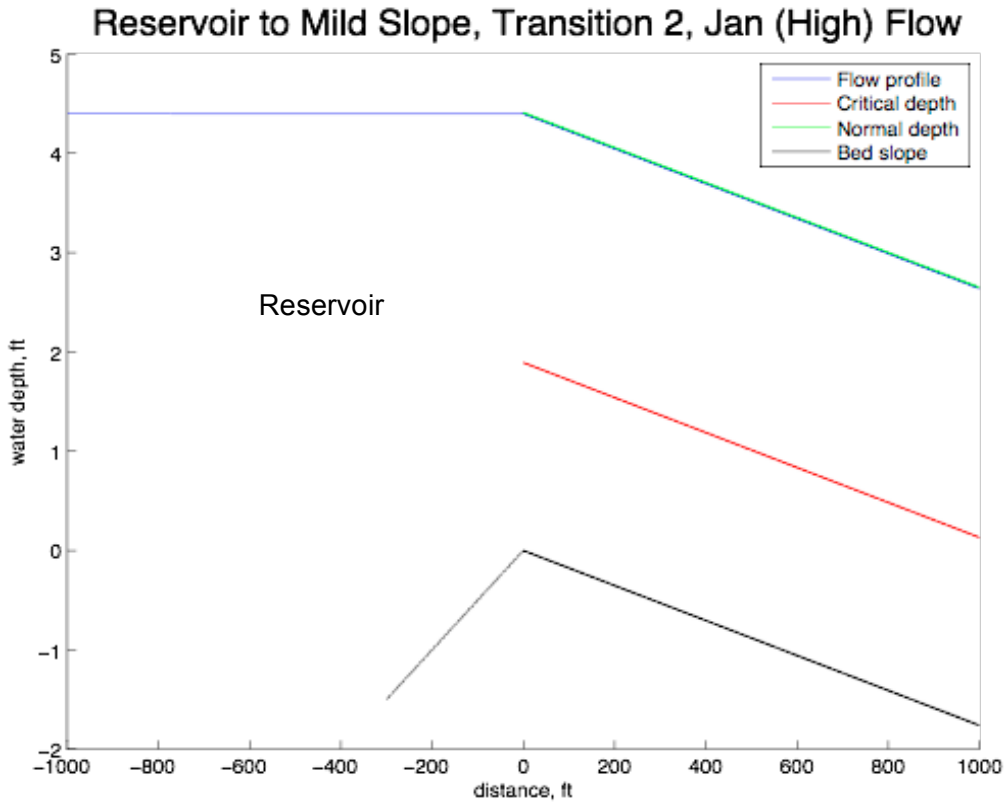


No Reservoir

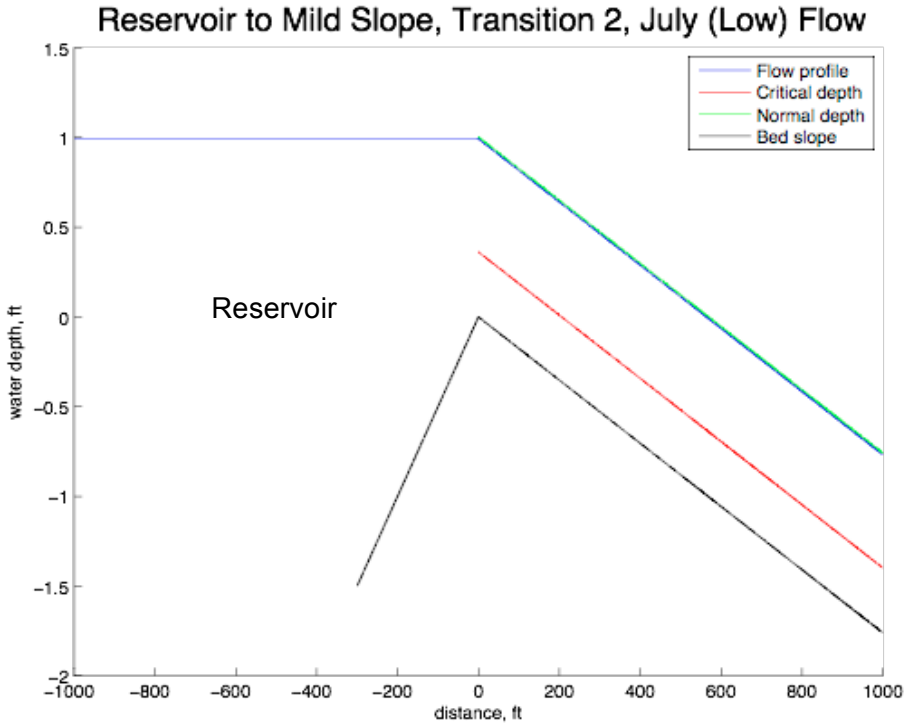
Transition 2: Flow Out of Ruth Reservoir



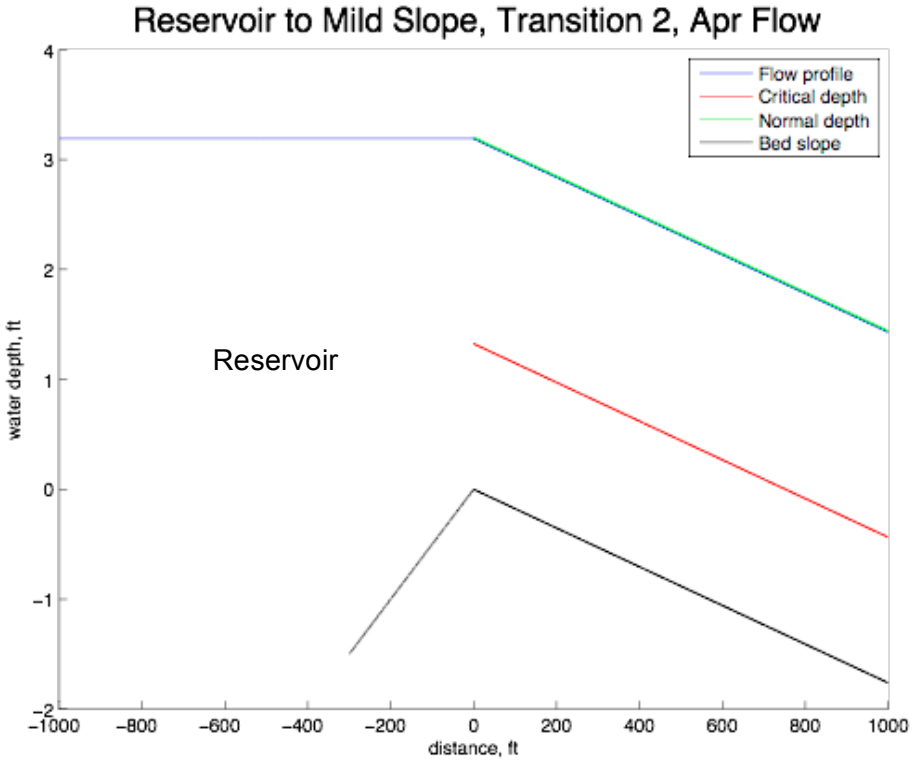
January (High) Flow



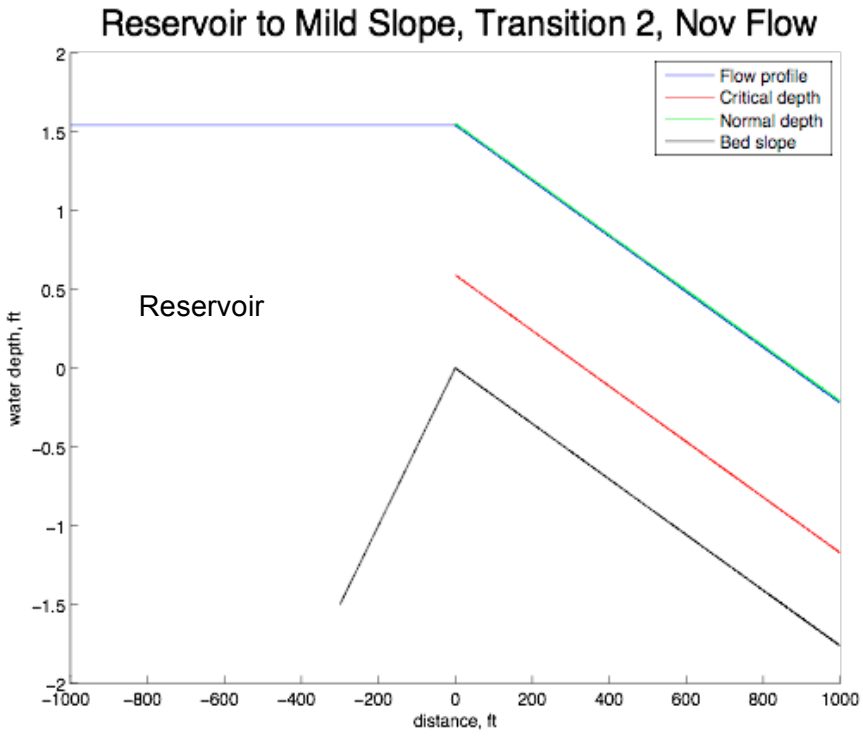
July (Low) Flow



April Flow

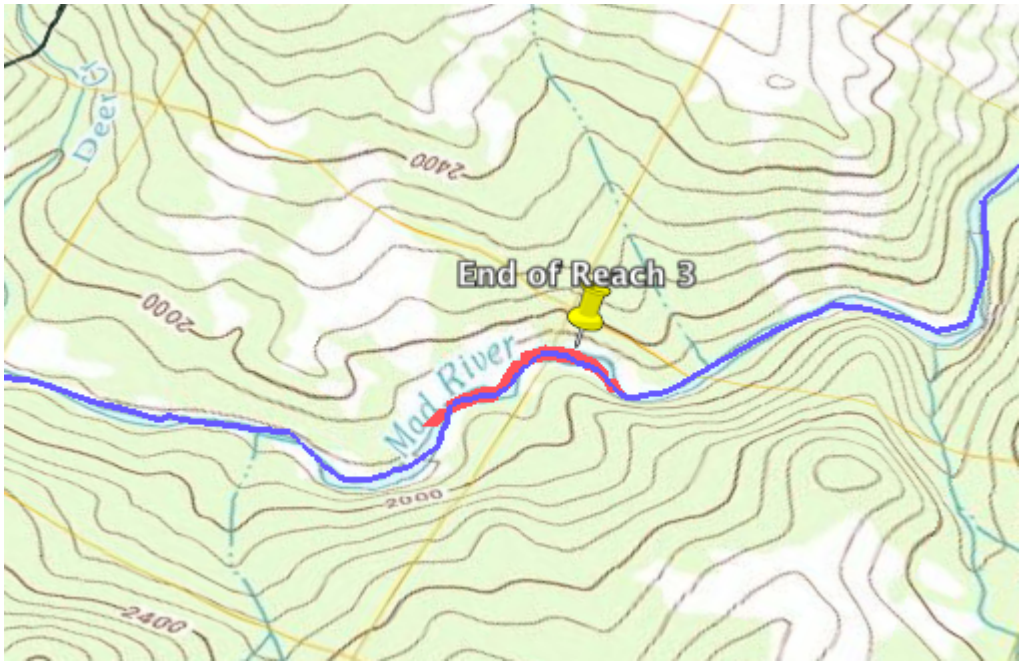


November Flow

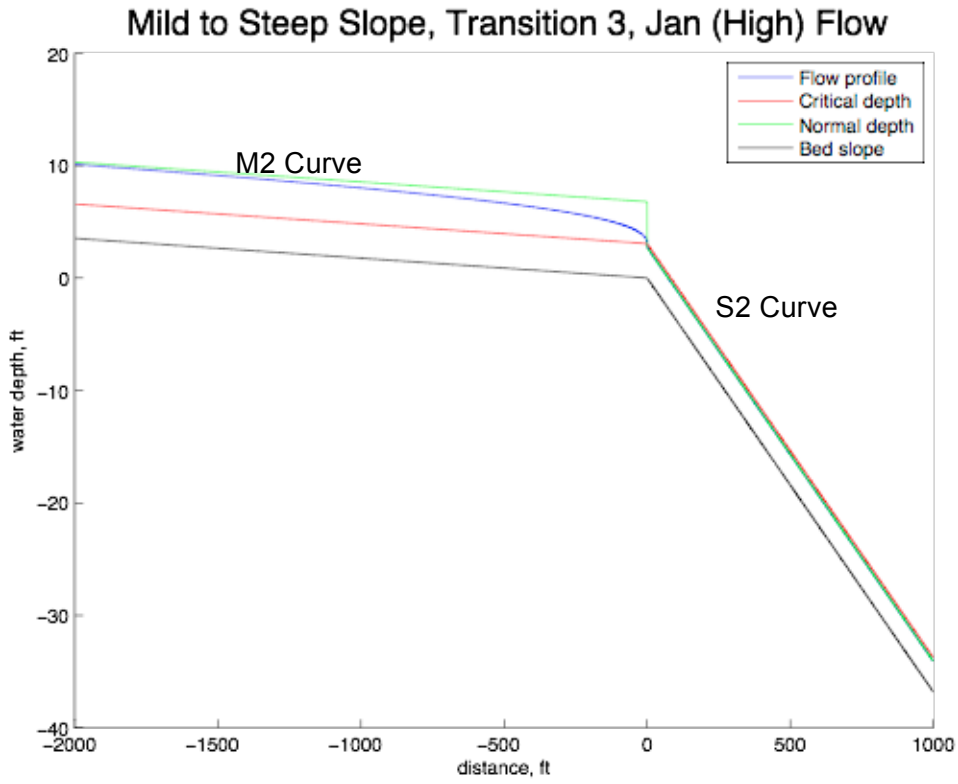


No Dam High Flow

Transition 3: Mild to Steep Slope (Near Confluence of Deer Creek)

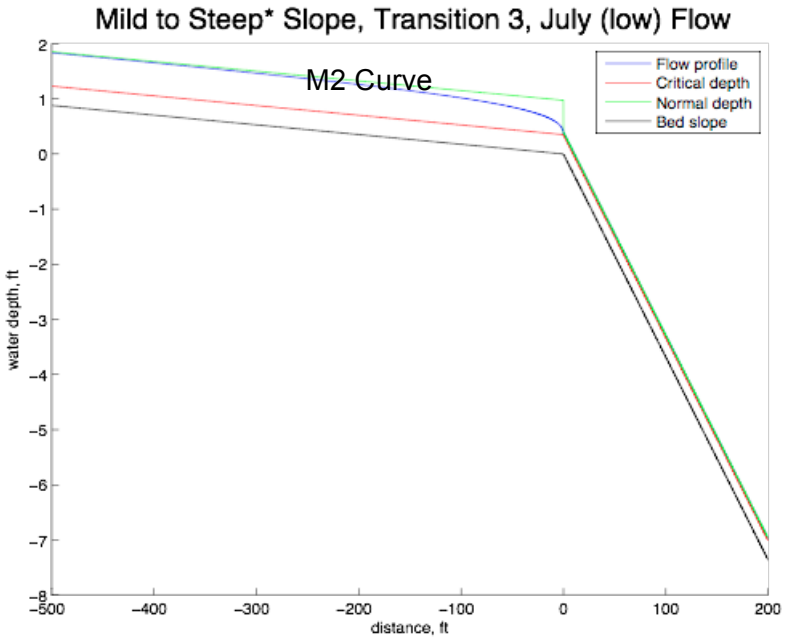


January (High) Flow

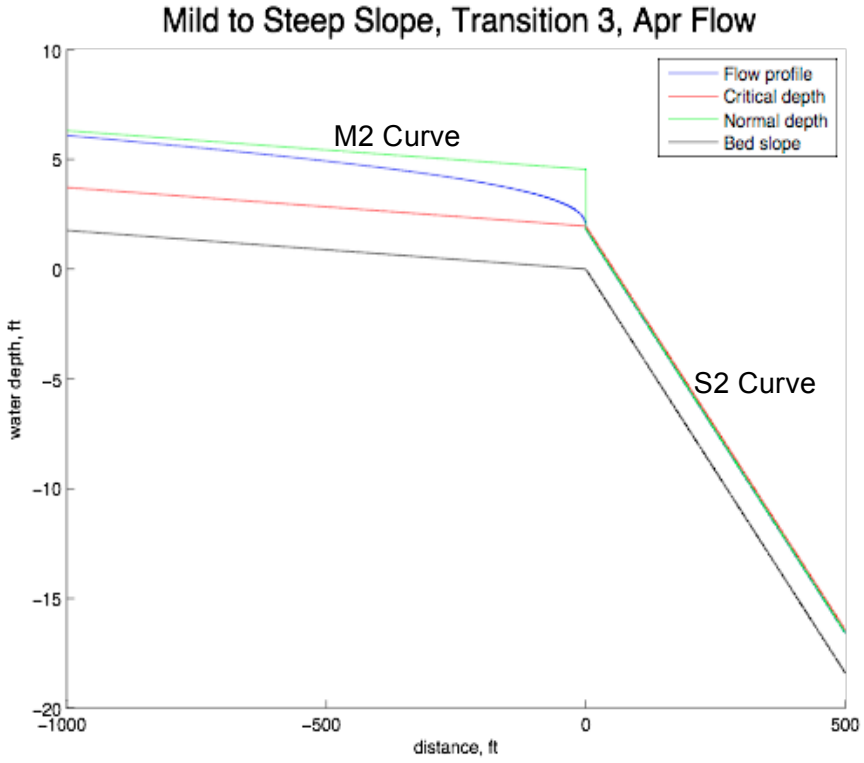


July (Low) Flow

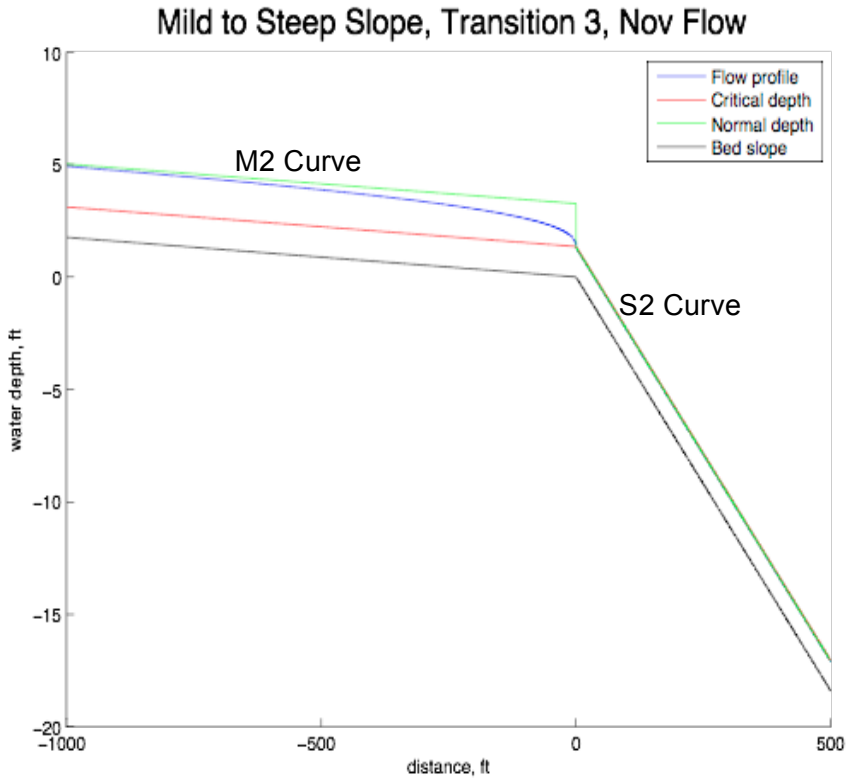
*Note: Flow is so low, that in the "steep section" the normal depth is above the critical depth, so this section is now classified as mild. Therefore, the transition for this flow is from one mild slope to another mild slope.



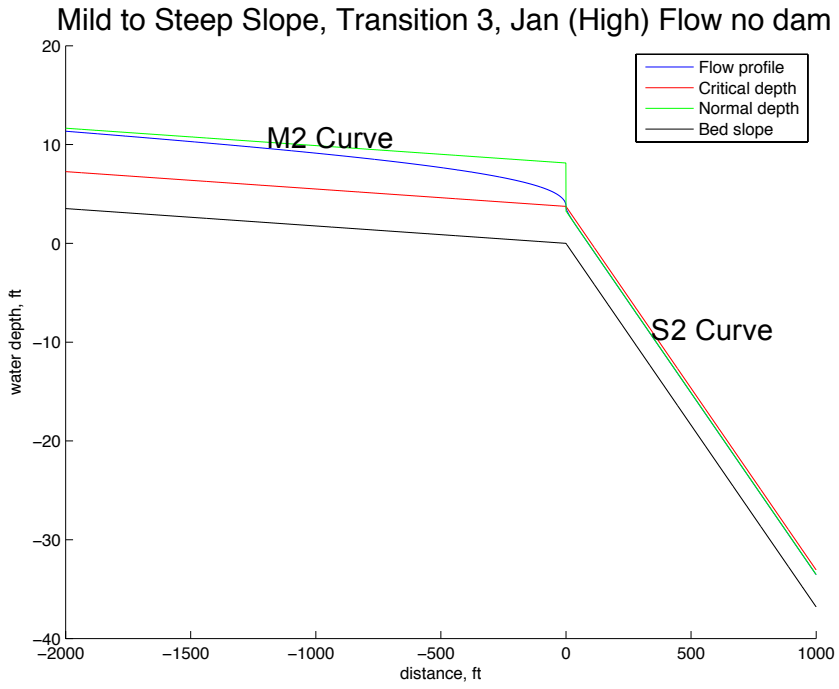
April Flow



November Flow

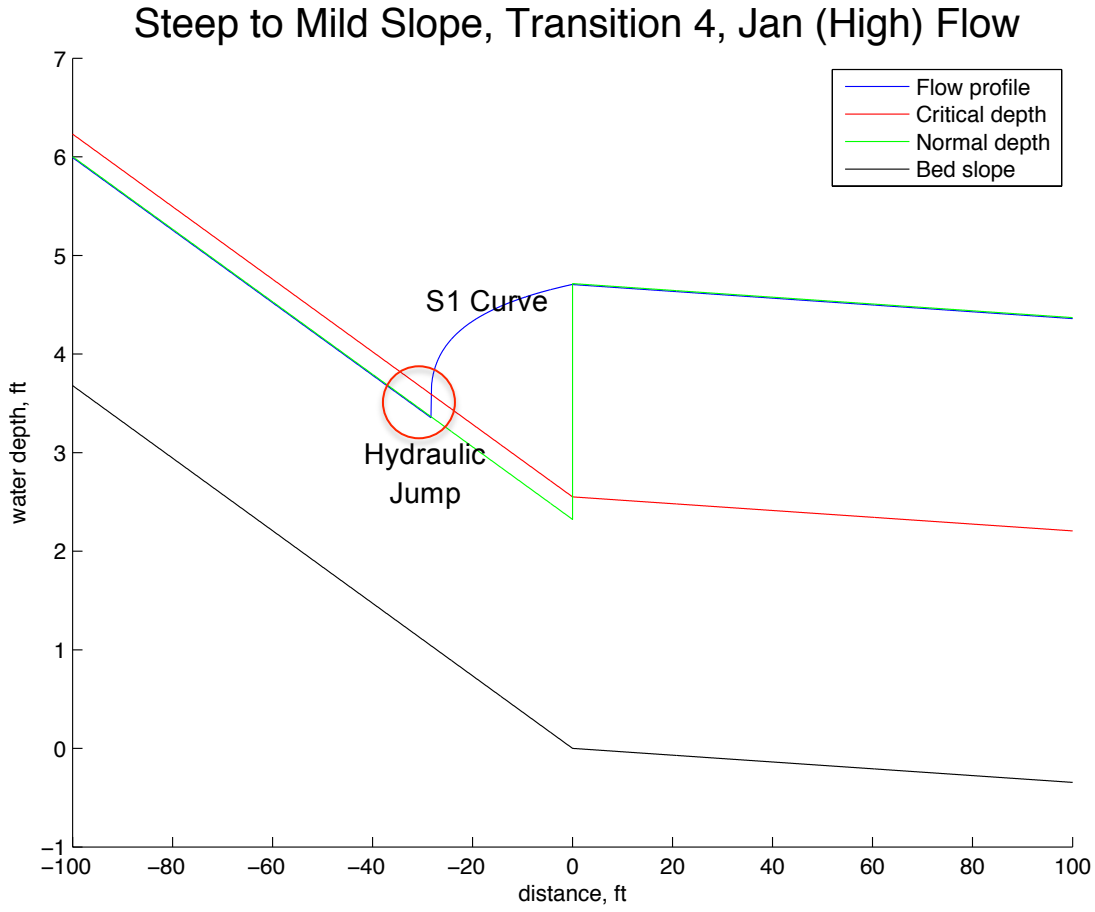


No Dam High Flow



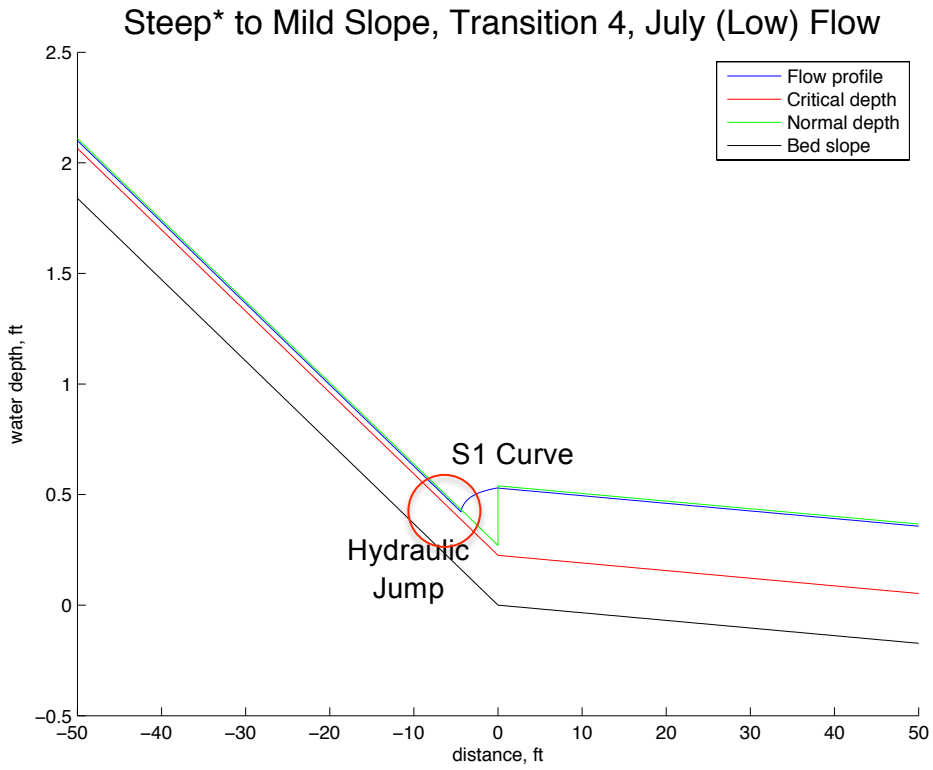
Transition 4: Steep to Mild Slope (Near Big Bend)

January (High) Flow

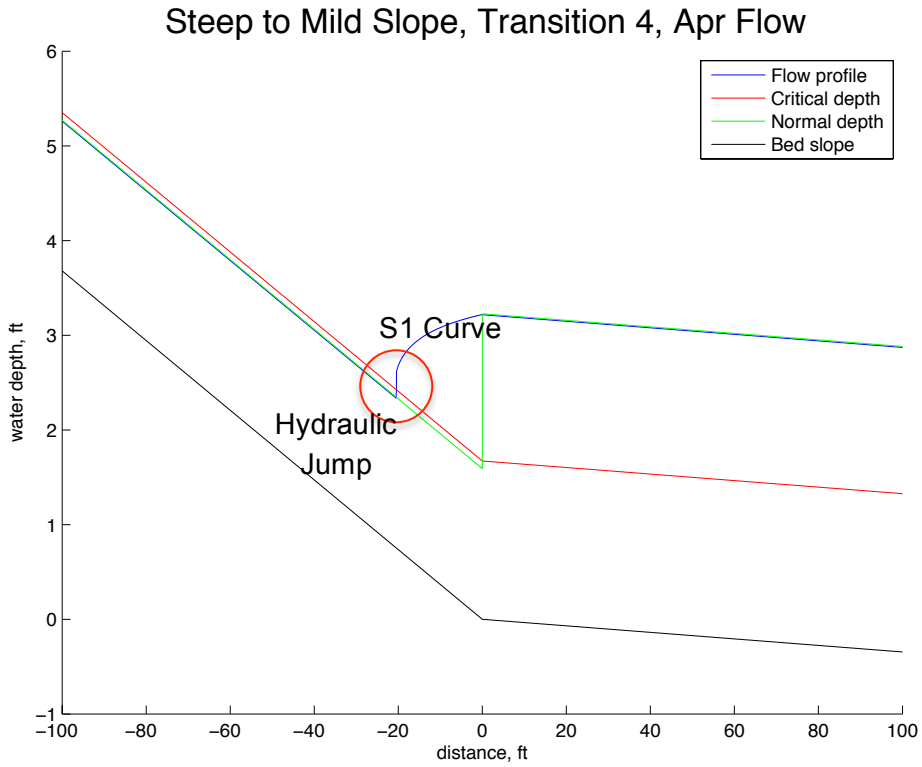


July (Low) Flow

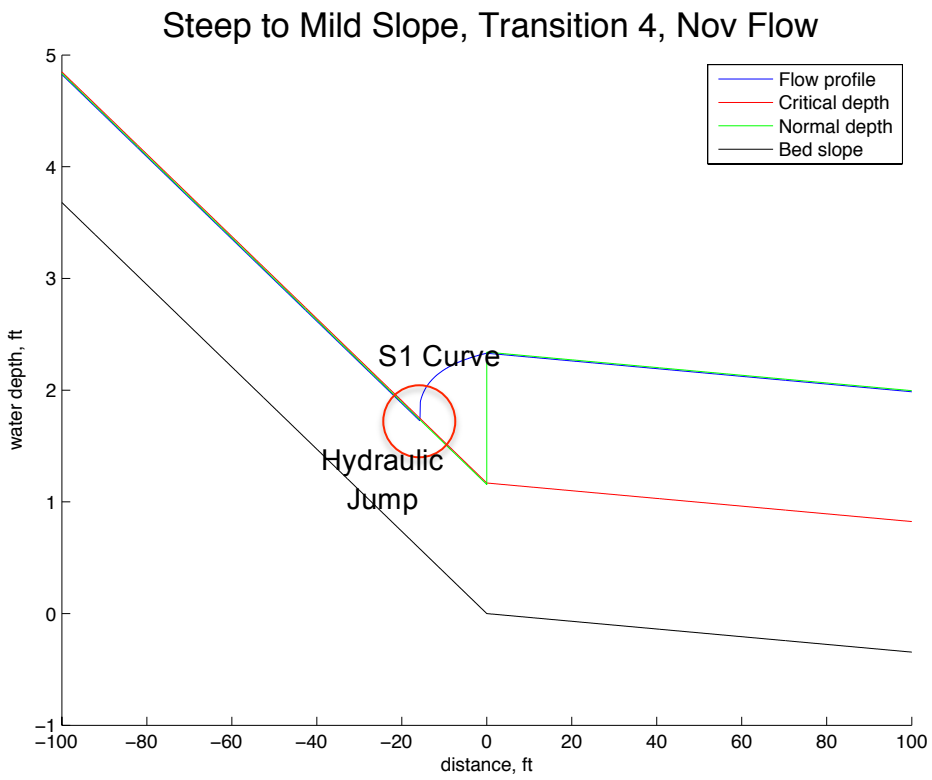
Note: Flow is so low, that in the "steep section" the normal depth is above the critical depth, so this section is now classified as mild. Therefore, the transition for this flow is from one mild slope to another mild slope.



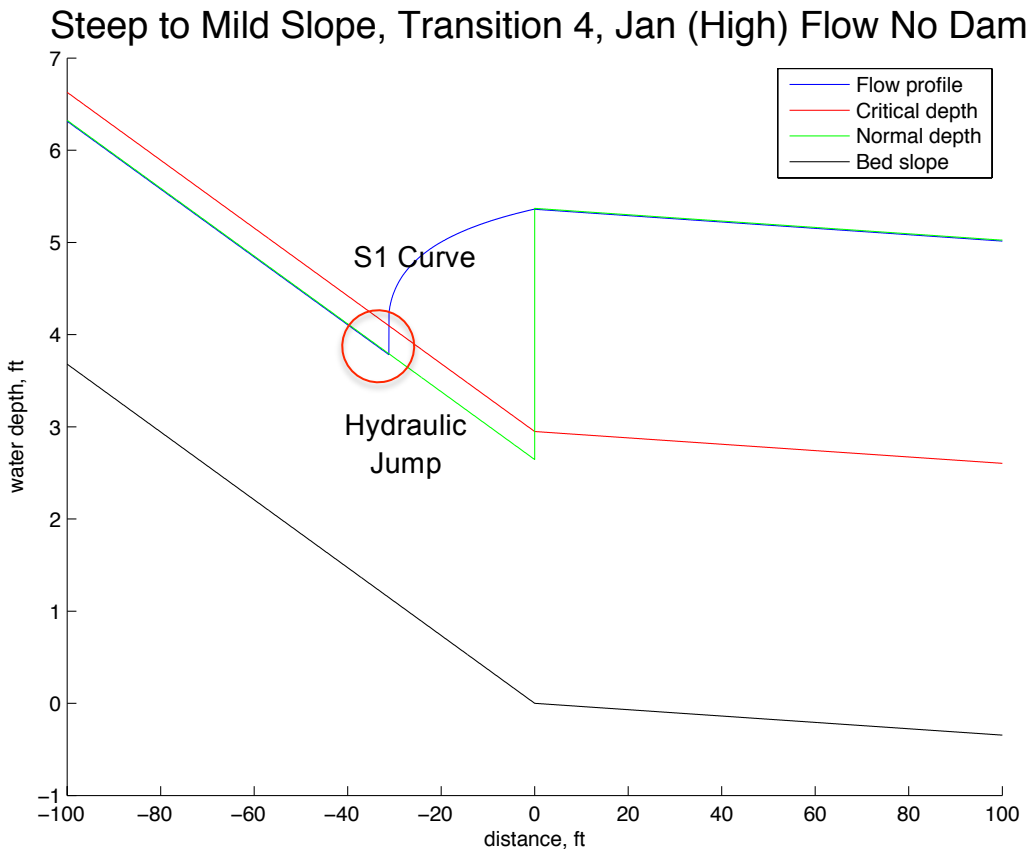
April Flow



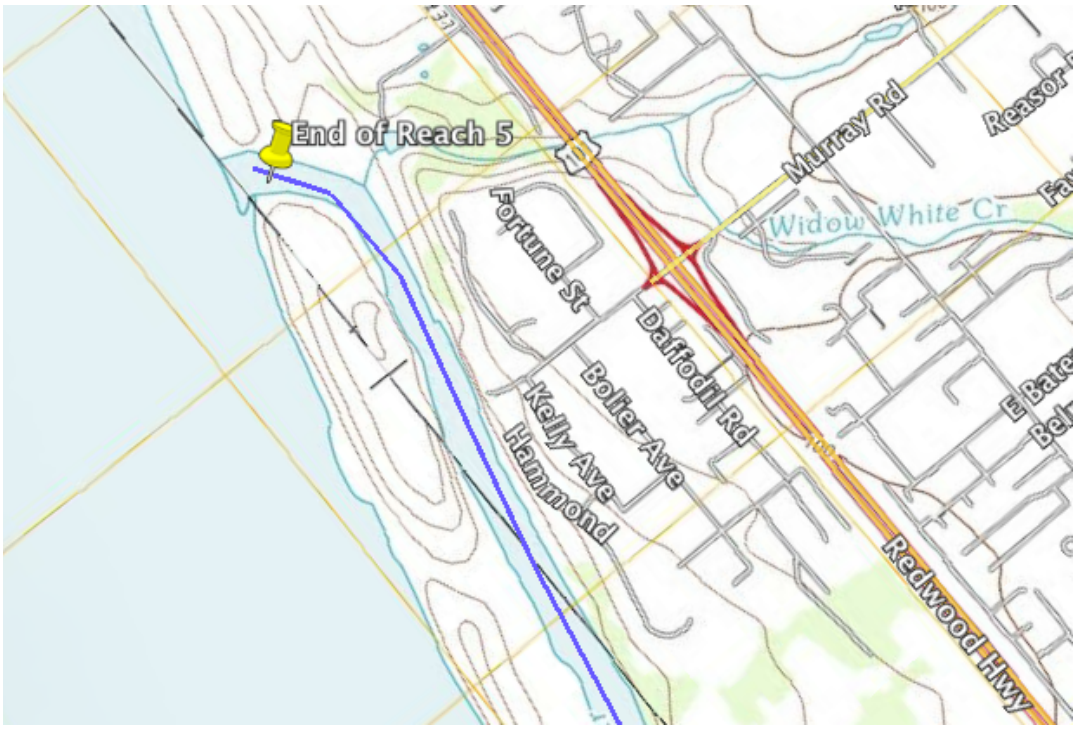
November Flow



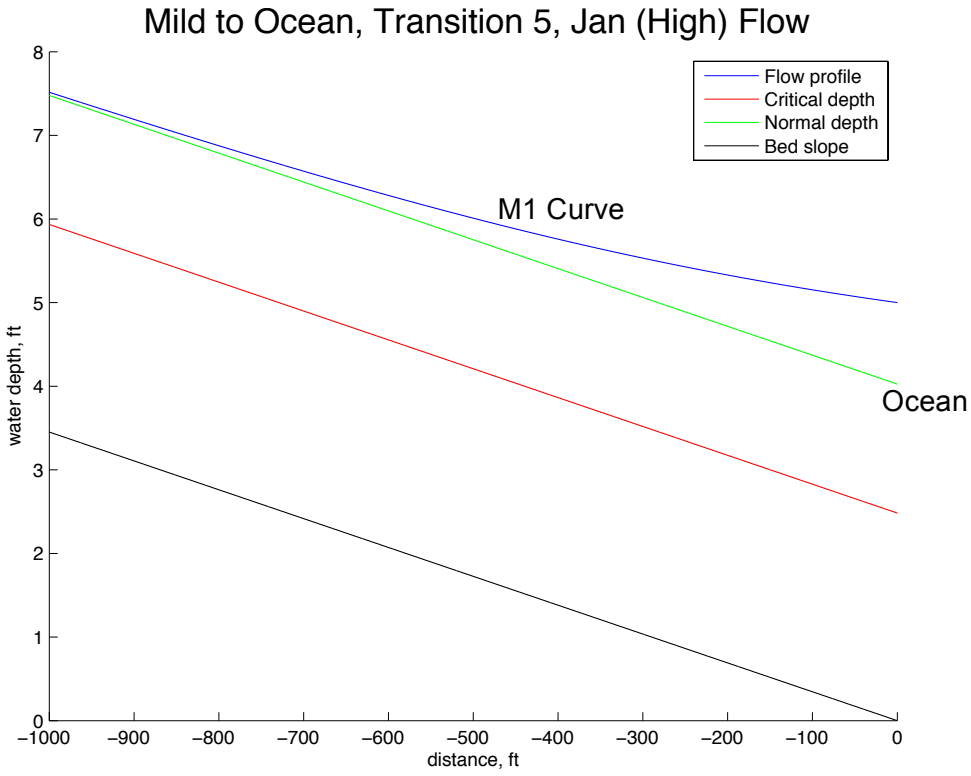
No Dam High Flow



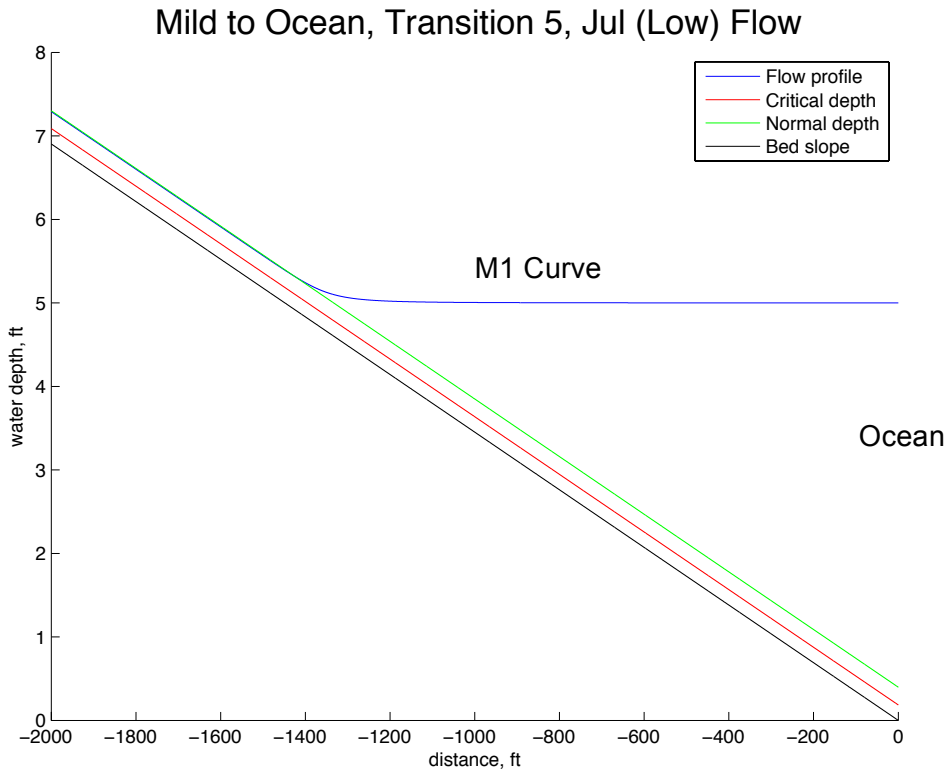
Transition 5: Mild Slope to Pacific Ocean



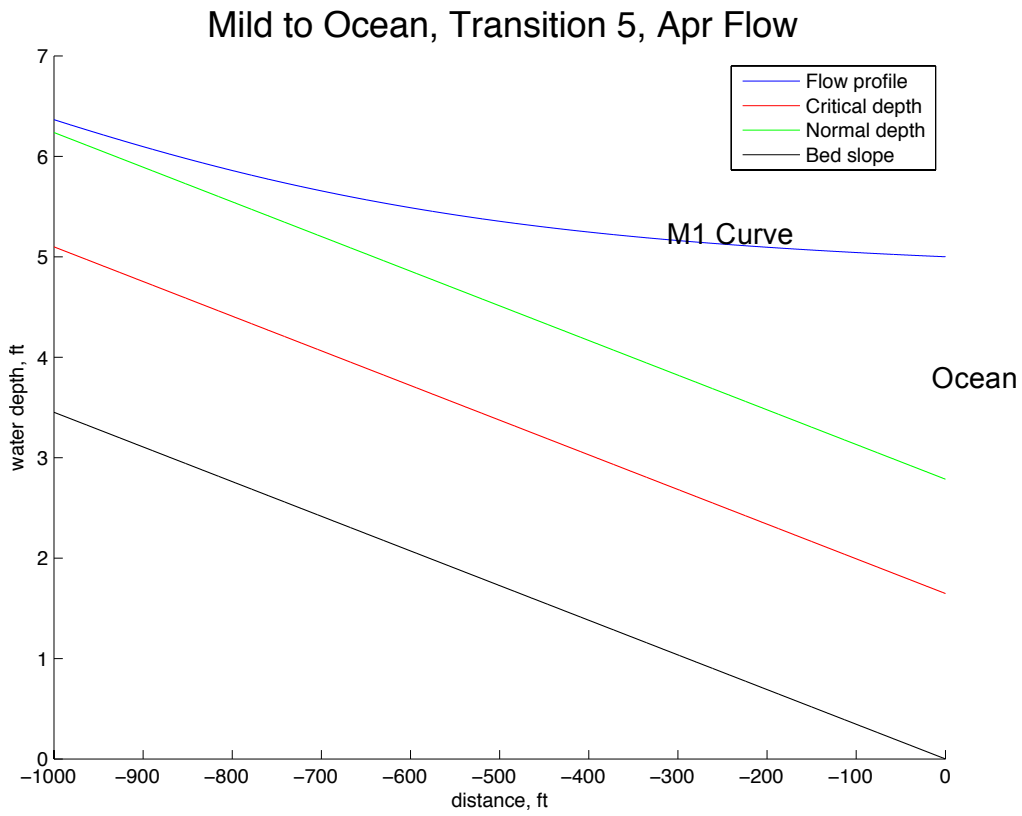
January (High) Flow



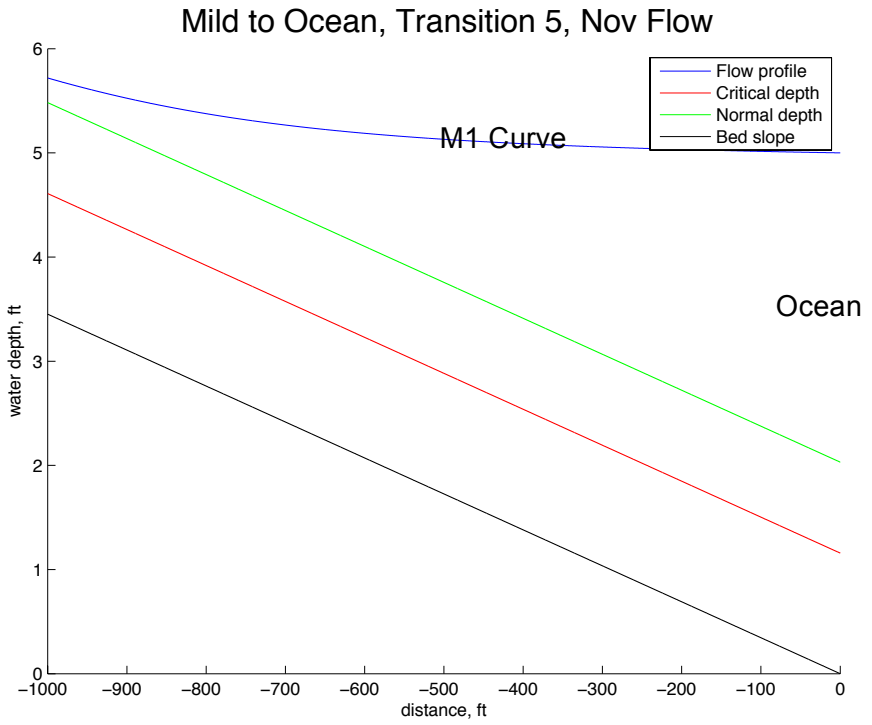
July (Low) Flow



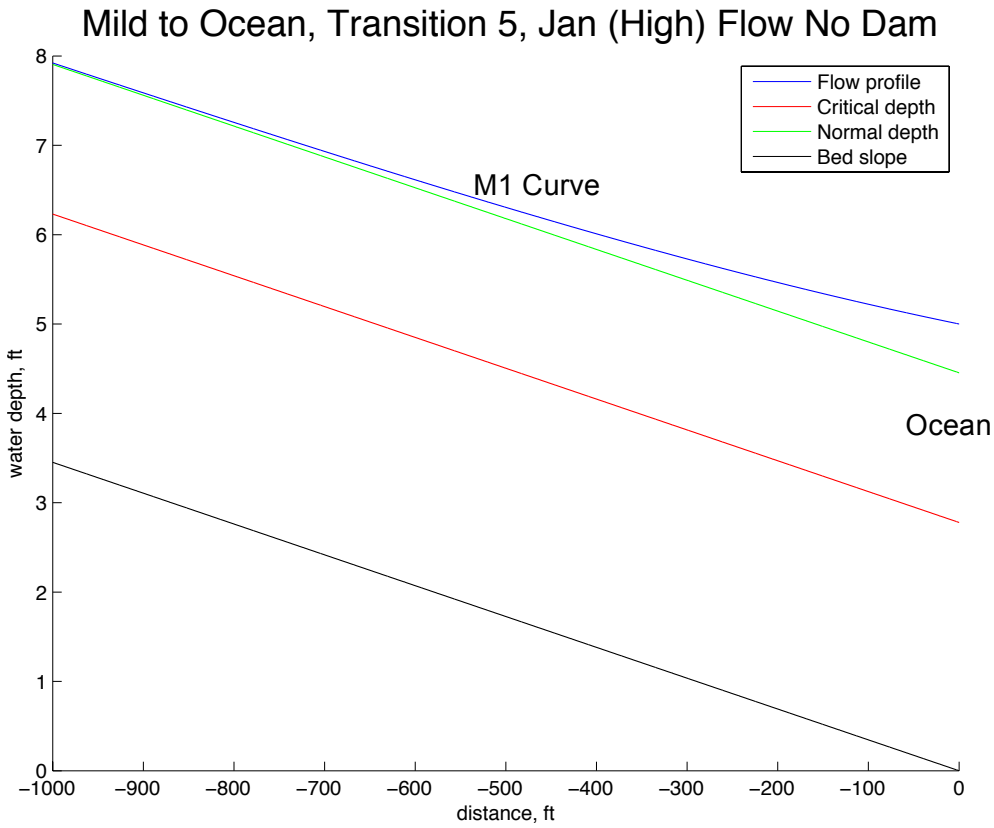
April Flow



November Flow



No Dam High Flow



Data

Table 1: Reach Information

Reach	Upstream Limit	Downstream Limit	Start El (ft)	End El (ft)	Length (ft)	Slope	Manning's n	Width 1 (ft)	Width 2 (ft)	Width 3 (ft)	Average Width (ft)
1	Ruth Dump Rd.	Beginning of Dam	2693	2661	8976	0.003565	0.05	82	55	92	76.33333
2	Top of dam	End of dam	2661	2565	36696	n\a	0.05	56.8	28.92	54.28	46.6667
3	End of dam	Confluence of Deer Creek	2565	2332	132316 .8	0.001761	0.05	44.48	59.14	70.77	58.13
4	Confluence of Deer Creek	Big Bend	2332	836	40656	0.03680	0.05	81.25	156.6	96.83	111.56
5	Big Bend	Pacific Ocean	822	42	225984	0.003452	0.04	75.7	97.5	153.06	108.7533

Table 2: Transition Information

Transition	Transition Location	Transition Type
1	Reach 1 to Reach 2	Mild Slope to Reservoir
2	Reach 2 to Reach 3	Reservoir to Mild Slope
3	Reach 3 to Reach 4	Mild Slope to Steep Slope
4	Reach 4 to Reach 5	Steep Slope to Mild Slope
5	Reach 5 to Ocean	Mild Slope to Ocean

Table 3: Flow Data

Transition	Jan (max) Flow (ft^3/sec)	July (min) Flow (ft^3/sec)	Apr Flow (ft^3/s)	Nov Flow (ft^3/s)	No Dam Max Flow (ft^3/s)
1	571.90	7.11	281.20	123.90	571.90
2	689.35	57.65	403.70	119.93	1,315.37
3	1,760.12	68.29	902.38	518.54	2,386.14
4	2,578.97	67.65	1,368.49	799.85	3,204.99
5	3,397.00	68.94	1,836.00	1,082.00	4,023.02

Table 4: Critical Depth Data

Reach	Critical Depth (High Flow) (ft)	Critical Depth (Low Flow) (ft)	Critical Depth (Apr Flow) (ft)	Critical Depth (Nov Flow) (ft)
1	1.204	0.0646	0.750	0.434
2	1.892	0.362	1.325	0.590
3	3.056	0.350	1.956	1.352
4	2.551	0.225	1.672	1.169
5	3.118	0.232	2.069	1.454

Table 5: Normal Depth Data

Reach	Normal Depth (High Flow) (ft)	Normal Depth (Low Flow) (ft)	Normal Depth (Apr Flow) (ft)	Normal Depth (Nov Flow) (ft)
1	2.369	0.170	1.548	0.946
2	4.400	0.993	3.191	1.541
3	6.768	0.963	4.533	3.251
4	2.313	0.260	1.581	1.146
5	4.928	0.475	3.407	2.481