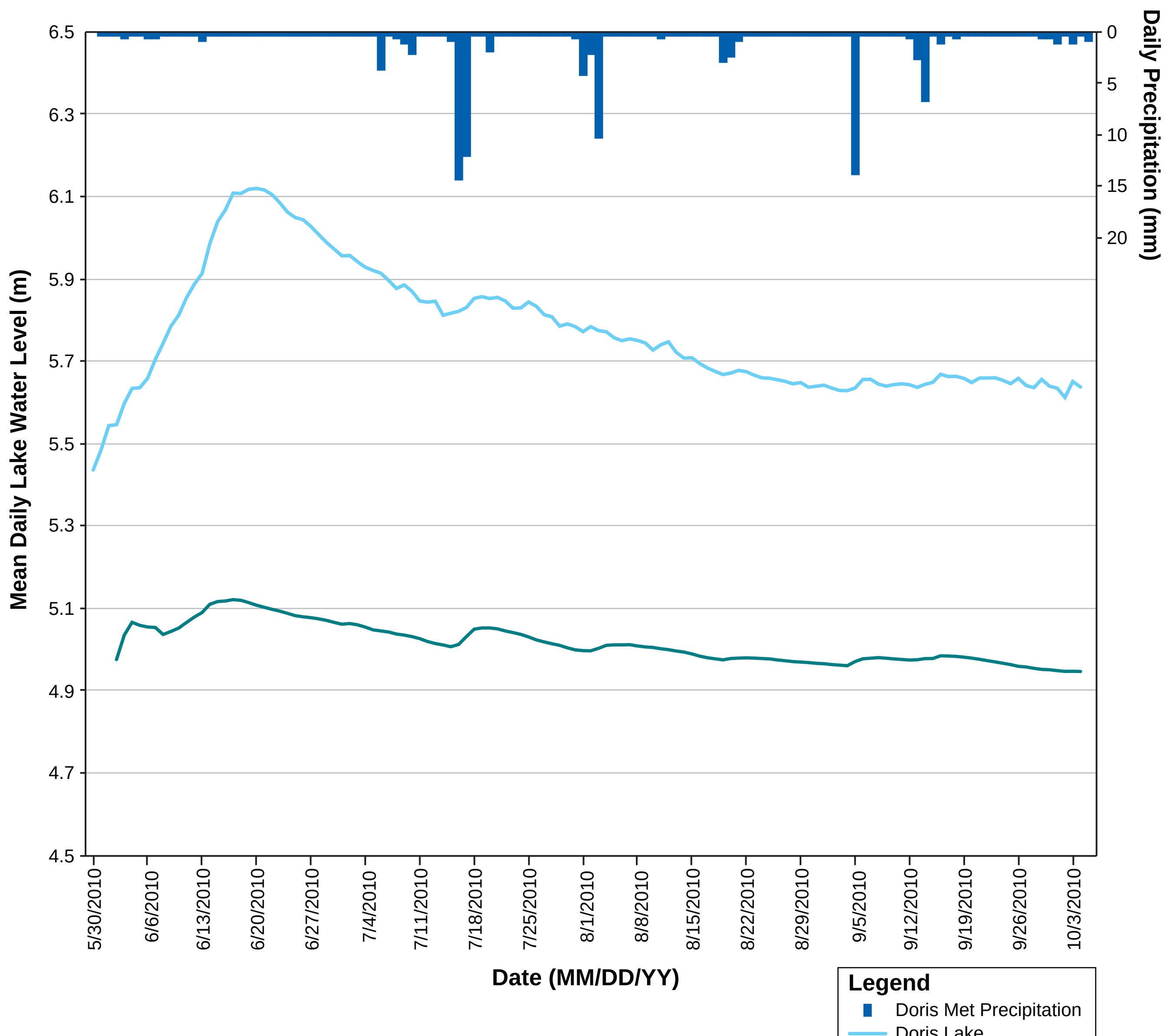

Note: Lake water levels referenced to pressure transducer.

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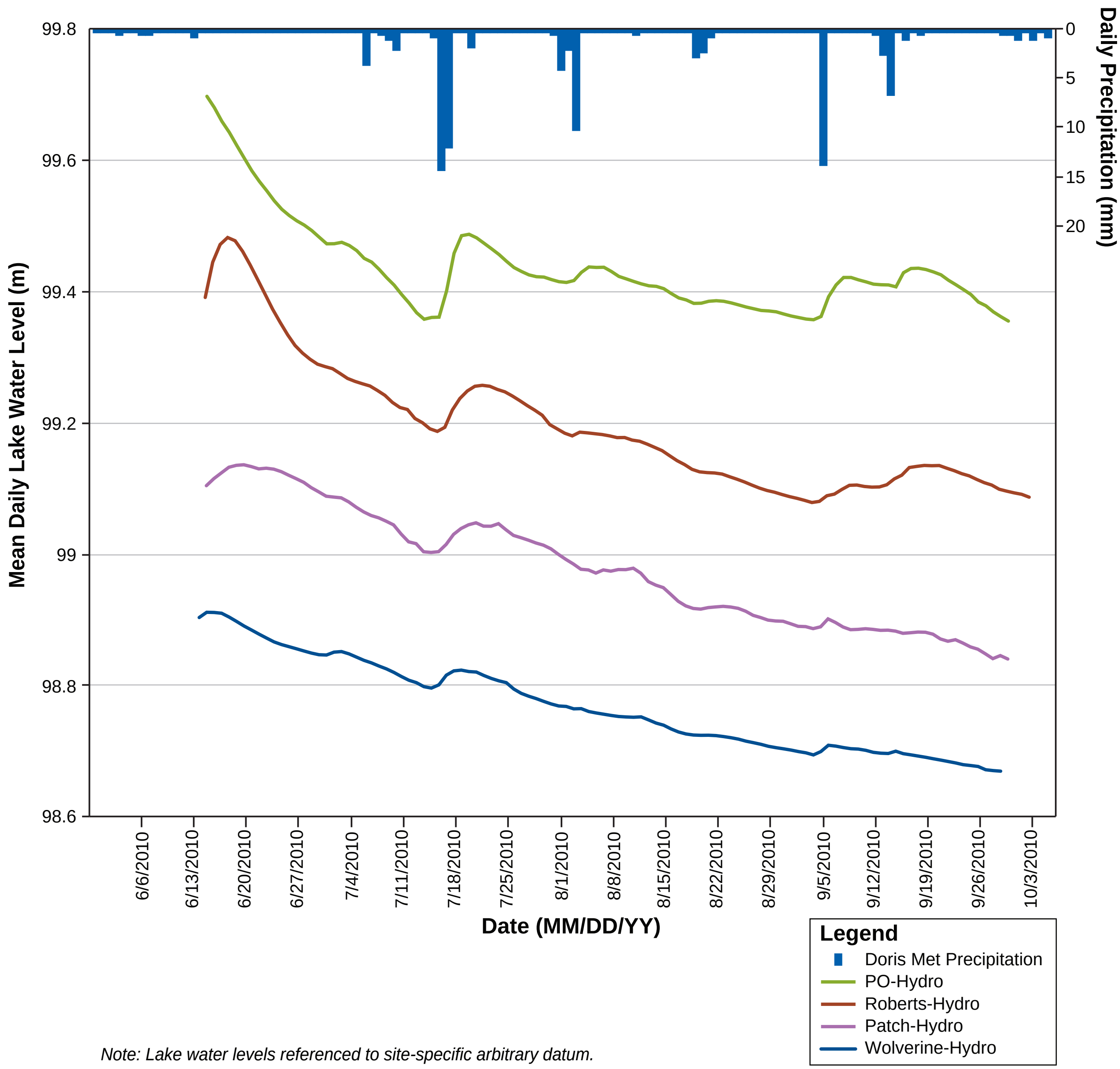
2010 Recorded Lake Water Levels in the Doris/Madrid Area

Figure 4.1-1

Rescan Engineers & Scientists



Note: Lake water levels referenced to site-specific arbitrary datum.

Figure 4.1-2

2010 Recorded Lake Water Levels in the Doris/Madrid Area

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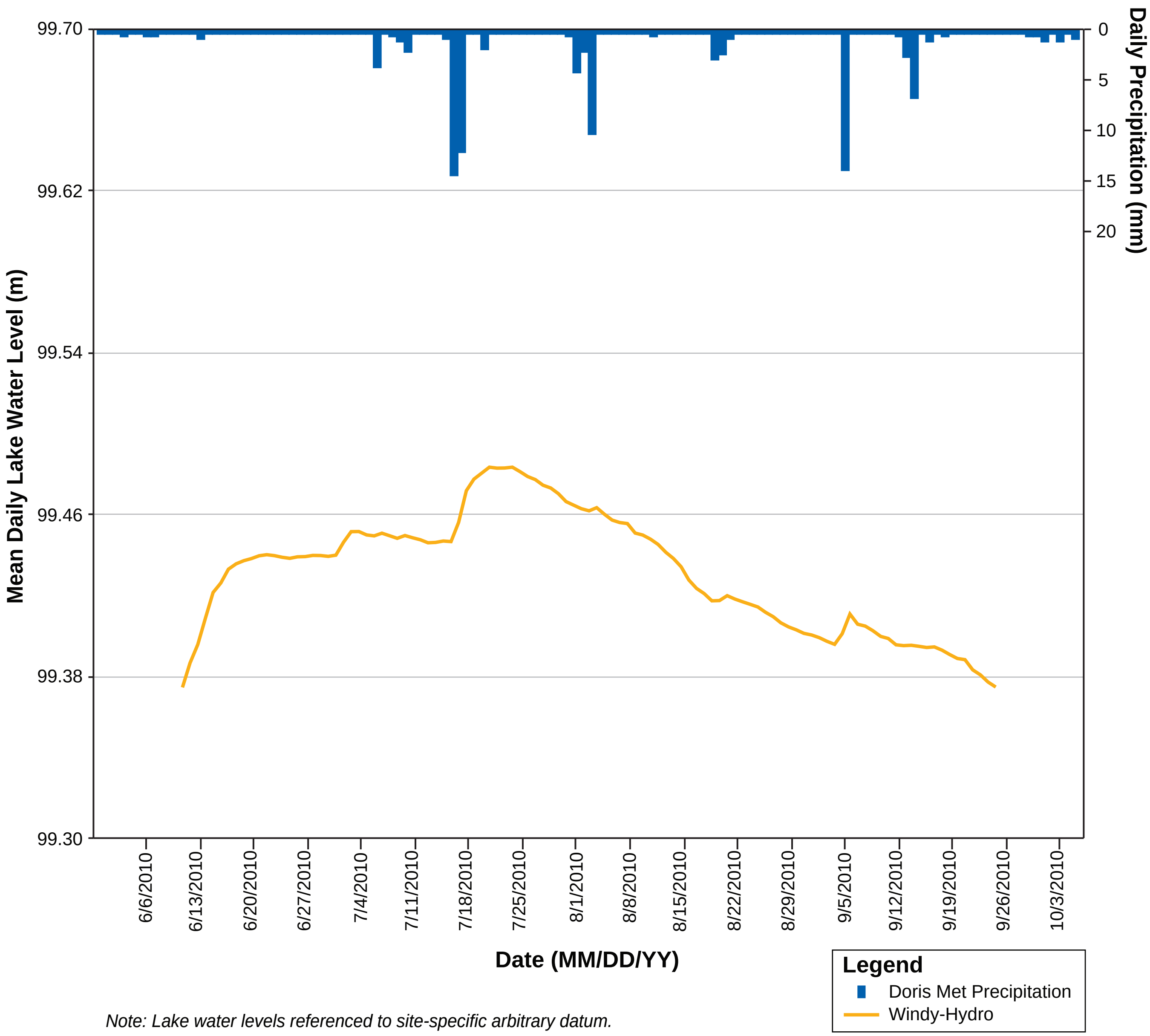

Note: Lake water levels referenced to site-specific arbitrary datum.

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2010 Recorded Lake Water Levels in the Doris/Madrid Area

Figure 4.1-3

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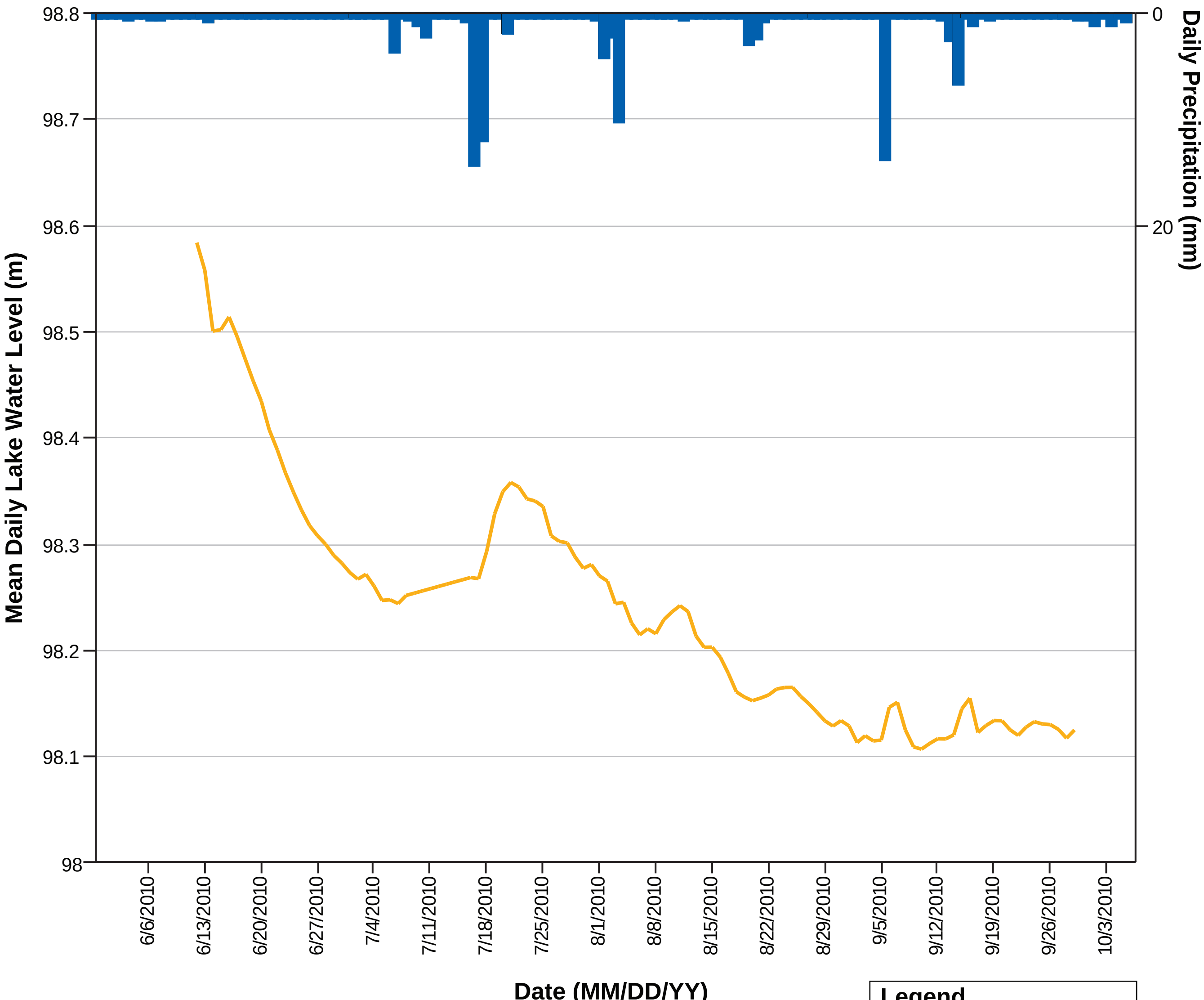

Note: Lake water levels referenced to site-specific arbitrary datum.

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2010 Recorded Lake Water Levels in the Doris/Madrid Area

Figure 4.1-4

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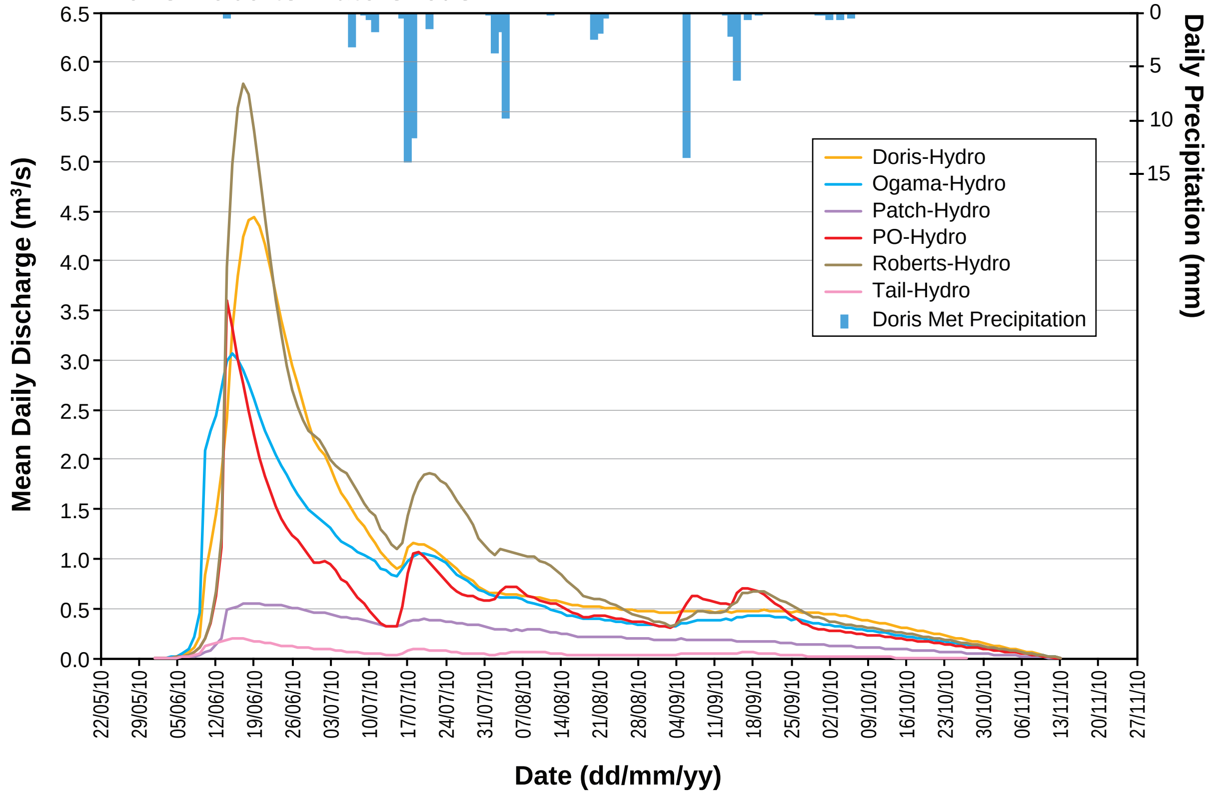
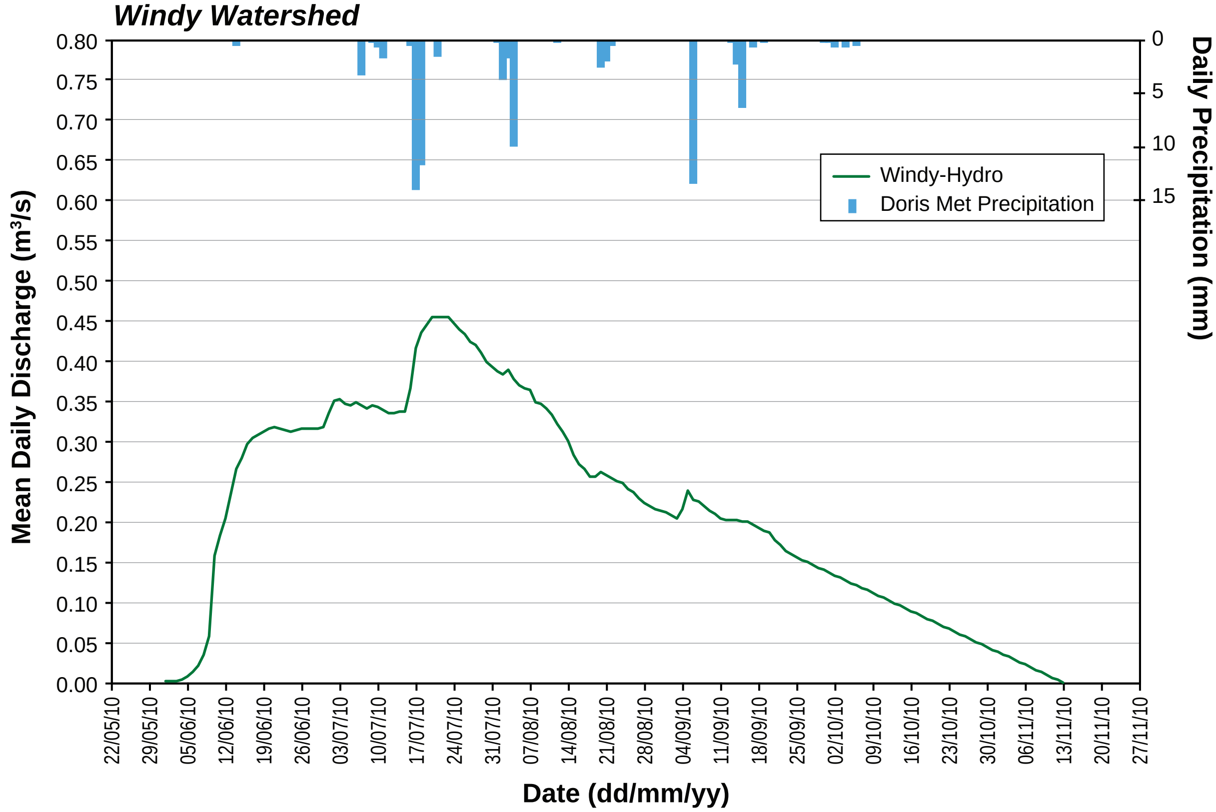
Doris-Roberts Watersheds



Windy Watershed



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2010 Annual Discharge Hydrographs Doris/Madrid Area

Figure 4.1-5

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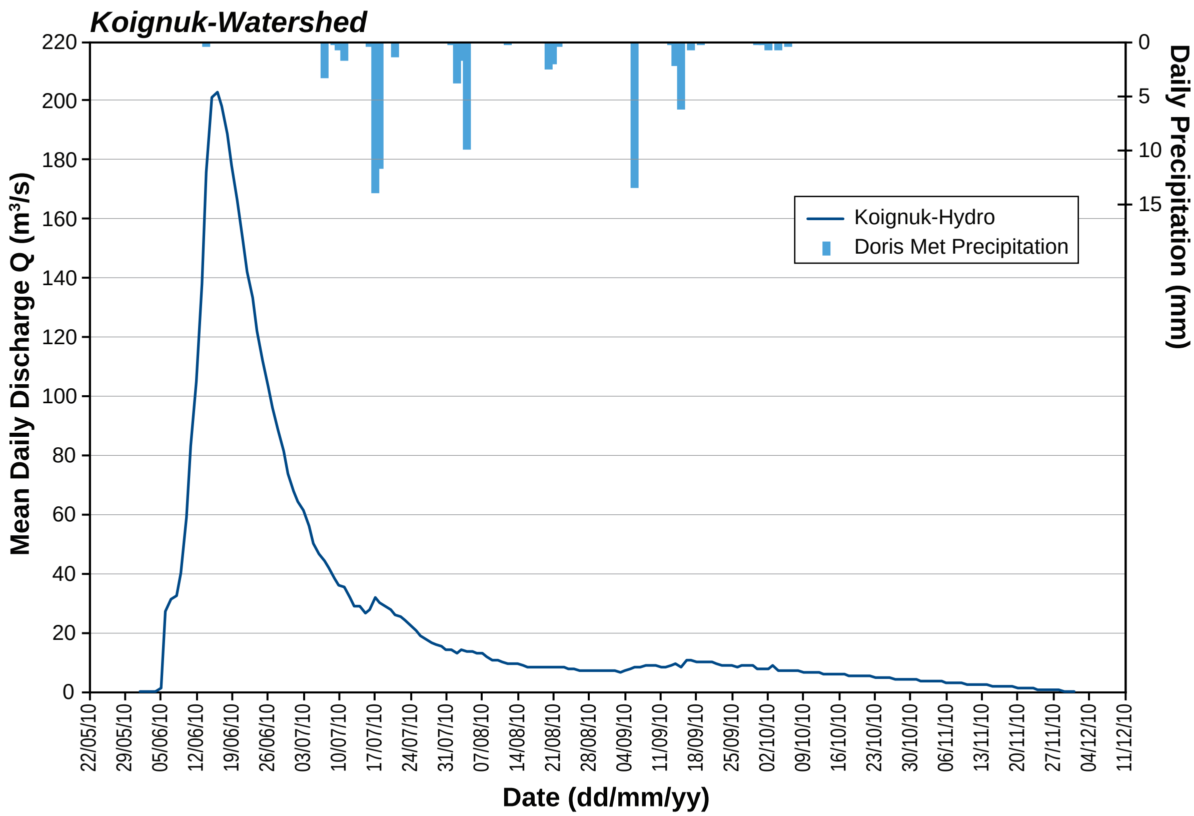

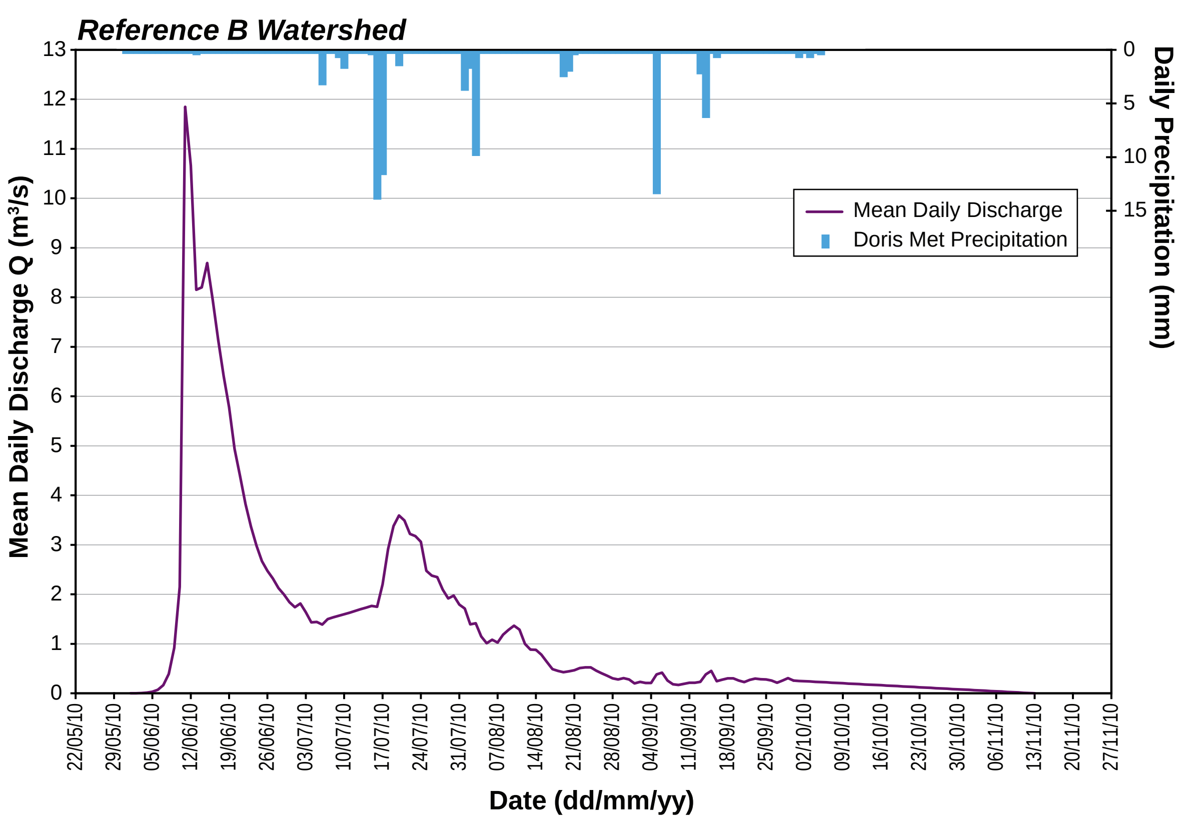

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2010 Annual Discharge Hydrographs Doris/Madrid Area

Figure 4.1-6

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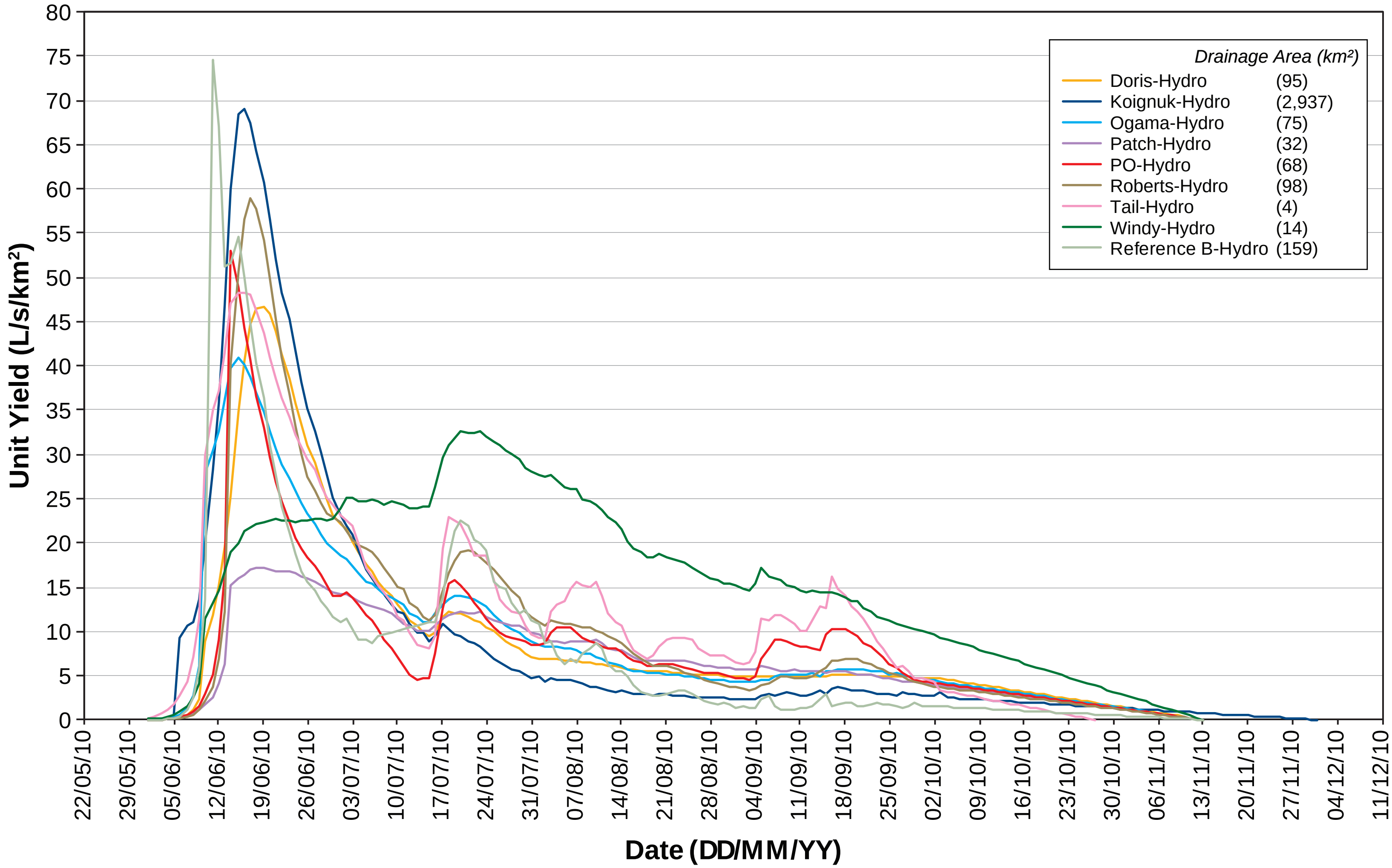

Figure 4.1-7

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2010 Open Water Season Unit Yield Hydrographs Doris/Madrid Area

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4.1.4.1 Unit Yield Hydrograph

The daily unit yield hydrographs also show interesting results. It has been reported in the literature that smaller drainage basins typically exhibit higher discharge per unit area than larger ones (Linsley et al 1982, Eaton et al 2007). As catchment size increases the potential for hydrologic losses increases proportionally, since larger catchments tend to have a larger number of land depressions where water is stored compared to smaller catchments.

Results show that the unit yield is independent from drainage area, showing a consistent trend across basins ranging from 4 km^2 to 3200 km^2. This could be explained by the similar amount of depressions (lakes, ponds, and wetlands) that can store water in these catchments. Even though Koignuk Watershed is almost three orders of magnitude larger than Tail Watershed, the surface area of both catchments is roughly 19% covered by depressions, thus the potential for water storage is similar in both basins.

4.1.5 Tide Range

The data recorded by the tide gauge primarily reflect changes in tide height, but also reflect waves and wind-driven seiches within Roberts Bay. Tides with one cycle (1 high and 1 low) per lunar day (24 hours, 50 minutes) are diurnal and tides with two cycles per lunar day are semi-diurnal. The results from Roberts Bay (Figure 4.1-7) show that the tides in Roberts Bay are predominantly semi-diurnal. A diurnal tide frequency also occurs every two weeks preceding the spring tides of the new and full moons. Hence, the tides in Roberts Bay are classified as mixed tides.

The tides in Roberts Bay were microtidal (less than 2 m tide range). Daily tide ranges were generally between 0.20 and 0.44 m (average: 0.34±0.07 m), with a maximum tidal range (the difference between high and low water in one tidal cycle) of 0.53 m on September 7, 2010 during the spring tide.

Typical of mixed tides, those in Roberts Bay are characterized by a relatively large diurnal inequality. That is, there is usually a large difference between higher high-water and lower high-water during the semi-diurnal cycle of each lunar day. Indeed, oscillations in the diurnal inequality drive the tidal system between semi-diurnal and diurnal frequencies, with minimum diurnal inequalities during neap tides and maximum during spring tides. The low tidal ranges of Roberts Bay are typical of tides in the Arctic Ocean.

4.1.6 Hydrologic Indices

4.1.6.1 Annual Runoff

In 2010, the calculated average runoff for all the gauged watersheds in the Doris/Madrid area was 131 mm. It ranged from a low of 88 mm at Patch-Hydro to a high of 197 mm at Windy-Hydro. Average calculated runoff was higher in the Windy Watershed (197 mm) than in the Doris-Roberts Watersheds (123 mm) and the Reference B Watershed (112 mm). The estimated average runoff for the open-water season from the gauged watersheds in the northern part of the belt was 141 mm; ranging from a low of 98 mm to a high of 222 mm at Patch-Hydro and Windy-Hydro, respectively (Table 4.1-4).

In 2010 conditions were wetter than in 2009. The annual runoff in 2010 was 22% greater than in 2009. The estimated annual runoff values from the gauged watersheds in the Doris/Madrid area for 2009 and 2010 were 116 mm and 141 mm, respectively.

The mean annual discharge was calculated as an average of the daily discharge values from June 1st to November 13th and ranged from 0.05 m^3/s to 25.85 m^3/s at Tail-Hydro and Koignuk-Hydro, respectively (Table 4.1-4).

Table 4.1-4. 2010 Annual Runoff and Mean Annual Discharge in the Doris/Madrid Area

Hydrometric Station	Drainage Area (km^2)	Percent lake coverage in watershed[†]	Calculated Runoff (mm)	Estimated Annual Runoff[b] (mm)	Mean Annual Discharge[a] (m^3/s)
Doris-Roberts Watersheds					
Doris-Hydro	95	20	121 (June 10 to October 4)	129	0.86
Ogama-Hydro	75	19	119 (June 10 to September 29)	129	0.68
Patch-Hydro	32	27	88 (June 14 to September 29)	98	0.22
PO-Hydro	68	19	108 (June 14 to September 29)	120	0.57
Roberts-Hydro	98	17	137 (June 14 to October 2)	146	1.0
Tail-Hydro	4	19	162 (June 10 to October 3)	168	0.05
Windy Watershed					
Windy-Hydro	14	39	197 (June 10 to September 24)	222	0.22
Koignuk Watershed					
Koignuk-Hydro	2,937	18	134 (June 6 to October 4)	140	25.85
Reference B Watershed					
Reference B-Hydro	159	26	112 (June 11 to September 30)	117	1.30
Mean			***131***	***141***	

[a]-Mean annual discharge (MAD) based on estimated annual runoff
[b]- Estimated for the 2010 open water season.
[†]- this percentage includes depressions (lakes, ponds, and wetlands) that can store water in the catchment

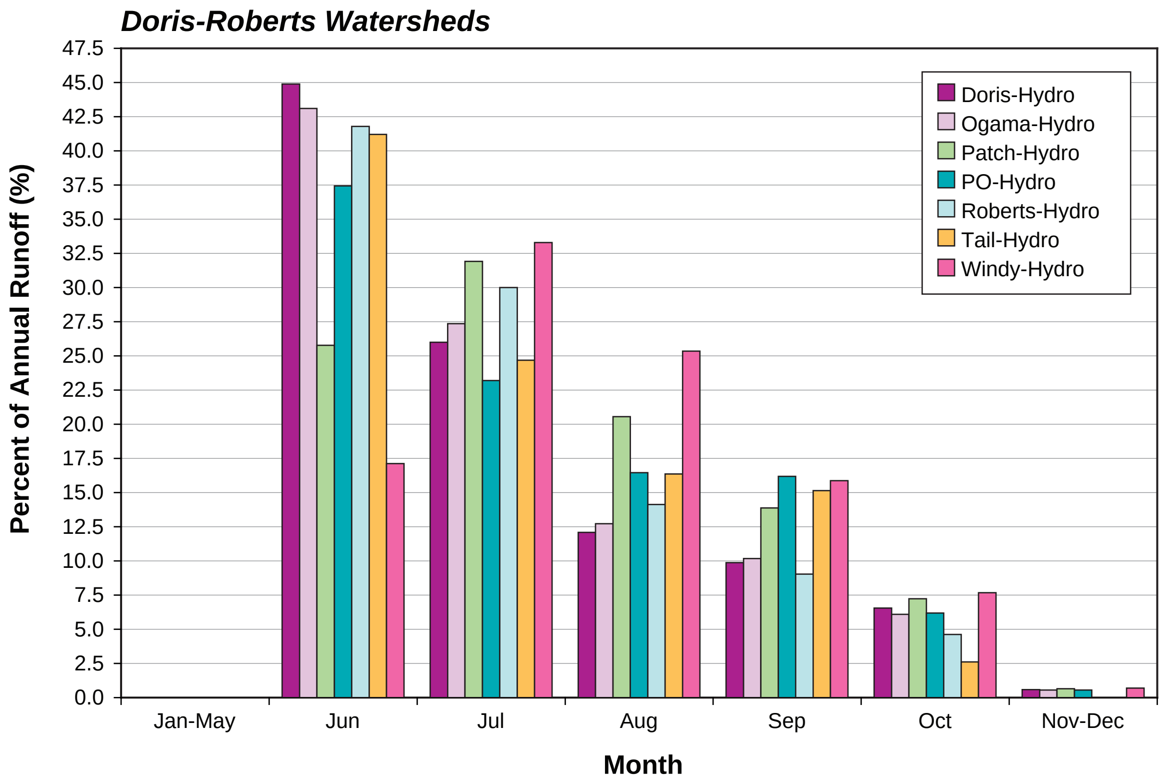
4.1.6.2 Monthly Runoff Distribution

The monthly distribution of runoff is similar among the gauged catchments in the Doris/Madrid area. On average, approximately 70% of the runoff occurred between June and July. By late-August 84% of the annual runoff had occurred. The maximum monthly runoff occurred during June in the majority of the watersheds, except for Patch-Hydro and Windy-Hydro where it occurred during July (Table 4.1-5, Figures 4.1-8 and 4.1-9).

Table 4.1-5. 2010 Monthly Runoff Distribution (mm) in the Doris/Madrid Area

Hydrometric Station	Jan-May	Jun	Jul	Aug	Sep	Oct	Nov-Dec
Doris-Roberts Watersheds							
Doris-Hydro	0	58	34	16	13	8	1
Ogama-Hydro	0	56	35	16	13	8	1
Patch-Hydro	0	25	31	20	14	7	1
PO-Hydro	0	45	28	20	19	7	1
Roberts-Hydro	0	61	44	21	13	7	1
Tail-Hydro	0	69	42	27	25	4	0
Windy Watershed							
Windy-Hydro	0	38	74	56	35	17	2
Koignuk Watershed							
Koignuk-Hydro	0	86	30	9	8	5	2
Reference B Watershed							
Reference B-Hydro	0	61	36	13	4	3	0

Italicized values are based on estimated mean daily discharge data



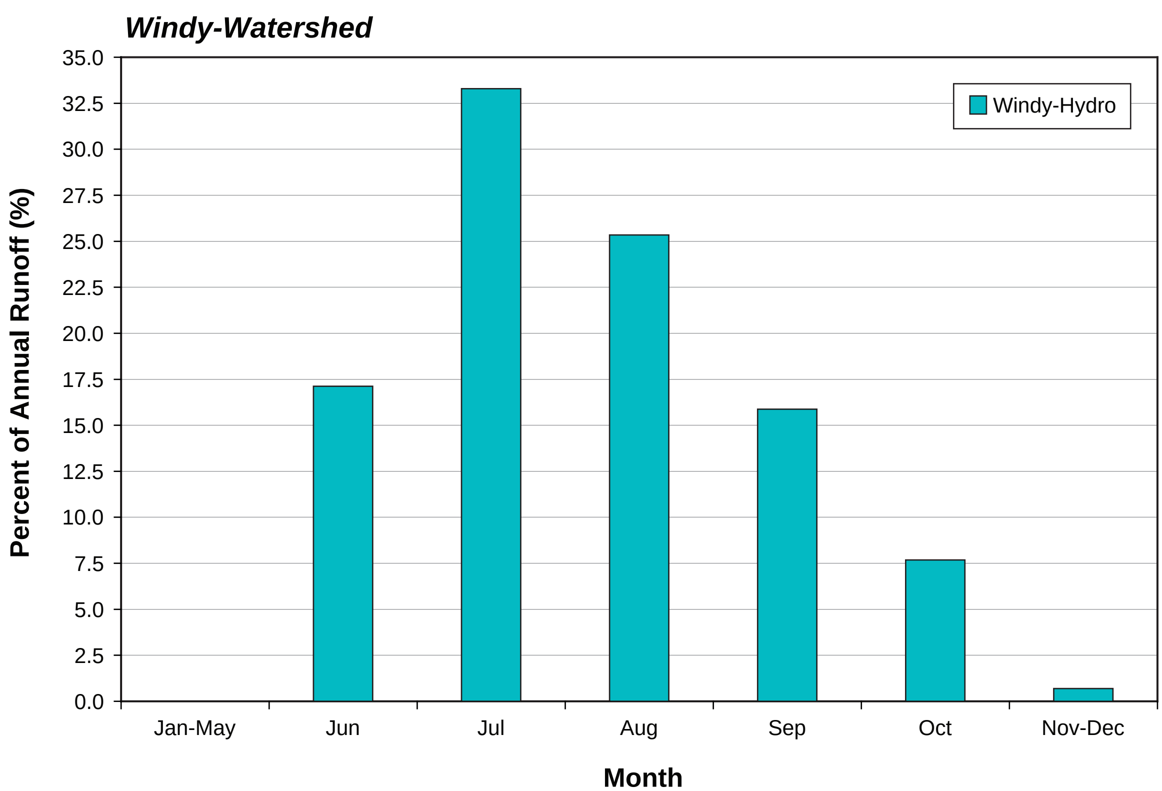


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Figure 4.1-8

Monthly Runoff Distribution (%) for 2010 for Watersheds in the Doris/Madrid Area

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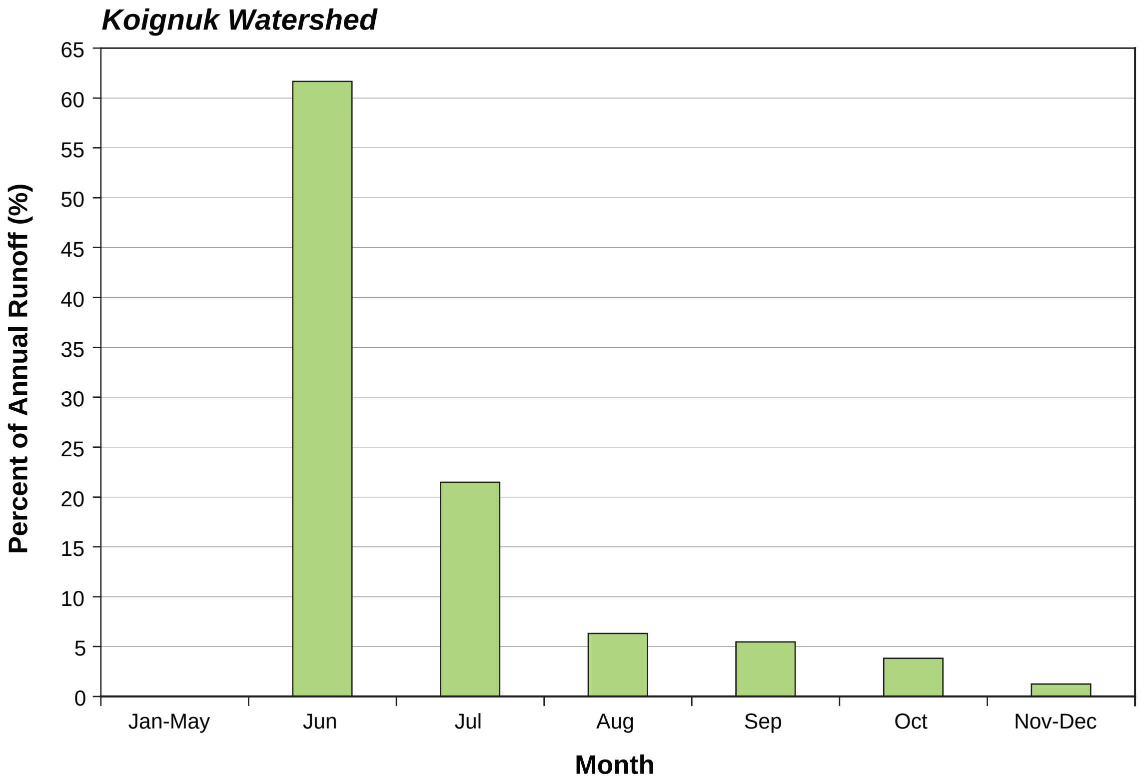

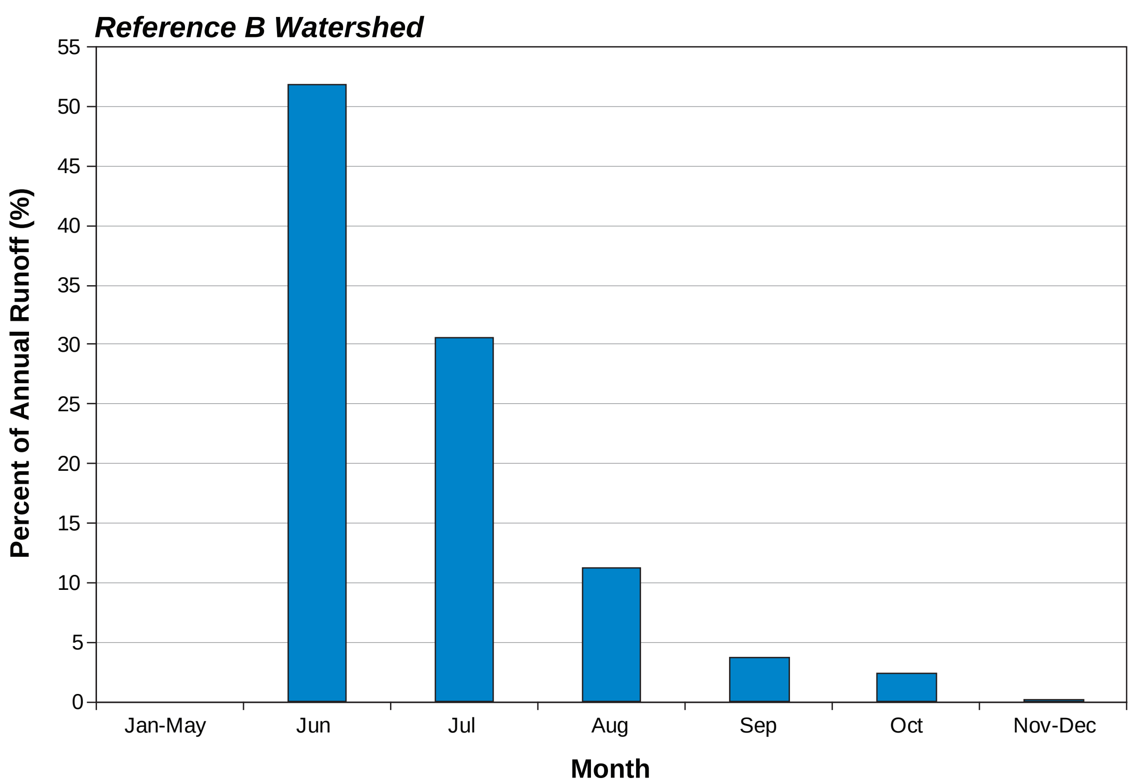

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Monthly Runoff Distribution (%) for 2010 for Watersheds in the Doris/Madrid Area

Figure 4.1-9

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The difference in timing and the magnitude of runoff in these two basins can be explained by the differences in the percent of lake coverage. Lakes represent a large proportion of the drainage area of the two basins draining past these two hydrometric stations. The lakes account for as much as 39% of the total drainage area at Windy-Hydro and 27% at Patch-Hydro. In contrast, the average percent of drainage area covered by lakes in other basins within the Doris/Madrid area is 19%. A larger portion of lake coverage in the Windy-hydro and Patch-Hydro basins translates into a reduced contribution of basin meltwater to runoff from adjacent hillslopes and other land areas. Thus, the relatively larger lake area in these two basins suggests that a protracted storage of runoff is occurring.

4.1.6.3 Peak and Low Flows

Observed instantaneous peak flows for the majority of the basins located within the Doris/Madrid area occurred in mid-June and ranged from 0.2 m^3/s at Tail-Hydro to 205 m^3/s at Koignuk-Hydro. The peak flow at the Windy-Hydro hydrometric station was attenuated and delayed by Windy Lake and occurred approximately a month later, on July 23rd. Instantaneous peak unit yields ranged from 17 $L/s/km^2$ at Patch-Hydro to 79 $L/s/km^2$ at Reference B-Hydro (Table 4.1-6).

Table 4.1-6. 2010 Annual Peak Flow and Unit Yield in the Doris/Madrid Area

Hydrometric Station	Drainage Area (km^2)	Peak Flow (m^3/s)			Peak Unit Yield ($L/s/km^2$)	
		Instantaneous	Daily	Date	Instantaneous	Daily
Doris-Roberts Watersheds						
Doris-Hydro	95	4.61	4.42	June 19	48.57	46.73
Ogama-Hydro	75	3.15	3.06	June 15	41.95	40.84
Patch-Hydro	32	0.56	0.55	June 19	17.65	17.21
PO-Hydro	68	3.69	3.60	June 14	54.23	52.93
Roberts-Hydro	98	5.84	5.78	June 17	59.59	58.97
Tail-Hydro	4	0.20	0.19	June 16	49.79	48.29
Windy Watershed						
Windy-Hydro	14	0.49	0.46	July 23	34.95	32.55
Koignuk Watershed						
Koignuk-Hydro	2,937	205.36	202.95	June 19	69.92	69.10
Reference B Watershed						
Reference B-Hydro	159	12.61	11.85	June 12	79.31	74.52

The observed low flows at the hydrometric stations in the northern part of the belt occurred in late-September in most watersheds, except at Ogama-Hydro, Roberts-hydro, Koignuk-Hydro, and Reference B-Hydro where they occurred in early-September (Table 4.1-7). Minimum flows ranged from 0.02 m^3/s at Tail-Hydro to 6.75 m^3/s at Koignuk-Hydro. Low flows in the Arctic occur at two different times of year depending on the size of the river and its catchment. Smaller streams reach their lowest flows in the open-water season in summer or early fall and then produce zero flow throughout the winter. Larger rivers may produce flow year round and reach their lowest flows during late winter (e.g., March or April).

Table 4.1-7. Daily Low Flows (July-September 2010) in the Doris/Madrid Area

Hydrometric Station	Daily Low Flow (m^3/s)	Date	Drainage Area (km^2)	% Lake coverage in watershed
Doris-Roberts Watersheds				
Doris-Hydro	0.463	September 29	95	20
Ogama-Hydro	0.322	September 2	75	19
Patch-Hydro	0.136	September 29	32	27
PO-Hydro	0.302	September 29	68	19
Roberts-Hydro	0.327	September 3	98	17
Tail-Hydro	0.019	September 29	4	19
Windy Watershed				
Windy-Hydro	0.159	September 24	33	39
Koignuk Watersheds				
Koignuk-Hydro	6.752	September 3	2,937	18
Reference B Watershed				
Reference B-Hydro	0.172	September 9	159	26

[a]*Based on average daily flows (m^3/s).*

4.2 BOSTON AREA

Results from the 2010 Hydrology Monitoring Program in the Boston area are presented as follows: (1) completed discharge measurements, (2) determined stage-discharge relationships, (3) discharge hydrographs, and (4) additional hydrologic indices for the area.

4.2.1 Current Velocity Measurements and Discharge Calculations

Discharge measurements were taken during the June freshet period at each hydrometric station with additional measurements conducted in July, August, September, and October 2010, for a total of 23 measurements. The measurements were collected through the open water season in order to obtain a range of discharges at different flow conditions (Table 4.2-1 and Appendix B1).

Table 4.2-1. Summary of 2010 Discharge Measurements in the Boston Area

Hydrometric Station and Drainage Area	Date Measured	Pressure Transducer Stage (m)a	Measured Discharge (m^3/s)	Method (Equipment Used)
Aimao Out – Hydro ($1,224\ km^2$)	June 12	98.252	12.08	Velocity-Area (ADCP)[b]
	June 15	99.314	42.37	Velocity-Area (ADCP)
	July 20	98.307	15.15	Velocity-Area (ADCP)
	August 15	97.793	4.78	Velocity-Area (ADCP)
	September 26	97.688	3.17	Velocity-Area (ADCP)
Aimao In – Hydro ($725\ km^2$)	June 8	98.683	2.90	Velocity-Area (ADCP)
	July 22	n/a	2.84	Velocity-Area (ADCP)
	August 16	n/a	1.42	Velocity-Area (Swoffer current meter)
	September 26	n/a	2.09	Velocity-Area (Swoffer current meter)

(continued)

Table 4.2-1. Summary of 2010 Discharge Measurements in the Boston Area (completed)

Hydrometric Station and Drainage Area	Date Measured	Pressure Transducer Stage (m)a	Measured Discharge (m^3/s)	Method (Equipment Used)
Trout – Hydro ($27\ km^2$)	June 9	94.982	0.60	Velocity-Area (Swoffer current meter)
	June 17	94.815	0.77	Velocity-Area (Swoffer current meter)
	July 19	94.741	0.07	Velocity-Area (Swoffer current meter)
	August 16	94.786	0.08	Velocity-Area (Swoffer current meter)
	September 29	94.762	0.04	Velocity-Area (Swoffer current meter)
East Aimao – Hydro ($363\ km^2$)	June 8	98.347	3.54	Velocity-Area (ADCP)
	June 17	98.800	33.57	Velocity-Area (ADCP)
	July 21	98.209	1.45	Velocity-Area (Swoffer current meter)
	August 15	98.143	0.89	Velocity-Area (Swoffer current meter)
	September 29	98.163	0.74	Velocity-Area (Swoffer current meter)
East Tailings – Hydro ($8\ km^2$)	June 9	99.666	0.35	Velocity-Area (Swoffer current meter)
	June 17	99.627	0.22	Velocity-Area (Swoffer current meter)
	July 19	99.500	0.02	Velocity-Area (Swoffer current meter)
	August 17	99.416	0.002	Velocity-Area (Swoffer current meter)

[a-] *Pressure transducer stage referenced to site-specific arbitrary datum*
[b-] *Discharge measured with an acoustic Doppler current profiler.*
[n/a-] *not applicable station was not active due to damage by floating ice.*

4.2.2 Stage-Discharge Relationships

The work program for 2010 included the construction of the hydrometric monitoring stations and the completion of manual velocity measurements and discharge calculations. Between four to five discharge measurements were used in the development of preliminary rating equations for the hydrometric stations in the Boston area. Additional discharge measurements are required in order to increase the range and robustness of the stage-discharge relationships. Rating equations are summarized in Table 4.2-2 and rating curves are provided in Appendix B2. The survey control points used at each of the hydrometric stations are provided in Appendix B3.

Table 4.2-2. Summary of 2010 Rating Equations for Hydrometric Stations in the Boston Area

Hydrometric Station	Rating Equation $Q = C\ (h-a)^B$
East Tailings-Hydro	
low stage	$Q = 263.60\ (h-99.4)^{1.12}$
high stage	$Q = 14{,}260.03\ (h-99.4)^{2.77}$
Aimao Out-Hydro	$Q = 12.34(h-97.22)^{1.69}$
East Aimao-Hydro	$Q = 52.72(h-97.97)^{2.59}$

Q= discharge [m^3/s]; C= y intercept; h= recorded stage [m];
a= stage at zero flow (datum correction) [m]; B= slope

At the East Tailings-Hydro hydrometric station a two stage (high and low) rating curve provided a better fit to the observed data than a single stage curve. Low flows were confined to the main channel but at medium to high flows the channel overflowed its banks thus creating a shift in the slope of the curve.

4.2.3 Lake Levels

The determined relationship used to estimate missing water level data at the Aimao Lake hydrometric station has a relatively high coefficient of determination (R2 = 0.99). This indicates that the regression-based equation describe the data properly for prediction purposes (Figure 4.2-1).

The estimated level variation for Aimaokatalok Lake was 2.13 m, ranging from a low of 3.18 m on June 7, 2010 to a high of 5.31 m on June 19, 2010 (Table 4.2-3 and Figure 4.2-2). The estimated lake level variation in 2010 is in close agreement with the mean level variation calculated using historical data (Table 4.2-3). The 2010 estimated mean daily lake levels are presented in tabular form in Appendix B4.

Table 4.2-3. Estimated Water Levels at Aimaokatalok Lake from June 7 to September 26, 2010

Lake Water Level (m)	2010	2009	2008	2007	Mean 2007-2009
Minimum	3.18	2.86	3.10	2.81	2.92
Maximum	5.31	5.08	6.14	4.80	5.34
Variation	2.13	2.23	3.04	1.99	2.42

4.2.4 Annual Discharge Hydrographs

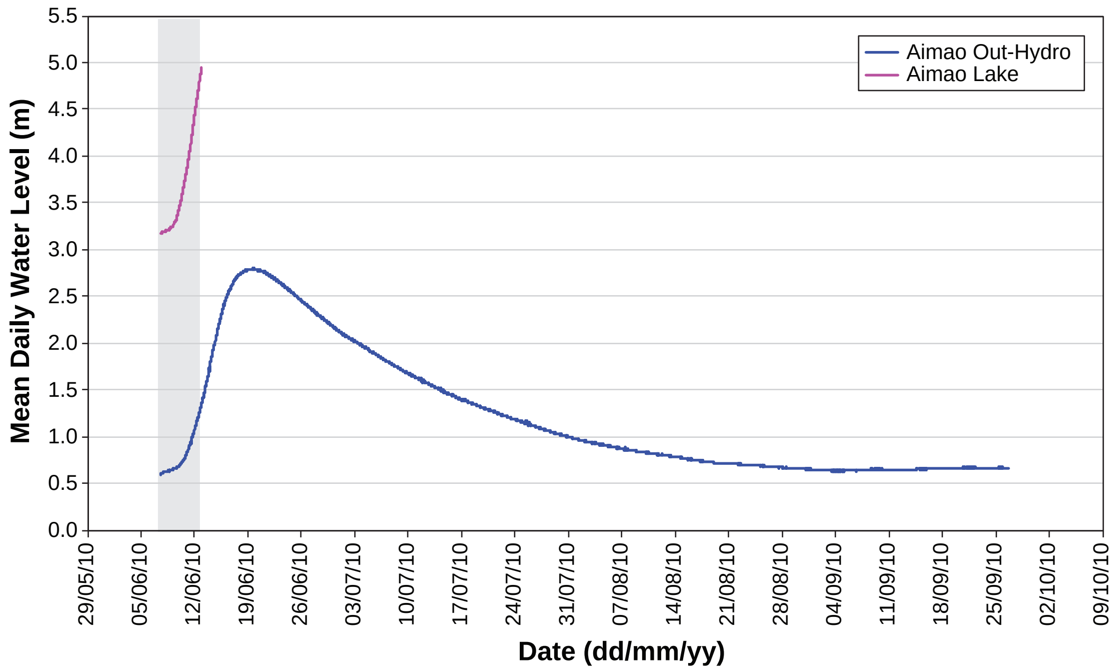
Hydrographs were generated for three of the five hydrometric stations monitoring stream water level in the Boston area: Aimao-Hydro, East Aimao-Hydro, and East Tailings-Hydro (for detailed hydrographs in tabular and graphical form refer to Appendix B4).

Hydrographs were not generated for the Trout-Hydro and Aimao In-Hydro hydrometric stations. At the Trout –Hydro hydrometric station a defined stage-discharge relationship could not be determined using the discharge measurements taken in 2010. At the Aimao In-Hydro hydrometric station, the instrumentation was damaged by floating ice on June 12, 2010. Personnel were able to recover the lost instrumentation during a site visit on July 22, 2010. A new pressure transducer was not installed because by that date the spring freshet period was over.

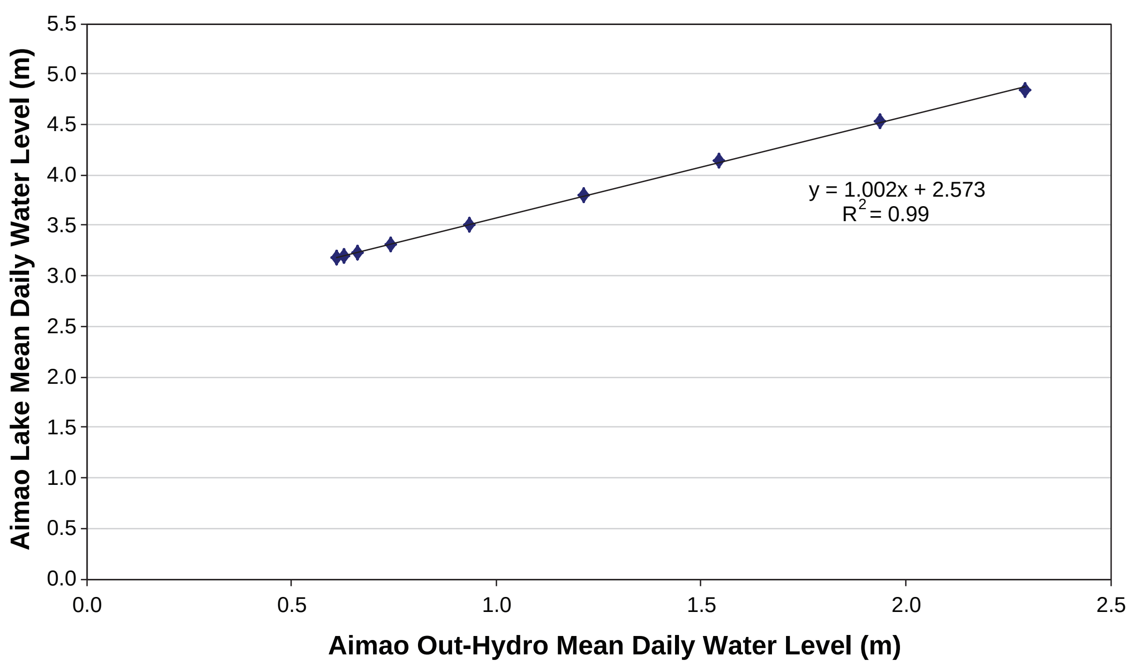
Annual hydrographs are presented as mean daily discharges (Figures 4.2-3 and 4.2-4) and as mean daily unit yield (Figure 4.2-5) for the open-water season.

The mean daily discharge hydrographs show that the onset of the spring freshet occurred in early June throughout the watersheds in the Boston area. Annual peak flows occurred in mid-June in most basins except at the basin that drains past the East Tailings-Hydro hydrometric station where it occurred in early-June. Peak flows in most watersheds resulted from inputs of water from melting snow (between June 10 and June 19, 2010). On average the freshet peak occurred approximately two weeks after streams began to flow.

After the spring freshet period, discharge steadily decreased throughout the Boston area until estimated freeze up dates of October 27 for the East Tailings-Hydro hydrometric station and November 13 for the East Aimao-Hydro hydrometric station. There are no historical observations between 2006-2008 of the winter flow conditions of the outflow at the Aimao Out-Hydro hydrometric station. However, the outlet channel remained open during the winter 2009-2010. The same condition was assumed for the 2010-2011 winter; thus, a freeze up date was not considered at this site.



Notes: The greyed area denotes the period of concurrent water level data (June 7 to June 14, 2010) used to develop the relationship between Aimao Out-Hydro and Aimao Lake.
Note that the water level values are referenced to pressure trasnducer stage (m).



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Relationship Used to Estimate Daily Water Levels at Aimao Lake Based on Daily Water Levels Recorded at Aimao Out-Hydro from June 7 to June 15, 2010

Figure 4.2-1

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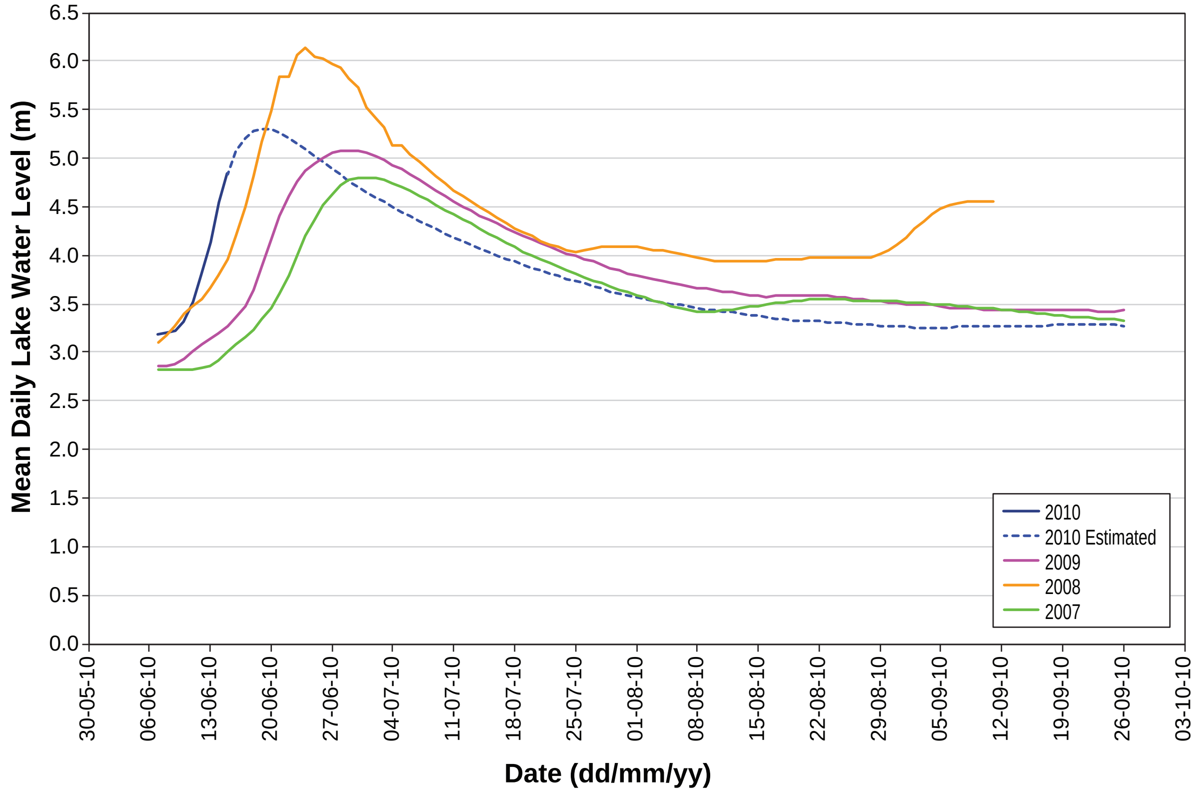

Note: Water levels are referenced to pressure transducer stage (m)

Figure 4.2-2

2010 Estimated Water Levels at Aimao Lake Compared to Historical Information (2007-2009)

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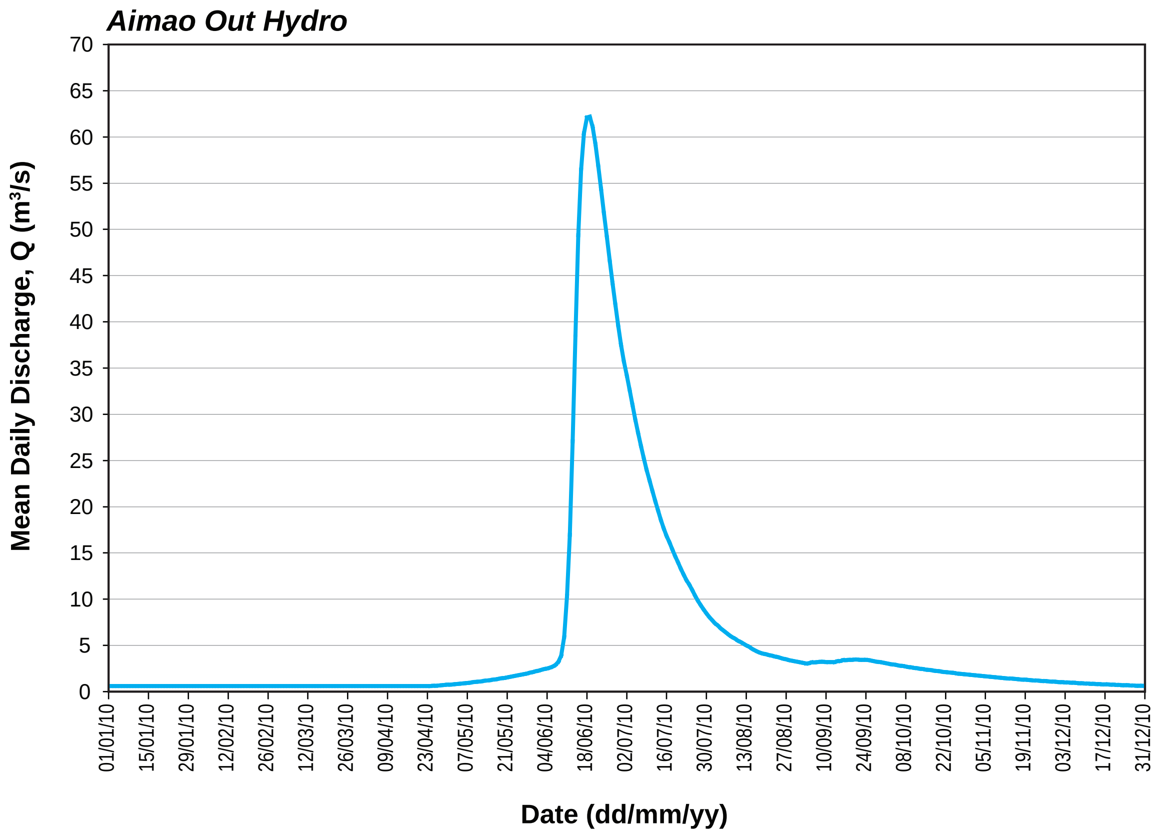

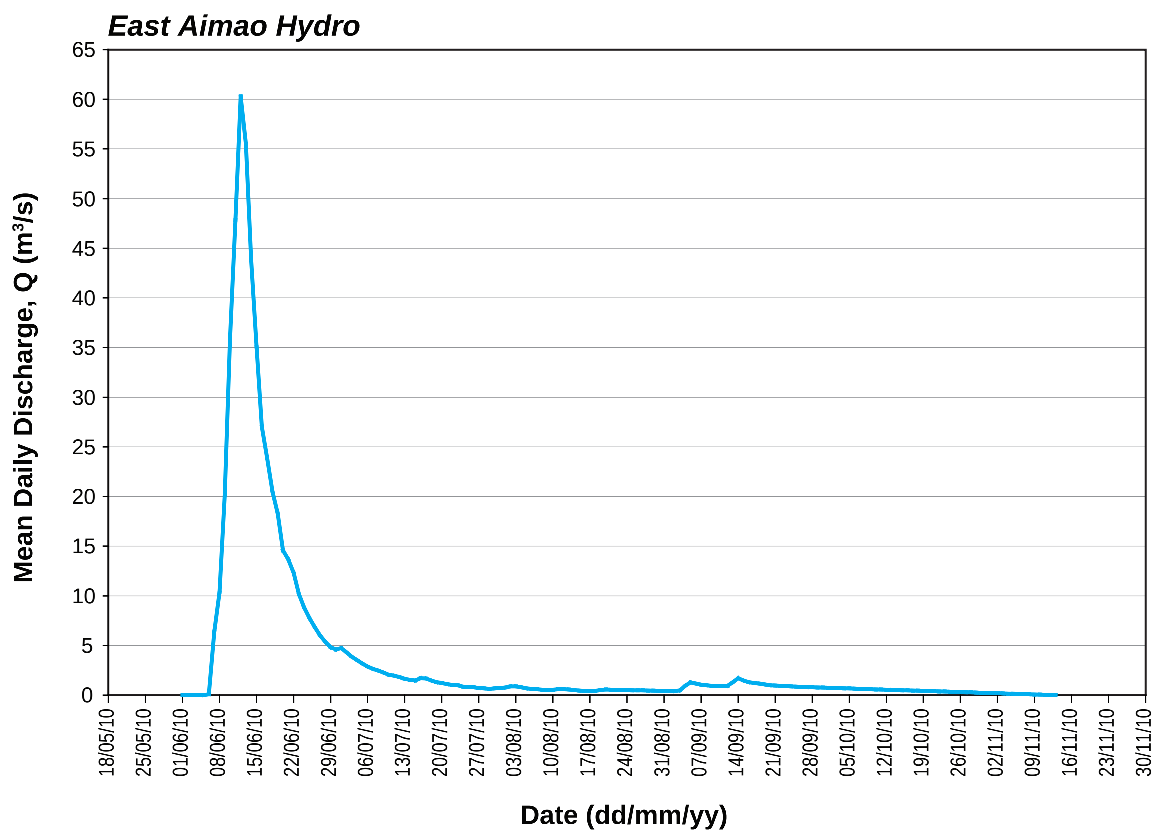

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2010 Annual Discharge Hydrographs in the Boston Area

Figure 4.2-3

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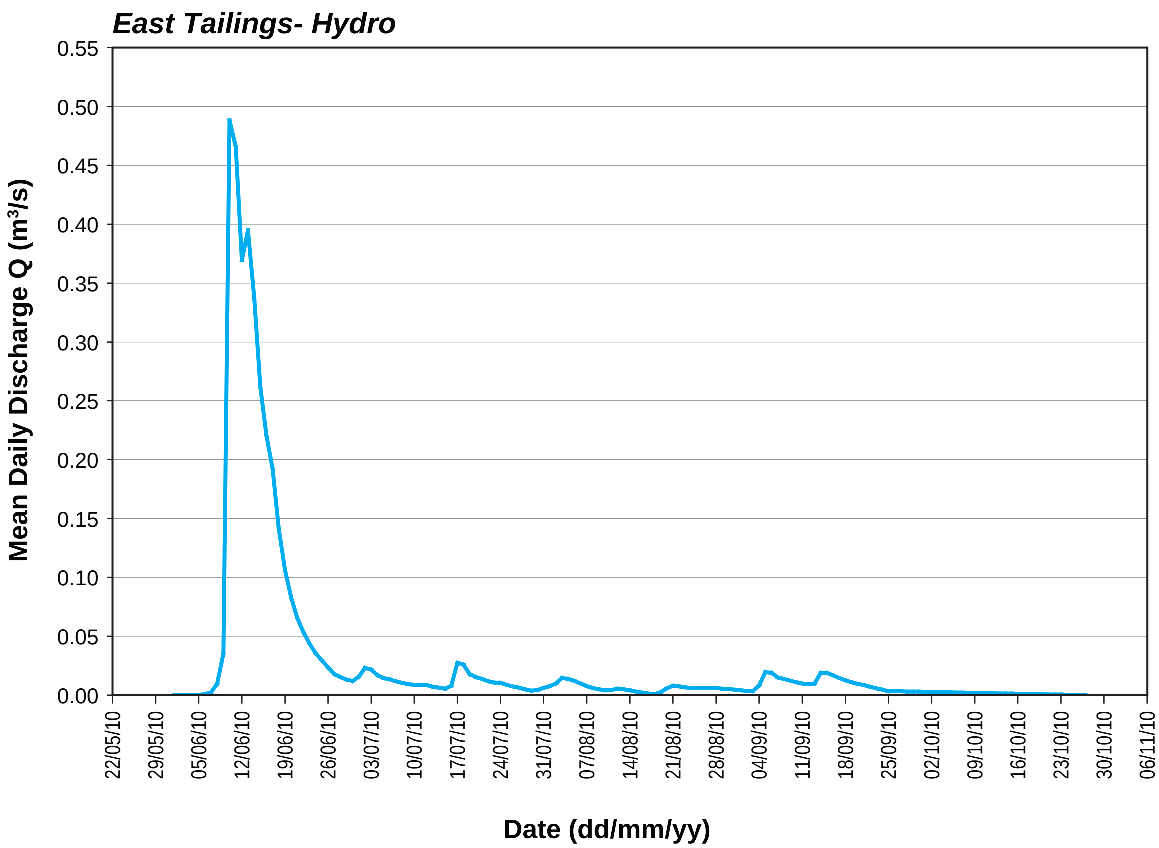
East Tailings- Hydro
Mean Daily Discharge Q (m³/s)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
22/05/10
29/05/10
05/06/10
12/06/10
19/06/10
26/06/10
03/07/10
10/07/10
17/07/10
24/07/10
31/07/10
07/08/10
14/08/10
21/08/10
28/08/10
04/09/10
11/09/10
18/09/10
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06/11/10
Date (dd/mm/yy)

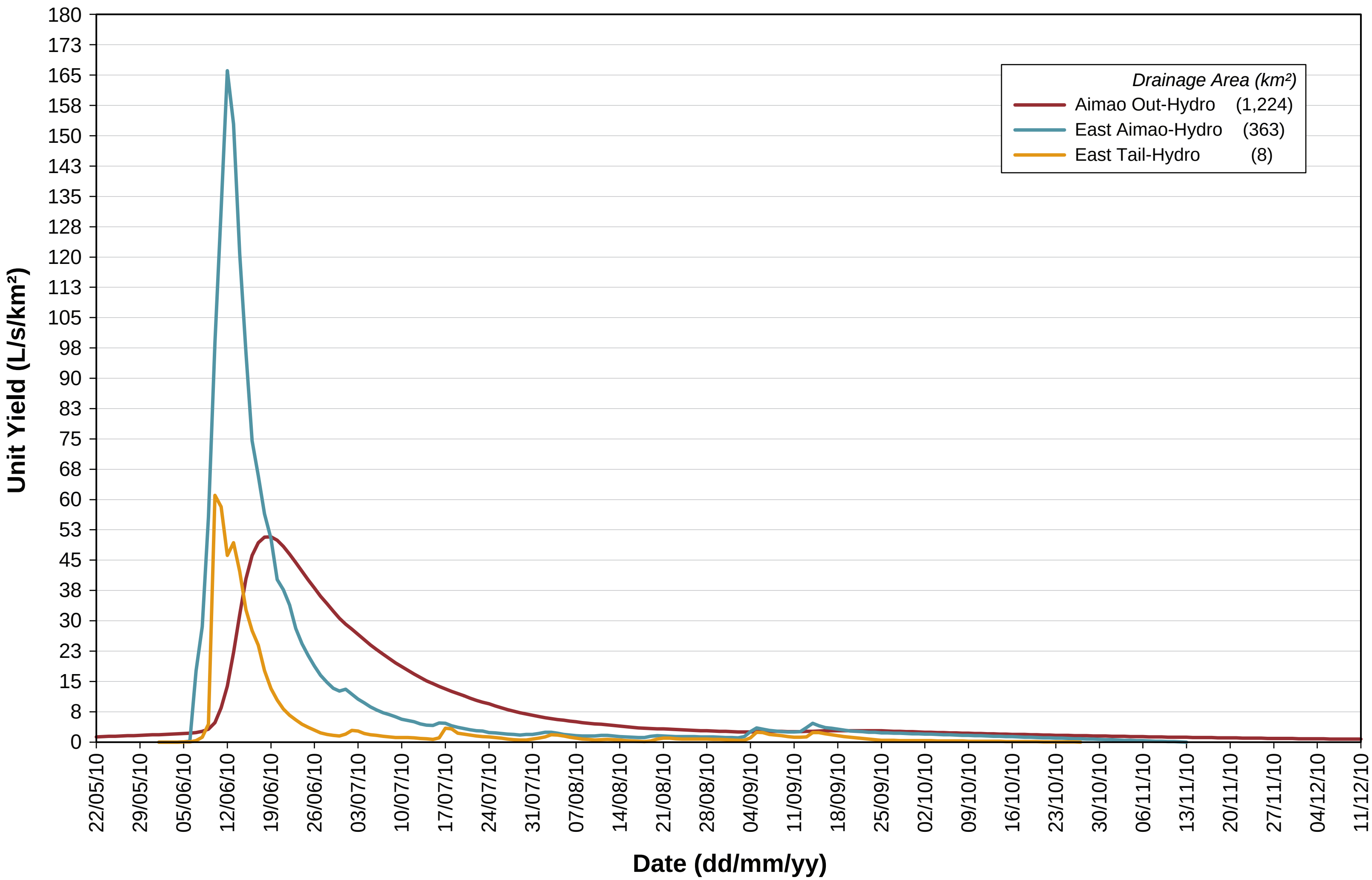

Figure 4.2-3

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2010 Boston Area Open Water Season Unit Yield Hydrographs

Figure 4.2-5

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4.2.4.1 Unit Yield Hydrographs

The daily unit yield hydrographs show that the unit yield is proportional to drainage area for the Aimao Out-Hydro and the East Aimao-Hydro hydrometric stations. A higher unit yield is observed at the smaller East-Aimao-Hydro (363 km^2) than at the larger Aimao Out-Hydro (1,224 km^2). In contrast, a different trend is observed at the smallest of the three basins which drains past the East Tailings-Hydro (8 km^2) hydrometric station. Interestingly, results from the East Tailings-Hydro hydrometric station are in close agreement with the results from the largest Aimao Out-Hydro hydrometric station.

4.2.5 Hydrologic Indices

4.2.5.1 Calculated Annual Runoff

In 2010, the calculated average runoff from gauged watersheds in the Boston area was 104 mm, ranging from a low of 45 mm at East Tailings-Hydro to a high of 143 mm at East Aimao-Hydro. The estimated average runoff for the open-water season from gauged watersheds in the Boston area was 113 mm, ranging from 46 mm to 147 mm at East Tailings-Hydro and East Aimao-Hydro, respectively. The estimated annual runoff values for the Aimao Out-Hydro and East Aimao-Hydro hydrometric stations were in close agreement (Table 4.2-4).

Table 4.2-4. 2010 Annual Runoff and Mean Annual Discharge in the Boston Area

Hydrometric Station	Drainage Area (km^2)	Percent lake coverage in watershed	Calculated Runoff (mm)	Estimated Annual Runoff (mm)	Mean Annual Discharge (m^3/s)
Aimao Out-Hydro	1,224	19	124 (June 7 to September 25)	144	5.59
East Aimao-Hydro	363	15	143 (June 7 to September 25)	147	4.04
East Tailings -Hydro	8	7	45 (June 10 to September 25)	46	0.03
Mean			*134*	*146*	

It is important to note that the mean runoff values for catchments in the Boston area do not include results from the hydrometric station East Tailings-Hydro. Runoff values for this catchment are approximately three times smaller than the mean runoff estimated from other gauged catchments in the Boston area. The basin draining past the East Tailings-Hydro hydrometric station is the smallest in this area and compared to the other basins located within the Boston area it has the lowest percentage of its drainage area covered by lakes. This suggests that the processes related to the regulation and storage of runoff in lakes are absent in this catchment.

Mean Annual Discharge (MAD) was calculated using mean daily discharge values from June to October at the East Aimao-Hydro and East-Tail-Hydro hydrometric stations and from January to December for the Aimao Out-Hydro hydrometric station. Calculated MAD ranged from 0.03 m^3/s to 5.59 m^3/s at the East Tailings-Hydro and Aimao Out-Hydro hydrometric stations, respectively (Table 4.2-4).

4.2.5.2 Monthly Runoff Distribution

The maximum monthly runoff occurred during June in the three basins located within the Boston area. The monthly distribution of runoff was similar between the gauged basins East Aimao-Hydro and East Tailings-Hydro. On average 80% of the annual runoff occurred during June in these basins. In contrast, at the basin draining past the Aimao Out-Hydro hydrometric station the majority of the annual runoff (75%) occurred between June and July. This suggests that the Aimaokatalok Lake plays a significant role in attenuating runoff in this basin (Table 4.2-5, Figure 4.2-6).

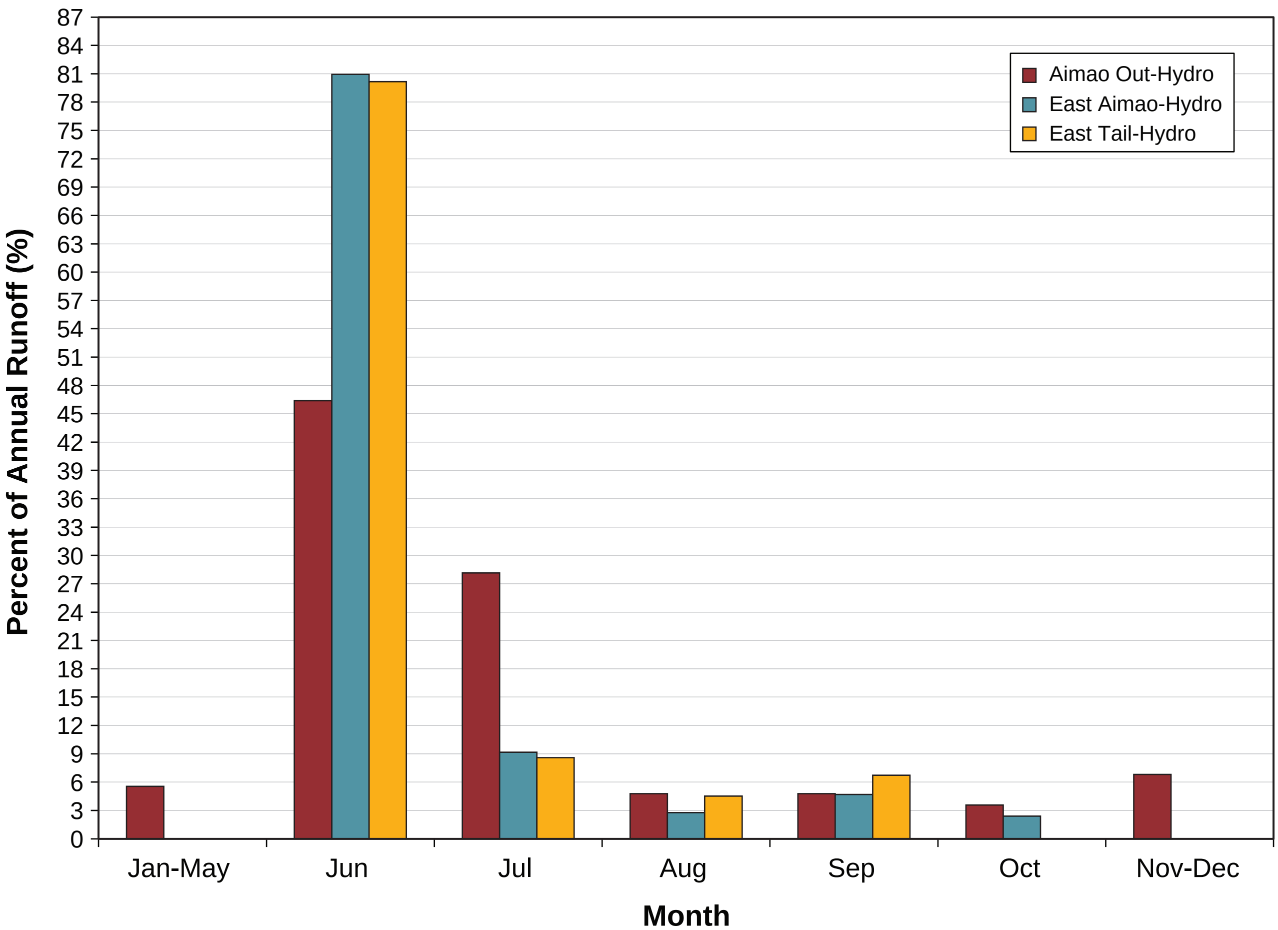

Figure 4.2-6

Monthly Runoff Distribution (%) for 2010 in the Boston Area

Table 4.2-5. 2010 Monthly Runoff Distribution (mm) in the Boston Area

Hydrometric Station	Jan-May	Jun	Jul	Aug	Sep	Oct	Nov-Dec
Aimao Out-Hydro	8	*68*	41	7	*7*	*5*	*10*
East Aimao-Hydro	0	*119*	13	4	*7*	*4*	*0*
East Tailings-Hydro	0	*37*	4	2	*3*	*0*	0

Italicized values are based on estimated mean daily discharge data

4.2.5.3 Peak and Low Flows

The observed instantaneous peak flows for the basins in the Boston Area occurred in mid-June and ranged from 0.6 m^3/s at East Tailings-Hydro to 66 m^3/s at East Aimao-Hydro (Table 4.2-6). Instantaneous peak unit yields ranged from 51 $L/s/km^2$ at Aimao Out-Hydro to 183 $L/s/km^2$ at East Aimao-Hydro (Figure 4.2-3).

Table 4.2-6. 2010 Annual Peak Flow and Unit Yield in the Boston Area

Station Name	Drainage Area (km^2)	Peak Flow (m^3/s)			Peak Unit Yield ($L/s/km^2$)	
		Instantaneous	Daily	Date	Instantaneous	Daily
Aimao Out-Hydro	1,224	62.64	62.19	June 19	51.18	50.81
East Aimao-Hydro	363	66.69	60.30	June 13	183.73	166.11
East Tailings-Hydro	8	0.60	0.49	June 10	74.41	61.01

The observed low flows at the hydrometric stations located within the Boston area occurred in early-September in most watersheds, except at the hydrometric station East Tailings-Hydro where it occurred in mid-August (Table 4.2-7). Minimum flows ranged from 0.001 m^3/s at East Tailings-Hydro to 3.05 m^3/s at Aimao Out-Hydro.

Table 4.2-7. Daily Minimum Flows (July-September 2010) in the Boston Area

Station	Daily minimum Flow (m^3/s)		Drainage Area (km^2)
Aimao Out-Hydro	3.05	September 03	1,224
East Aimao-Hydro	0.390	September 03	363
East Tailings-Hydro	0.001	August 18	8

5. Discussion

5. Discussion

This section presents the following: (1) a summary of the general climatic conditions of the study area, (2) a comparison between the data collected in 2010 and historical site data; (3) a comparison of the 2010 results obtained between the Doris/Madrid and Boston areas, and (4) a comparison between the results obtained in 2010 and the Regional estimates presented by Rescan (2009).

5.1 GENERAL CLIMATIC CONDITIONS OF THE STUDY AREA

According to the Climate Trends and Variations Bulleting (EC 2010), the Hope Bay Project is located within the Arctic Tundra climate region of Canada. General climatic conditions for the region in 2010 can be summarized as follows:

- The winter 2009/2010 was 5.4°C above the normal for the region and was the warmest winter on record (1948-2010).
- The 2010 winter was considered wetter than a normal year, having a departure from the mean of 17% (rank 23/63). It is important to note that the winter 2009 was also wetter than normal having a departure from the mean of 14% (rank 26/63).
- Temperatures during the spring of 2010 were 5°C above the normal and were the warmest on record. Precipitation was slightly wetter than the normal and showed a departure from the mean of 3% (rank 32/63).
- Temperatures during the summer 2010 were 2°C above the normal; 2010 was one of the warmest years on record (rank 3/63); precipitation was wetter than the normal and showed a departure from the mean of 7% (rank 26/63).

5.2 COMPARISON OF 2010 DATA TO HISTORICAL SITE DATA

In summary, 2010 was considered as a year with conditions warmer and wetter than normal. These conditions were reflected in the hydrologic response of the drainage basins located in the Hope Bay Belt Project area.

Figures 5.2-1 to 5.2-11 show the 2010 hydrographs for site-specific hydrometric stations along with available historical data. In most catchments in the Doris/Madrid area the flows during 2010 equalled or exceeded the flows registered during 2008, which was previously the year that produced the flow of record at most sites in this area. In the Boston area, flow conditions were above average but below the 2008 hydrograph which produced the flow of record at sites located in this area.

5.3 COMPARISON OF RESULTS BETWEEN THE DORIS/MADRID AND BOSTON AREAS

Geographically, the Doris/Madrid and Boston study areas are approximately 60 km apart. The results obtained in 2010 show that hydrologic conditions in the two areas are similar. Observed runoff patterns are consistent with hydrologic conditions of the Arctic-nival regime. Seasonal peak flows are caused by snowmelt. Freshet high flows are followed by rapid recession to base flow, which is occasionally punctuated by rainstorm-generated peaks (Woo 1990). The timing of the freshet was similar in the Doris/Madrid and Boston areas with flow beginning in the first week of June peaking approximately two weeks after streams began to flow, between June 10 and June 19.

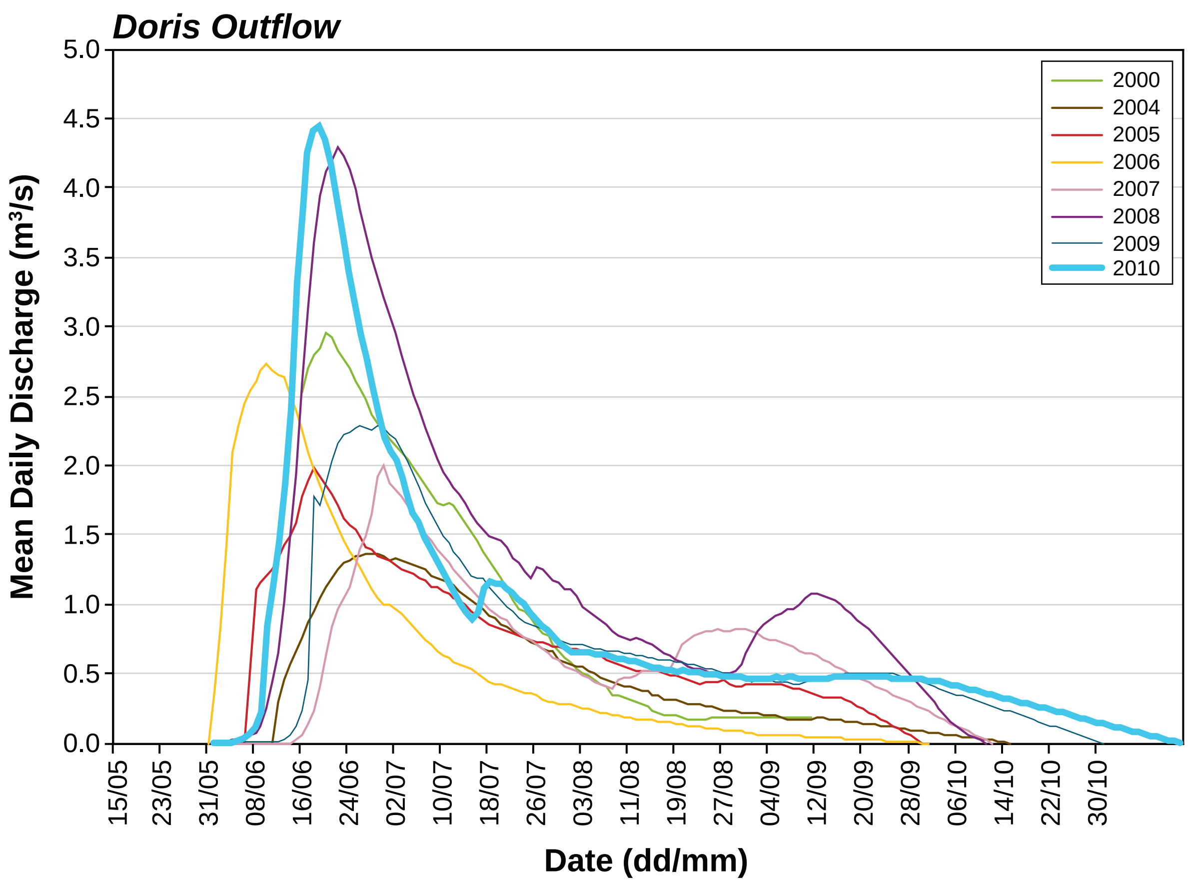

Figure 5.2-1

Historical Hydrographs for the Doris/Madrid Area

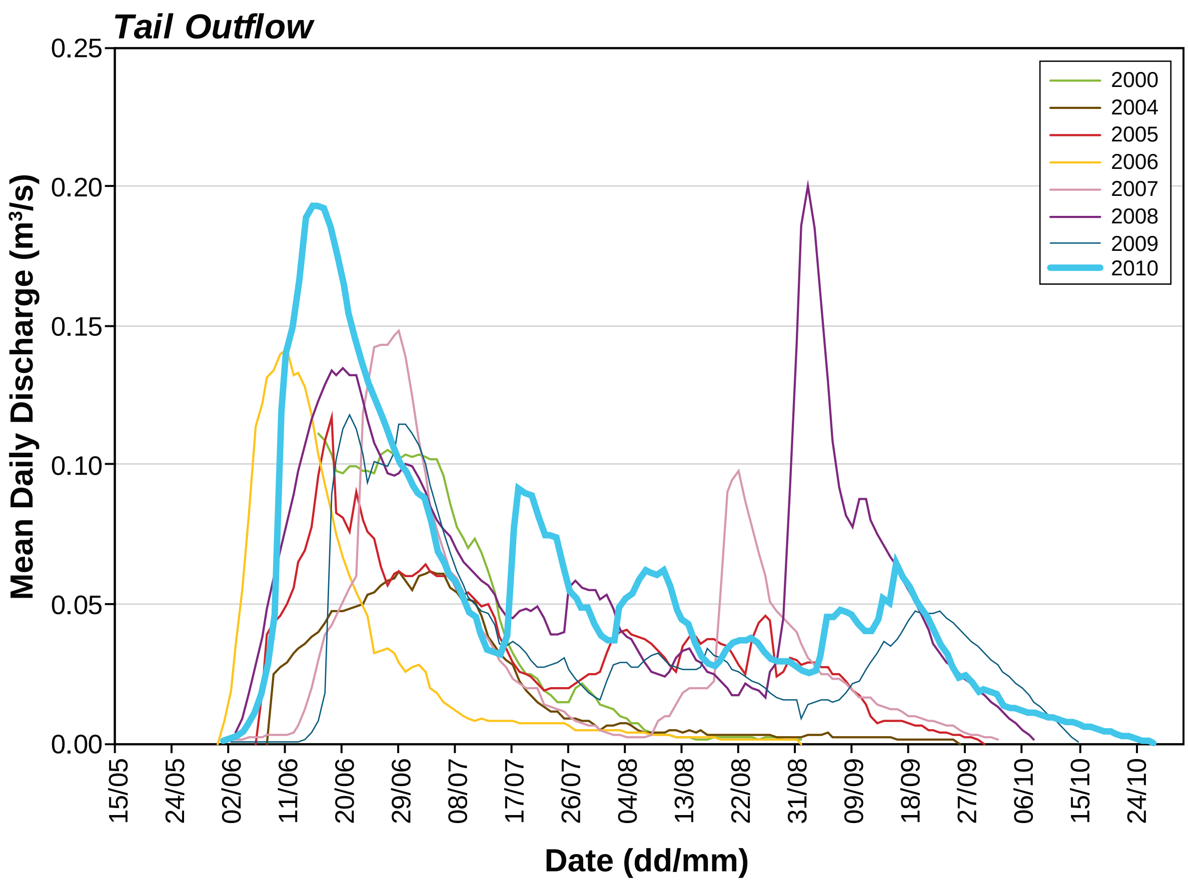

Figure 5.2-2

Historical Hydrographs for the Doris/Madrid Area

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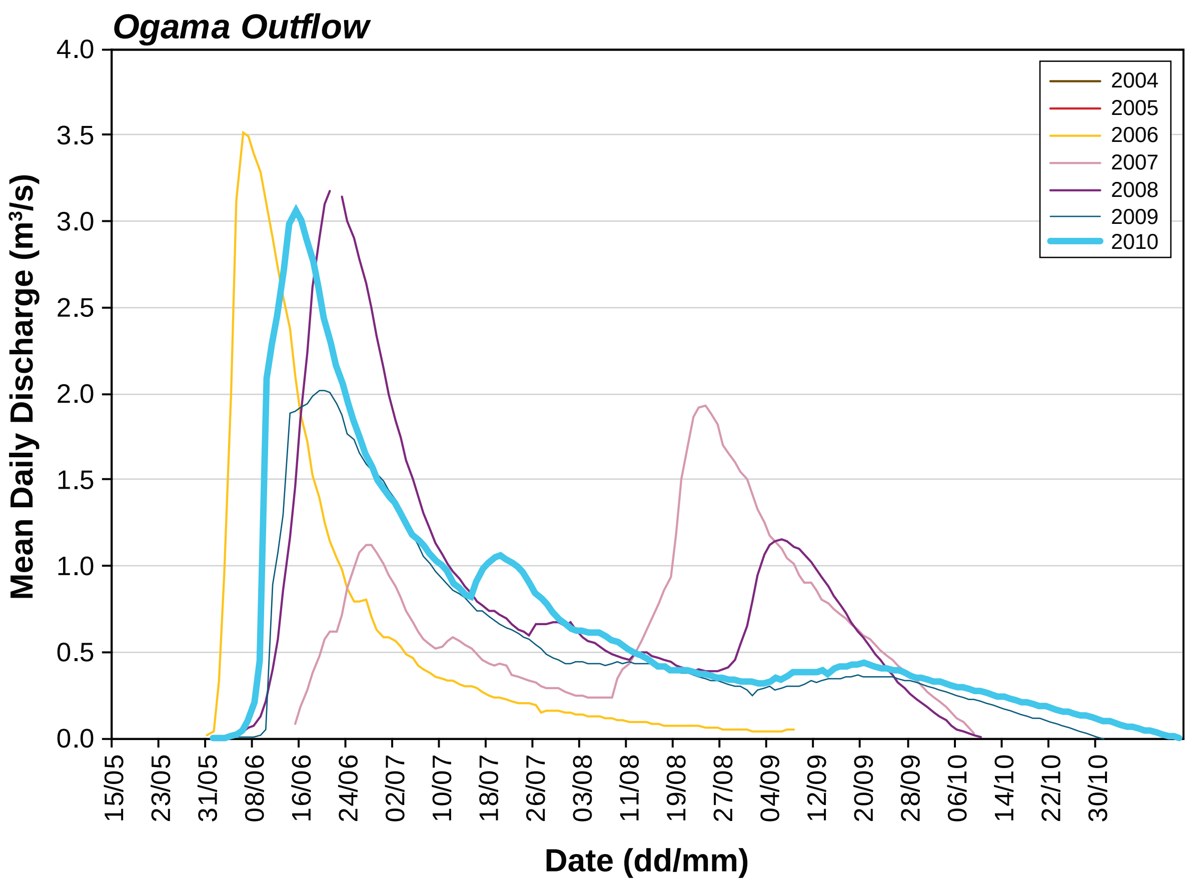
Ogama Outflow
Mean Daily Discharge (m³/s)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
15/05
23/05
31/05
08/06
16/06
24/06
02/07
10/07
18/07
26/07
03/08
11/08
19/08
27/08
04/09
12/09
20/09
28/09
06/10
14/10
22/10
30/10
Date (dd/mm)
2004
2005
2006
2007
2008
2009
2010

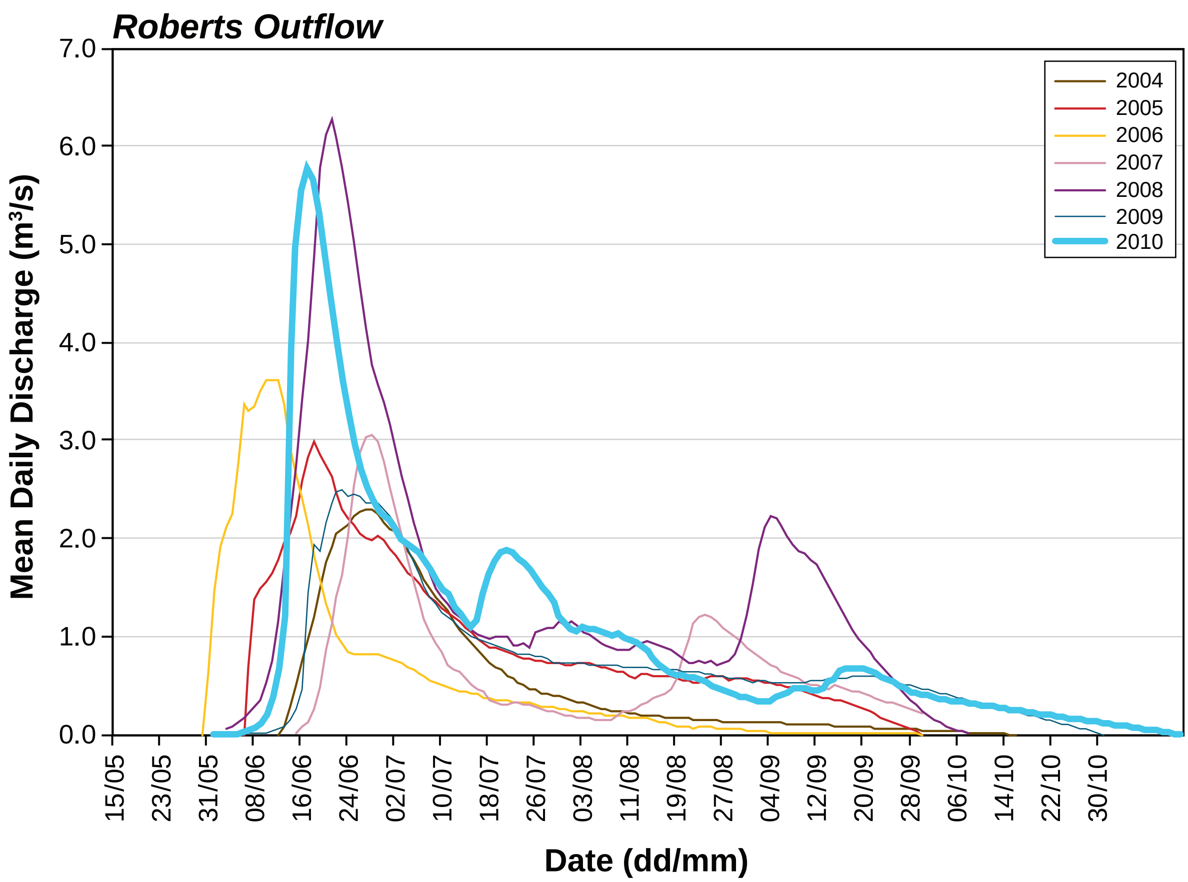

Figure 5.2-4

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Historical Hydrographs for the Doris/Madrid Area

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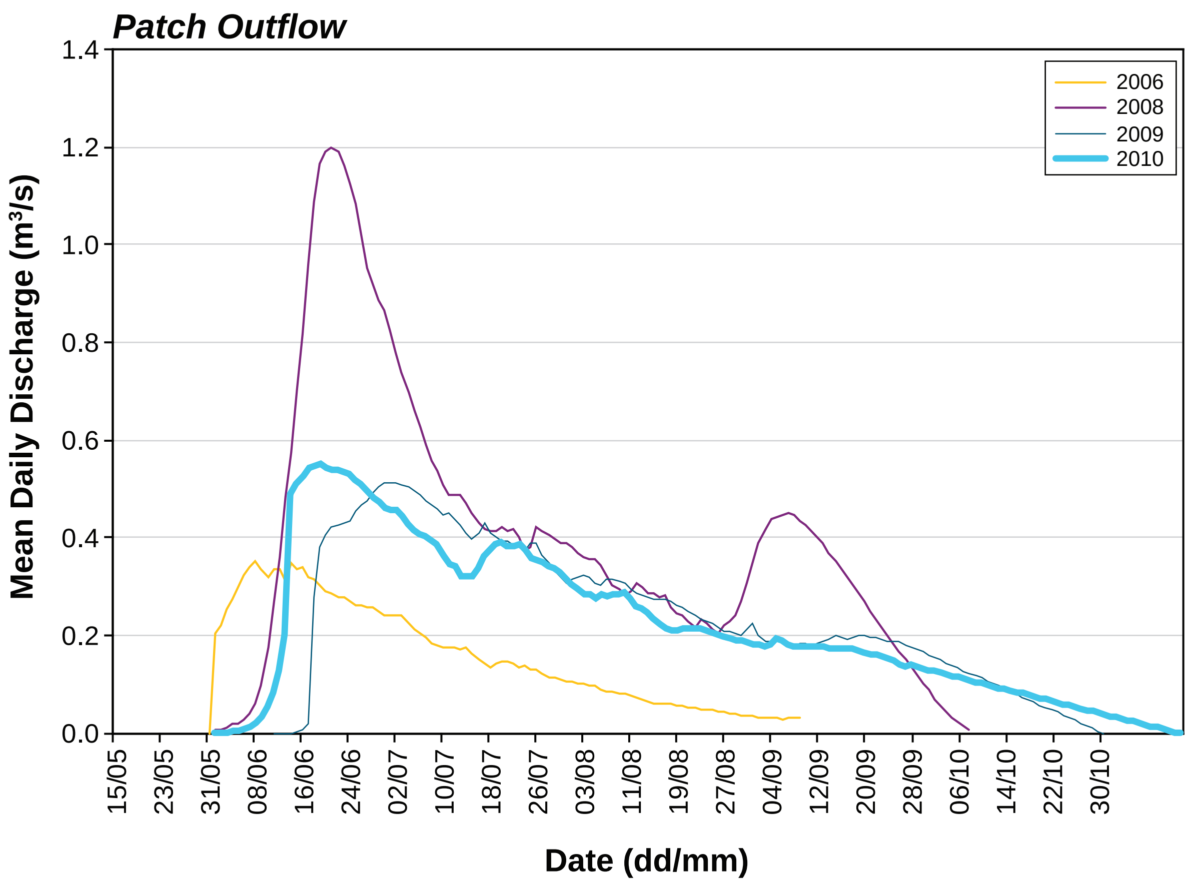

Figure 5.2-5

Historical Hydrographs for the Doris/Madrid Area

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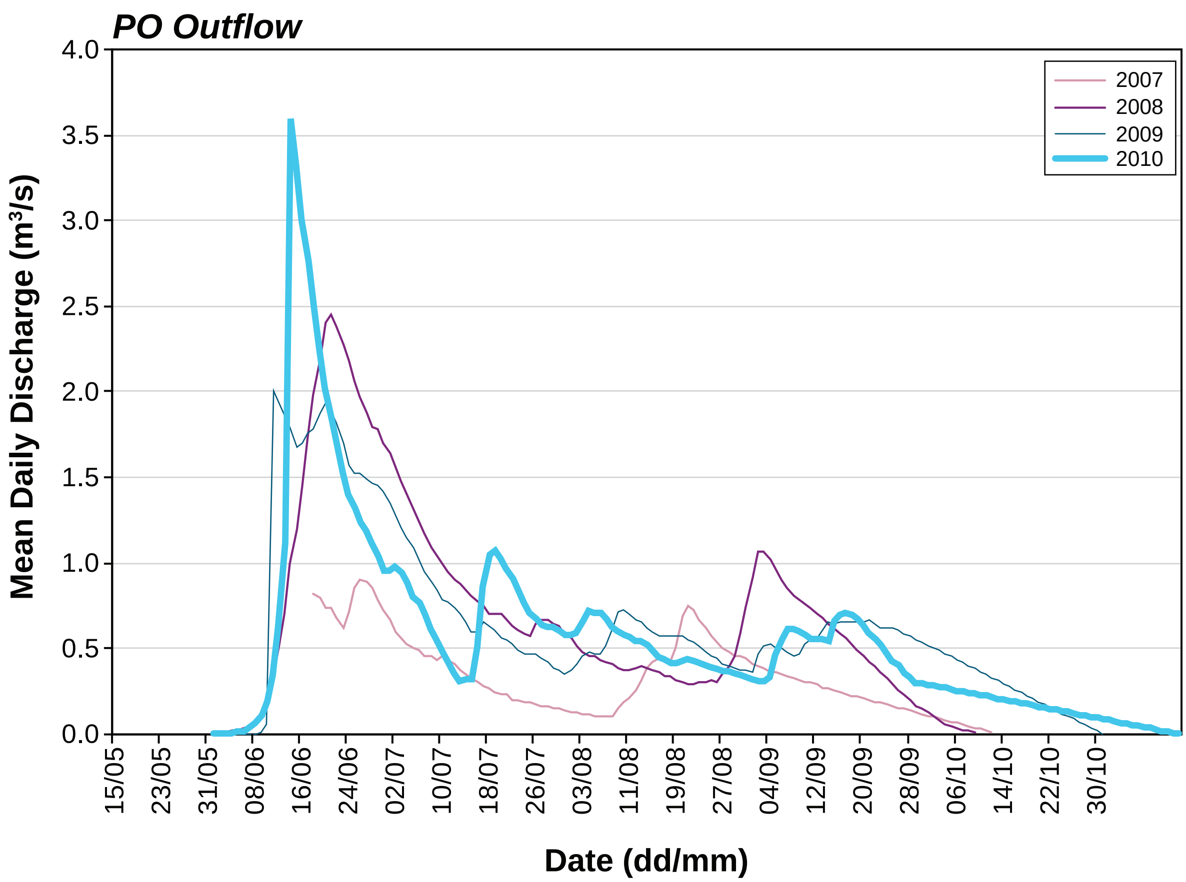

Figure 5.2-6

Historical Hydrographs for the Doris/Madrid Area

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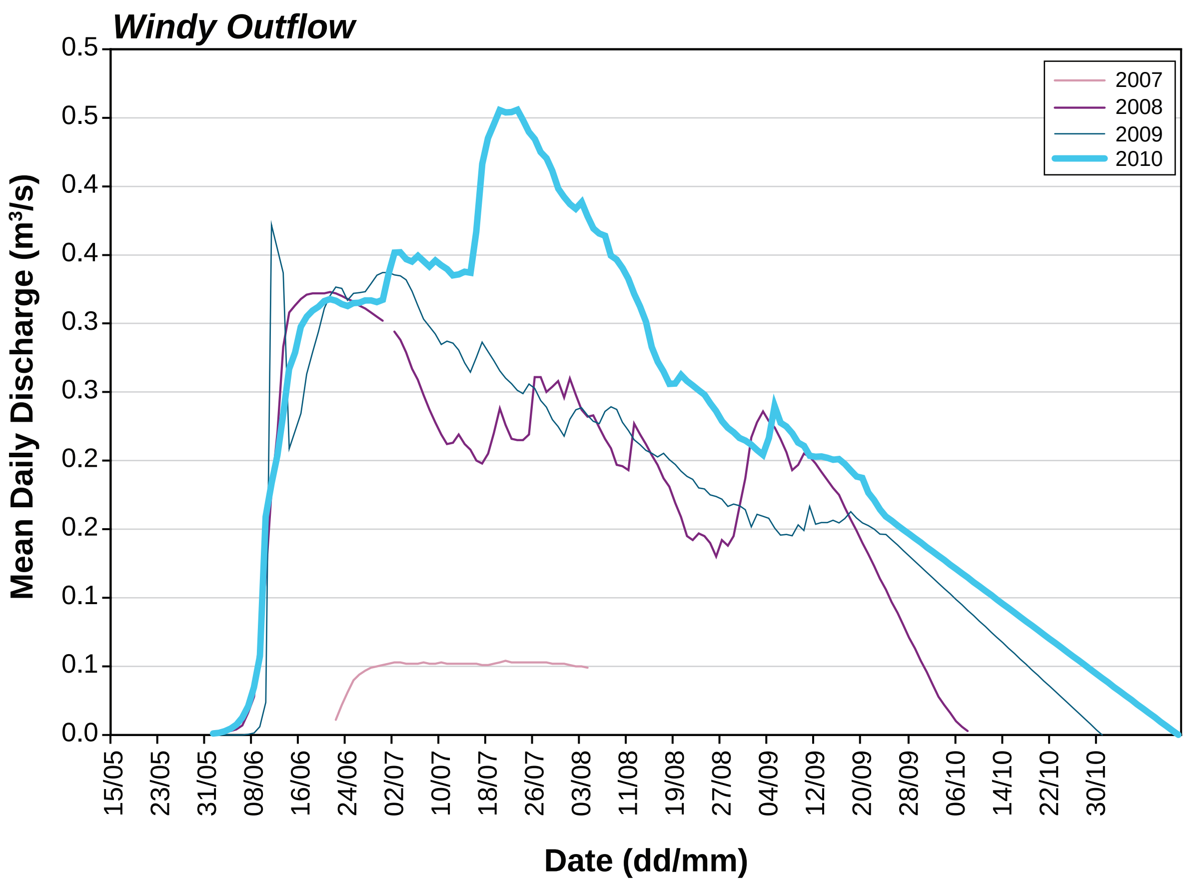
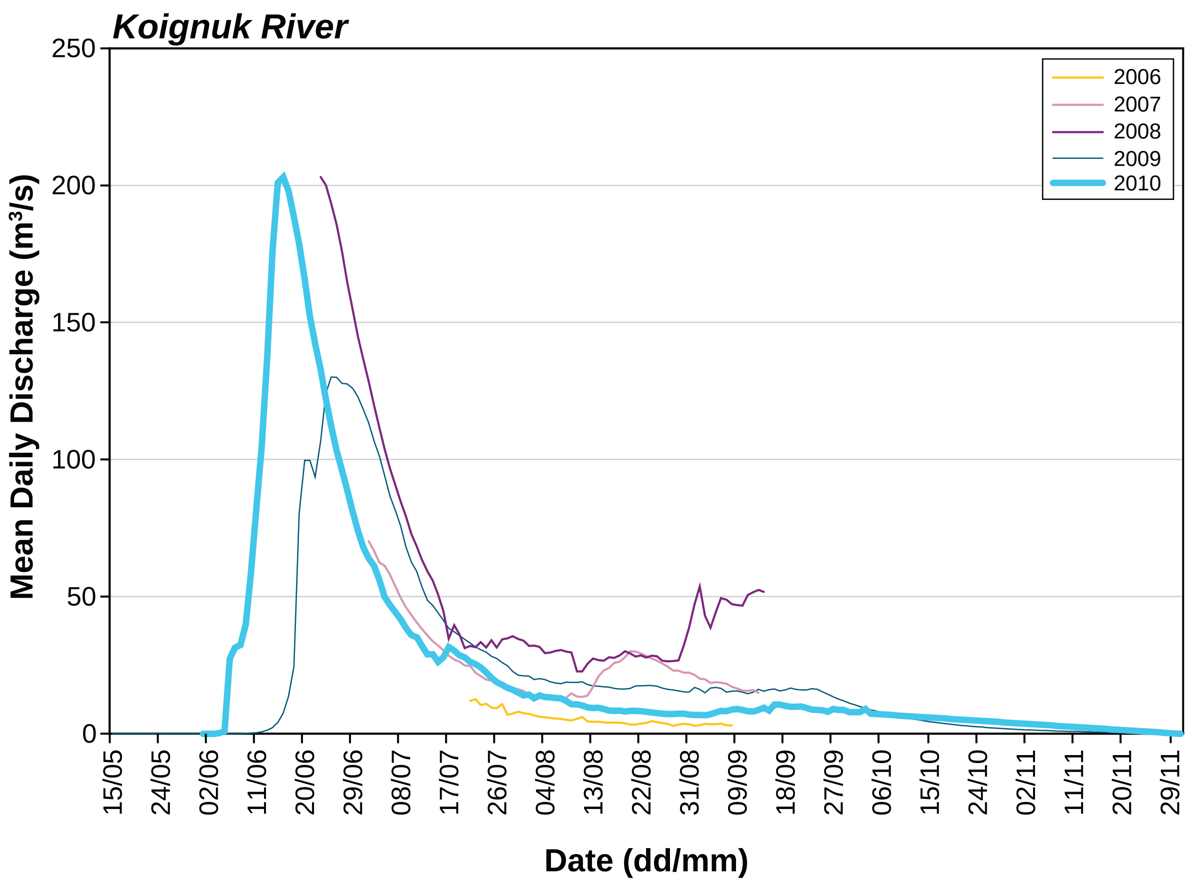


Figure 5.2-7

Historical Hydrographs for the Doris/Madrid Area



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Historical Hydrographs for the Doris/Madrid Area

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